UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON D.C. 20460

OFFICE OF THE ADMINISTRATOR
SCIENCE ADVISORY BOARD

October 24, 2008

EPA-SAB-09-002

The Honorable Stephen L. Johnson
Administrator
U.S. Environmental Protection Agency
1200 Pennsylvania Avenue, N.W.
Washington, D.C. 20460

Subject: SAB Advisory Report "Preparing for Environmental Disasters"

Dear Administrator Johnson:

I am pleased to send to you a self-initiated Advisory Report of the EPA Science Advisory Board (SAB) titled "Preparing for Environmental Disasters." Our primary motivation in this effort has been to help the Agency become less reactive and more anticipatory and to think more broadly about how it identifies and assesses possible future large-scale environmental disasters and develops plans for responding to and communicating about them.

EPA's statutory responsibilities in such settings are limited, and in the context of an environmental disaster, "that's not my department" is not a satisfactory answer to a concerned general public that will look at the Agency's name and expect it to take a wider range of responsibilities than it is likely to actually have. The public may not understand, or in the face of a major environmental disaster care very much, about the intricacies of bureaucratic or political constraints. Thus, they may blame EPA for the shortcomings of others.

It is very much in the Agency's interest to assure that preparations for possible future disasters have been well developed and that there are not gaps in responsibility or response. While it is clear that the Agency has already undertaken extensive preparations to deal with a range of specific environmental disasters, we also recommend that EPA also invest modest additional resources in some broader efforts.

To this end the SAB recommends that the EPA establish a small interdisciplinary Environmental Disaster Assessment Team of five to seven professionals who are charged with identifying, prioritizing and assessing potential environmental disasters. This team should develop a system to identify potential environmental disasters, prioritize them based on probability and consequence, and identify common attributes and response strategies that could improve the efficiency and effectiveness of agency responses.

In addition, the proposed Environmental Disaster Assessment Team should perform, or arrange for others to perform, reasonably comprehensive assessments of those disasters deemed to be of greatest concern. It should then help and advise the Agency to fully: 1) identify gaps in coverage by Federal, State and Local authorities and needs for improved coverage, coordination and preplanning; 2) develop prior arrangements with experts and organizations who can provided the needed knowledge and skills and develop a geo-coded list of this expertise so that these connections can be made rapidly in an emergency; and 3) identify short term waivers to regulations that might be needed and prearranged mechanisms to achieve these waivers in a way that balances efficiency with protection and other objectives.

In undertaking this self-initiated study, one of the first steps the SAB took was to invite a set of briefings from a range of organizations that have extensive experience in dealing with a wide variety of environmental disasters. We did this because we wanted to see if there were general lessons to be drawn that might be relevant to the EPA's needs, and because we wanted to get ourselves "grounded" in examples of a number of real events so that our deliberations would not be too abstract.

From these examples we concluded that the Agency would be well advised to more systematically examine and seek to learn from the best practices of other public and private organizations. In so doing, it should seek strategies by which it, and other responsible parties, might better:

1) *anticipate, assess, plan for, and practice responses* to deal with major events that plausibly might occur in coming years;
2) *learn rapidly* what is going on and developing a rapid and rough sense of what risks may exist to people and the environment*;*
3) *effectively coordinate and communicate* with other key players including first responders and the public;
4) *respond with flexibility* to the specific needs and circumstances of the event at hand, including the ability to adapt procedures and make real-time decisions when previous plans are not working;
5) *delegate* decision authority to responsible individuals in the field; and
6) *mobilize* personnel and resources in a rapid and orderly way.

Beyond these general recommendations the report makes a number of more specific recommendations, many of which should help to improve EPA’s capacity in the emergency response program.

The SAB recommends that the EPA compile an inventory of existing models, tools, data and resources, *including those that, while developed for other purposes, might be made useful for disaster response*; perform a comprehensive assessment and develop a report on the gaps in the available resource systems; solicit feedback from users of these tools, particularly local and state personnel and regional EPA managers, regarding resource systems; and identify further development and research needs.

The SAB recognizes that field measurements made during the early stages of a disaster have a different purpose than field measurements made for long-term monitoring and remediation. Emergency responders and citizens need fast order-of-magnitude

indications of the nature and level of hazards they may face. Accordingly instrumentation, quality assurance procedures for authorizing the release of data, and measurement priorities should be designed to appropriately meet those needs. While recognizing the progress that has been made in the development of the Environmental Response Laboratory Network, the report recommends that the agency pay additional attention to developing procedures for rapid field measurement, data analysis and data release during the early stages of emergencies, as well as protocols for how those procedures will be modified to assure greater precision and quality control as needed in later stages of the life-cycle of an environmental disaster.

The report makes a variety of other more specific recommendations related to tools for data display and analysis, documentation of decisions, routine *post-hoc* performance audits, and improving communication.

In this latter context, the report notes that virtually all of the Agency's work in communication with the general public lacks a key empirical foundation. To correct this deficiency, the SAB recommends that the Agency reinvigorate its program in behavioral social science application and research, perhaps by reestablishing the very successful collaboration it once had with National Science Foundation's Decision Research and Management Science program. This should include a strong program in empirically based methods of risk communication as well as development, demonstration and evaluation of mechanisms for better including public values and preferences in post-disaster clean-up decisions.

Clearly the SAB is not the right organization to develop detailed operational plans to deal with environmental disasters. Rather, it is our hope that by taking a fresh independent look, this report may persuade the Agency to begin to add to its current activities the kind of broader, more anticipatory approach we believe is needed.

In the future, once the agency has developed a broader planning process and plans, the SAB would be happy to provide thoughtful expert reviews and advice on the technical and behavioral dimensions of those processes and plans.

Sincerely,

/Signed/

Dr. M. Granger Morgan
Chair
U.S. EPA Science Advisory Board

NOTICE

This report has been written as part of the activities of the EPA Science Advisory Board (SAB), a public advisory group providing extramural scientific information and advice to the Administrator and other officials of the Environmental Protection Agency. The SAB is structured to provide balanced, expert assessment of scientific matters related to problems facing the Agency. This report has not been reviewed for approval by the Agency and, hence, the contents of this report do not necessarily represent the views and policies of the Environmental Protection Agency, nor of other agencies in the Executive Branch of the Federal government, nor does mention of trade names of commercial products constitute a recommendation for use. Reports of the SAB are posted on the EPA website at http://www.epa.gov/sab.

U.S. Environmental Protection Agency
Science Advisory Board*

CHAIR
Dr. M. Granger Morgan, Lord Chair Professor in Engineering, Department of Engineering and Public Policy, Carnegie Mellon University, Pittsburgh, PA

SAB MEMBERS
Dr. Gregory Biddinger, Coordinator, Natural Land Management Programs, Toxicology and Environmental Sciences, ExxonMobil Biomedical Sciences, Inc., Houston, TX

Dr. Thomas Burke, Professor, Department of Health Policy and Management, Johns Hopkins Bloomberg School of Public Health, Johns Hopkins University, Baltimore, MD

Dr. James Bus, Director of External Technology, Toxicology and Environmental Research and Consulting, The Dow Chemical Company, Midland, MI

Dr. Deborah Cory-Slechta, Professor, Department of Environmental Medicine, School of Medicine and Dentistry, University of Rochester, Rochester, NY

Dr. Maureen L. Cropper, Professor, Department of Economics, University of Maryland, College Park, MD

Dr. Virginia Dale, Corporate Fellow, Environmental Sciences Division, Oak Ridge National Laboratory, Oak Ridge, TN

Dr. Kenneth Dickson, Regents Professor, Department of Biological Sciences, University of North Texas, Aubrey, TX

Dr. David A. Dzombak, Walter J. Blenko Sr. Professor of Environmental Engineering, Department of Civil and Environmental Engineering, College of Engineering, Carnegie Mellon University, Pittsburgh, PA

Dr. Baruch Fischhoff, Howard Heinz University Professor, Department of Social and Decision Sciences, Department of Engineering and Public Policy, Carnegie Mellon University, Pittsburgh, PA

Dr. James Galloway, Professor, Department of Environmental Sciences, University of Virginia, Charlottesville, VA

Dr. James K. Hammitt, Professor, Center for Risk Analysis, Harvard University, Boston, MA

*This roster reflects the SAB membership during 2007 and 2008 when the activity was conducted.

