Michigan's Environment and Relative Risk

Michigan Relative Risk Analysis Project

Funded by the U.S. Environmental Protection Agency and administered by the Michigan Department of Natural Resources

July 1992

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STATE OF MICHIGAN

OFFICE OF THE GOVERNOR

LANSING

JOHN ENGLER
GOVERNOR

July 17, 1992

Dear Michigan citizen:

Too often in the past, Michigan's environmental priorities have been set by the crisis of the moment, budget uncertainties, media attention, or conflicting data. I am convinced that it is time to carefully review and evaluate our priorities and base those priorities on careful thought and scientific information. We must do this in order to efficiently apply our limited resources to addressing the most serious environmental risks that our state faces.

This report is the culmination of many months of research, analysis, and debate about the most important environmental issues facing Michigan. The result of these efforts is a list of issues ranked according to their relative importance to the health and welfare of the people of this state and Michigan's ecology.

As a first step in the process, this report will help us formulate environmental protection and pollution-prevention policies that will protect and enhance the quality of life for us and our children. I have asked the Chair of the Natural Resources Commission, Larry DeVuyst, to have the Commission solicit your comments on the report. Please carefully consider what is contained in this report. With your support, we will be able to address these problems with intelligent, cost-effective strategies that will provide the greatest benefits for the environment and our citizens.

Sincerely,

John Engler
Governor

JE/CM/jlf

RECYCLED PAPER

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Acknowledgements

The Michigan Relative Risk Analysis Project was completed after many months of volunteer assistance from many highly qualified individuals. They were selected on the basis of their experience and ability to think objectively. In some cases, the participants are nationally recognized experts in their fields. Without their assistance, this project could not have produced objective, meaningful results.

This report reflects the common ground reached by people with diverse backgrounds and opinions. Although not everyone necessarily agreed on each issue, there was general consensus on the material presented here.

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Executive Summary

Michigan's environmental problems were once obvious, and during the last two decades we have addressed many of the most serious concerns. Today, however, environmental issues are more complex and the Michigan Relative Risk Analysis Project (RRAP) was created to identify and rank the most pressing issues.

The RRAP used committees of scientists, agency representatives, and citizens to study environmental problems, decide which were of particular concern, and then rank the issues by comparing the risks they pose to the environment and quality of life. Scientific information was provided through a workshop, background papers, and presentations. The committees worked on the project for about eight months and, except for the agency representatives who received their regular salary, all committee members volunteered their time and expertise. Their work was overseen by a steering committee of the heads of key state agencies and a representative from Governor Engler's office. Public comment about the issues and the process was received during four public hearings held across the state as well as through written comments.

During the project, the committees dealt only with residual risks, those risks remaining after considering the effects of current controls. Therefore, the RRAP results should not be construed to mean that program support can necessarily be shifted from low to high priority issues.

The RRAP was funded by the U.S. Environmental Protection Agency and produced a list of 24 issues ranked in four categories. Population growth, density, and distribution were considered broad factors that affect virtually all environmental concerns in the state. Because many of the issues are complicated and may involve many facets of a particular problem, the committees developed rationales to accompany the issues and rankings. They believe the rationales are critical to understanding the issues and their rankings.

This report will be distributed to key officials in state and federal government as well as environmental organizations and interested citizens. This information will provide a framework for responding to Michigan's environmental problems.

Introduction

Michigan citizens enjoy a quality of life envied by much of the world. This quality of life is directly related to environmental quality and the many sensitive environments that can be affected by a wide range of human activities. The state has sand dunes, more than 11,000 inland lakes, 36,000 miles of streams, 38,000 square miles of Great Lakes, and 3,288 miles of Great Lakes coastline, including islands. Farming, manufacturing, transportation, and tourism are among the activities that can affect these resources.

Unfortunately, financial resources for protecting Michigan's environment are limited, and these resources are keenly sought by state agencies, educational and research institutions, and special interests. This made objectively defining and ranking the state's most important environmental issues critical. The best means of accomplishing this task was to organize a group of citizens, scientists, and state agency representatives who could use scientific knowledge as the basis for comparing the relative risks of various environmental problems.

Population issues, although not addressed directly, were important considerations throughout this project and affect the severity of environmental concerns. Of particular importance is the effect of population growth, density, and distribution. A joint statement by the National Academy of Sciences and the Royal Society of London provides a timely warning: "If current predictions of population growth prove accurate and patterns of human activity on the planet remain unchanged, science and technology may not be able to prevent either irreversible degradation of the environment or continued poverty for much of the world."

It was not the intention of this project to minimize any environmental issues. In fact, the committees recognized that all of the issues ranked are important, and this is reflected in the ranking categories. It is a mistake to think that the project was designed to remove any issue from the environmental action agenda. It is also important to note that this project dealt with residual risks, that is, risks as they exist with current controls—regulations, programs, and infrastructure. Removing controls or diminishing support in any of these areas would be likely to increase problems and elevate the importance of those issues.

The result of the project is a blueprint for environmental action that will enable state officials to formulate practical and effective policies for addressing the most important issues facing the state today. This report explains the process in detail and includes important points made during debates.

While everyone may not agree completely with the approach taken by the participants, this report should be read carefully because its conclusions were reached only after careful consideration by many highly qualified people. They took a hodgepodge of difficult issues and organized them in a logical, systematic fashion. Their findings are certain to have a significant effect on the state's environmental policy for many years.

It is anticipated that important comment on this report will be forthcoming from the public and other interests after it is distributed and reviewed. This input is encouraged and should be constructive in viewing the proposed relative risks and developing the steps for addressing them.

Background

On the first Earth Day in 1970, people around the world recognized the importance of the environment

to their health, the health of plants and animals, and the quality of life. At that time, environmental problems were obvious; rivers were catching fire, dark clouds of smog filled the air, and sensitive wildlife was threatened with extinction.

