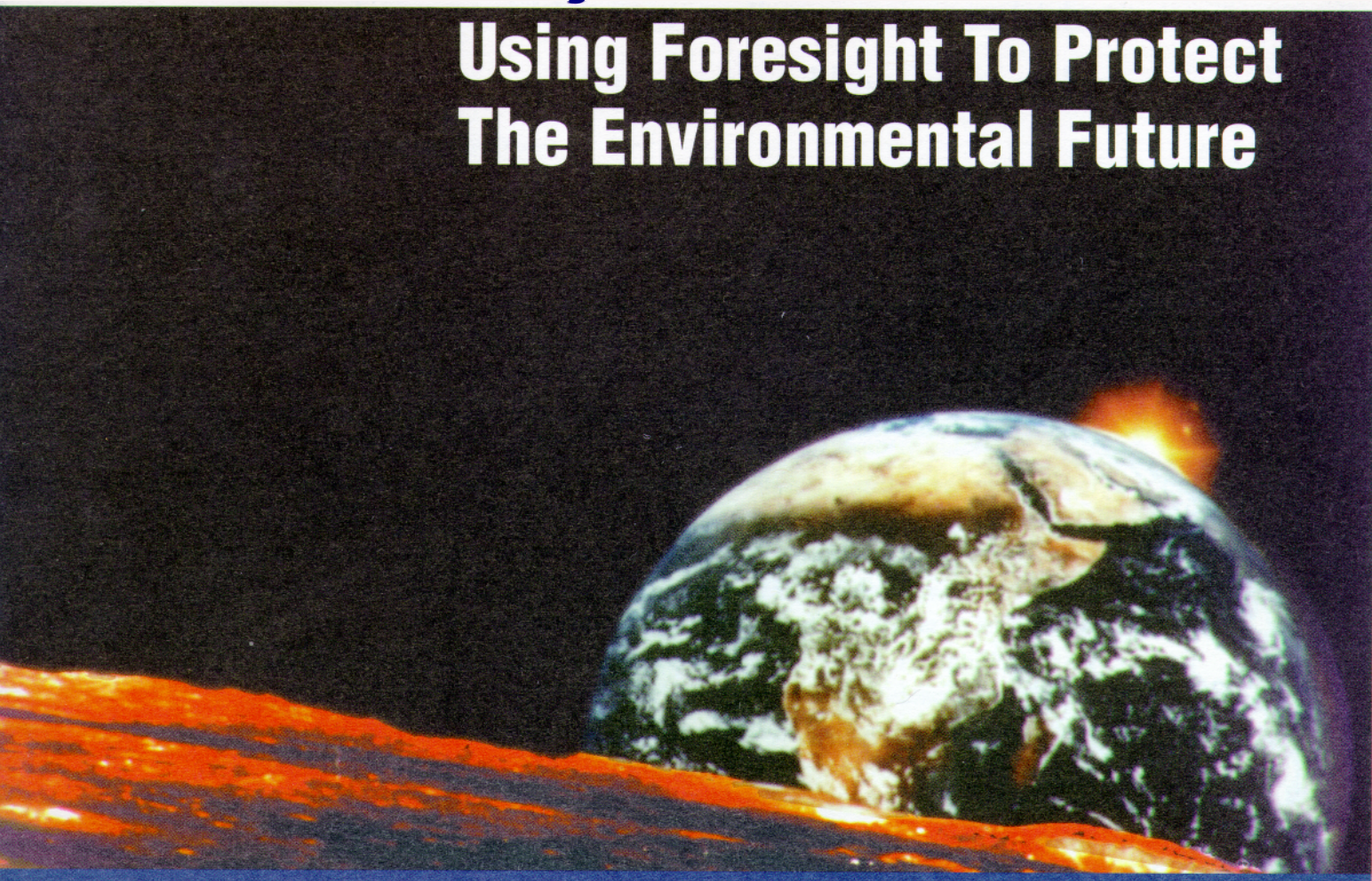
United States
Environmental Protection
Agency

Science Advisory
Board

January 1995
EPA-SAB-EC-95-007

EPA Beyond The Horizon:

Using Foresight To Protect The Environmental Future



U.S. Environmental Protection Agency
Science Advisory Board
Environmental Futures Committee
January 1995

"If we could first know where we are and whither we are tending, we could better judge what to do, and how to do it."

-Abraham Lincoln

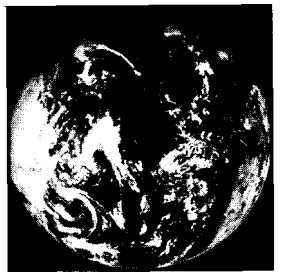
The Science Advisory Board (SAB) is a Congressionally-mandated, independent group of scientists, engineers, and other professionals who provide technical advice and information to the Administrator and other officials of the Environmental Protection Agency (EPA). The value of SAB's advice is a function of its independence from the Agency and the highly-qualified, balanced expertise it can apply to technical questions.

In most cases, the SAB assesses scientific or engineering issues related to environmental problems of immediate concern to EPA. On occasion, however, past EPA Administrators and the Congress have requested the SAB's formal opinion on matters related to EPA's future operations, research needs, management priorities, and budgets. In such cases, the SAB has provided advice with an explicitly future-oriented policy dimension.

For example, in September 1988 the SAB issued Future Risk: Research Strategies for the 1990s, which recommended ways to strengthen EPA's research capabilities and increase the emphasis on long-term research. In September 1990 the SAB released Reducing Risk: Setting Priorities and Strategies for Environmental Protection, which recommended that the Agency use relative risk to shape a more integrated, prioritized approach to environmental protection.

This report, Beyond the Horizon: Using Foresight to Protect the Environmental Future, also contains SAB findings and recommendations that have broad, future-oriented policy implications. The contents of this report reflect the findings and recommendations of the SAB, and they are not necessarily the views of EPA or any other Federal agency.

Cover photograph courtesy of the National Aeronautics and Space Administration (NASA)



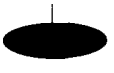
Beyond The Horizon: Using Foresight To Protect The Environmental Future

U.S. Environmental Protection Agency

Science Advisory Board

Environmental Futures Committee

January 1995



Printed on Recyc/ed Paper

Letter to the Administrator

January 15, 1995

Science Advisory Board
U.S. Environmental Protection Agency
Washington, DC 20460

Ms. Carol Browner
Administrator
U.S. Environmental Protection Agency
Washington, DC 20460

Dear Ms. Browner:

The Science Advisory Board is pleased to present to you our most recent report, *Beyond the Horizon: Using Foresight to Protect Our Environmental Future*. Prepared by the Environmental Futures Committee with the assistance of several SAB standing committees, this report responds to a request from you and Assistant Administrator David Gardiner to advise the Agency on ways to prepare for environmental problems that may emerge in the 21st century.

In the past, EPA's response to environmental problems has been driven by environmental deterioration, widespread public concern, Federal law, or a combination of the three. In virtually all cases, EPA has acted to reduce environmental threats that were immediate or near-term.

The SAB believes, however, that there is value for EPA, and for a prudent nation, in anticipating problems that may emerge in the future, and, if necessary, taking action in the present to reduce them or to avoid them entirely. The benefits of foresight are economic (as the costs of solving problems are reduced), environmental (as environmental losses are avoided), and social (as environmental debts are not passed on to future generations). For these reasons, the SAB in this report recommends that EPA, working with other appropriate organizations both inside and outside the government, develop a "futures" capability, a capability to anticipate future environmental conditions and analyze the actions needed to improve them.

The members of the Environmental Futures Committee recognize that EPA often is criticized for overreacting to immediate environmental problems, and for imposing costs out of proportion to the environmental risks involved. Such criticisms are likely to be directed at any Agency effort to anticipate possible future problems, or propose actions to address them before they emerge.

Nevertheless, such a futures capability IS desirable. In this report the SAB is not predicting that particular environmental problems will emerge in the future, nor are we suggesting the kinds or extent of the actions that EPA should take in the near term to avoid them. Rather, we strongly suggest that EPA should include, among its repertoire of technical and analytical skills, a capability to routinely and systematically study the range of possible environmental futures ahead, and advise the nation on possible actions in response.

All Americans-those of us alive today, and those of us to come-would be well served by this attentiveness to the future.

Sincerely, Dr. Raymond Loehr
Chair, Environmental Futures Committee

Dr. Genevieve Matanoski
Chair, Science Advisory Board

Contents

Executive Summary

1. Why Think About the Future? 1
2. The Environmental Futures Committee 3
3. A System of Inquiry 3
4. Beyond the Horizon 5
5. The Recommendations 5

Findings on Environmental Futures

1. The Forces of Change 7
2. Current Uses of Foresight 9
3. Foresight Methodologies 11
4. The Value-and Uncertainty-of Foresight.. 12
5. Possible Emerging Problem Areas.. 13
6. The Environment: A Strategic National Interest 17
7. Thinking of Futures at EPA 18

Recommendations On Environmental Futures

Recommendation 1 21

Recommendation 2 22

Recommendation 3 22

Recommendation 4 25

Recommendation 5 29

Science Advisory Board
Environmental Futures Committee

Chair

Dr. Raymond Loehr
H. M. Alharthy Centennial Chair and Professor
Environmental and Water Resources Program
The University of Texas at Austin
Austin, TX

Members[1]

Mr. Alvin Alm
Sector Vice President
Science Applications International Corporation
McLean, VA

Mr. Richard Conway
Senior Corporate Fellow
Union Carbide Corporation
South Charleston, WV
(Liaison to the Environmental Engineering Committee)

Dr. Paul Deisler
(Retired)
Austin, TX

Dr. Kenneth Dickson
Director, Institute of Applied Science
University of North Texas
Denton, TX
(Liaison to the Ecological Processes and Effects Committee)

Mr. Theodore J. Gordon
(Retired)
Vero Beach, FL

Mr. Fred Hansen[2]
Director, Oregon Department of Environmental Quality
Portland, OR

Dr. Morton Lippmann
Institute for Environmental Medicine
New York University
Tuxedo, NY
(Liaison to the Indoor Air Quality and Total Human Exposure Committee)

Dr. Genevieve M. Matanoski
Department of Epidemiology
School of Public Health
The Johns Hopkins University
Baltimore, MD
(Executive Committee Chair and Liaison to the Radiation Advisory Committee)

Dr. Paulette Middleton
Science & Policy Associates, Inc.
Boulder, CO
(Liaison to the Clean Air Scientific Advisory Committee)

Dr. Verne Ray
Medical Research Laboratory
Pfizer Inc.
Groton, CT
(Liaison to the Drinking Water Committee)

Dr. Terry Yosie
Vice President
E. Bruce Harrison Company
Washington, DC

Designated Federal Officals

Dr. Edward S. Bender

Mr. A. Robert Flaak

Staff Secretaries

Ms. Diana L. Pozun

Ms. Lori Anne Gross

[2] The Committee also was assisted by Ms. Linda Greer, Natural Resources Defense Council (Washington, DC).

[3] Mr. Hansen served on the Environmental Futures Committee from December 1993 until September 1994, when he resigned to become the Deputy Admimstrator of EPA.

1. Why Think About the Future?

For the past quarter century, the basic approach to environmental protection in this country has been, for the most part, reactive. Institutions have been established, laws passed, and regulations written in response to problems that already were posing substantial ecological and public health risks and costs, or that already were causing deep-seated public concern.