Dr. Rogene Henderson, Senior Scientist Emeritus, Lovelace Respiratory Research Institute, Albuquerque, NM

Dr. James H. Johnson, Professor and Dean, College of Engineering, Architecture & Computer Sciences, Howard University, Washington, DC

Dr. Bernd Kahn, Professor Emeritus and Director, Environmental Radiation Center, Nuclear and Radiological Engineering Program, Georgia Institute of Technology, Atlanta, GA

Dr. Agnes Kane, Professor and Chair, Department of Pathology and Laboratory Medicine, Brown University, Providence, RI

Dr. Meryl Karol, Professor Emerita, Graduate School of Public Health, University of Pittsburgh, Pittsburgh, PA

Dr. Catherine Kling, Professor, Department of Economics, Iowa State University, Ames, IA

Dr. George Lambert, Associate Professor of Pediatrics, Director, Center for Childhood Neurotoxicology, Robert Wood Johnson Medical School-UMDNJ, Belle Mead, NJ

Dr. Jill Lipoti, Director, Division of Environmental Safety and Health, New Jersey Department of Environmental Protection, Trenton, NJ

Dr. Michael J. McFarland, Associate Professor, Department of Civil and Environmental Engineering, Utah State University, Logan, UT

Dr. Judith L. Meyer, Distinguished Research Professor Emeritus, University of Georgia, Lopez Island, WA

Dr. Jana Milford, Associate Professor, Department of Mechanical Engineering, University of Colorado, Boulder, CO

Dr. Rebecca Parkin, Professor and Associate Dean, Environmental and Occupational Health, School of Public Health and Health Services, The George Washington University Medical Center, Washington, DC

Mr. David Rejeski, Director, Foresight and Governance Project, Woodrow Wilson International Center for Scholars, Washington, DC

Dr. Stephen M. Roberts, Professor, Department of Physiological Sciences, Director, Center for Environmental and Human Toxicology, University of Florida, Gainesville, FL

Dr. Joan B. Rose, Professor and Homer Nowlin Chair for Water Research, Department of Fisheries and Wildlife, Michigan State University, East Lansing, MI

Dr. James Sanders, Director and Professor, Skidaway Institute of Oceanography, Savannah, GA

Dr. Jerald Schnoor, Allen S. Henry Chair Professor, Department of Civil and Environmental Engineering, Co-Director, Center for Global and Regional Environmental Research, University of Iowa, Iowa City, IA

Dr. Kathleen Segerson, Professor, Department of Economics, University of Connecticut, Storrs, CT

Dr. Kristin Shrader-Frechette, O'Neil Professor of Philosophy, Department of Biological Sciences and Philosophy Department, University of Notre Dame, Notre Dame, IN

Dr. V. Kerry Smith, W.P. Carey Professor of Economics , Department of Economics , W.P Carey School of Business , Arizona State University, Tempe, AZ

Dr. Deborah Swackhamer, Interim Director and Professor, Institute on the Environment, University of Minnesota, St. Paul, MN

Dr. Thomas L. Theis, Director, Institute for Environmental Science and Policy, University of Illinois at Chicago, Chicago, IL

Dr. Valerie Thomas, Anderson Interface Associate Professor, School of Industrial and Systems Engineering, Georgia Institute of Technology, Atlanta, GA

Dr. Barton H. (Buzz) Thompson, Jr., Robert E. Paradise Professor of Natural Resources Law at the Stanford Law School and Director, Woods Institute for the Environment Director, Stanford University, Stanford, CA

Dr. Robert Twiss, Professor Emeritus, University of California-Berkeley, Ross, CA

Dr. Lauren Zeise, Chief, Reproductive and Cancer Hazard Assessment Branch, Office of Environmental Health Hazard Assessment, California Environmental Protection Agency, Oakland, CA

LIAISONS

Dr. Steven Heeringa, (FIFRA SAP), Research Scientist and Director, Statistical Design Group, Institute for Social Research (ISR), University of Michigan, Ann Arbor, MI

Dr. Melanie Marty, (CHPAC Chair), Chief, Air Toxicology and Epidemiology Branch, Office of Environmental Health Hazard Assessment, California EPA, Oakland, CA

SCIENCE ADVISORY BOARD STAFF

Mr. Thomas Miller, Designated Federal Officer, EPA SAB, Washington, DC

Table of Contents

SAB Advisory Report: Preparing for Environmental Disasters

1. Background.....1

2. Learning from Others.....2

3. Identifying a Range of Potential Environmental Disasters.....4

4. Geographically Specific Tools for Data Display, Analysis and Decision Support.....7

5. QA/QC for Data During Emergencies.....11

6. Improved Communication and Public Consultation.....11

7. Summary and Restatement of Key Recommendations.....14

SAB Advisory Report: Preparing for Environmental Disasters

1. Background

Even with improved preparation and careful advanced preventive actions, occasional environmental disasters are inevitable. They will arise from natural events, such as storms, earthquakes, and volcanic eruptions that have significant human and environmental impacts (SAB, 1995, 1999). Unfortunately they may also result from accidental or intentional human events, such as large spills, structural collapse, facility explosions or terrorist attacks.

When disasters with large environmental consequences occur, the public naturally looks to EPA to play a central role in characterizing environmental impacts, protecting human health and ecosystems, and in coordinating and overseeing post disaster clean-up.

However, EPA's authority covers only a subset of the issues that may arise in an environmental disaster (See Box 1, Appendix A). These include protection of drinking water supplies, the cleanup of contaminated buildings, and the development of a nationwide laboratory network to support response. EPA has developed an Emergency Response Business Plan[1] and continues to work hard to prepare for those aspects of disasters for which it has responsibility, following the general framework laid out in the National Response Framework (see Figure 1, Appendix A)

Other federal, state, and local agencies have primary responsibility for other aspects of dealing with environmental disasters, including First Response. When the scale of a disaster is large, or especially politically salient, senior political leaders also become involved. In such situations, EPA has found itself buffeted by forces over which it has little or no control or authority. At the same time, the public may not understand, or in the face of a disaster care very much, about the intricacies of bureaucratic or political constraints and blame EPA for the shortcomings of others.

While no one can predict the future, we believe that it should be possible to identify, at least in general terms, the range of large-scale environmental disasters that could plausibly arise from natural causes (earthquakes, hurricanes), accidents (accidental explosions, structural collapse) and terrorist events. The EPA has already done some of this, partly in response to previous SAB investigations and recommendations (SAB, 1995, 1999). However, in crisis situations large organizations are rarely capable of rapid innovation. Rather, they respond with previously developed "standard operating procedures" (Allison and Zelikow, 1999). As a result, if EPA is to improve its response to future large-scale environmental disasters it must have performed needed research and developed plans in anticipation of the range of plausible contingencies. At least as important, Agency personnel must have practiced and refined these plans in "table-top" or

[1]The Emergency Response Business Plan is designed to facilitate readiness to deal with five simultaneous incidents of national significance (INS) while also maintaining effective "day-to-day" capabilities.

other exercises that address both the risks and the likely complex institutional setting in which the Agency will likely have to execute its plans. The agency has already been doing these things for those aspects of a number of potential environmental disasters for which it has statutory authority. This report recommends that the Agency expand the range of those activities and invest modest resources in some broader efforts to scope and prioritize potential disasters with large environmental consequences. Indeed, if it does this well, EPA may even be able to assist other government and private sector entities to identify gaps and blind spots in their current thinking and improve their current preparation and response plans.