In the 22 years since the first Earth Day, however, we have made great strides in environmental protection. We have set air and water quality standards, banned the production and use of certain chemicals, and designed new ways for humans to conserve natural resources. The 1990s is a new era for environmental quality.

Unseen chemicals continue to contaminate our soil, water, and air; wildlife habitat is disappearing at a rapid rate; and we are now learning about how the atmosphere has been damaged by human activities. These issues are both global and local and are related to population growth and unwise patterns of consumption. Unfortunately, recognition of these problems comes at a time when financial resources are strained by huge deficits and competing needs. While the committee recognized that all environmental problems are important, the need to identify and rank these issues for action was obvious.

In 1986 the Environmental Protection Agency (EPA) embarked on a unique effort to examine environmental risks to U.S. citizens. Specifically, the agency identified critical risks and compared them with each other to develop a hierarchy for remediation and pollution prevention. This hierarchy, based on scientific knowledge, could then be used to design strategies that would yield the most positive results given the funds available.

The EPA project produced a report in September 1990 entitled *Reducing Risk: Setting Priorities and Strategies for Environmental Protection*. This report is the basis for new initiatives by the agency to deal with critical problems and limited resources. Relative risk projects were initiated in all of EPA's regional offices prior to publication of the *Reducing Risk* report.

In late 1991 Michigan became one of the first states to embark on a relative risk project of its own. Such a project was especially important for Michigan because of its proximity to the Great Lakes, its many inland lakes and streams, and a variety of human activities within the state that could threaten these resources.

Michigan

Currently, Michigan's environmental priorities are determined in a complicated manner that leaves considerable doubt as to its efficiency and effectiveness. The legislature can set priorities through annual general fund appropriations and statutes. Certain priorities can also be determined by commissions such as the Natural Resources Commission (NRC) and by a variety of state agencies. Constituent and special interest groups also pursue their own priority issues through a variety of channels.

The wide diversity of responsibility vested in departments of state government makes priority setting especially cumbersome. The departments of Natural Resources (DNR), Agriculture (DOA), and Public Health (DPH) have statutory responsibility for environmental and health protection, but some other departments undertake activities that can have a significant effect on the quality of Michigan's environment. These include the Michigan Department of Transportation (MDOT) and the Michigan Public Ser-

vice Commission (MPSC), which has responsibility for energy policy in the state.

Changes in the budgets of programs are determined by the availability of restricted funds, general funds, federal funds, and by initiatives of the legislature and the agencies themselves. In addition, many current state government priorities are the result of a series of historical decisions that may have been correct at the time they were made but may now need to be changed to accommodate new trends or information.

Rarely has state government had the opportunity to step back and complete a detailed evaluation of its environmental priorities. In September 1991 the EPA awarded a grant to the DNR to conduct the Relative Risk Analysis Project (RRAP). The goal of the project was to use input from citizens, scientists, and state agencies to identify and rank Michigan's environmental concerns. The results are summarized in this report and are intended to provide information to legislators, the governor, environmental groups, and others involved in formulating environmental policies.

For the purposes of this project, risk was considered to be any involuntary exposure to harmful substances or conditions outside the workplace. Risk was defined as "residual," meaning that risk remaining after current regulatory and other measures were considered. This approach meant that risks such as smoking, which is voluntary exposure, were not considered. Because only residual risks were evaluated, certain risks could increase greatly if current controls are diminished or removed.

It is also important to note that no environmental issues were considered unimportant; however, ranking required consideration of the most important issues. Thus, readers should not construe the results to mean that it is appropriate to ignore any environmental issues. Population growth and density, for example, is an issue that permeated the entire process; but instead of handling it separately, the committee members decided that it should be identified as an overriding issue that affects virtually all other environmental concerns.

It is important to explain why those involved in the RRAP made the decisions they did about environmental problems. Understanding perceptual differences about the relative importance of issues is critical to understanding the process and its value. This report will examine the debate that occurred during the RRAP to help explain the rationale for identifying and ranking issues.

The results of this project will enable the governor, legislators, agency personnel, and other policymakers to evaluate the relative risks associated with the most pressing environmental issues in the state. This information also will enable them to incorporate scientific, social, and agency perspectives in their decisions as they strive to make the best use of limited financial and human resources.

The Process

Public Sector Consultants, Inc., was contracted by the DNR to design, facilitate, and staff the Michigan RRAP. This firm was selected because of its expertise in consensus building and its extensive experience with environmental issues. It designed a process that brought together the public, the scientific community, and representatives from key state agencies to ensure practical recommendations that could be implemented effectively.

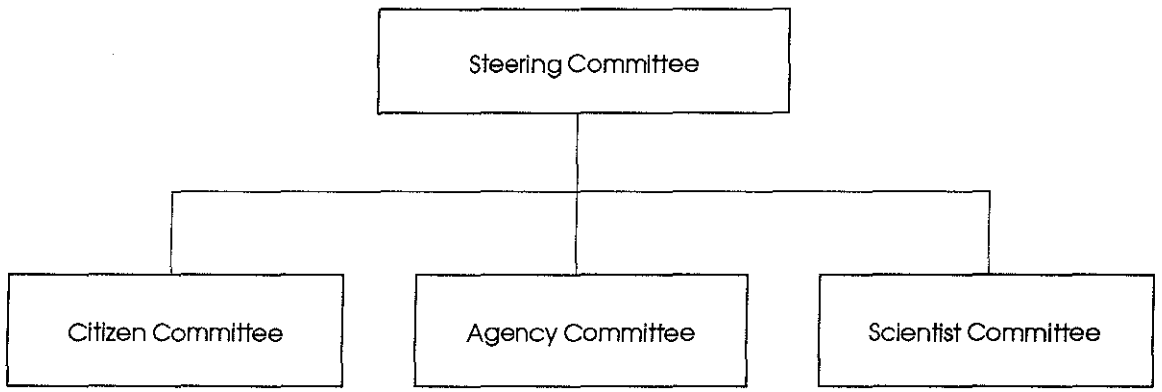
The project was administered by the DNR, which approved its design and oversaw all of its components during performance. The department received quarterly reports of progress, and DNR staff met regularly with Public Sector Consultants staff to deal with logistical problems and other issues that arose in the course of the project.