Since its inception, the Environmental Protection Agency (EPA)-like the nation-has focused its environmental attention almost exclusively on the present and the past. The political will to establish the Agency grew out of a series of highly-publicized, well-advanced environmental problems, like the fire on the Cuyahoga River, smog in Los Angeles, and the near-extinction of the bald eagle. During the 1970s and 1980s, the U.S. Congress enacted a series of laws intended to solve serious existing environmental problems, and EPA was given the responsibility to administer most of them. The Superfund program, by definition, was intended to clean up the environmental mistakes of the past. Even those EPA activities like pollution prevention programs and new source performance standards, that are intended explicitly to avoid future problems, are given impetus by problems that already exist.

Despite the nation's demonstrable success in ameliorating a number of existing environmental problems, an almost exclusive reliance on after-the-fact response (i.e., not responding to environmental problems until they pose immediate and unambiguous risks) will not protect the environment adequately in the future. It is essential for EPA-and for other agencies and organizations whose activities affect the environment-to begin to *anticipate* future environmental problems, and then take steps to avoid them, not **just** respond to them after the fact. Indeed, one of the most important lessons taught by this country's environmental history is that the failure to think about the future environmental consequences of prospective social, economic, and technological changes (i.e., the failure to engage in environmental foresight) may impose substantial-and avoidable-economic and environmental costs on future generations.

Thinking about the future is more important today than ever before, because ever-faster change is shrinking the distance between the present and the future. Technological capabilities-in computers, for example-that seemed beyond the horizon just a few years ago are now out-dated. Scientific understanding and the flow of information are accelerating. Similarly, the environmental effects of global economic activity are being felt more rapidly by both nations and individuals.

As a result, traditional responses to environmental problems, i.e., the actions taken by government or the private sector to solve problems after they emerge, will not be effective enough, or take effect quickly enough, to protect vital economic and environmental resources. If, for example, natural habitats such as temperate forests deteriorated quickly and extensively, it probably would be too late to save many indigenous species by the time population declines were noticed. In short, the increased pace of economic and technological change dictates an increased emphasis on foresight to protect the environment over the long term.

Thinking about the future is valuable because, by initiating thought and analysis well in advance of anticipated

"When one generation's behavior necessitates environmental remediation in the future, a burden of environmental debt is bequeathed to its children just as surely as unbalanced government budgets bequeath a burden of future financial debt."

change, it can shorten the time needed and improve the quality of the response to such change, were it to occur, and reduce-or avoid entirely-the losses that result when pollution problems persist over time. Because such losses may be irreversible, response time may well be a critical measure of society's ability to protect environmental quality in the future.

The bald eagle has soared back from the edge of extinction, but the loss of that species very nearly became irreversible because of inattention to the possible side effects of some pesticides. Even when losses are potentially reversible, like the respiratory effects that result from short-term human exposure to ground-level ozone, high costs may be imposed on human health or the economy before ozone exposures are reduced.

Thinking about the future also is valuable because the cost of avoiding a problem is often far less than the cost of solving it later. The national experience with hazardous waste disposal provides a compelling example. Some private companies and Federal facilities undoubtedly saved money in the short term by disposing of hazardous wastes inadequately, but those savings were dwarfed by the cost of cleaning up hazardous waste sites years later. In that case, foresight could have saved private industry, insurance companies, and the Federal government (i.e., taxpayers) billions of dollars, while reducing the pollutant exposures-and resulting anxieties-in neighboring communities.

Besides reducing both the response time and the cost of protective actions, thinking about the future also can help preserve a wider variety of response options. For example, there are several ways to limit the potential future effects of solid waste disposal on groundwater, e.g., improving disposal facilities, separating wastes before disposal, preventing waste generation, and recycling. There are fewer-and more expensive-alternatives for cleaning up groundwater after contamination. Environmental foresight preserves flexibility for the future.

Thinking about the future has another value, one that goes beyond the immediate costs and benefits of environmental protection. Actions driven by environmental foresight can help strengthen intergenerational equity by preserving the environmental inheritance of future generations. When one generation's behavior necessitates environmental remediation in the future, a burden of environmental debt is bequeathed to its children just as surely as unbalanced government budgets bequeath a burden of future financial debt. By anticipating the emergence of environmental problems, and by taking steps now to prevent them, the present generation can minimize the environmental and financial debts that future generations will incur.

Finally, thinking about the future is valuable because it allows people to shape the world in which they live. The future undoubtedly will be different from the present; change is inexorable.

But humanity is not powerless in the face of change. The kinds of change that will occur, and their effects on the environment, are not inevitable and immutable. The future can be changed-and improved-through commitment and action in the present.

In summary, environmental foresight can help identify potential issues and options for action that, if taken today, would help protect the environment from the adverse effects of future change. By thinking of the future, by engaging in environmental foresight, the American people can better understand the full range of risks and opportunities-environmental and economic-possible in the future, and then better define the actions needed today to reduce the risks and preserve the opportunities.

2. The Environmental Futures Committee

In July 1993, EPA Administrator Carol Browner and David Gardiner, the EPA Assistant Administrator for the Office of Policy, Planning, and Evaluation (OPPE), asked the Science Advisory Board (SAB) to investigate environmental futures. They solicited the SAB's advice on the value of anticipating environmental problems that might emerge in the future, the tools that might be used to anticipate them, and examples of possible emerging ecological and human health problems. In other words, EPA asked the SAB to apply its scientific expertise, look beyond the horizon, and then advise the Agency on the use of foresight as a tool for protecting the environment for future generations.

In response to EPA's request, the SAB formed the Environmental Futures Committee (EFC) to undertake a study of environmental foresight. (The members of the EFC are listed at the front of this report.) The EFC's major objectives were to:

- Assess different methodologies currently being used to study possible futures and anticipate likely future events;
- Identify some environmental issues that could emerge over the long term (through the year 2025); and
- Advise EPA on ways to incorporate futures research into the Agency's activities.

This report, *Beyond the Horizon: Using Foresight to Protect the Environmental Future,* summarizes the results of the EFC's study.

To support its investigation into environmental futures, the EFC held more than a dozen public meetings and six fact-finding sessions with various organizations inside and outside the Federal government. The individuals and organizations that provided information for this report are listed in Appendix I of the technical annex.

In addition, five of the SAB's standing committees prepared full reports that include conclusions and recommendations related to possible future environmental issues in their areas of special expertise. These reports, which contain more detailed information than this summary report, are available to the public. Information on how to obtain them, together with a short description of each standing committee's conclusions and recommendations, can be found at the back of this report.

3. A System of Inquiry

To meet the objectives of this study, the EFC first outlined a formal system of inquiry capable of anticipating possible environmental issues that could emerge over the next five to 30 years. Then it tested that system in order to define specific issues that could emerge. Thus, the EFC not only delineated the various methodologies currently available to futures research, but it tested one of them. Both elements-the generic analysis and the specific application-contributed to the conclusions and recommendations in this report.

> "...looking beyond the horizon is essential to the nation's future success in protecting the environment."

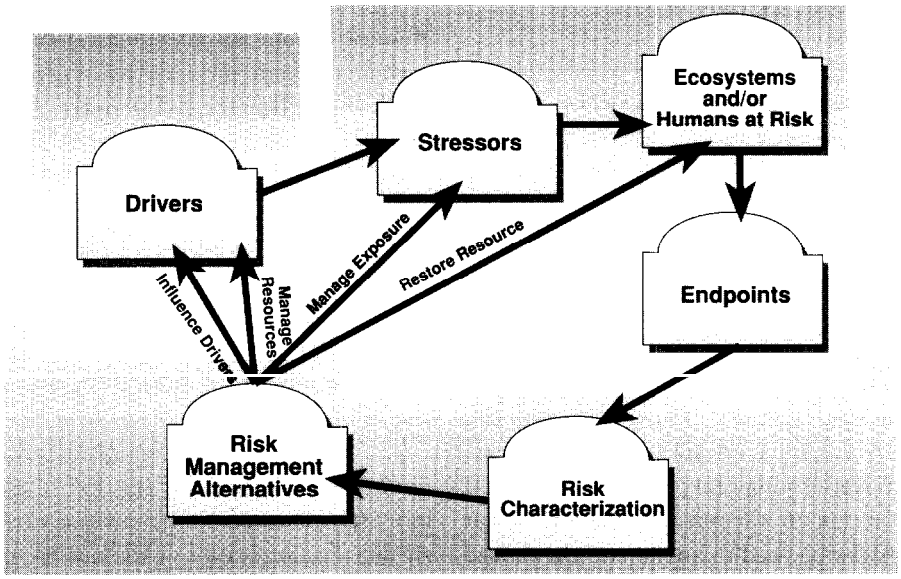
From the outset, the EFC recognized that it was not possible to anticipate future environmental problems without attempting to identify the large social, economic, and technological forces that were likely to drive future changes in environmental conditions. Such drivers (e.g., population growth, economic expansion) can generate environmental stressors (e.g., habitat alteration, global climate change) that cause adverse effects on specific human health and ecological endpoints (loss of particular species, lung cancer in humans). Figure 1 presents a conceptual model of the relationship between drivers, stressors, and endpoints.

Because understanding the drivers of change is critical to understanding change itself, the EFC attempted to identify possible drivers of environmental change in the future. Although there are many such drivers, the EFC identified four as especially important: population growth and urbanization, economic expansion and resource consumption, technological development, and environmental attitudes and institutions. These drivers are discussed in more detail in Section 4 of the technical annex to this report.

The EFC also reviewed methodologies currently available for anticipating environmental issues that could emerge in the future. A detailed summary of these methodologies is presented in Section 3 of the technical annex.

Finally, by applying one of the foresight methodologies, the EFC compiled an initial list of possible future environmental issues. A more detailed discussion of these issues is contained in Section 5 of the technical annex.

Figure 1. Conceptual Model of Drivers, Stressors, and Endpoints



4. Beyond the Horizon

The process of assessing and applying the formal system of inquiry called futures research led the EFC to the major conclusions of this report: **EPA, and other agencies and organizations whose activities affect the environment, should give as much attention to avoiding future environmental problems as to controlling current ones. In particular, EPA should establish a strong environmental futures capability that serves as an early-warning system for emerging environmental problems.**

Because EPA is responsible for protecting the environment now and over the long term, the Agency has an obligation to search for the "weak signals" that portend future risk to human health and to ecosystems, and that provide early clues about how to ameliorate or avoid those problems entirely. EPA's futures research should be global in scope, eclectic in its use of information sources, and quantitative whenever possible. It should be continuous, interactive with other organizations, and subject to scrutiny from outside the Agency. It should be linked to the futures research of other agencies and organizations, and its results should be shared openly with the public.

EPA's traditional methods of identifying-and solving-environmental problems will not be adequate to protect against problems that may emerge several years-or decades-from now. They were not designed to determine the costs of future environmental problems or the benefits of actions taken today to avoid them, both of which are difficult to estimate accurately. Futures research has to be extraordinarily tolerant of omissions, uncertainties, inaccuracies, and errors, because any view beyond the horizon is inevitably dim.

Yet looking beyond the horizon is essential to the nation's future success in protecting the environment. Protecting the future with foresight is a critical part of EPA's responsibility, and it is a forward-looking extension of the pollution prevention concept.

EPA alone is not responsible for looking beyond the horizon in order to protect future environmental quality. Many other organizations, both inside and outside of government, have substantial roles to play. Thus, this summary report contains detailed recommendations intended to help EPA, other Federal agencies, the private sector, and the nation clarify their view of, and better protect, the environment of the future.