The purpose of this SAB self-initiated study has been to stimulate the agency to become less reactive and more anticipatory and to think more broadly about how it identifies and assesses possible future large-scale environmental disasters and develops plans for responding to and communicating about them. Clearly, the SAB is *not* the right organization to develop detailed operational plans. Rather, it is our hope that by taking a fresh independent look at the problem, and building on previous SAB efforts on the topic of preparedness for environmental disasters (SAB, 1995, 1999) we can persuade the Agency to begin to adopt the kind of broader, more anticipatory approach we believe is needed. In the future, once the agency has developed a broader planning process and plans, the Science Advisory Board would be happy to provide thoughtful expert reviews and advice on the technical and behavioral dimensions of those processes and plans.

The Board would like to recognize and thank Agency staff for its insights, critical commentary, and assistance in this effort.

2. Learning from Others

In undertaking this self-initiated study, one of the first steps the SAB took was to invite a set of briefings from a range of organizations that have extensive experience in dealing with a wide variety of environmental disasters. This was done for two reasons: a) because the SAB wanted to see if there were general lessons to be drawn that might be relevant to the EPA's needs; and, b) because the SAB wanted to get itself "grounded" in examples of a number of real events so that our deliberations would not be too abstract.

People who graciously shared their time and experiences in disaster prevention and management with the SAB over the course of the study are listed in Appendix B to this report. In reviewing the most successful of the efforts the SAB identified a number of themes and approaches that it believes will likely be common to any effort to deal effectively with environmental disasters. These include:

1) *Anticipating, assessing, planning and practicing* to deal with events that can reasonably be anticipated to occur. When this is done, previously developed operational and communication plans, trained personnel, and previously identified instrumentation and materials can all be rapidly and efficiently brought to bear on the problem.

2) *Learning rapidly* about what is going on and developing a rapid and rough sense of what risks may exist to people and the environment. This means, for example, that field measurements made in the early stages of a disaster should probably be

designed quite differently (different instruments, quality assurance, etc.) than measurements that are made for long-term monitoring and remediation. It means that one needs to have access to and prior experience with appropriate fast modeling and monitoring tools. It also means that with some prior geo-coded inventories of what materials (sewage, chemical stores, etc.) might be available for release during a disaster one should be able to anticipate some aspect of likely exposures, and the consequent measurement and modeling needs.

3) *Communication* with the general public and with non-technical decision makers in a meaningful way. There is clear empirical evidence that such communication will be much more effective if it is based on the prior development and iterative empirical testing of at least the kernels of key messages and disseminated by trusted organizations or individuals. There is also clear evidence that helping people figure out what numbers mean, what their choices are, and what they should do to protect themselves, their children, their employees, and the environment, are all critical.

4) *Coordination* and communication with other key players. EPA has specific statutory responsibilities in terms of what it is and is not responsible for. However, in the context of an environmental emergency, "that's not my department" is not a satisfactory answer. The general public is likely to look at the Agency's name and expect it to take a wider range of responsibilities than it is likely to actually have. In order to avoid serious misunderstanding and inadequate response, there clearly needs to be coordination in both message and action. The SAB saw the briefings it received as strongly suggesting that such coordination and effective communication would almost certainly *not* happen unless there are pre-developed plans and messages that have been developed and rehearsed among relevant parties.

5) *Flexibility*, including the ability to adapt procedures and make real-time decisions when previous plans are not working. It was clear from the briefings that the most successful private organizations the SAB heard from have been very good at identifying strategies that are not working and making improvement rapidly. Figuring out how to replicate this ability to adopt an iterative approach in federal agencies clearly presents challenges that need to be addressed.

6) *Delegation* to folks in the field, and the willingness of senior management to back their decisions, was another characteristic of the successful private organizations the SAB heard from. Again, figuring out how to replicate this capability in Federal agencies clearly presents challenges that need to be addressed.

7) *Mobilization* of personnel and resources in a rapid and orderly way was a characteristic of the successful private organizations the SAB heard from. In the case of EPA, there is considerable expertise across the agency, including its laboratories, which might be mobilized if there were adequate prior planning, training and rehearsal. How much of this has already occurred is not clear to the SAB.

The SAB recommends that as EPA works to improve the way in which it identifies, assesses, prepares for, and responds to possible future environmental disasters, it should examine and seek to learn from the best practices of other public and private organizations.

3. Identifying a Range of Potential Environmental Disasters

There is no way to know the future. Some enormous but imaginable environmental disasters, such as the impact of a large meteorite, or a continental-scale lava flow, are of such low probability that it would make little sense for EPA, with its limited resources and large set of obligations, to spend time thinking very much about them (Smil, 2008). Other environmental disasters will be sufficiently small or local in extent that it is unlikely that EPA would become involved. However, there are other regularly occurring environmental disasters, such as floods and hurricanes that have significant human health and environmental impacts (SAB, 1995, 1999).

When Agency staff think about environmental disasters, typically, they start with one of the 15 DHS National Planning Scenarios[2] and the Agency's authorities (Box 1, Appendix A) and go from there. While this is appropriate, the committee believes that it would also be wise for the Agency to develop a systematic taxonomy of plausible events and plausible combinations of events[3], ask what would be the environmental consequences of each, and then in a systematic way, starting with those whose consequences are potentially most serious, ask:

- what agencies would deal with the various consequences?
- what responses and coordination would be needed?
- where are the gaps in authority and expertise?
- what other parties are likely to have key roles?
- what if any short term waivers to regulations and other rules might be needed and what mechanisms are needed to achieve these in a way that balances efficiency with protection and other objectives?
- what needs to be done to facilitate good coordination within EPA, with other Federal Agencies, with state and local government, and with the private sector?
- where are there commonalties across different types of environmental disasters that could be exploited to develop more efficient and effective response plans? and
- what would the public expect of the EPA?

A very simple illustration of how such a taxonomy might be developed is provided in Table 1 (see Appendix A). Other structures are also possible. The key point is to first

[2]EPA is an active participant in the DHS-coordinated Incident Planning Management Team (IMPT), which, among other activities, is conducting detailed panning related to the National Planning Scenarios. Note that all of the scenarios involving chemical releases involve "attacks." While these events could be extremely dangerous, so too could a wide range of accidental releases. The latter may actually be more likely.

[3]By combinations of events we mean things such as a large earthquake combined with wildfires, a consideration of whether key infrastructures such as power and communication continue to operate, or whether there are cross linkages between infrastructures (e.g. power available to run compressor stations in natural gas supply systems or to run pumps in water and sewer systems), etc.

develop some way to think systematically about the full range of plausible disasters the Agency might be called upon to address.

The entries in Table 1 are still abstract. The next step, once a taxonomy of this sort is developed, is to select a range of specific events and think through their consequences. Suppose, for example, that a major volcanic event was to occur in the Pacific Northwest - essentially a larger scale version of the Mt. St. Helens eruption but with impacts that extend to a number of population centers such as Seattle, Tacoma, Olympia, or the Portland area. Clearly, such an event could have a large number of consequences. In Addition, to wide-spread devastation of precious terrestrial and aquatic ecosystems and forest resources, there could be extensive loss of life, widespread destruction of built property, and disruptions of critical infrastructures, such as power supply, communication, roads and water. One way to explore these would be to build a set of "influence diagrams" that trace out various causal chains. Figure 2 (see Appendix A) shows a highly simplified example of the impacts that such an event might have on the sustained contamination of a water supply.