Steering Committee

The Michigan RRAP was directed by a Steering Committee consisting of the directors of the DNR, DPH, and DOA, the chairman of the MPSC, a policy advisor from the governor's office, and project advisor William E. Cooper, Ph.D., of the Institute for Environmental Toxicology at Michigan State University. The chairman of the Steering Committee was the DNR director. The Steering Committee met to endorse the project and process, to review the issues identified by the project working committees, and to discuss implementation.

The Steering Committee appointed three working committees: Agency, Citizen, and Scientist (see Figure 1).

Figure 1: Michigan's Relative Risk Analysis Project



Agency Committee

The Agency Committee consisted of seventeen people from the DNR, DOA, DPH, MPSC, MDOT, and a county health department. Some members of the Agency Committee wrote or reviewed scientific white papers on the issues to be ranked. Committee members also attended public hearings as observers. The committee chairman was Gary Guenther, the DNR's director of research and program development.

Citizen Committee

The Citizen Committee consisted of fourteen representatives from a variety of backgrounds. Many of the Citizen Committee members are current or former members of state commissions that deal with natural resource or environmental issues. The Citizen Committee conducted four public hearings and an environmental roundtable discussion. The committee was chaired by William Rustem, senior vice president of Public Sector Consultants.

Scientist Committee

The Scientist Committee consisted of fourteen Michigan scientists from academia, government, and business. This committee was representative of a wide diversity of disciplines in the sciences including, but not limited to, biology, environmental chemistry, human health, and toxicology. The Scientist Committee was responsible primarily for writing and reviewing white papers that explained the extent of scientific knowledge for each issue. The committee also briefed the Citizen and Agency committees about the information contained in the white papers. The committee was chaired by William E. Cooper, project advisor.

Selection of Participants

All committees were organized with the advice of key members of public and private organizations. The process was overseen by the Steering Committee. Selection of working committee members was based primarily on their background and experience and their ability to work with others to reach consensus. From the outset, and throughout the process, members of the working committees were reminded that they were not advocating a particular special interest. Instead, they were representing the broader interests of the general public, the state government, and the scientific community.

Committee Activities

In September 1991 the working committees met for a two-day session. The first meeting was an introduction to the relative risk process, ecological and environmental concepts, and each other. The meetings began with an overview of the project and a description of a similar project in Vermont. During the session, nationally renowned scientists presented material on a variety of environmental issues: multimedia transport and fate, toxicology, in-place toxicants, biodiversity, and landscape ecology. Members were also provided with background material for later reading.

The committees met individually for one day in late October and early November 1991. Each committee identified key environmental issues to be ranked later. Individual sessions were followed by a one-day general meeting in early November 1991, so that working committees could reconcile differences and develop a single list. The result was a list of 23 issues that included both environmental and human health concerns.

In December 1991 the Citizen Committee hosted public hearings in Detroit, Gaylord, Grand Rapids, and Marquette. The purpose of these four hearings was to inform the public about the project and obtain their views on the list of issues. The public was also invited to submit written comments. All comments were summarized for review by the Steering and Working committees. The deputy directors of the DOA, DNR, and DPH and the MPSC commissioners were also asked to comment on and review the issue list. Their comments were sought to ensure that the list would be comprehensive and address Michigan's most pressing environmental concerns.

In February 1992 the Steering Committee met to review and comment on the list of issues identified by the working committees and the concerns raised in public hearings, in written comments, and by state officials. Urban pesticides was an important issue raised in the public hearings, and some believed it should be considered separately. The Steering Committee decided that urban pesticides could be addressed under the more general issue of *degradation of urban environments.*

Between December 1991 and February 1992 the Scientist Committee prepared white papers for each of the 23 issues. These papers were assigned to individuals specializing in relevant subjects. The documents, each about ten pages, were reviewed by others knowledgeable about the issues. In a few cases a member of the Agency or Citizen committees wrote or reviewed a white paper. The purpose of the papers was to provide Michigan-specific background information about each issue so that relative rankings would be based on common understandings of scientific knowledge.

The white papers also illustrated the current state of scientific knowledge and the major scientific uncertainties pertaining to the risks. They included a statement of the issue; a description of the problem source, including the extent to which Michigan is a responsible party; a description of the effects and recovery time; and a description of the risks. These risks could involve a combination of ecological, economic, human health, and social effects. The white papers addressed only the residual risks of problems-those risks remaining given current control programs.

The white papers were distributed to all committee members, and in March 1992 the working committees met as a single group for a one-day session. The authors of the white papers briefly presented their

work and answered questions. The methods for the final ranking, including explanations of how similar projects had compared issues to create a hierarchy of environmental concerns, were also discussed.

One week after discussing the white papers, the committees met for a two-day session. All committees again met as one group to discuss and agree on the ranking method to be used. The participants decided that they would include quality of life, human health, and ecological risks in one ranking. Participants also agreed that issues should be ranked according to scientific knowledge of residual risks without regard to political concerns, ease of remediation, or popular perceptions. Economic costs were not considered during the ranking process, so the rankings reflect only relative risks and not risk management concerns. Each committee then met separately and ranked the issues.

On the second day all committees met to discuss their respective committee rankings, reach a consensus, and develop a single list of ranked issues. During the discussions the committees decided that *generation and disposal of hazardous and low-level radioactive wastes* should be considered separately. As a result the final ranking included 24 issues. During the ranking the committees emphasized that the rate of population growth, and its density and distribution, was an important issue that affected virtually all the other environmental problems considered.

Although two committees used a three-tier ranking system in their rankings, a four-tier system was finally agreed upon. The system used the following categories: high-high, high, medium-high, and medium. This terminology was selected because the committees felt that none of the issues should be misinterpreted as unimportant. The committees also believed it was critical that the ranked issues always appear with explanatory statements"rationales"that evolved during the ranking process. These rationales describe the scope of issues and provide readers with important information that explains why issues were ranked as they were.