5. The Recommendations

As society plans for the future, it is legitimate and appropriate for EPA to take responsibility for anticipating and attempting to mitigate future environmental problems, particularly those that may be only "dots on the horizon" now, but whose potential effects in the future may be large. An anticipatory role is especially appropriate, given the fact that some future environmental problems will be different, and possibly more far-reaching, than environmental problems in the past.

EPA cannot undertake this effort by itself. The involvement of many other agencies and organizations, as well as the private sector and the general public-all of whose activities affect environmental quality-is essential to the success of this forward-looking, evaluative, and ultimately pollution-preventing effort.

This report does not predict or even suggest that environmental calamities are inevitable in the future. Rather, through the investigation of future possibilities, this report emphasizes the value of anticipating, understanding, and-if necessary-responding to environmental problems before they emerge in the future, rather than continuing to play "catch-up" with problems **after** they emerge. The following recommendations are intended to strengthen the nation's ability to protect the future using the tools of foresight.

Summary of Recommendations

1. As much attention should be given to avoiding future environmental problems as to controlling current ones.

EPA should incorporate futures research and analysis into all of its programs and activities, particularly strategic planning and budgeting, and then be prepared to act-in conjunction with other public and private-sector organizations-on the basis of that information.

2. As an essential part of its futures capabilities, EPA should establish an early-warning system to identify potential future environmental risks.

Working with other agencies and organizations as appropriate, EPA should establish a look-out panel-made up of individuals from inside and outside government-to provide the Agency, and the nation, with an early warning of environmental issues that may emerge in the future.

3. In a longer-term, more comprehensive effort, EPA should evaluate five overarching problem areas related to a number of potential future environmental issues.

As EPA strengthens its futures capabilities, it should pay particular-and ongoing-attention to five major problem areas:

- Sustainability of terrestrial ecosystems;
- Non-cancer human health effects;
- Total air pollutant loadings;
- Non-traditional environmental stressors; and
- Health of the oceans.

4. EPA should stimulate coordinated national efforts to anticipate and respond to environmental change.

Because an integrated, national effort is essential to environmental protection, EPA should spur cooperative activities among Federal agencies, different levels of government, and the private sector in four key areas:

- Improving and integrating environment-related futures studies;
- Focusing attention on the broad causes of environmental change, not just the end results;
- Improving environmental awareness and education; and
- Establishing a broad-based data system for anticipating future environmental risks.

5. EPA, as well as other agencies and organizations, should recognize that global environmental quality is a matter of strategic national interest.

Recognizing that the United States is part of a global ecosystem that is affected by the actions of all countries, EPA should begin working with relevant agencies and organizations to develop strategic national policies that link national security, foreign relatrons, environmental quality, and economic growth.

1. The Forces of Change

Large social, economic, technological, and institutional forces will cause future environmental risks that are potentially greater than those currently recognized and managed.

Any attempt to anticipate future change must begin with the forces that drive such change. These forces-so-called "drivers''-suggest how change will manifest itself in the future, and how the environmental effects of such change can be altered by action in the present.

Environmental foresight requires an understanding of the large social, economic, technological, and institutional forces that contain the seeds of future environmental problems. Although many forces-seen and unforeseen-no doubt will affect future environmental quality, four of the most likely-and important-are: 1) the increase and rapid urbanization of global populations; 2) economic expansion and related energy use and natural resource consumption; 3) technological advances; and 4) the environmental attitudes and institutions that reflect and condition the responses of people everywhere to environmental change.

These drivers are interdependent, and the changes they drive could have both positive and negative effects on the environment. Population growth and higher per capita income, for example, most likely will drive increased demands for energy, natural resources, and manufactured goods. At the same time, higher per capita income, combined with improved education and an expanded range of personal choices, could reduce population pressures, while cleaner fuels and higher end-use efficiencies could reduce the local and global environmental effects of increased energy use. Technological changes could either exacerbate or ameliorate environmental pressures.

Clearly, the drivers of future change are not static, passive forces. They are the consequences of personal, community, and national choices. Thus the drivers of change are themselves subject to change, and, viewed separately, they suggest the range, significance, and complexity of the forces that will affect environmental quality in the future.

Population Growth and Urbanization

The continuing growth in human population, and the concentration of growing populations in large urban areas, will pose enormous environmental challenges in the future. The United Nations projects that the global population will increase from 5.6 billion currently to between 7.9 and 12 billion by the year 2050. (See Figure 2.) Urban areas will grow even faster, thus increasing the number of megacities with populations numbering from 10 to 20 million or more. As populations become more concentrated, environmental problems will intensify. Providing safe drinking water, wastewater and solid waste disposal systems, as well as environmentally-sustainable transportation systems will pose a daunting challenge in urban areas worldwide, including in some parts of the United States. Failure to provide for those needs will contribute to new or exacerbated environmental problems that could have regional or international social, economic, and political ramifications.

Economic Expansion and Resource Consumption

Over the next 20 years, per capita income in many developing countries is likely to increase. Currently, Latin

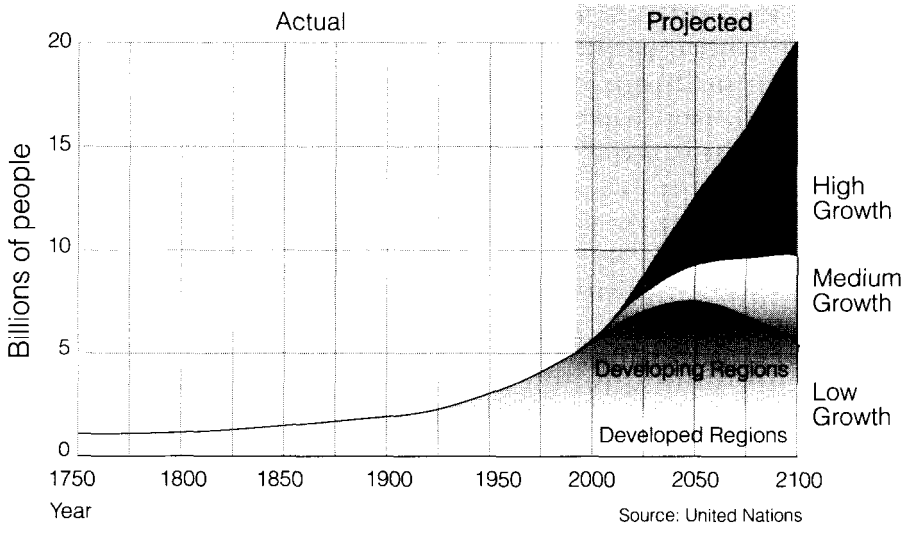
America and the Asian Pacific Rim economies are experiencing rapid economic growth, and substantial growth also is likely in other Asian nations and Central and Eastern Europe. This development, coupled with population growth, will result in greater consumption of energy, natural resources, and consumer goods.

Although recent U.S. and Western European experience indicates that energy use does not necessarily grow in direct proportion to economic growth, there is little doubt that energy use will rise dramatically in the developing world over the next 20 to 30 years. According to Department of Energy projections, energy demand in developing nations is likely to reach 240 quadrillion BTUs (quads) by the year 2010, an increase of over 40 percent in 20 years. During the same period, U.S. energy demand is projected to reach 105 quads, a 26 percent increase. By 2010, developing nations could account for more than half of the world's total energy demand. This level of growth is likely, even if per capita energy consumption in developing countries remains at much lower levels than in the industrialized world.

The fuels used to provide energy could have a profound impact on the environment. If countries such as China and India choose to generate electricity with conventional coal technologies and minimum pollution controls, the local, regional, and global environmental impacts could be substantial. On the other hand, alternative fuels and higher energy efficiency could help reduce those effects.

The potentially devastating effects of population growth, economic expansion, and individual behavior on natural resources already are evident in many parts of the world. All major ocean fishing areas presently are being fished at or beyond capacity, according to the United Nations, and global per capita seafood supplies have declined by nine percent within the past five years. (See Figure 3.) Approximately 5 - 10 percent of the world's living reefs-the rainforests of the oceans-have died because of economic activity along coastlines and in coastal waters. Continuation of trends like these, especially in light of expected population growth, would have adverse environmental and economic consequences for people everywhere.

Figure 2. Population Growth, 1750-2100



Technological Development

Throughout history, technological change has been one of the most important factors driving economic and environmental change. Technology is likely to play an even greater role in the future, as technological development proceeds at a faster pace and has a more pervasive impact on societies and individuals.

In the past, the adverse environmental effects of growing populations and expanding economies have been ameliorated by the development of new technologies-centralized wastewater treatment systems, for example. Technological advances in the future (e.g., cleaner fuels, more energy-efficient transportation and power distribution systems, less wasteful manufacturing processes) are likely to yield similar environmental benefits.

At the same time, new products (e.g., alternative transportation fuels) and materials (e.g., in photovoltaic cells or next-generation batteries) may result in new exposures and pose potential new risks to human health and ecosystems. In this sense, the future will be much like the past: technological change will bring with it both environmental improvements and environmental problems.

One of the central challenges facing society today is anticipating the likely environmental effects of future technological development, and including a concern for environmental quality in the design of future technologies and products. New technologies-in transportation, communications, health care, and manufacturing-undoubtedly will change the world of the future; many of those changes will have environmental benefits. But neither society nor industry can afford to wait until then to begin addressing the environmental problems those technologies may bring with them.

Environmental Attitudes and Institutions

In the long run, environmental quality is not determined solely by the actions of governments, regulated industries, or non-government organizations. It is largely a function of the decisions and behavior of individuals, families, businesses, and communities everywhere. Consequently, the extent of environmental awareness and the strength of environmental institutions will be two critical factors driving changes in environmental quality in the future.

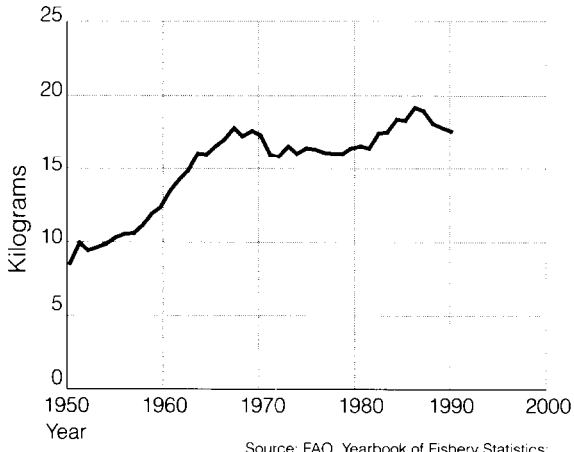
A concerned, educated public, acting through responsive local, national, and international institutions, will serve as effective agents for avoiding future environmental problems, no matter what they are. Environmental institutions, strengthened by informed public support, will play a critical role in devising and implementing effective national and international responses to emerging issues.

There are several promising ways to shape environmental attitudes and institutions, and thus help protect the environmental future. These include empowering women worldwide to reduce population growth, educating consumers on the benefits of purchasing environmentally-preferable products, and strengthening the ability of non-government organizations to provide technical assistance, training, and other services to support public health and ecosystem protection in developed and developing nations.

2. Current Uses of Foresight

Foresight-or futures research and analysis-already is being used by government, private business, and non-government organizations to anticipate future change.

Figure 3. World Fish Catch Per Person, 1950-92



Source: FAO, Yearbook of Fishery Statistics: Catches and Landings (Rome: various years)

Some government agencies, private businesses, and non-government organizations already use foresight-or futures research and analysis, as it is sometimes called-in planning, goal-setting, and policy-shaping. Although different organizations use foresight for different purposes, in all cases the participation of management in the foresight process has been essential to its success.