Figure 3 (see Appendix A) presents an illustrative time line for pre- and post-event planning and action. The main features of pre-event analysis include: identifying likely measurement needs; developing measurement tools and protocols, and risk analysis and consequence analysis tools; identifying likely communication needs and developing pre-tested communication modules that can be modified once the specifics of an event are known; identifying issues of jurisdiction/coordination; planning for longer term remediation needs; and identifying and implementing mitigating actions and strategies that could reduce or eliminate risks. Illustrations of a few post-event actions are shown on the right hand side of Figure 3.

Over the course of the past two years, the SAB has had occasion to review a number of geographical information systems being developed by different regional EPA offices. If these efforts were better coordinated, the result could be a very useful tool for pre-event analysis to identify and assess the various facilities that could result in sources of difficulty (such as chemical or other contamination). The availability of such a system or systems could also prove invaluable during the actual management of an event once it had happened.

Clearly, developing such assessments will take time and care. The agency will not be able to do this for a large number of potential natural, accidental and terrorist-caused disasters all at once. Accordingly,

> **the SAB recommends that the EPA establish a small interdisciplinary Environmental Disaster Assessment Team of five to seven fulltime professionals who are charged with working across the agency to identify, prioritize and assess potential environmental disasters**.

We believe that with the right people, resources, and mandate, such a group could make very substantial progress in just a few years. After developing a taxonomy of possible risk events, and working up a modest number of example assessments, such a group could then use these results as a basis to consult with Regional Offices, The National Homeland Security Research Center, key mission offices across the Agency, and the

Agency's Office of Research and Development, in order to set priorities across potential disaster scenarios (some of which would be generic in nature, some of which, like earthquakes or volcanic events, would be specific to geographical regions). As the work of such a small assessment team progressed, they would certainly find many situations in which the same sequences and responses apply across many different events and contingencies.

EPA does not have a mandate to deal with all aspects of environmental disasters. Indeed, in many cases, the legal mandate is limited to only a modest sub-set of all the issues that may arise. However,

the SAB recommends that the small Environmental Disaster Assessment Team recommended above start by prioritizing a systematically developed list of potential disasters and then that it perform, or arrange for others to perform, a reasonably comprehensive assessment of those that are deemed to be of greatest concern.

The SAB makes this recommendation for three reasons. First, without such a comprehensive anticipatory approach, the EPA runs a high risk of finding itself unprepared and playing catch-up in the face of future environmental disasters. Second, without such an approach, coordination with other Agencies may be spotty. Finally, without such a systematic approach, eventualities will likely arise in which no clear preparation has been made by *any* Federal agency to deal with at least some aspect of an acute environmental problem and, even if EPA's mission does not encompass that contingency, the public will likely look to the Agency for leadership, or blame the Agency for an inadequate response.

Of course, there are others at EPA's Homeland Security Research Center, EPA ORD, regional EPA offices, in DHS research centers, at Department of Energy National Labs, in universities, and in other research and operational entities, who have done portions of such assessments. Clearly, the proposed Environmental Disaster Assessment Team should build upon the prior work of such groups as it proceeds with this effort.

Having put in place an ongoing process to perform such assessments (starting with the highest priority issues), the Agency will be in a much better position to:

- prepare and practice response plans for a range of high probability events;
- identify likely gaps in expertise and develop prior arrangements with experts and organizations who can provide the needed knowledge and skills;
- develop a geo-coded list of this expertise so that these connections can be made rapidly in an emergency;
- identify short term waivers to regulations and other rules that might be needed and prearrange mechanisms to achieve these waivers in a way that balances efficiency with protection and other objectives;
- develop and pre-test public communications messages, that can be easily modified to meet the specific needs of different contexts, to deal with those events;
- engage in coordination activities with other Federal, State and private parties; and
- develop measurement and quality assurance protocols that will allow rapid dissemination and use of field measurements in the early stages of a disaster.

While the Agency is already doing many of these things in the context of specific risk scenarios and legislative authority, the SAB believes that great benefit could be obtained from a parallel effort that adopts a more holistic and comprehensive approach of the sort outlined.

4. Geographically Specific Tools for Data Display, Analysis and Decision Support

In this and the following section, we turn to a more detailed set of issues, some of which relate to the small Environmental Disaster Assessment Team proposed in Section 3, but most of which are more relevant to the ongoing work of the EPA emergency response program.

Assessing potential future disasters, planning for response, and executing an effective response once a disaster has occurred, all require information and modeling and analysis capabilities at a variety of scales (local, regional, and national). Local first responders such as fire, emergency services, or police, can respond and routinely are first to address the immediate needs created by small local disasters. However, as the spatial scale of the disaster increases additional resources, information and tools are needed to respond and address the consequences of the disaster.

EPA has developed a variety of spatial analysis tools incorporating geographic information systems (GIS) and fate and transport models that, while developed for other purposes, could be made applicable to the needs of emergency responders by providing information helpful in identifying vulnerable populations and environmental resources at the state, regional, and national scales. These tools incorporate GIS data layers such as land use, infrastructure, location of chemical storage facilities, industrial facilities, human census tract data, sensitive environmental and public health receptors, and a myriad of other spatially explicit databases into decision support systems. EPA has also developed and uses transport and fate models capable of estimating the dispersion of chemicals, particles, microorganisms, and radiation released by a disaster into the air and water. If modified for use in disaster setting, some of these tools could be particularly valuable for disaster managers responding to incidents at the regional scale. The following paragraphs provide details on a number of salient issues.

a) *Models, Tools, and Resources.* Maximum preparedness for short- and long-term emergency response actions requires development and maintenance and deployment of a variety of models, tools and other resources (resource systems). Consultations by EPA with SAB and Homeland Security Advisory Committee (HSAC) have addressed specific elements of this overall system resource portfolio but have not provided the overall context for SAB and SAB's Homeland Security Advisory Committee (HSAC) consideration of these reviews.

The SAB recommends that EPA compile an inventory of existing models, tools and resources, including those that, while developed for other purposes, might be made useful for disaster response.

Once these "assets" have been listed (including applicable assets from other agencies) they should be mapped against the list of disasters identified in National Planning Scenarios and by the proposed Environmental Disaster Assessment Team and their applicability to each should be established. EPA has special expertise in risk assessment of building disasters and building decontamination, water and wastewater infrastructure assessment, surface water and groundwater quality modeling, air quality modeling, emission locations and databases, municipal and industrial site locations, and ecological risk assessment. EPA tools may be especially useful in decision support for certain types of disaster response, and these applications should be identified *a priori*.

One example where this may already have happened is the Water Security Initiative (WSI), successor to the Water Sentinel Model that EPA developed for assessing the vulnerability of water distribution systems under various contamination scenarios. WSI consists of models and other tools to provide: enhanced physical security monitoring; water quality monitoring; routine and triggered sampling of high priority contaminants; public health surveillance; and, consumer complaint surveillance.

b) *Identification of Gaps and Prioritization of Research Needs.* Following completion of such an inventory of models and other tools,

The SAB recommends a comprehensive assessment and report of the gaps in the available resource systems, and a listing of needs for further development and research.

The list of gaps in the resource system inventory should be prioritized. This prioritization process should consider the environmental and human health consequences caused by missing tools or information, the impacts of related consequences (including spatial and temporal scales), and other relevant criteria. This analysis should enable optimization of the allocation of EPA resources to fill these gaps over the short-, intermediate- and long-term.

The SAB recommends that the listing of development and research needs (identified in the gap analysis) be prioritized and conveyed across the Agency.