This final report discussing the project, process, and results was circulated for comment among all committees. After comments on the draft final report were received, the working committees had completed their duties.

Results

The Issues

Initially, the three working committees (Agency, Citizen, and Scientist) met separately to identify issues for ranking. In each group the issues that were chosen were important enough and/or of a high enough level of public concern to warrant ranking. Hundreds of issues could have been chosen; if issues are not on the list, they are thought to present a lower residual risk by definition. Many smaller issues were incorporated in the broader issues selected.

No group was given detailed instructions on how to define the issues. Participants wished to resist the tendency to overdefine, codify, and constrain the intellectual process by standardizing it at the outset. The three-committee framework and the individual committee members were chosen to maximize breadth of knowledge, experience, and values. The process was, in fact, strengthened by the diversity that individuals brought to the table. These diverse groups were able to reach consensus, and each committee independently came to similar rankings for many of these issues.

Tables 1-3 present the three initial committee lists of the issues, and Table 4 presents the final consensus list. The number of issues varied initially. The Agency Committee began with 25 issues, the Citizen Committee with 24, and the Scientist Committee with 19. Of these, nine issues were identical in all three committees, and another eight were identical in two of the three committees.

The consensus list of 23 items resulted from a six-hour healthy debate among all of the participants. Issues were clarified, items aggregated and/or separated, and definitions specified until there were no terms or categories unacceptable to any group. For example, the *air toxics* issue was redefined as *atmospheric transport and deposition of air toxics* in recognition that outdoor air in Michigan is not a medium of significant exposure to toxic substances. Rather, air is a transport and deposition medium for persistent toxicants such as mercury (Hg), lead (Pb), PCBs, and dioxin outside of the workplace. The *biodiversity/habitat modification* issue was expanded to include the *introduction of exotic species*. The energy issues were combined as *energy production and consumption: practices and consequences*.

Table 1: Agency Committee Problem Sets

Acid Deposition
Air Toxins
Alteration of Natural Hydrology
Biodiversity
Childhood Lead Exposures
Consequences of Fossil Fuel Consumption
Degradation of Great Lakes Shoreline
Electromagnetic Fields
Environmental Emergency Preparedness
Global Climate Changes
Hazardous Waste Including Low- and High-Level Radioactive Materials
Inadequate Infrastructure Maintenance
Indoor Air Pollution
Inefficient Energy/Environment Policy
In-Place Contaminants
Lack of Effective Pollution Prevention Strategies
Loss of Natural Habitat
Loss of Prime Farmland
Loss of Upper Ozone Layer (Stratospheric Ozone Depletion)
Persistent Toxins
Point-Source Water Degradation
Surface Level Ozone (Photochemical Smog)
Waste Management and Disposal
Water Degradation from Nonpoint Sources
Urban Environments

Table 2: Citizen Committee Problem Sets

Acid Deposition	Habitat Loss
Air Toxics	Inadequate Scientific Knowledge About the Effect of Compounds, Materials, and Practices Prior to Introduction or Application in the Environment
Biodiversity (Loss of Biodiversity)	Indoor Air Pollution
Contaminated Sediments of Surface Waters, Including Great Lakes	Introduction of Exotic Species
Contaminated Sites	Lack of Coordinated Land Use Planning
Electromagnetic Field Effects	Nonpoint Source Pollution
Energy Consumption (Inadequate Energy Efficiency and Conservation)	Point-Source Water Pollution
Environmental Education (Inadequate Environmental Education)	Soil Erosion
Global Climate Change	Solid Waste (Excessive Waste and Improper Disposal)
Great Lakes Water Quality and Quantity	Stratospheric Ozone Depletion
Ground-level Ozone (Photochemical Smog)	Urban Environment
Groundwater (Aggregated Groundwater Problems)	World Population Growth

Table 3: Scientist Committee Problem Sets

Acid Deposition/Pollutant Deposition	Indoor Pollutants in Private Homes
Air Toxics	Land Use Patterns/Landscape Management
Biodiversity	Other Air Pollutants
Ecological Aspects of Water/Habitat Degradation	Photochemical Smog
Environmental Illiteracy/Apathy	Releases of Untreated Raw Sewage from Combined Sewer Overflows
Geopolitical Considerations	Solid Waste Management
Global Climate Change	Stratospheric Ozone Depletion
Habitat Modification	Toxic Organic Chemicals
Heavy Metals in the Ecosystem	Water Resource Management
High-level Radioactive Waste Management	

Rankings

The procedure and rationale used for ranking issues paralleled that used for defining the issue list. Each of the three committees ranked the issues independently. Each chose a system with which it felt comfortable. Again, the participants were not instructed on how to proceed. The Agency and the Citizen committees chose a three-category ranking system (*high*-H, *medium*-M and *low*-L). The Scientist Committee chose a four-category system using *high-high, medium-high, low-high* and *low-low* categories. Table 5 represents the intermediate rankings organized in the subgroupings that were used in the final consensus rankings. One can easily see the remarkable agreement on the rankings. The few outstanding exceptions are *indoor air pollution, generation and disposal of high-level radioactive waste, biodiversity/habitat modification,* and *degradation of urban environments.*

Table 4: List of Committee Issues

Absence of Land Use Planning that Considers Resources and the Integrity of Ecosystems	Generation and Disposal of High-level Radioactive Waste
Accidental Releases and Responses	Generation and Disposal of Low-level Radioactive Waste
Acid Deposition	Generation and Disposal of Municipal and Industrial Solid Waste
Alteration of Surface Water and Groundwater Hydrology, Including the Great Lakes	Global Climate Change
Atmospheric Transport and Deposition of Air Toxics	Indoor Pollutants
Biodiversity/Habitat Modification	Lack of Environmental Awareness
Contaminated Sites	Nonpoint Source Discharges to Surface Water and Groundwater, Including the Great Lakes
Contaminated Surface Water Sediments	Photochemical Smog
Criteria and Related Air Pollutants	Point Source Discharges to Surface Water and Groundwater, Including the Great Lakes
Degradation of Urban Environments	Stratospheric Ozone Depletion
Electromagnetic Field Effects	Trace Metals in the Ecosystem
Energy Production and Consumption: Practices and Consequences	
Generation and Disposal of Hazardous Waste	

Part of the design of this risk-assessment process was to test whether differences in knowledge base or differences in perceptions were associated with differences in ranking. In the process of the RRAP, the knowledge base of each participant was brought up to a fairly high and consistent level for all three groups. This was accomplished through the selection of key individuals, as well as through the lectures presented by the visiting scientists, the white papers, and the interpersonal interactions of the committee participants.