While most futures studies focus on the nearer term (less than five years), some reach considerably further into the future. For example, within the Federal government, several agencies use quantitative forecasting techniques that employ statistical models to project long-term future conditions. The Energy Information Administration within the Department of Energy develops detailed energy use projections as far as 20 years into the future. With a shorter-term focus, the Internal Revenue Service, the Department of Defense, and the intelligence community employ scanning systems and trend analysis as part of institutional planning. The Department of Defense uses "gaming" exercises to anticipate the possible circumstances of future warfare and prepare a range of options in response.

Over the past several years, many regional, state, and local governments have applied the tools of foresight to assess issues associated with demographics, economic development, global climate change, education, criminal justice, and agriculture. To date, 30 states have established State Futures Commissions to help set long-term goals, strategies, and action agendas for the states.

A number of foresight activities have been supported by the governments of other countries and by international organizations (e.g., the Organization for Economic Cooperation and Development, the World Bank). The Dutch government, in particular, has been a leading advocate for national-level foresight and long-range planning. Five Dutch ministries currently are sponsoring a research program to identify new technologies or technical systems that will support economic growth and environmental quality 50 years in the future.

In the private sector, foresight generally is used in relatively short-term business planning in several ways: to anticipate changing circumstances that can affect markets or competitive forces; to forecast the size of current and potential markets under varying assumptions about price and competition; to select a set of corporate financial and other goals; and to elicit and test corporate strategy and potential actions. The techniques used in the private sector include demographic and geographic analyses, statistical consumer polling, formalized environmental scanning, scenario construction, expert panels, and econometrics and other forms of computer modeling.

Examples of corporations that use such techniques can be found in essentially all industries, including communications, electronics, transportation, finance, energy, publishing, insurance, agriculture, manufacturing, pharmaceuticals, health care, and biotechnology. Underlying these corporate activities is the central assumption that opportunities can be discovered and problems avoided by thinking about what lies ahead.

EPA has relatively little institutional experience with futures research. A small Futures Office has been established to identify and test environmental foresight tools, and futures research is beginning to shape policy decisions in some program offices. For example, EPA has been working with other government agencies to anticipate and respond to the possibility of global climate change, since measurements of carbon dioxide buildup in the atmosphere have provided an early warning of possible global warming. In order to avoid potential environmental problems in the future, the Agency has begun working with other Federal and state agencies to encourage energy conservation and thus reduce or limit carbon dioxide emissions. (See Figure 4.)

3. Foresight Methodologies

Futures research and analysis can be systematically organized as an early-warning system to identify-and then help prevent-future environmental problems.

In general, there are three basic techniques widely used to identify possible future conditions. One is a top-down approach; it involves the use of "scenarios" that postulate certain circumstances about the future and then draw some likely implications from those circumstances. The second is a bottom-up approach; it draws future implications from early warning signals, which are based either on the extrapolation of current data and trends, or on the observations of knowledgeable individuals-so-called "look-out panels." The third is *scanning,* which involves a continual, planned, deliberate, and thorough review of selected published information, and contacts with other "futures watching" organizations.

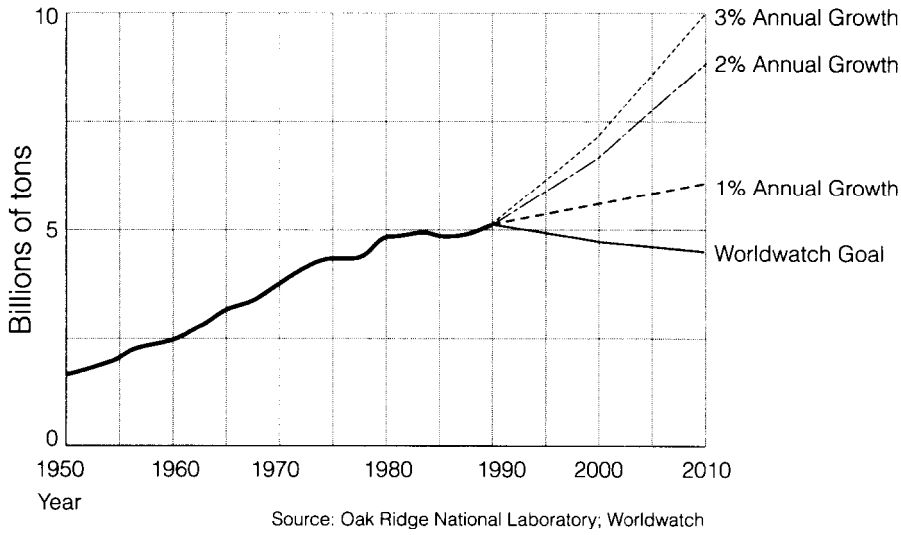
All three approaches individually-and particularly in combination-can provide valuable insights into the possible emergence of environmental problems in the future. (Figure 5 shows the major features of an environmental foresight process.)

In the first case, the top-down approach, scenarios are constructed to study the environmental implications of assumed future developments in "drivers" like energy use, population growth and density, technological advances, waste generation, and demand for natural resources like potable water. These images of possible futures can be studied systematically to estimate when and where environmental problems could emerge, and to assess different types of policies that could be used to obviate them.

Within a given scenario, assumptions concerning the future can be varied to reflect different rates of change (e.g., in energy use, population growth). Postulated conditions about the future also can be changed to reflect a future that is *possible* (exploratory scenarios), or a future that is desirable (normative scenarios). As long as these scenarios display changes in important variables over time within a consistent analytical framework, they can be useful tools for anticipating environmental problems in the future, and analyzing the range of possible responses to them.

In the second case, the bottom-up approach, a specialized "look-out panel" can provide perceptions, observations, and information about important environmental changes on--or just beyond-the horizon. Look-out panels, which can include laboratory scientists, professional

Figure 4. Carbon Emissions from Fossil Fuels, 1950-2010



Source: Oak Ridge National Laboratory; Worldwatch

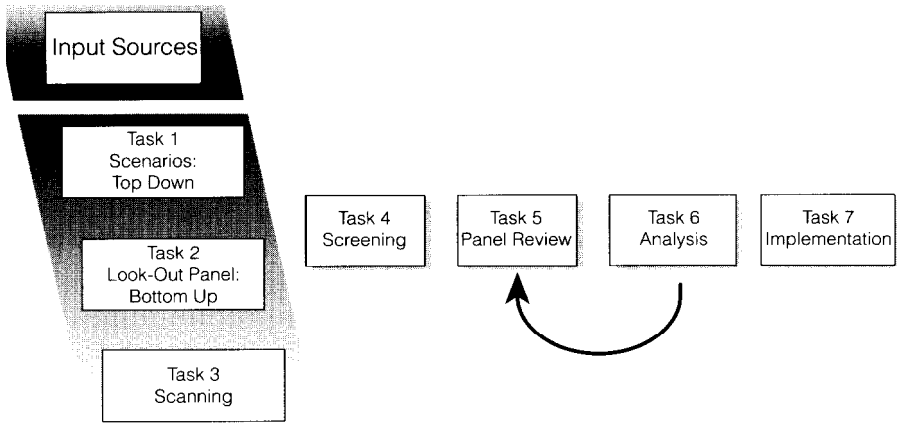
field data collectors, or neighborhood volunteers, function continuously. Through systematic questioning and feedback, panelists can provide observations about the environment that can serve as early warnings of environmental changes, and they can assess the implications of these changes to human health and ecosystem viability.

In the third case, information related to emerging environmental problems can be gleaned from scholarly journals, newspapers, newsletters, business plans, and science-oriented computer bulletin boards. Such sources of information, which can be found in the United States and abroad, include literature and academic disciplines well beyond the bounds of traditional environmental science. Scanning also can be part of the foresight activities of look-out panels.

All three approaches are independently useful in identifying the first weak signals-the dots on the horizon-that warn of emerging environmental problems. In addition, the techniques reinforce one another by providing early warnings from different perspectives. Scenario analyses tend to raise top-down issues generated by the assumptions used in the scenarios (e.g., CO2 buildup as a result of the energy strategies of large countries like China and India). The look-out panels call attention to specific emerging issues (e.g., the introduction of new toxic chemicals). Scanning cuts across both approaches.

All three techniques can help identify potential environmental issues that could be subjected to in-depth risk analysis. All three, if used continuously and interactively, could serve as a first line of defense in protecting future environmental quality.

Figure 5. An Environmental Foresight Process



4. The Value-and Uncertainty-of Foresight

The value of futures research and analysis lies not in making predictions, but in analyzing and organizing information that can help shape decisions and actions.

Futures research and analysis will not result in a complete or accurate picture of the future. The future, after all, is dependent upon personal and institutional decisions, chance, and natural processes, all of which interact in an uncertain and sometimes chaotic fashion, the results of which are impossible to predict with accuracy.

Because of its analytical processes and organizing principles, however, futures research can enlighten contemporary understanding of future possibilities and options. Foresight need not be entirely accurate or complete to be of value to decisionmakers or to society as a whole. The intellectual rigor necessitated by futures research is valuable in and of itself.

The methodological processes of foresight force new ways of thinking and new ways of looking at old realities. They demand comprehensiveness, a receptivity to unusual ideas, and the ability to reconfigure old data from new perspectives. They help set an agenda for discussion and debate within organizations, and they provide a more cohesive basis for planning that can extend across organizations. Because they stretch the bounds of thought, they help decisionmakers discern new paths to organizational goals that may themselves be changing. In short, the processes of futures research can help people explore, understand, prepare for, and shape the future while it is still beyond the horizon, despite the uncertainties inherent in such a distant view.

5. Possible Emerging Problem Areas

Because of large-scale social, economic, technological, and institutional changes already underway, future environmental issues may emerge in at least five different problem areas.

In preparing this report, the EFC applied one of the issue-identification methodologies (i.e., the bottom-up, look-out panel approach) to test the methodology and, in the process, compile a list of possible future environmental issues. The standing committees of the SAB and individual members were asked to use their specific knowledge and expertise to identify potential issues that, given existing "drivers" and data trends, could emerge within the next 5 - 30 years. The EFC then compiled and consolidated the information into a list of 50 specific possible issues. (This list is presented on pages 14 and 15.)

After compiling the list, the EFC applied six criteria that it considers useful in selecting issues that should be analyzed further. (A short description of these six criteria is included in the box below.) Based on the results of its selection process and the inherent similarities among some potential issues, the EFC consolidated them under five large, overarching problem areas: sustainability of terrestrial ecosystems; non-cancer human health effects; total air pollutant loadings; non-traditional environmental stressors; and health of the oceans.

All of these broad problem areas are affected by the major drivers of change discussed earlier in this report. Because they encompass a number of specific environmental issues, they merit more detailed study.

Sustainability of Terrestrial Ecosystems

In the future, the health of biosystems and the sustainable use of natural resources will be stressed by a growing human population, expanding energy use, natural resource consumption, and

Six Major Issue-Selection Criteria

Timing: How soon is this problem likely to emerge, how important is early recognition, and how rapidly can the problem be reversed?

Novelty: To what extent is this a new problem that has not been addressed adequately?

Scope: How extensive-in terms of geography or population affected, for example-is this problem?

Severity: How intensive are the likely health, ecological, economic, and other impacts of this problem, and are they reversible?

Visibility: How much public concern is this problem likely to arouse?

Probability: What is the likelihood of this problem emerging, and necessitating a response, in the future?