Once gaps and research needs have been identified, the SAB would be pleased to review the results and offer its advice.

c) *Characteristics of Models, Tools and Resources.* Effective use of resource systems requires functionality and reliability under a wide variety of circumstances and conditions, including disaster response situations. These characteristics should include:

- *Portability*. To the extent possible, resource systems should be portable to allow transportation and usage in difficult field conditions. The systems should be designed to be field-ready.

- *Redundancy.* There should not be any single expert or expert-system that cannot be replaced in an emergency. Duplication of function is a necessity.
- *Interoperability.* Models and databases must be compatible with those from other agencies. Personnel with various backgrounds, and from other agencies, should be able to use them.
- *Resiliency.* These systems should be robust and have limited vulnerability. To the extent possible, resource systems should be able to operate when central power sources and direct internet access are not available, and they should not rely solely on standard communication lines to function.

d) *Dissemination and Maintenance of Resource Systems.* To achieve maximum effectiveness, resource systems must be disseminated to the full range of potential users, including first responders and long term-managers at the local and State level, in addition to EPA central office and regional staff and other federal agencies. Relevant databases such as the Toxics Release Inventory (TRI), which is under threat of losing essential data due to proposed changes in thresholds of reporting, is nationally computerized and available and should be preserved. The Chemical Storage Inventory under the Clean Air Act 112(r) is another example of data that can be helpful in emergency disaster planning and response and should be digitized for ready access by first responders. Resource systems should be maintained to keep their contents current, reliable and easily searchable.

The SAB recommends that EPA solicit feedback from users, particularly local and state personnel including first responders, and regional EPA managers, regarding resource systems and where necessary digitized databases to support improved disaster response decisions.

Periodic updates of resource systems should consider comments and criticisms from users. The results of audits of response performance following actual events and trials should also be used in maintenance and updating of resource systems.

e) *Document the Basis of Decisions.* During a disaster decision makers have little time and thus it would be inappropriate to require detailed written justification of all decisions that are made. At the same time, if the Agency is to learn from past experience, some documentation of the considerations and factors that lead to key decisions would be extremely valuable.

The SAB recommends that EPA develop simple streamlined methods to document the basis of decisions made in the course of managing environmental disasters.

For example, this might be as simple as equipping key decision makers with small digital audio recorders which would allow verbal documentation that could subsequently be transcribed.

f) *Audits of Event Response Performance.* EPA should play a special role as compiler and synthesizer of performance results and characteristics. The Agency often identifies problems which are commonly referred to as “lessons learned”, but "lessons" are not really "learned" and have little value until procedures and behaviors are changed (continuous improvement). While we are aware of and have read the reports by the Agency's Inspector General on EPA's performance during several recent environmental disasters, we are not persuaded that these sufficiently meet this need.

The SAB recommends that EPA perform and encourage performance audits of event responses by its staff at the local, state, regional and national level.

g) *Sensitivity of Resource Systems.* In some cases, components of resource systems developed by EPA may be too sensitive to warrant general release to the public or to local and state entities.

The SAB recommends that EPA carefully assess the content of its resource systems to evaluate the security risks associated with their release.

Criteria recommended by SAB for this evaluation include the ability of system resources to be used to implement an attack, or to optimize consequences of an attack. Examples of resource systems that have components with considerable risk associated with release include the “consequence modeling” component of the Water Sentinel program and, to a lesser extent, the incident modeling in Emergency Consequence Assessment Tool (ECAT). For example, if a calibrated Water Sentinel model for a specific utility falls into the wrong hands, it could be used against that utility by attacking them at their most vulnerable distribution system locations.

h) *Development of Resource Clearinghouse.* The SAB endorses efforts like those in ECAT to compile a wide breadth of information in a user-friendly form. This work should also include internet enabled tools (with and without security-related access controls) and coordination of spatial data bases (land use, land cover, census data, chemical plants). It is presumed that all counties in the US have an inventory of all chemical facilities, power plants, water and wastewater treatment facilities, hazardous waste generators, storage facilities, hospitals, research labs, universities, etc. located within their jurisdictional boundaries, in terms of types and amounts of potential contaminants and their coordinates. These inventories, as well as Federal databases in which EPA has primary authority, need to be updated annually. Thus,

The SAB recommends that EPA emphasize its role in the development of centralized and streamlined virtual libraries of references, guidance materials and models, and other resources.

Completion of the tasks outlined in this section should prove valuable to the small interdisciplinary Environmental Disaster Assessment Team recommended above in

Part 3 of this report, and that team should be consulted in the formulation and completion of these tasks. However, this team should not be given primary responsibility for completing these tasks so as not to divert its attention from the critically important job of identifying, ranking, assessing and planning for possible future environmental disasters.

5. QA/QC for Data During Emergencies

Field measurements made during the early stages of a disaster have a different purpose than field measurements made for long-term monitoring and remediation. Emergency responders and citizens need fast order-of-magnitude indications of the nature and level of hazards that they may face. Accordingly instrumentation, quality assurance procedures for authorizing the release of data, and measurement priorities need to be designed to appropriately meet those needs.

Many existing EPA data protocols do not emphasize rapid response, because they have been developed to meet the needs of long-term monitoring and regulatory activities. Especially in the early stages of an emergency, the quality of data may have to be balanced against the need to get information to users on the time-scale they require. This balance should be worked out in advance, so that procedures are already developed and approved before the emergency occurs, and a graceful transition can be achieved from rapid order-of-magnitude assessment to increasingly more time consuming and accurate characterizations as time goes by (See Figure 2 in Appendix A). While the SAB is pleased to see the creation of the Agency's Environmental Response Laboratory Network, with its focus on "screening/sentinel laboratories," "confirmatory laboratories," and "reference laboratories" this is an issue that warrants additional attention.

The SAB recommends that EPA develop procedures for rapid field measurement, data analysis and data release to the public during the early stages of emergencies, as well as protocols for how those procedures will be modified to assure greater precision and quality control as needed in later stages of the life-cycle of an environmental disaster.

6. Improved Communication and Public Consultation

Communication needs and content are highly context dependent. Before, during and after events, the goals and methods for effective communications should be different. For example, during an event when immediate protective actions are needed, rapid one-way approaches are critical. However, before and after events, these methods are rarely appropriate. In these periods, dialogues with decision makers, stakeholders and representatives of the public are key ways for building knowledge about current contexts and information needs and preferences. Development of messages based on knowledge and empirical testing enhances the probability of effective decisions and actions during events. Without such fundamental and current knowledge, communications may create problems where few or none existed.

Effective communication between many different parties is essential: a) in performing assessments and making plans before an environmental disaster occurs, b) in protecting human health and ecosystems during the initial stages of an environmental

disaster, and c) in managing long-term protection, clean-up and recovery from an environmental disaster.

Communications about environmental disaster requires two-way interactions within the U.S. EPA, across agencies, and with partners and the public.[4] In designing any communications program, one must ask the question: "How can information be transmitted to elicit well informed decisions and behavior by individuals, first responders, decision makers and organizations?"

Communications need to occur throughout the process of assessing, preparing for, and responding to environmental disasters. Of course, the purpose and form of the communication often needs to change at different stages along the life cycle of an event (Figure 2 Appendix A). For example, immediate protective guidance is often necessary during the initial response phase while there is great uncertainty, while more specific guidance is provided during later stages when more information is available and uncertainties have been reduced.

No aspect of communication is more important than communication with the public – including both those directly affected by the event and the general public. Too often, communication is seen as the one-way conveyance of facts, guidance and decisions from experts and those in charge to a passive receiving public. Sometimes in a crisis situation such one-way communication is necessary ("You need to stay in your house and seal the doors and window because a cloud of toxic gas is rapidly approaching"). As elaborated below, even in such situations, communications are likely to be far more effective if generic versions have been carefully developed, empirically evaluated and refined ahead of time through careful two-way interaction with individuals who are typical of the intended audience.