The issues and their individual rankings were discussed in great detail in the final meeting of all the participants. The discussion began by asking the group whose ranking differed most from the others to explain its logic to the rest of the participants. In every case, a consensus was reached with no minority positions. Although the committees originally identified 23 environmental issues, all decided to split the issue of *generation and disposal of low-level radioactive waste and hazardous waste* into two issues. The committees felt that the two problems contained in this single issue were significantly different and merited individual ranking. As a result, the final RRAP list contains 24 issues.

Four issues received a particularly large amount of discussion; this was due in large part to the variation in the rankings from group to group.

In regard to the issue of the *degradation of urban environments*, the Agency Committee assumed that if the other issues were controlled, many of the urban environment problems would be greatly reduced. When considering *indoor pollutants*, the Citizen Committee chose not to include indoor smoke (fireplaces, smoking, etc.) and reasoned that the duration of exposure, the sensitivity of children and the elderly, who are in the housebound age groups, and the range of potent volatile organic compounds (VOCs) should have produced evidence of effects, morbidity and/or mortality. They thought that this empirical

Table 5: Rankings by Committee (prior to final consensus ranking)

Issues	Agency*	Citizen*	Scientist
Absence of Land Use Planning that Considers Resources and the Integrity of Ecosystems	H	H	HH
Accidental Releases and Responses	M/L	L	LL
Acid Deposition	L	L	LL
Alteration of Surface Water and Groundwater Hydrology, Including the Great Lakes	M	H	MH
Atmospheric Transport and Deposition of Air Toxics	H/M	M	MH
Biodiversity/Habitat Modification	H/M	H/M	MH
Contaminated Sites	M/L	M	LH
Contaminated Surface Water Sediments	L	M	LH
Criteria and Related Air Pollutants	L	L	LH
Degradation of Urban Environments	M	H	MH
Electromagnetic Field Effects	L	L	LL
Energy Production and Consumption: Practices and Consequences	H	H	HH
Generation and Disposal of Hazardous and Low-level Radioactive Waste	L/M	M	LH
Generation and Disposal of High-level Radioactive Waste	H	M	LL
Generation and Disposal of Municipal and Industrial Solid Waste	M	L	LH
Global Climate Change	H/M	H	HH
Indoor Pollutants	H	L	HH
Lack of Environmental Awareness	H/M	H	HH
Nonpoint-Source Discharges to Surface Water and Groundwater, Including the Great Lakes	H/M	H	MH
Photochemical Smog	M	L	LH
Point Source Discharges to Surface Water and Groundwater, Including the Great Lakes	M	M	MH
Stratospheric Ozone Depletion	H	H	HH
Trace Metals in the Ecosystem	M	M	MH

*Dual rankings indicate disagreement among committee members on how to rank that issue; both rankings are indicated.

evidence did not exist and therefore gave these pollutants a lower relative ranking.

The *generation and disposal of high-level radioactive waste* issue was given a wide array of ranks because of differences in the basic assumptions of the committees. The Agency Committee assumed that the issue would not be adequately addressed by the federal government and ranked this issue *high*. It did agree that, when and if the federal terminal storage facility is available to the state, the issue would be of less concern. The Scientist Committee assumed that the federal government will have the terminal storage facilities available to the state prior to the decommissioning of the existing nuclear plants in Michigan. Assuming the present management, it

ranked the issue *low-low*. If the federal government is unable to provide adequate storage for these nuclear wastes, the issue would rank in the Scientist Committee's *high-high* category. The decision was split in the Citizen Committee, which gave it a *medium* ranking. All three committees basically agreed on the scientific facts relevant to this issue. They initially disagreed on the validity of assumptions.

Biodiversity/habitat modification was the subject of much debate because of the scope of the issue. Potential problems associated with the introduction of exotic species—both aquatic and terrestrial—and the need for the preservation of certain plant species around the world for medicine development were part of the debate. The committees finally agreed that this issue warranted ranking in the *high* category.

The group decided on four categories (*high-high*-HH, *high*-H, *medium-high*-MH, and *medium*-M) to provide more degrees of discrimination. Participants assigned issues to their respective categories only when all three committees were in complete agreement with their independent rankings. The groups began ranking issues where there was consensus or agreement and then discussed how the remaining issues compared with those that were already ranked.

The consensus rankings of 24 issues are presented in Table 6. The issues within one category are not ranked in relation to each other. The rationales are as essential as the issue definition. More detailed explanations are contained in the white papers. Again the consensus was obtained if, and only if, the rationales accompanied the rankings.

Because each committee ranked issues separately, debate was spontaneous and candid. Separate rankings enabled the groups to rely more directly on their own perspectives to determine relative risks. Surprisingly, the diverse backgrounds produced very similar rankings.

Table 6: Final Combined Committee Rankings and Rationales
(Issues of equal rank are listed alphabetically within their group)

HIGH HIGH

Absence of Land Use Planning that Considers Resources and the Integrity of Ecosystems
This issue involves broad changes in the landscape that affect environmental quality. It has many aspects, including farmland, Great Lakes and other shorelines, habitat modification, inefficient use of public money, lack of an integrated state land use plan, loss of open space, multiple jurisdictions, soil erosion, timber management, urban sprawl/urban flight, and wetlands.