Potential Future Environmental Issues Identified by the EFC Look-Out Panel

The following summary statements of the 50 potential future environmental issues describe each issue as if it were, in fact, to emerge. However, the EFC is not predicting that these issues actually will emerge, nor does the EFC believe this list is comprehensive. A different group of people might well produce a somewhat different list. This list is simply one set of possibilities requiring further investigation, analysis, and-if necessary-action.

This list is not meant to connote an order of priority or relative importance. Several issues that will be important in the future-such as cleaning up toxic waste sites-are not listed because they already are well-recognized. More detailed information on each potential issue can be found in Section 5 of the technical annex to this report, available from the SAB.

Human Health Effects and Human Health Risk Assessment

- Health problems and social disorder result from environmental stress.
- The information highway is found to produce psychological and societal impacts.
- New understanding of secondary air pollutants and their risks requires new risk control strategies.
- The total toxic air burden, including synergistic effects among pollutants, requires new, simultaneous risk management strategies.
- Emphasis is placed on multiple end-points and multiple exposures requiring new risk management criteria.
- The application of major advances in basic biomedical sciences leads to radically new methods of human health risk assessment and management.
- Methods to assess and manage exposures and risks from infectious agents are found to be inadequate.
- Technology to control newly recognized pathogens in drinking water is found to be inadequate.

Climatological Effects and Their Assessment And Management

- The need to understand the mechanisms and effects of local climate change is recognized.
- The need to understand the dynamics of the counteracting effects of atmospheric particles and greenhouse gases on global climate change becomes critical.

Combined Human Health and Ecological Effects and Their Assessment and Management

- Animal and human health (e.g., reproductive capacity) and ecosystems are affected adversely by global dispersion of estrogen-mimicking chemicals.
- Long-range transport and global accumulations of pollutants are found to be sources of adverse health and ecological effects.
- The need to develop and use early warning signs of potential environmental problems is recognized.
- The introduction of exotic species into ecosystems requires the development of new methods of risk assessment and management.
- The need to establish and maintain an encompassing environmental data resource for risk management purposes is recognized.
- The need to assess unregulated, unevaluated agents (existing and newly introduced) and their unforeseen environmental impacts is recognized.

Radiation: Health and Environmental Assessment And Management

- Major health hazards of non-ionizing radiation are demonstrated.
- Increasing ground-level ultraviolet radiation results in massive adverse effects on plant and animal life.
- Releases of radioactive materials through accident, war, or terrorism lead to the search for better control mechanisms.

Intergovernmental - Governmental - Institutional

- Local, regional, and global transport and accumulation of pollutants from developing countries becomes a major international environmental problem.
- Inefficient use of energy in transportation and other sectors has growing adverse impact on global environmental quality.
- Increased use of lead and other metals in "clean" vehicles leads to increased potential for adverse impacts on environmental quality.
- Urban infrastructure decay leads to additional and unexpected sources of adverse environmental incidents.
- The environment and U.S. industrial competitiveness are at risk from non-optimal environmental strategies and their costs.
- Industrial uses of wastes cause new problems.
- Scientific/technical core competencies in EPA prove to be inadequate as future challenges arise.
- Environmental problems result from rapid growth in developing countries.
- Local climate changes and environmental impacts result from the use of alternative energy sources.
- Environmental emergencies caused by accidents, terrorism, or crime require enhanced capabilities for international response.
- Environmental degradation in developing countries is exacerbated by poorly controlled exports from developed countries.

Socioeconomic Factors

- Voluntary initiatives fail to produce changes in behavior needed to sustain and improve environmental quality.
- Environmental inequity leads to environmental apathy and violence.

Land Use Issues

- Increasing environmental pressures require improved land-use practices.
- Increasing agricultural intensity in developing countries increases soil depletion, atmospheric particulates, and desertification.
- Inadequate capabilities exist to cope with the environmental consequences of natural disasters.

Ecological Effects, Their Assessment and Management

- The development of regional strategies for environmental assessment and protection is necessary.
- Increasing light pollution is found to be seriously disruptive to many species' physiology and behavior.
- Increasing noise pollution is found to disrupt many species' essential behavior patterns.
- Cumulative environmental stresses lead to increasing decline and die-off of sentinel species.
- The use of alternate energy sources leads to adverse impacts on environmental quality.
- Global climate changes and stratospheric ozone depletion lead to adverse impacts on ecological systems.
- Losses of monoculture crops occur because of unexpected pathogens.

Resource Use and Depletion

- Biodiversity is lost as a result of habitat alteration and destruction.
- The "health" of the oceans deteriorates further.
- Fossil fuel depletion leads to the use of other contaminating, habitat-destructive alternatives.
- Adverse ecological effects result from over-exploitation of natural terrestrial resources.
- The quality and quantity of surface and groundwater diminish as a result of inefficient use and contamination.

Other Risk Management Issues

- The continuing lack of societal consensus on criteria for "acceptable" risk leads to policy gridlock.
- Preventing dispersion of chemicals from diverse sources becomes more critical than point source management.
- The discovery that adverse effects occur at ever-lower exposures leads to the need to develop new means of managing the net risks of multiple pollutant exposures.

land development. As the stresses on biosystems intensify, the preservation of biodiversity will become increasingly important for both economic and environmental reasons. As populations grow and urban areas expand, heightened competition for the use of land will put new strains on natural habitats.

"Management of human health risks in the future will have to consider the full range of health effects under conditions of both single and multiple exposures."

In the years ahead, failure to maintain healthy terrestrial ecosystems could lead to natural resource damage, irreversible losses of species, and fragmentation of habitats, thus endangering both economic and environmental sustainability and seriously threatening human and ecological wellbeing.

Non-Cancer Human Health Effects

The human health effects that can result from environmental pollution include many endpoints in addition to cancer. The loss of fertility and birth defects, for example, have been linked to certain organic chemicals. Developmental problems in children, neurological deficits, faster aging of the lung, and increased rates of mortality and morbidity have been associated with lead, mercury, ozone, and ambient particulate matter, respectively. Management of human health risks in the future will have to consider the full range of health effects under conditions of both single and multiple exposures.

A good example of the kind of human health problem that already is sending early warning signals is the possible "feminization" of animals and humans. An increased occurrence of adverse health effects (e.g., immature male sex organs) in wildlife may be associated with exposures to estrogen-mimicking compounds in the environment. Since humans are exposed to the same chemical compounds, they may be subject to similar risks. For example, lower sperm counts currently being detected in human males could be linked to exposures to estrogen-mimicking compounds.

Total Air Pollutant Loadings

In the future, total loadings of pollutants in and from the atmosphere may pose environmental problems not seen before, or intensify familiar problems beyond the point where conventional controls will solve them. For example, aggregate increases in the use of fossil fuels, combined with long-range transport and local conditions, could lead to regional or global air quality problems (e.g., acid rain and global warming). Deposition of air-borne contaminants could exacerbate problems on land or in the water, problems that demand new kinds of responses. Because many air-borne chemicals are more harmful to human health and ecological systems when acting in the presence of other chemicals, the deposition and accumulation of multiple chemicals over time may lead to human health and ecological damage (e.g., problems related to the leaching of heavy metals from soil).

Non-traditional Environmental Stressors

In the future, previously unrecognized environmental stressors, and recognized stressors that are not adequately monitored or regulated, may be found to pose serious risks to human health or ecosystems. Many unregulated chemicals present in complex mixtures have been linked to such problems as sick building syndrome, multiple chemical sensitivity, and excess morbidity and mortality rates related to air-borne fine particles. Control-resistant microbes, plants, and insects; new kinds of water-borne pathogens; the accidental or misguided introduction of an exotic species into susceptible ecosystems: any of

these factors could lead to human health or ecological problems in the future. Moreover, relatively well-understood stressors could begin to cause new kinds of problems through the slow building of cumulative effects, or the subtle effects of well-understood stressors (e.g., developmental defects in children exposed to low levels of lead) could cause new public concerns.

Health of the Oceans

The oceans, their complex biosystems, and their related food webs are likely to come under increasing stress from the worldwide activities of a growing global population. The adverse effects of overfishing, air and water-borne pollutants, and coastal development on the health and abundance of marine life, including the ecologically critical coral reefs, already are causing concerns in coastal areas. The migration of coastal stressors far from shore threatens the future health of the deep, open ocean as well. Pollutants like PCBs, pesticides, and lead have been found not only in the tissues of fish and marine mammals, but also in bottom sediments and in the seawater itself. Solid waste can be found sparsely distributed throughout the open ocean. Moreover, future exploitation of minerals and oceanic plant life could degrade the ocean environment even further, as similar activities on land have done.

6. The Environment: A Strategic National Interest

National and international environmental issues are rapidly becoming a matter of strategic national interest.

The United States is part of a single global ecosystem. Political, economic, and environmental trends and events in other countries affect the United States; pollution generated in this country affects the rest of the world as well. Because of international environmental and economic linkages, environmental issues rapidly are becoming an issue of strategic national interest.

Within the past few years, the American people have seen firsthand the links between the environment and national security. Nations have gone to war to protect their access to vital natural resources. Others have used environmental destruction in combat as a major instrument of war. Terrorism, environmental accidents like Chernobyl, and nuclear proliferation all have major implications for public and ecosystem health in this country and around the world.

Possible natural resource shortages, competition for scarce resources like potable water, and the transborder movement of refugees driven by deteriorating environmental conditions could lead to destabilized governments, international disagreements, and regional warfare. Overfishing, acid rain, and raw wastewater discharges along and across national borders also are examples of how environmental and natural resource issues can lead to contentious relations among countries, and necessitate international negotiations and agreements related to environmental quality.

Moreover, the future quality of the global environment will be a factor in determining how economic activities are conducted in all countries, including the United States. Based on present trends, the future growth of the economies in regions such as Asia and Latin America, for example, with an attendant increase in energy use, could contribute to global atmospheric pollution that today is caused primarily by economically developed nations. The loss of biodiversity through the clearing of rain forests in South America and Indonesia would be felt by everyone on earth. The stripfishing of marine life in the open ocean is diminishing the foodstocks available to global populations over the long term.

As can be seen from these examples, many future environmental issues, and their relationship to economic development, are likely to be matters of strategic national interest, both to the United States and to other coun-

tries, at the dawn of a new century. Environmental and natural resource-related issues almost certainly will be linked to U.S. national security concerns and to a range of bilateral and multilateral relationships.

> "EPA must look beyond the horizon. And the Agency must be prepared to think in new ways, and act in new ways, based on what it sees."

7. Thinking of Futures at EPA

To limit or avoid future environmental problems, there is a need for EPA to expand its current capabilities and look beyond near-term problems to long-term environmental protection.

As the Federal agency primarily responsible for protecting the environment, EPA has been charged with implementing environmental laws that have been, in large part, reactive. Just as those laws were enacted in response to existing problems, EPA spends most of its time and budget cleaning up, or remediating, pollution problems that already are relatively serious, or that already are causing public concern because of real or perceived environmental impacts. This approach has achieved considerable success in the past.

However, EPA will not be able to limit or prevent future environmental problems with the same regulatory tools and reactive approaches that it has used-and used effectively-in the past. As EPA prepares for a future that will be as challenging as it is uncertain, the Agency must develop new analytical tools, new approaches to decisionmaking, and new partnerships with stakeholders. It must develop a capacity to anticipate problems and respond to them long before their adverse effects are widely felt. The Agency must broaden its understanding of what causes environmental problems, and it must broaden its approach-both internal and external-to solving them.