Recent years have witnessed considerable progress in developing a scientific basis for risk communication. The key insight from this work is that *a priori* there is no such thing as an expert in the design of the content of effective risk communication messages. It is essential to adopt an empirical approach. Unless one understands the way in which a recipient will interpret and understand a message, even as simple a message as "Take a wet cloth to cover your face in the event you find yourself being exposed," one can have no confidence that it will be properly understood.

Behavioral social scientists have developed a variety of strategies to determine, through empirical studies, the "mental models" that people adopt in thinking about risks (Fischhoff, 2005; Morgan *et al.*, 2002). They have also developed empirical strategies for testing and refining possible messages (Fischhoff, in press). Unfortunately, with almost no behavioral social scientists on staff, EPA does not possess the expertise to make use of such methods.[5]

---

[4]In this connection the EPA is developing and deploying an emergency management data architecture known as Emergency Management Portal (EMP). The office is also working closely with regions to establish communication standards and assure that needed equipment is available. Finally the Agency has developed a Crisis Communication Plan. However, none of these activities appear to be well informed by modern behavioral social science.

[5]EPA's National Homeland Security Research Center has run a series of workshops on "message mapping" (Covello et al., 2007). While these have identified many issues that deserve consideration in the event of

This absence of understanding and expertise also has implications for other aspects of EPA's mission. For this reason the SAB makes two related recommendations:

First, **ORD should re-establish its program in behavioral social science and risk communication research, perhaps by reinvigorating the very successful collaboration it once had with the NSF Program in Decision Research and Management Science (DRMS)**.

Second, in assembling the small interdisciplinary Environmental Disaster Assessment Team proposed above in Part 3, **at least one or two of the members should have a strong working understanding of, and ability to apply, modern methods of empirical social science for developing risk communication strategies, and the design, testing and refinement of risk communication messages.**

Frequent, transparent interactions with partners (within the Agency, across agencies, and with others) in advance of events are an important part of building communication readiness. Purposes of these interactions and related research include:

- Determination of how *people form their concepts of risk* and related issues, as well as how people make decisions and what information influences their decisions.
- Development and rigorous *pre-testing of consistent messages* for a variety of scenarios and receivers. Scenarios formulation should include representatives of the public and mass media to ensure that exercises involve their perspectives and gauge the likelihood of behaviors that would have significant impacts in real events. Representatives of other partners appropriate to the scenario should also be involved both in drills as well as in debriefings after exercises. During an event, zero tolerance for false positives often works against providing the public with timely and useful protective information. The tradeoffs in risks (e.g., public health and environmental vs. organizational) are important considerations that should be clearly identified and articulated by decision makers. When uncertainty prevents a definitive decision, warnings that include protective actions and specific guidance should be issued with a caveat to stay tuned in for more certain information. Pre-testing such messages would yield considerable insights about what will and will not work well in eliciting desirable behaviors.
- Anticipation of how *people would respond to communication initiatives* (messages and interactive engagements), especially under stressful conditions. Research is needed to identify how first responders, decision makers and the public are most likely to respond to communication initiatives.
- Empirical research involving formative and summative *evaluations* of risk communication activities is essential to ensure continuing progress.

In environmental disasters EPA should endeavor to ensure that information the Agency has developed gets to the persons or organization that are trusted by the intended receivers (in crisis conditions) or partners (in routine conditions). In some situations, another entity or person (e.g., local official or community leader) will be seen as a more

---

possible water security emergencies, no empirical studies are included of how various audiences might understand and interpret alternative messages.

trusted source of information. In those circumstances, the EPA should focus on getting the best possible information to that party and helping him/her promptly interpret and use the information correctly. In preparation for an event, EPA should a) recognize and be in contact with trusted *social networks* within a community, and discover the ways in which information is currently and rapidly *disseminated* (e.g., reverse 911, e-mail, instant messaging, YouTube and other networks)

There is an urgent need to improve consultation with the public on a variety of tough choices that many environmental disasters can present. An obvious example is decisions about "how clean is clean enough" when restoration to pre-disaster conditions is neither technically nor economically feasible. Effective mechanisms to perform such consultation are lacking.

The SAB recommends that the development, demonstration and evaluation of mechanisms for better including public values and preferences in clean-up decisions should be an element of the reinvigorated program of behavior research in ORD.

The SAB understands that EPA has developed a Crisis Communication Plan and already participates in a wide variety of multi-agency drills and exercises on disaster response. The SAB also recognizes that selected employees within EPA have been assigned to red or blue response teams, and they are already recognized for their capabilities in specialized areas of disaster response. These employees are expected to stop all other duties in the event of a disaster and devote themselves solely to the response for however long it takes. Such employees have laptop computers especially dedicated for disaster response, and they have successfully executed drills in “bunker” locations. However, it is our belief that shortcomings may still exist in the area of communications, and that the ability to locate and contact each person in the network during a disaster has not been given proper attention by the agency or by Homeland Security.

The SAB recommends that a failsafe method for communication among key members of the disaster response team be designed, implemented and tested on a regular basis.

Obviously, responders must be able also to communicate with critical models, databases, and decision support tools and convey the results of their analysis to responsible parties.

7. Summary and Restatement of Key Recommendations

Thinking broadly and becoming more anticipatory should be a goal of every agency. While it is doing a good job of addressing those aspects of environmental disasters for which it is responsible in the context of DHS National Planning Scenarios EPA would be well advised to *also* think more broadly and in a more anticipatory way about the full range of possible environmental disasters that could arise from natural causes, accidents or the actions of terrorists. To this end the Science Advisory Board recommends that the EPA:

a) Establish a small interdisciplinary Environmental Disaster Assessment Team of five to seven professionals who are charged with identifying, prioritizing and

assessing potential environmental disasters. This team should develop a system to identify potential environmental disasters, prioritize them based on probability and consequence, and identify common attributes and response strategies that could improve the efficiency and effectiveness of agency response.

b) The Environmental Disaster Assessment Team should perform, or arrange for others to perform, reasonably comprehensive assessments of those disasters deemed to be of greatest concern. It should then help and advise the Agency to further:

- Identify gaps in coverage by Federal, state and local authorities and needs for improved coverage, coordination and preplanning;
- Develop prior arrangements with experts and organizations who can provide the needed knowledge and skills and develop a geo-coded list of this expertise so that these connections can be made rapidly in an emergency;
- Identify short-term waivers to regulations and other rules that might be needed and prearranged mechanisms to achieve these waivers in a way that balances efficiency with protection and other objectives.