Degradation of Urban Environments
The effects of population density are wide ranging and complicated by multiple stresses. This issue includes all urban environments and is closely related to land use. Degradation of the infrastructure associated with drinking and wastewater treatment, the effects of urban sprawl, and pesticides are part of this issue. Certain exposures to heavy metals, such as lead in paint, are also included.

Energy Production and Consumption: Practices and Consequences
Energy consumption drives the infrastructure that sustains Michigan's standard of living. The inefficient use of energy and the deleterious by-products of production and consumption threaten the economic security and environmental quality of the state and nation.

(Table 6 continued)

Global Climate Change
This issue includes the "greenhouse effect" and associated long-term changes in weather patterns that could have profound effects on Michigan. Certain activities in Michigan contribute to the buildup of greenhouse gases. Michigan sources contribute to the buildup of greenhouse gases, and state policies may affect the problem. One consideration is the fact that the atmospheric lifetimes of some greenhouse gases are on the order of hundreds of years. Consequently, if climate change is detected, it may take generations to reverse the effect.

Lack of Environmental Awareness
People are uninformed about environmental issues, and lack of information may make it more difficult to make lifestyle changes that may be necessary to correct many of the problems identified in this project. This issue is broader than K-12 education and extends into adulthood.

Stratospheric Ozone Depletion
Ozone acts as a filter for ultraviolet radiation emitted by the sun. As ozone levels decrease, humans will be exposed to increased ultraviolet radiation and there may be an increase in eye disease and skin cancer. Plant growth also could be affected, resulting in lower crop and timber yields. Michigan sources contribute to the buildup of ozone depleting gases, and state policies may affect the problem. An immediate ban of destructive chemicals would not eliminate the threat until the middle of the next century because of the long lifetime of some of these gases in the atmosphere.

HIGH

Alteration of Surface Water and Groundwater Hydrology, Including the Great Lakes
Michigan's water resources are among the most important to the state. This issue includes changes in water levels that result from natural and human activities, such as channelization, dredging, dams, and withdrawals. This issue includes modification of streams and construction and maintenance of county drains as well as groundwater reserves.

Atmospheric Transport and Deposition of Air Toxics
There are more than 200 contaminants designated as air toxics. Many of these substances are known or suspected carcinogens while the rest pose other health risks or may have unknown biological effects. This issue considers the effects of human exposure to air toxics as well as their effects on ecosystems. At concentrations measured in Michigan, inhalation of air toxics does not appear to pose a measurable health risk. However, PCBs, mercury, dioxin, and a handful of other persistent toxics are the main concern because they can be transported hundreds (maybe thousands) of miles before depositing and accumulating in the environment. Persistent toxics are responsible for fish advisories in the Great Lakes and inland lakes in Michigan. Atmospheric deposition is the principal source.

Biodiversity and Habitat Modification
This issue includes the introduction of exotic species, biotechnology, wetland loss, forest monoculture, sedimentation in streams, and species extinction. Loss of species is irreversible and global in scope; these changes could affect ecological balances. State land management policies and lack of a land use plan may contribute to the problem.

Indoor Pollutants
Americans spend the majority of their time indoors and may be exposed to a variety of contaminants that include asbestos, lead, radon, VOCs (volatile organic compounds), and many others. This issue involves homes as well as office buildings, but not workplaces regulated by the Occupational Safety and Health Act. Some aspects of this problem are related to energy consumption and conservation practices. In some cases, conserving energy has meant an increase in indoor air pollutants because of reduced air circulation and exchange.

Nonpoint-Source Discharges to Surface Water and Groundwater, Including the Great Lakes
Widely distributed sources expose surface water and groundwater to a variety of pollutants. Such sources include fertilizers, pesticides, soil erosion, and sewer systems. Many of these pollutants are carried to water systems by the runoff from streets, parking lots, agricultural land, and lawns.

(Table 6 continued)

Trace Metals in the Ecosystem
Exposure to heavy metals results in a wide variety of toxic effects to all organisms, including humans. Heavy metals present a particularly difficult problem because they are common and occur naturally. Mercury is most critical, especially in aquatic environments. Some natural processes can make metals more mobile and toxic in the environment. Lead and cadmium are also a considerable concern because of the effects on children.

MEDIUM HIGH

Contaminated Sites
This problem should be considered on a case-by-case basis. The risk depends upon how people are exposed, such as through groundwater, surface water, soil, etc. Individual sites can and do pose local risks, depending on the fate and transport of and exposure to contaminants. Considerable state and private efforts are key to reducing local exposure; continuation of current programs is critical.

Contaminated Surface Water Sediments
Pollutants captured in sediments can be re-released into surface water ecosystems. Sediments containing mercury, lead, polyaromatic hydrocarbons, and other persistent toxics could become lingering sources of contamination. There are indications that levels of certain contaminants are decreasing, but we must maintain current controls to ensure this trend. Catastrophic events, natural scouring, and dredging could release contaminants stored in surface water sediments.

Generation and Disposal of Hazardous Waste
Because Michigan is a significant generator and user of hazardous wastes, the need for pollution prevention practices and appropriate waste management is critical. Small-quantity generators are a problem because they are not regulated as large-quantity generators are, yet collectively they account for a significant amount of the hazardous waste generated. A major concern is what happens when hazardous waste never makes it into approved landfills. Continued funding of the existing regulatory framework is critical to maintain quality management.

Generation and Disposal of High-level Radioactive Waste
High-level radioactive waste is accumulating at nuclear power plants. Although regulation of this material is a federal issue, its presence in the state poses potential environmental and human health risks. The relative risk is dependent on federal government action or inaction. Several Michigan nuclear power plants and their radioactive wastes are located very close to the Great Lakes (within 200 feet), and this could pose particular disposal/management problems. Decommissioning of these plants may force the on-site containment issue to the forefront.