EPA cannot undertake this effort alone. For the past several years, the Agency has been increasing its cooperative efforts with other Federal agencies, state governments, nongovernment organizations, international groups, and the private sector in order to solve existing environmental problems. That cooperative role will be even more important as the Agency responds to environmental problems anticipated in the future.

EPA is positioned to play an influential role in focusing resources-both from within and outside the Agency-on environmental problems that may emerge in the future. EPA could help coordinate and assess the environmental implications of the futures research already underway in other parts of government. The Agency could work more closely with the U.S. business community to anticipate the future environmental implications of technological innovation. EPA could work more closely with the U.S. Department of State, international organizations, and the agencies of other nations to identify the drivers of emerging regional or global problems, and then help define possible responses to them.

The environmental problems of the future undoubtedly will be facets of large-scale economic, demographic, and technological change. Other organizations-government and non-government, within and outside this country-will have major responsibilities responding to that change. Thus, EPA's involvement in partnerships with other organizations will be even more important in the future.

A forward-looking EPA also will need to change its organizational philosophy and develop new analytical tools. EPA will be unable to respond quickly and effectively to what are likely to be complex, synergistic problems if it continues to use a one-at-a-time, single-stressor, single-species, single-medium, single-end-point approach.

In the face of expected change, EPA has to look beyond urban airsheds to a future where large, multi-state, or international regions are affected by total loadings of atmospheric pollutants that have been transported thousands of miles. EPA has to look beyond its pollutant-by-pollutant control of a relative handful of well-recognized stressors to a future where new chemicals, materials, bioengineered species, and other new agents-either singly or in combination-may cause unanticipated human health and ecological effects. EPA has to look beyond pesticide pollution to a future where habitat loss may be the critical ecological threat. EPA has to look beyond the cancer end-point to a future where several health endpoints may be affected synergistically by multiple stressors, some well-understood, but more unknown. EPA has to look beyond the protection of estuaries, coastal waters, and marine fish stocks to a future where the oceans themselves may be threatened by a variety of economic activities in countries thousands of miles apart and in the oceans themselves.

In short, EPA must look beyond the horizon. And the Agency must be prepared to think in new ways, and act in new ways, based on what it sees.

Recommendations On Environmental Futures

Recommendation 1

As much attention should be given to avoiding future environmental problems as to controlling current ones.

Solving the environmental problems of the future is not a responsibility that should be left entirely to future generations, or only to EPA. The forces of change that will cause those problems are at work now, and people today have a responsibility to shape those forces in ways that will reduce risks, and costs, in the future. Because actions taken today by government and non-government organizations, the private sector, and communities will influence environmental quality-for better or worse-in the future, people today have a responsibility to consider the future consequences of their choices and lifestyles.

Accepting responsibility for the future is not simply a matter of intergenerational equity. It is an idea that builds on the distinctly American belief that each generation should leave its children and grandchildren with a better life.

EPA, and the nation, must begin to think more systematically about environmental problems that could emerge in the future. EPA in particular must begin to focus public attention on environmental problems while they are still beyond the horizon, and then stimulate action-if needed-to solve them.

This orientation to the future requires a broader vision at EPA. It calls for an Agency that goes beyond environmental regulation to environmental protection in its broadest sense, an Agency committed to anticipating possible future environmental problems as well as controlling present and past ones.

To fulfill its basic responsibility to protect the environment, now and in the future, EPA needs to incorporate a new emphasis on environmental foresight into all its activities, including long-range planning, budgeting, research and development, and program management. In the past, these activities have been driven by near-term exigencies like legislative deadlines and the most recent environmental crisis. EPA always will be subject to such pressures, but it must be better prepared for the long term as well.

EPA should not consider this an exercise apart from or in addition to its existing responsibilities. If EPA's futures capabilities are to be effective, they must be integrated into EPA's ongoing programs as a unique but fully interrelated part. EPA should provide the resources necessary to establish environmental foresight as a critical EPA function to be carried out-continuously and systematically-over the long term.

To help communicate the results of its futures research to the public, EPA should consider issuing-once every two years at most-a report that describes potential environmental conditions 20 years into the future under several sets of assumptions. Although the prospective conditions described would be uncertain, the ensuing public discussion and debate would be an invaluable stimulus to public thinking about the future. The report and public debate also would stimulate research and data collection efforts to resolve uncertainties, and that research in turn would clarify the vision of the future described in subsequent reports. A periodic report on environmental futures thus would help focus public thinking

beyond the horizon, and provide a basis for public support of action-if necessary-in the present.

The development of futures capabilities at EPA carries with it an ongoing obligation. Besides providing a suitable budget for the processes of environmental foresight, the Agency must be prepared to evaluate findings, interact with other agencies and organizations, and possibly act on the early warnings that those processes might detect. Some of those early warnings undoubtedly will prove incorrect; nevertheless, if expectations are raised without appropriate budget and follow-through, opportunities will be missed, and results will be disappointing. On the other hand, if the Agency can infuse its policymaking with fresh insights, a sense of dynamism, and a more explicit understanding of future possibilities, the Agency and the nation will reap substantial environmental and economic benefits over the long run.

Recommendation 2

As an essential part of its futures capabilities, EPA should establish an early-warnig system to identify potential future environmental risks.

One essential part of EPA's futures capability should be an early-warning system that alerts the Agency and the nation to specific environmental issues that may emerge in the future. To help provide this early warning, EPA should establish a look-out panel made up of individuals from inside and outside the Federal government. Besides identifying issues, the look-out panel should screen, evaluate, and prioritize them. (One possible way for EPA to establish and use a look-out panel is described in the box on page 23.)

During the course of this project, the EFC itself acted as a look-out panel; i.e., it applied the experience and expertise of the SAB to identify 50 possible environmental issues that could emerge over the next 30 years. EPA should use this list as the starting point for a rigorous, ongoing effort to identify likely emerging issues, assess and prioritize them, and begin to define appropriate responses.

In particular, EPA should review the issues identified by the EFC, and subject one or two to a rigorous analysis that involves other agencies or organizations with relevant expertise. Trend data should be identified and analyzed, and possible response options assessed. EPA's periodic futures report should include this information.

This kind of pilot project would serve several purposes. It would help focus the Agency's initial futures research. It would initiate contacts with other government agencies and non-government organizations involved in futures research. It would begin to establish a process for prioritizing potential future issues for possible near-term response. Finally, it would help EPA gain experience in assessing the effectiveness of different response options.

The choice of initial issues to study is not as important as beginning the process itself. EPA needs to develop a much greater capacity to anticipate environmental futures and identify specific issues that could emerge. It must develop the capability to screen those issues, solicit an external review of findings, and then analyze the range of response options available.

The EFC has taken the first step in environmental foresight through the look-out panel that contributed to this report. EPA should build on this effort by establishing an early-warning system that would identify, rank, and begin the process of responding to environmental issues that are still beyond the horizon.

Recommendation 3

In a longer-term, more comprehensive effort, EPA should evaluate five overarching environmental problem areas related to a number of potential future environmental issues.

Over the next 5 to 30 years, future environmental quality could be affected by social, economic, and technological

changes already underway in the United States and around the world. Because of several factors (e.g., likely severity, visibility to the public, and probability of occurring), some of these problems merit more thorough analysis by EPA and other appropriate agencies. As EPA undertakes to strengthen its futures capabilities, it should pay particular attention to five major problem areas that encompass a number of related environmental issues that could emerge in the future.

Prototype EPA Look-Out Panel

- EPA sets up a prototype "look-out panel" with experts in public health, ecology, socioeconomics, and technology.
- Although managed by EPA, the panel also involves a variety of experts who can observe changes that may lead to problems beyond the horizon.
- Panelists are requested periodically to scan their fields and provide observations about new or intensifying trends and their possible consequences.
- These observations are collected and fed back to other panelists for comment.
- Candidate environmental issues are screened against established criteria.
- Selected issues are analyzed in the context of scenarios and goals developed by the Agency.

Sustainability of Terrestrial Ecosystems

Despite a growing awareness of the vital links between viable ecosystems and economic prosperity, scientific tools useful for assessing the ecological risks that result from the stressors on ecological resources are not well developed. The risks themselves are poorly understood.

Through its framework for ecological risk assessment, EPA has developed a valuable conceptual approach. However, ecological risk assessment guidelines-analogous to EPA's human health risk assessment guidelines-do not yet exist.

The Agency should place a high priority on identifying ecological endpoints-those aspects of biosystems that readily manifest adverse change-and developing guidelines for their use in ecological risk assessments. The endpoints should be selected for their reliability in assessing the effects of various stressors on ecosystem sustainability, and for their usefulness in monitoring ecosystem status and trends. Special attention should be given to the further development of ecological risk assessment guidelines that can address problems associated with loss and fragmentation of terrestrial habitats, freshwater and near coastal zone eutrophication, and the introduction of exotic species.

Non-Cancer Human Health Effects

Although EPA in the past has been concerned almost exclusively with a narrow range of health endpoints (i.e., the various forms of cancer), the Agency should place equal emphasis on non-cancer human health risks. An increasing body of data shows that, in many cases, a range of significant biological responses can be affected adversely by environmental factors. As part of its effort to anticipate future environmental problems, EPA should broaden its human health research and regulatory focus to include respiratory, cardiovascular, immunologic, neurologic, and reproductive endpoints.

For many endpoints, the biologic changes cannot be measured simply by effects on DNA. Such changes are complex, involving the interaction of many organ systems (e.g., the neural, hormonal, and immunologic systems).

Thus new dose-response models should be considered. In fact, the total dose or dose rate may not be the most important variable affecting some human health endpoints. Instead, a specific dose at a specific time in organ development may be a critical variable.

Different people are affected in different ways by exposures to the same environmental pollutants. As science expands its understanding of the differences in human susceptibility, EPA should continue broadening its approach to human health risk assessment by explicitly considering risks to susceptible populations.

Total Air Pollutant loadings

EPA historically has protected air quality by focusing on one pollutant or one impact at a time. This pollutant-by-pollutant approach does not effectively address complex interactions among atmospheric processes, the synergism of pollutants and their impacts, or the deposition of air-borne pollutants on water or land. The long-term, long-distance, and often international characteristics of air pollution are not adequately considered.

To improve current approaches, EPA needs to develop a broader definition of the total air burden, a definition that includes new and emerging air toxics as well as currently regulated pollutants. Also needed is a system for addressing diverse pollutant sources and the effects of the total air pollution burden on air, water, and land. Given the lower and perhaps more uncertain thresholds associated with the total air burden, EPA should shift its focus from the regulation of single pollutants to the control of multiple pollutants based on comparative risk estimates. Integrated assessments of the multimedia effects of air-borne pollutants also may be needed.

Finally, because all airsheds are interlinked across state and sometimes national borders, the long-term protection of U.S. air quality will depend to some extent on the protection of air quality in other countries. The United States should continue to provide international leadership in an effort to link air quality issues with other environmental, energy, social, and economic concerns.

Non-Traditional Environmental Stressors

Up to this point in its history, EPA has paid attention to-and attempted to control-only a limited number of environmental stressors (e.g., the most ubiquitous hazardous air pollutants and a limited number of drinking water contaminants and pesticide residues in food). EPA currently requires U.S. companies to regularly monitor only those chemicals likely to be released and therefore limited by permits and regulations. Larger companies are required to report, facility-by-facility, their releases of about 325 toxic chemicals. U.S. wastewater treatment facilities have to monitor and control a relatively small number of well-recognized pollutants. For infectious diseases, the indicator species monitored in drinking water and coastal beach waters are, at best, only crude indicators of infectious risk.