In support of the mission of the Agency's emergency response program, the SAB recommends that the EPA:

c) Examine and seek to learn from the best practices of other public and private organizations. In so doing, it should seek strategies by which it, and other responsible parties, might better:

- *anticipate, assess, plan for, and practice responses* to deal with major events that plausibly might occur in coming years;
- *learn rapidly* what is going on and develop a rapid and rough sense of what risks may exist to people and the environment*;*
- *effectively coordinate and communicate* with other key players including first responders and the public;
- *respond with flexibility* to the specific needs and circumstances of the event at hand, including the ability to adapt procedures and make real-time decisions when previous plans are not working;
- *delegate* decision authority to responsible individual in the field; and
- *mobilize* personnel and resources in a rapid and orderly way.

d) Compile an inventory of existing models, tools, data and resources, *including those that, while developed for other purposes, might be made useful for disaster response*; perform a comprehensive assessment and develop a report on the gaps in the available resource systems; solicit feedback from users of these tools, particularly local and state personnel and regional EPA managers, regarding resource systems; and identify further development and research needs. Since some of these tools may involve sensitive information, their content, and associated access policies should be carefully reviewed to assure an appropriate balance between needs of local and regional responder and the public and the necessity for protection against misuse. Emphasize EPA's role in development

of centralized and streamlined virtual libraries of references, guidance materials and models, and other resources.

e) Develop procedures for rapid field measurement, data analysis and data release during the early stages of emergencies, as well as protocols for how those procedures will be modified to assure greater precision and quality control as needed in later stages of the life-cycle of an environmental disaster.

f) Develop simple streamlined methods to document the basis of decisions made in the course of managing environmental disasters.

g) Conduct performance audits of event responses by EPA staff at the local, state, regional and national level.

h) Finally, to better ground its work on communications in modern behavioral social science, the SAB recommends that the EPA reinvigorate its program in behavioral social science research and application, perhaps by reestablishing the very successful collaboration it once had with NSF-DRMS. This should include: i) a strong program in empirically based methods of risk communication, and development, demonstration and evaluation of mechanisms for better including public values and preferences in post-disaster clean-up decisions.

References

Allison, Graham T. and Philip Zelikow, *Essence of Decision* Second Edition, Longman - Addison Wesley Longman, 1999, 416 pp.

Covello, Vincent, Scott Minamyer, Kathy Clayton, "Effective Risk and Crisis Communicaton during Water Security Emergencies: Summary report of EPA sponsored message mapping workshops," EPA/600/R-07/027, March 2007.

Fischhoff, B. (2005). Cognitive processes in stated preference methods. In K-G. Mäler & J. Vincent (Eds.), *Handbook of Environmental Economics*, pp. 937-968, Amsterdam: Elsevier.

Fischhoff, B. , "Risk perception and communication", in R.Detels, R.Beaglehole, M.A..Lansang, and M. Gulliford (eds), *Oxford Textbook of Public Health*, Fifth Edition, Oxford: Oxford University Press, in press.

Morgan, M. Granger, Baruch Fischhoff, Ann Bostrom and Cynthia Atman, *Risk Communication: A mental models approach*, 351pp., Cambridge University Press, New York, 2002.

SAB (1995), "Future Issues in Environmental Engineering," EPA-SAB_EEC-95-004, US EPA Science Advisory Board, Washington, DC.

SAB (1995), "Environmental Impacts of Natural Hazards: The need for Agency action," EPA-SAB_EEC-99-COM-003, US EPA Science Advisory Board, Washington, DC.

Smil, Vaclav, *Global Catastrophes and Trends: The Next 50 Years*, MIT Press, 320pp, 2008.

APPENDIX A

Tables, Figures, and Illustrations

Box 1: Summary of EPA's authorizations and responsibilities with respect to environmental disasters.

EPA has over 30 years experience in responding to releases of oil and hazardous materials under the National Contingency Plan (NCP) that was established and/or modified by the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), the Clean Water Act (CWA), and the Oil Pollution Act of 1990. Most of these responses do not rise to the level of Incidents of National Significance that are the focus of the National Response Framework (NRF) and the National Incident Management System (NIMS) which are required by various Homeland Security Presidential Directives (HSPDs). Typically, EPA receives over 30,000 release notifications per year (hazardous materials account for about 66% of the total notifications and oil spills for about 34%). Under this program EPA conducts 300 responses per year and assists in about 500 others. Specific EPA responses are to: i) environmental emergencies, ii) acutely hazardous sites/inland oil spills, iii) nationally-declared disasters, iv) terrorist incidents, and v) major national security events. Response activities include, but are not limited to: i) sampling and monitoring, ii) site screening, iii) decontamination, iv) disposal, v) dust mitigation, and vi) data management.

Under EPA's national approach to responses to Incidents of National Significance, the system that the Agency uses to respond to oil and hazardous material releases, under the NCP are integrated into the NRP and NIMS structure and are used when EPA responds within that structure as a part of the total national response to such incidents.

The National Response Framework provides a comprehensive and coordinated structure to prepare for and respond to all Incidents of National Significance. The NRP, coupled with the nationwide response template of the NIMS provides the response structure and mechanisms that enable government and nongovernmental agencies and organizations to provide an all-hazards approach to emergency response activities. The system established is able to address large-scale events needing national leadership (e.g., the Departments of Homeland Security, Justice, Defense, and Agencies such as EPA) for incident management and smaller events where localized management is more appropriate (e.g., state and local officials and organizations).

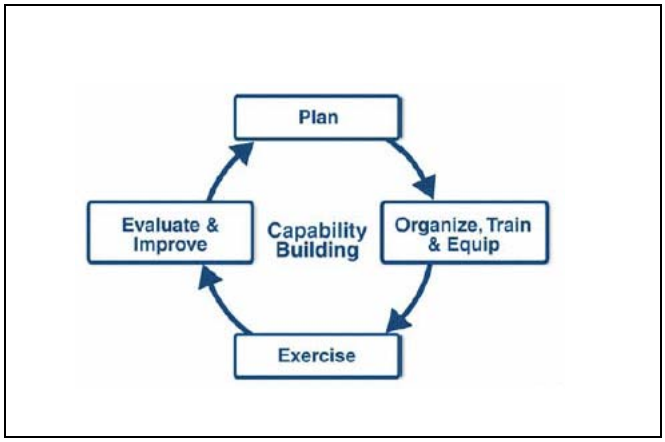

Figure 1: The preparedness cycle as outlined in the January 2008 National Response Framework. EPA has worked hard applying this approach to the aspects of many disasters for which it has primary responsibility.

Table 1: One possible example of a structure that EPA might use to develop a taxonomy of potential environmental disasters.

Natural events	**Events With Humans or their Systems in the Causal Chain**
Biologically related Disease (natural) Invasive species (natural) Geologically related Earthquake Flood plain events Volcanic eruptions Weather related Drought Flood (e.g., Tsunami, storm surge) Lightening Wildfire Wind (e.g., hurricane, tornado)	Complex network system failures Dam, levee, dike failures Disruption of network infrastructures (e.g., power, water, sewer, high-ways, rail, pipelines, etc.) Large structural collapse Nuclear events Human induced (unintentional and intentional) Biological Chemical release Explosions Fire Invasive species Radiological Water, air, food contamination

Note: While many of the items listed here involve precipitating events that happen suddenly, for completeness any such taxonomy should also include events that develop more gradually (e.g. droughts, invasive species) whose consequences are never-the-less disastrous. When more than one disturbance occurs, the response may be more extreme than would occur when these disturbances occur singly. (Paine et al., 1998)