Generation and Disposal of Low-level Radioactive Waste
Because Michigan is a significant generator of low-level radioactive wastes, the need for pollution prevention practices and appropriate storage facilities is critical. The problem is temporary storage before a final storage solution is found. Once the issue of final storage is resolved, risks will be reduced.

Generation and Disposal of Municipal and Industrial Solid Waste
Management of municipal and industrial solid wastes plays a crucial role in land use planning, protection of water resources, and similar environmental issues. The primary issue is waste volume and our decreasing ability to handle it. Part of managing this problem must entail waste minimization and recognition that continued landfilling is not a permanent solution. Household hazardous waste also can pose environmental problems when disposed of in solid waste landfills. A secondary issue is methane mobilization of toxic organic compounds.

Photochemical Smog
The principal concern with smog is ground level ozone, which, at high enough concentrations, is a lung irritant and can be harmful to plants. Ozone concentrations exceed EPA standards along the Lake Michigan shoreline and in southeast Michigan for an hour or two a few times during the summer. Along Lake Michigan this pollution primarily comes from emissions from other states, while southeast Michigan both imports and produces ozone. Efforts are under way to eliminate all exceedances by the mid to late 1990s.

(Table 6 continued)

Point-Source Discharges to Surface Water and Groundwater, Including the Great Lakes
While significant progress has been made in reducing the risk to surface water from other sources, the primary focus of this issue is combined sewer overflows. Sewage can be contaminated with biological pathogens such as hepatitis virus, polio, etc. Of particular concern is the effectiveness of the aging infrastructure, which, in many cities, is approaching time for replacement.

MEDIUM

Accidental Releases and Responses
This issue includes oil and chemical spills, and fires and the ability of authorities to respond to these events in a timely and effective manner. Terrestrial spills are relatively easily contained, and this is where most accidents occur. Water transport poses more risks, and there is some question about the preparedness for spills on Great Lakes. There is technology in the state for responding to accidental spills, but emergency plans are not tested adequately.

Acid Deposition
Acidity deposited in Michigan is primarily from regional atmospheric emissions although Michigan contributes to the problem. Potential problem areas exist in the western part of the Upper Peninsula and at Isle Royale. It is not clear whether acid deposition is enhancing the acidification of inland lakes in these areas. Fish species are fewer in these lakes, but evidence for historical declines is limited. Most other inland lakes and the Great Lakes are buffered from acid deposition effects. Acid deposition is a problem with soils of low alkalinity because it causes nutrients and metals to leach out of the soil (potentially into water systems). Acid snow melt mobilizes aluminum under more highly acidic conditions in the springtime and may flush metals into rivers and streams. This problem is related to energy issues because of the burning of high-sulfur coal in power plants. While adjacent states continue to use high-sulfur coal, Michigan does not.

Criteria and Related Air Pollutants
These air pollutants include everything in the air other than photochemical smog and the pollutants classified as air toxics. The most important are the criteria pollutants—carbon monoxide, sulfur dioxide, nitrogen dioxide, and fine particulates—acid aerosols, and visibility-reducing haze. Because of existing control programs these criteria pollutants occur in Michigan in concentrations lower than the federal standards. Acid aerosols do not appear to occur at concentrations of concern in Michigan. Visibility in Michigan has declined since the 1950s, but it has not attracted the attention of the public.

Electromagnetic Field Effects
This issue involves the potential for adverse human health and ecological effects related to electrical and magnetic fields radiating from powerlines, certain household appliances, and other sources. There is limited data about the effects of fields, and there is no known mechanism for environmental or human health damage to occur.

Analysis

The RRAP has clustered relative risk into four rankings and the committees considered **all** of these issues to be important. This project did not separate risk into human health and ecological risk; these risks were considered together by the committees. It is also important to note that not all of the risks can be resolved by state action. Some risks, such as *global climate change*, are broad issues that will require national and international efforts. The RRAP committees believed, however, that it was important to identify and rank these issues here so that readers could understand the relative importance of other issues and so that the report would attract attention to the most important issues we face.

Table 6 provides the listing of the committee rankings and rationales. It is impossible to separate the issues from the rationales and understand accurate meanings.

High-High Relative Risk

The following six issues were ranked as having the highest relative risk, *high-high*:

- *Absence of Land Use Planning that Considers Resources and Integrity of Ecosystems*
- *Degradation of Urban Environments*
- *Energy Production and Consumption: Practices and Consequences*
- *Global Climate Change*
- *Lack of Environmental Awareness*
- *Stratospheric Ozone Depletion*

The issues of *absence of land use planning that considers resources and the integrity of ecosystems, energy production and consumption: practices and consequences,* and *lack of environmental awareness* are broad issues that affect all others on the list. Addressing these problems could reduce the effects of other problems.

Degradation of urban environments is a unique category because about 80 percent of Michigan's population resides in an urban setting. This is an important issue because population density and the complications of multiple stresses compound environmental risk in urban areas. Urban problems include air and water pollution, land degradation (sprawl and land contamination), toxic releases, deteriorated and abandoned structures, pesticides, and lead poisoning. It is the coming together of all these environmental stresses in urban settings that creates a great relative risk.

Global climate change and *stratospheric ozone depletion* are important issues for Michigan not because Michigan is solely responsible for them or can solve the problem alone but because these issues have the potential for permanently disrupting the natural environment in the state. They affect the entire planet, and the effects are lasting and broad. The state cannot solve these problems alone, but it can take a leadership position. Michigan can set an example and contribute to the solution by ensuring that state policies do not exacerbate the problem.