Because future environmental quality may be at risk from environmental stressors other than the chemical and microbiological contaminants monitored and regulated in the past, EPA needs to improve its capabilities to identify, understand, and, if necessary, target for control a greater number of those stressors that could lead to future risks. Examples of some potentially important stressors not presently monitored include the new technologies that could increase human exposure to various forms of non-ionizing radiation, the persistent chlorinated hydrocarbons that could disrupt endocrine systems in humans and animals, and the newly-recognized pathogens that are being found in drinking water. EPA should attempt to identify, monitor, and analyze the most potentially serious of these unconventional stressors, and then assess their adverse effects on human health and ecological systems.

Health of the Oceans

Although indications of deterioration in ocean health are still preliminary and subject to scientific debate, the scope and value of the resource at risk are undeniably enormous. Thus the early warning signs of possible ocean deterioration-the "dot on the horizon"-should be taken seriously. Coordinated, international steps should be taken now to better define the causes and effects of ocean pollution, and to anticipate problems that may require a coordinated international response in the future.

For example, much more needs to be known about conditions and trends in the open ocean. Current adverse effects already evident in the oceans need to be monitored more widely and better understood. Although the effects of overfishing on human nutrition and international economics are apparent, more needs to be learned about the effect of these "holes" in the food web on other marine organisms.

Further, international cooperation is needed to gather and analyze information that now is scattered among different agencies and countries. This effort is essential to identifying gaps in knowledge and directing future research. Coordinated action should include studies of the life cycles of ocean flora and fauna, sampling and analysis of their tissues and the ocean's waters and sediments, and efforts to expand current understanding of marine toxicology, ecotoxicology, and the relationships between coastal and deep waters and between oceanic and terrestrial environments.

These types of studies will require many years of coordinated international effort. Given the early warning signals now being observed, and the value of oceans to long-term economic and ecosystem sustainability, such coordinated efforts should begin as soon as possible.

Recommendation 4

EPA should stimulate coordinated national efforts to anticipate and respond to environmental change.

In its report Reducing Risk (September 1990), the SAB recommended that EPA increase its efforts to integrate environmental considerations into broader aspects of public policy. That recommendation was based on a finding that environmental quality is affected by national policies related to energy use, agriculture, economic development, transportation, and foreign relations. Consequently, EPA was advised to work closely with the appropriate Federal agencies to ensure their policies are sensitive to potential environmental impacts.

Since 1990, this integration of environmental considerations into broader national policy has taken place in a number of areas. For example, EPA has worked fruitfully with the Department of Transportation to implement the Intermodal Surface Transportation Efficiency Act (ISTEA), and the Agency is playing an important role working with the Department of Energy's implementation of the Energy Policy Act. EPA has participated with a number of Federal agencies to develop its Environmental Monitoring and Assessment Program (EMAP) and the National Human Exposure Assessment Survey (NHEXAS). This progress is encouraging.

The same kind of cooperation is needed to anticipate, and respond to, potential environmental risks in the future. EPA should develop stronger partnerships with other Federal agencies, state governments, and relevant non-government organizations involved in futures-related activities. In particular, EPA should undertake cooperative efforts to: 1) improve and integrate environment-related futures research; 2) focus national attention on drivers of environmental change; 3) improve environmental education and awareness; and 4) develop an integrated environmental data system.

Improve and Integrate Environment-Related Futures Research

A number of Federal agencies, private businesses, and non-government organizations currently conduct foresight activities, but those activities tend to be discontinuous-depending on budgets-and coordinated poorly, if at all. EPA should work with them to improve the methodologies used in futures research, strengthen the linkages between the various efforts, and ensure that the environmental implications of futures research are not ignored.

In particular, EPA may wish to conduct its own analysis of the environmental implications of futures research at other Federal agencies, or it may choose to work with the primary agency involved. In any case, EPA should work to make Federal foresight efforts thorough, complementary, and supportive of environmental policymaking.

Moreover, EPA should reach out to private businesses, state governments, and to other agencies and organizations within and outside the United States that have experience in futures research, especially environmental futures research. Such research should feed into and complement EPA's work. In fact, one of the most important contributions that EPA could make in this area is to help establish a forceful Federal presence that helps link the valuable foresight activities being conducted elsewhere.

Finally, EPA should work with other organizations to improve the understanding and expand the use of environment-related futures research by other parts of the Federal government. The U.S. Congress and the science offices in the White House, for example, should use environmental foresight more extensively in their activities. EPA can help make that happen.

Focus National Attention on Drivers o Environmental Change

Because of historical circumstances and its legislative mandates, EPA has tended to focus its energies on the environmental end results of broad economic, demographic, and technological changes (e.g., controlling emissions from cars and forcing changes in fuel to reduce urban ozone pollution, improving the design and operation of landfills and incinerators to minimize waste-related contamination of soil and groundwater). Only recently has EPA begun to attack the roots of such problems (e.g., influencing the design of consumer products to reduce environmental impacts, encouraging reductions in waste streams through pollution prevention).

To limit or avoid future environmental problems, the nation and EPA must pay more attention to the forces-or drivers-behind those problems. The increased concentration of people in urban corridors; the development and use of new technologies, manufacturing processes, and materials; the expanded use of fossil fuels both in this country and abroad: these kinds of future, large-scale changes are likely to give impetus to new kinds of environmental problems that demand new kinds of responses. To the extent that the American people and EPA understand-and anticipate-the drivers of change, and then take action to avoid the problems they may engender, the risks and costs imposed on future generations will be reduced.

For example, EPA may not be able to influence the growth of heavily-populated urban transportation corridors, but anticipating that growth before the fact, and recognizing that such growth may overwhelm current techniques and technologies for controlling air pollution, may give EPA and other agencies the head start they need to develop new, more effective options for remediation. Similarly, by anticipating the future widespread use of new materials (in the batteries of electric vehicles, for example), EPA could begin to assess potential recycling, reuse, and disposal problems.

In short, future environmental conditions are likely to be shaped in large part by forces of change already

evident. EPA should not wait for those conditions to manifest themselves before the Agency begins to formulate its response. It should begin studying the forces of change now, and then give the nation an early evaluation of how those changes could affect the environment.

Improve Environmental Awareness and Education

One of the single most important drivers of environmental change in the future will be the environmental awareness and attitudes of people in this country and abroad. Environmental awareness influences individual behavior, and individual behavior is a fundamental factor affecting environmental conditions. A country's environmental laws and institutions are shaped by the environmental awareness of its citizens, as awareness is translated into policy. Because environmental awareness will exert such a strong influence on future environmental conditions, EPA's efforts to anticipate and respond to future environmental problems should include a strengthened commitment to environmental information and education.

In its 1990 report Reducing Risk, the SAB made a similar recommendation in the context of expanding the types of tools used to reduce risk. The SAB recommended that EPA use information and education, among other things, to complement the Agency's more traditional command-and-control regulatory approach. Information and education clearly are the most useful risk reduction tools for certain kinds of environmental problems, and, as demonstrated by EPA's pollution prevention and environmental education programs, the Agency has been using those tools more often and more effectively over the past few years.

Seen in the context of potential future environmental problems, the improved environmental awareness of the general public is even more important. An informed and alert public serves, in fact, as a broad-based lookout panel that can see and draw attention to the first signs of unusual environmental degradation in the future. An aware and concerned public will be more likely to volunteer to collect the sampling data (e.g., during nationwide bird counts and beach cleanups) that is useful in illustrating particular environmental conditions. Most important, a public that is sensitive to the environmental implications of personal behavior will be more willing to act quickly if behavioral changes are needed in response to future environmental problems.

"A country's environmental laws and institutions are shaped by the environmental awareness of its citizens, as awareness is translated into policy."

While EPA is only one of several government agencies that have a role in providing public education and information, it has the primary Federal responsibility for environmental protection. Consequently, it is appropriate for EPA to take the lead in formulating a national environmental education and information program explicitly focused on environmental futures. Key participants in this effort should include state

and local school administrators, teachers, parents, students, businesses, and the media.

Futures-oriented environmental education also should be promoted on an international basis. Given the important linkages between personal behavior and cultural values-and their influential role in national economic and environmental policies-information as to how citizens can improve environmental quality will be a critical component in reducing future environmental risks. Multilateral institutions and non-government organizations are especially suited for funding and implementing environmental education and awareness programs in cooperation with national and local governments.

Develop an Integrated Environmental Data System

To better understand the different mechanisms of future environmental stress, and the range of possible human health and ecosystem effects, EPA should begin working with states, industry, other Federal agencies, and international organizations to construct a broad, integrated database that could be used to link perceived or suspected effects with possible stressors. Such a database would help users identify previously undetected and incipient ecological or human health changes. Data analysis could provide early-warning signals of increased human or ecosystem exposures to conventional and unconventional stressors. When combined with improved understanding of biological responses to such exposures, this analysis could help guide policy and action well before severe ecological and human health effects were documented.

Before trends in atmospheric, aquatic, and soil contamination can be studied, baseline data must be collected over a sustained period from a network of background sampling stations. Data collected at such stations, whether they are fixed-site, mobile, or satellite monitoring systems, have to be subject to quality-control and made available to analysts inside and outside government. Most important, these data have to fit together to paint a consistent, coherent picture of environmental quality. In other words, if the data to be included are selected carefully, their analytical value in the aggregate will be greater than the value of their separate parts.

Much of the data needed for such a database already is being collected by EPA and other agencies. For example, earth-observing satellite systems operated by the National Aeronautics and Space Administration (NASA) currently collect data on vegetative growth patterns, atmospheric haze, and trace gases. A National Health and Nutrition Examination Survey (NHANES) is conducted on a regular basis by the Department of Health and Human Services (DHHS). EPA collects an enormous amount of data related to air quality, drinking water quality, human exposure (NHEXAS), and ecological status and trends (EMAP), among other things. The Fish and Wildlife Service, the Forest Service, the National Oceanographic and Atmospheric Administration, scientists under contract to the National Science Foundation, and others collect data describing a variety of environmental conditions. The Federal and state health care systems collect detailed information on overall U.S. mortality and morbidity rates, while DHHS and various states collect occupational health and exposure data in surveillance networks.

A particularly useful, and previously unavailable, source of environmental data is the Department of Defense (DOD). DOD already has in place data-gathering equipment and databases useful for assessing global-scale ecosystems. EPA should tap into DOD's expertise in this area, and integrate DOD's equipment and methods with more traditional environmental data-gathering efforts.

As evidenced by this partial list of Federal data-gathering activities, the problem in constructing an integrated data network useful for anticipating future environmental issues is not necessarily the need for more data or larger

data collection budgets. Rather, the challenge will be to assemble useful data already being collected into a coherent database that is accessible to a wide variety of users.

EPA should review the different kinds of environmental and health surveillance data currently available, and then identify the set that is potentially most useful for anticipating environmental futures. If there are clear gaps in the data, the Agency should recommend ways for closing those gaps. Working with the primary collectors of data, EPA should help design a comprehensive system for aggregating critical data elements, updating the data, assuring its quality, and making the information widely available to users inside and outside the government, and inside and outside the United States.

Recommendation 5

EPA, as well as other agencies and organizations, should recognize that global environmental quality is a matter of strategic nutional interest.

There is little doubt that political, economic, and environmental events in other countries can affect environmental quality in the United States. Even when such events do not affect the U.S. environment directly, as with the oil fires in Kuwait, they can affect international environmental and economic resources in which the United States has a strategic interest. Consequently, to protect both the national interest and the quality of the U.S. environment over the long term, it is essential that global environmental quality be recognized-publicly and formally-as a strategic interest of the United States.