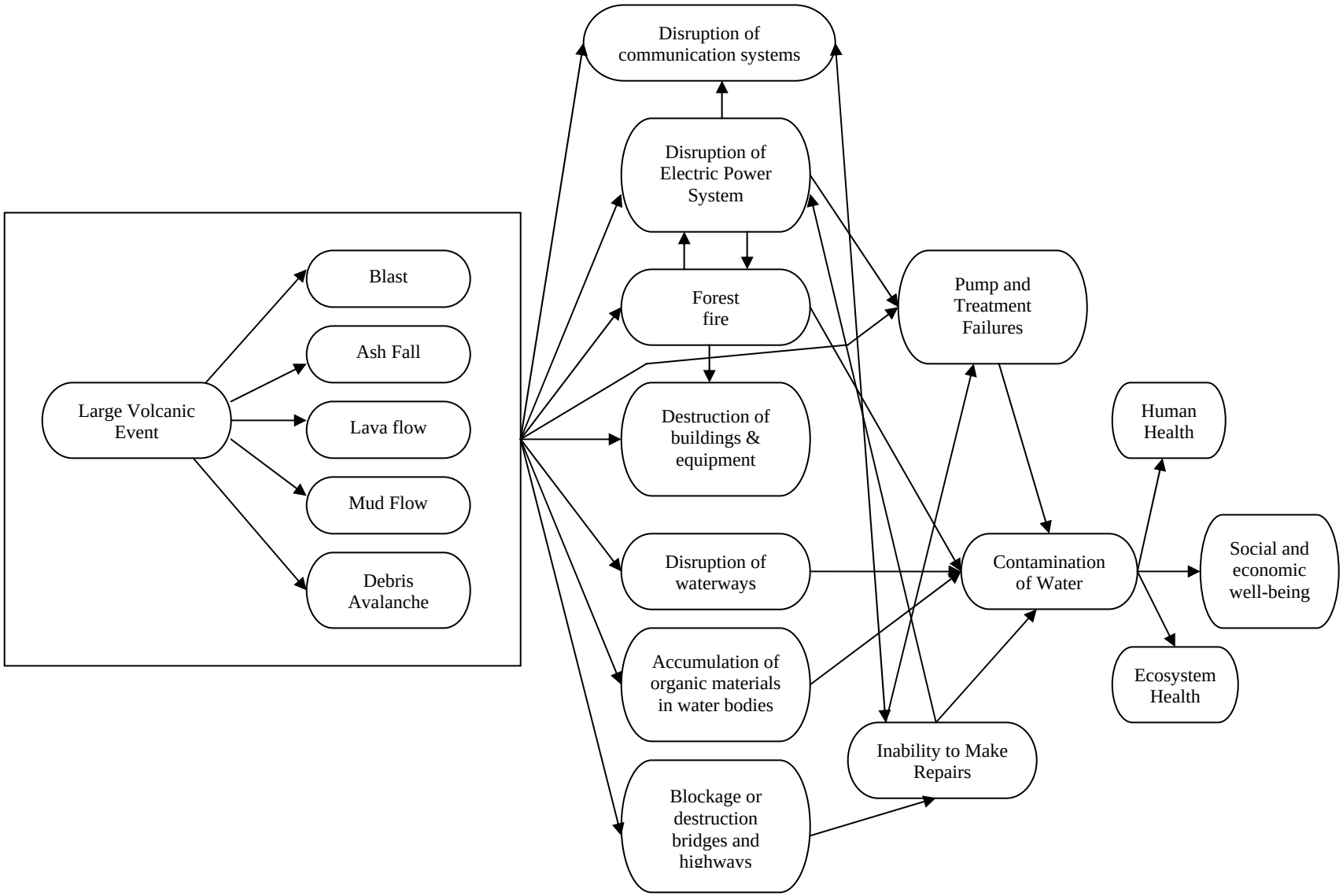

Figure 2: Simplified illustration of an influence diagram tracing some of the routes by which a volcanic event might result in sustained contamination of water supply

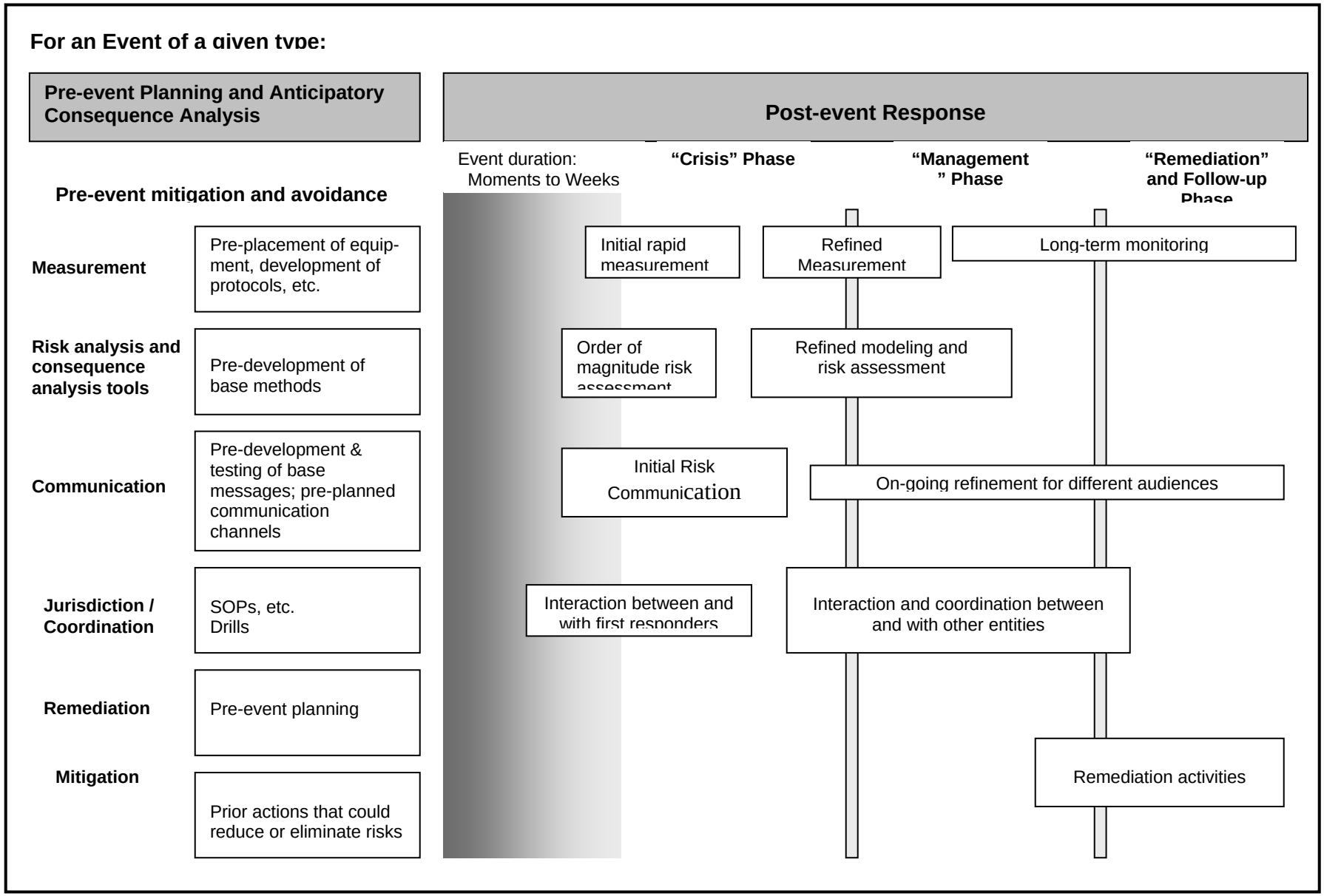

Figure 3. Pre- and post-event tasks for an environmental disaster. Many of the actions noted sh9ould be performed at the regional level.

APPENDIX B

Disaster Prevention and Management Experts Presenting Information to the SAB

Name	Organization
Mr. Joseph Becker	The American Red Cross
Mr. Patrick Brady	BNSF Railway
Ms. Debbie Dietrich	EPA Office of Emergency Management
Dr. Baruch Fischhoff	Carnegie Mellon University
Mr. Michael Lunsford	CSX Transportation
Ms. Suzanne Mattei	The Sierra Club
Dr. L.D. McMullen	Des Moines Water Works
Mr. Alan Nelson	Nuclear Energy Institute
Mr. Timothy Overton	Dow Chemical Company
Mr. Timothy Scott	Dow Chemical Company
Dr. Gayle Sugiyama	Lawrence Livermore National Laboratory
Ms. Dana Tulis	EPA Office of Emergency Management
Mr. William Wark	Unites States Chemical Safety and Hazard Investigation Board
Dr. Henry Willis	The Rand Corporation