In the past, the role of environmental issues in U.S. foreign policy has been determined on a case-by-case basis. An overall, strategic environmental policy has never been defined for this country. U.S. foreign policy objectives related to the environment have not been articulated, environmental risk contingencies have not been identified, and the criteria for various levels of U.S. action in the face of an environmental emergency have not been laid out.

This shortfall in strategic thinking could be detrimental in a future where international competition for natural resources like ocean fish and potable water may pose as much of a threat to international political stability as an interrupted oil supply does today. Moreover, environmental terrorism, the large-scale dislocation and migration of people because of deteriorating environmental conditions, and the rapid growth and urbanization of global populations all could pose potential risks to global environmental quality.

In this context, the protection of environmental quality represents one of the most important strategic issues facing the United States in the 21st century. To anticipate and forestall the environmental problems of the future, the United States must begin to develop strategic national policies that link national security, foreign relations, environmental quality, and economic growth. EPA should play a strongly supportive role in this process.

Over a number of years, the U.S. government-including EPA-has undertaken a series of cooperative environmental activities with other countries such as China, Russia, and Japan. EPA is contributing to an environmental office in Budapest to assist Central European countries redress the environmental problems created and neglected while they were part of the Soviet Bloc. These efforts, and others like them in the Caribbean region and Asia, contribute U.S. experience and technical expertise to cooperative efforts aimed at remediating existing environmental problems in other parts of the world.

The U.S. Government should expand such cooperative international activities and target them not only at existing problems but also at the larger forces or drivers (e.g., population

growth and urbanization, increased fossil fuel use, technological developments, environmental attitudes) that may contribute to future problems. Besides helping other countries control air pollution in urban areas, for example, EPA should be prepared to assist them in identifying options for minimizing such problems in the first place (i.e., through the use of alternative fuels or innovative energy-efficient technologies). In other words, as EPA begins to anticipate future environmental problems in this country, the Agency should join with other nations to apply the same process internationally.

While EPA's technical and financial involvement in such activities may provide substantial benefits to other countries, this work also supports a well-defined national self-interest. EPA simply will not be able to anticipate, and respond to, U.S. environmental problems in the future without considering the drivers of change in other countries, and without involving other countries, multilateral institutions, and non-government organizations. In the future, many of the same environmental problems that emerge in other countries are likely to emerge here, and they are likely to be linked.

Many facets of this kind of broad, futures-oriented activity lie outside EPA's area of expertise. Some nations, for example, may request and need assistance in areas such as population planning and alternative fuels development, where other U.S. agencies hold the primary responsibility. Consequently, EPA should join with other Federal agencies, multilateral institutions, and non-government organizations in futures-oriented partnerships beyond its borders.

The Reports of The SAB Standing Committees

The Environmental Futures Committee invited the standing committees of the SAB to conduct futures exercises in their areas of expertise, and then prepare reports on their conclusions and recommendations. The five reports that resulted from this effort are summarized below. Anyone wishing a copy of these reports should write or call:

Committee Evaluation and Support Staff
Science Advisory Board
401 M St., S. W. (Mail Stop 1400)
Washington, D.C. 20460
(202) 260-8414

Report of the Drinking Water Committee (EPA-SAB-DWC-95-002)

The Drinking Water Committee examined trends in water resource demands, water treatment technologies, and drinking water quality, and their likely impacts on the country's ability to provide safe drinking water in the future. The committee offered five major recommendations:

1. Improve the existing management of renewable water resources.

   A national program to improve existing renewable water supplies should include: 1) prevention of further water supply deterioration and better management of land-use and forestry practices; 2) improved ability to capture a larger portion of renewable water supplies, including through wetland protection and expansion; and 3) implementation of water recycling and conservation practices to improve efficiencies of water use, including lining of irrigation canals, installation of more efficient plumbing, and consideration of reallocation of water rights.

2. Support the consolidation of small distribution systems.

   Consolidation of small water systems should be encouraged to improve the overall quality of water and provide the necessary revenue to implement treatment technologies now available to the larger systems. The drive toward consolidation should take advantage of the replacement of distribution systems that will be necessary in the near future in many communities.

3. Support changes in treatment technologies.

   The traditional concepts of water treatment and distribution can be expected to change substantially in the future as a result of the changing profiles of contaminants of concern. A number of promising technologies, including membrane treatment, will need to be improved and implemented. In addition, methods will need to be developed for stabilizing water in distribution systems that do not depend on maintenance of a residual oxidant.

4. Greatly accelerate research to spur advances in risk assessment methodologies for both chemical and microbiological contaminants.

   Modifications of current water disinfection treatments must consider the magnitude of microbial risks that may be introduced as a result of those modifications, as well as the creation of other disinfection by-products. To do this effectively, substantial research into risk assessment methodology for both chemical and microbial risks is needed. Without such research, large public investments for changes in drinking water treatment plants may be made on an inadequate and possibly incorrect scientific basis.

5. Establish a surveillance or alert system for emerging water-borne pathogens.

   The almost certain changes in water treatment and distribution systems in the next decades, and the increased consolidation into larger systems for efficiency of control and delivery, pose the possibility of generating and transmitting to large populations heretofore unknown microorganisms that may pose serious health risks. A surveillance or alert system to detect these microorganisms early should be put in place.

Report of the Ecological Processes and Effects Committee (EPA-SAB-EPEC-95-003)

The Ecological Processes and Effects Committee developed an approach for examining key future developments, and then applied it to assess the potential future ecological consequences of human activities. Based on its study, the committee came to four key conclusions:

1. The conceptual model for futures analysis, which combines the use of scenarios and the analytical framework for ecological risk assessment (ecorisk framework), provided a formalized approach for assessing future environmental risks.
2. This approach, when applied to two scenarios making differing assumptions about future energy costs, revealed possible ecological consequences that probably would not have been determined through an unstructured brainstorming.
3. Attempting to identify the ecological consequences of the two different energy scenarios demonstrated to the committee that the value of examining futures lies in the process rather than the results of that examination.
4. The committee's scenarios/futures analysis reaffirmed the conclusions in *Reducing* Risk that national ecological risks are dominated by larger-scale and longer-time issues, including global climate change and habitat alteration, ozone depletion, and the introduction of exotic species.

Report of the Environmental Engineering Committee (EPA-SAB-EEC-95-004)

The Environmental Engineering Committee chose to study four technology-related issues that may emerge in the future: 1) fostering environmental protection while helping to assure sustained industrial development in an increasingly competitive manufacturing economy; 2) responding to increasing societal pressures for the redevelopment of industrial sites and remediation of land; 3) preparing to address threats posed to human health and natural resources by transient phenomena; and 4) correcting insufficiencies in core technical competencies that are needed to address future environmental challenges.

Using a look-out panel, the committee identified eight additional issues that EPA should consider evaluating: 1) fossil fuel depletion; 2) industrial accidents and/or terrorist activities; 3) deterioration of urban infrastructure; 4) low-cost benefits of some environmental management strategies; 5) reservoirs of environmental contaminants; 6) pathogens in drinking water; 7) electromagnetic radiation; and 8) industrial ecology.

Based upon its study, the committee prepared four recommendations for EPA:

1. EPA policy recommendations concerning clean technologies should be constructed and balanced carefully to benefit both the environment *and* U.S. industrial competitiveness.
2. EPA should ensure the development and use of appropriate technology to enable the redevelopment of contaminated urban industrial sites and remediated land.
3. EPA should strengthen its capabilities and readiness to address potential environmental consequences of natural disasters associated with transient events such as river floods and violent regional storms, especially considering trends in population growth and land use.
4. EPA should systematically identify and examine the essential and distinct scientific and engineering capabilities (core competencies) needed to address technical aspects of its present and anticipated future mission, and then strengthen them where needed.

Report of the Indoor Air Quality and Total Human Exposure Committee

(EPA-SAB-IAQ-95-005)

The Indoor Air Quality and Total Human Exposure Committee studied opportunities for advances in the science and art of human exposure assessment, and the opportunities that such advances could offer EPA and the nation for improving risk assessment and management. The committee recognized that significant advances could be made in three critical areas:

- Microsensor and microprocessor technologies;
- Biomarkers of exposure; and
- Database resources.

Based upon its study, the committee prepared five specific recommendations to EPA:

1. Develop a mechanism to support the research, validation, and application of: a) more sensitive and specific microsensors, biomarkers, and other monitoring technologies and approaches for measuring exposures; and b) validated data on associated exposure determinants, including demographic characteristics, time-activity patterns, locations of activities, and behavioral and lifestyle factors.
2. Establish a mechanism to develop, validate with field data, and iteratively improve models that integrate: a) measurements of total exposure and their determinants; b) a better knowledge of exposure distributions across different populations; and c) the most current understanding of exposure-dose relationships.
3. Develop, in cooperation with other agencies and stakeholders, a robust database that reflects the status and trends in national exposure to environmental contaminants.
4. Develop sustained mechanisms and incentives to ensure a greater degree of interdisciplinary collaboration in exposure assessment and, by extension, in risk assessment and risk management activities.
5. Take advantage of improving capabilities in exposure assessment technology, electronic handling of data, and electronic communications to establish and disseminate early warnings of emerging environmental stressors.

Report of the Radiation Advisory Committee (EPA-SAB-RAC-95-006)

The Radiation Advisory Committee (RAC) formed the Radiation Environmental Futures Subcommittee to assess future potential problems in environmental radiation. The subcommittee scanned potential future developments in the field of radiation, particularly as they pertained to environmental radiation. Based on its study, the subcommittee recommended that EPA consider the following activities:

1. Place greater emphasis on providing scientifically credible information, while relying less on a regulatory role in risk management.
2. Participate in the joint development of national energy policies, focusing on the overall environmental consequences of different energy production options, the roles of alternative energy sources-including nuclear electricity generation-in curtailing greenhouse gases, potential releases of radioactive materials to the environment, radioactive waste management issues, and possible increases in ultraviolet radiation.
3. Incorporate into its program activities research findings related to radiation exposures, dose-response models, and radiation effects, especially in regard to differences in individual susceptibility.
4. Provide an environmental perspective to assure control of nuclear weapons materials through conversion to energy use and/or secure disposal.
5. Stimulate and track research on the potential health effects of exposure to non-ionizing radiation, and provide non-regulatory Federal guidance and advice on the prudent avoidance of unnecessary risks from potential sources of exposure, if such risks are shown to exist.
6. Provide Federal leadership in activities involving pollution prevention, the management and disposal of radioactive wastes, and development of criteria and standards for cleanup of sites containing radioactive and mixed wastes.
7. Exercise its Federal radiation guidance role, in collaboration with other Federal and state agencies, to reduce human exposure during medical uses of radiation.
8. Continue efforts to characterize potentially high-risk radon regions, improve knowledge about radon risks, and develop more accurate methods of measuring and mitigating radon in buildings.
9. Become the primary source of information on environmental radiation by providing advice, and guidance where appropriate, on the scientific basis for risk management decisions and by identifying research needs in radiation-related areas.
10. Use a process of foresight to develop a capability for scanning the future in order to be proactive, rather than reactive, in shaping environmental radiation policies.

The technical annex to this report, Futures Methods and issues (EPA-SAB-EC-95-007A), provides detailed background material prepared by the Environmental Futures Committee of the SAB. To receive a copy, contact:

Committee Evaluation and Support Staff
Science Advisory Board
401 M St., S. W. (Mail Stop 1400)
Washington, D.C. 20460
(202) 260-8414