High Relative Risk

Six issues were ranked as having *high* relative risk. They are:

- *Alteration of Surface Water and Groundwater Hydrology, Including the Great Lakes*
- *Atmospheric Transport and Deposition of Air Toxics*
- *Biodiversity/Habitat Modification*
- *Indoor Pollutants*

- *Nonpoint Source Discharges to Surface Water and Groundwater, Including the Great Lakes*
- *Trace Metals in the Environment*

The state has direct control over solutions to most of these problems. Although many of the problems associated with *atmospheric transport and deposition of air toxics* are the result of industrial activity along the southern Lake Michigan shore, there are sources of these airborne contaminants within the state that can be directly controlled. This issue is related to *trace metals in the ecosystem* because some metals, such as mercury, are transported in the atmosphere and are later deposited on land where they enter the Great Lakes watershed through runoff or enter the Great Lakes directly.

Biodiversity/habitat modification are important issues because the committee believed that failure to address these issues could require long-term solutions, and in the case of species extinction, there are no remedies. The introduction of exotic species also poses certain risks to Michigan habitats and, in some cases, can modify them greatly. Risks associated with other ecosystem changes are reflected in the issues of *alteration of surface water and groundwater hydrology* and *nonpoint source discharges to surface water and groundwater.* The committees stressed the importance of Michigan's water resources, the link between surface water and groundwater, and the desire to maintain the quality and quantity of these resources.

The amount of time people spend indoors focused attention on the variety and amount of airborne substances that could cause health problems. As a result, *indoor pollutants* was ranked in this category.

Medium-High Relative Risk

Eight issues were ranked as having *medium-high* relative risk. They are:

- *Contaminated Sites*
- *Contaminated Surface Water Sediments*
- *Generation and Disposal of Hazardous Waste*
- *Generation and Disposal of High-level Radioactive Waste*
- *Generation and Disposal of Low-level Radioactive Waste*
- *Generation and Disposal of Municipal and Industrial Solid Waste*
- *Photochemical Smog*
- *Point Source Discharges to Surface Water and Groundwater, Including the Great Lakes*

With the exception of *generation and disposal of high-level radioactive waste,* state government has made major efforts to deal with these issues. These efforts are at least partially responsible for minimizing the effects of these problems and account for lower rankings than the issues would have received otherwise. The results of state government efforts are especially evident in the case of *point source discharges to surface water and groundwater, photochemical smog,* and *contaminated sites.* In addition to disposal issues, generation of various wastes was also considered. The committee believed that disposal solutions must also address the generation of wastes.

Contaminated surface water sediments can pose particularly difficult problems when toxic substances are continually recycled in the environment through natural processes such as aquatic plant growth and decomposition of organic matter.

Medium Relative Risk

Four issues were ranked as having *medium* relative risk:

- *Accidental Releases and Responses*
- *Acid Deposition*
- *Criteria and Related Air Pollutants*
- *Electromagnetic Field Effects*

In regard to the issues in this category, there is some debate about the actual existence of the problem or the number of individuals or the ecosystems affected. *Electromagnetic field effects* was included because of the potentially large effect and difficulty of remediation if human health risks are proven. In some cases there are significant state programs addressing the issue, as in the case of *acid deposition* and *criteria and related air pollutants*.

Known *accidental releases and responses* often occur on land, and Michigan has had no major difficulties in minimizing the environmental effects of this problem. There are state and federal government programs already established to handle such accidents through reporting mechanisms and availability of containment and cleanup devices.

RRAP Rankings in Context

It is interesting to compare the RRAP results with the results from the EPA's Region V risk assessment program (Table 7). The Region V process separated ecological risks from human health risks. While many of the issues are ranked similarly, the issue definitions are different, and the EPA definitions reflect regulatory mandates. Some major differences between Michigan and Region V rankings exist by omission. For example, the EPA does not list *degradation of urban environments, absence of land use planning that considers resources and integrity of ecosystems,* or *lack of environmental awareness.* Some rankings differ, for example, those for *accidental releases and responses* and *criteria and related air pollutants.* Future discussions should focus on reasons for the differences and similarities and then on actions to solve these problems.

A similar comparison can be made between the RRAP results and the existing state programs established by the DNR and DPH. The major efforts of these departments are in areas where the residual risks are considered *medium or medium-high.* This means either that many of the existing programs have worked and these risks to human health and ecology have been reduced, or, in some cases, that the risks were not great and could be addressed on a site-specific basis. This also means that new initiatives and new resources should be directed toward the high-risk areas where little effort is currently being made while maintaining existing programs. There are few state programs that deal directly with issues in the *high-high* and *high* categories. That is a reflection that we have failed to address these issues effectively or that the issues are beyond the authority of state government. In some cases, some state programs have contributed to problems.

Table 7: Rankings of Risk—A Comparison

	EPA Region V	
Michigan's RRAP	**Ecological Risk**	**Human Health Risk**
High High	**High**	**High**
Absence of Land Use Planning Degradation of Urban Environments Energy Production and Consumption: Practices and Consequences Global Climate Change Lack of Environmental Awareness Stratospheric Ozone Depletion	Accidental Chemical Releases CO_2 and Global Warming Hazardous/Toxic Air Pollutants Nonpoint Source Discharges to Surface Waters Physical Degradation of Terrestrial Ecosystems Physical Degradation of Water and Wetlands Habitat Stratospheric Ozone Depletion	Accidental Chemical Releases Indoor Air Pollutants Indoor Radon Municipal Wastewater Discharges Stratospheric Ozone Depletion
High	**Medium High**	**Medium High**
Alteration of Surface Water and Groundwater Hydrology Atmospheric Transport and Deposition of Air Toxics Biodiversity/Habitat Modification Indoor Pollutants Nonpoint Source Discharges to Surface Water and Groundwater Trace Metals in the Ecosystem	Abandoned/Superfund Sites Industrial Wastewater Discharges Ozone and Carbon Monoxide Pesticides Sulfur and Nitrogen Oxides	Hazardous/Toxic Air Pollutants Lead Nonpoint Source Discharges Ozone and Carbon Monoxide Pesticides Radiation Other than Radon Sulfur and Nitrogen Oxides
Medium High	**Medium Low**	**Medium Low**
Contaminated Sites Contaminated Surface Water Sediments Generation and Disposal of Hazardous Waste Generation and Disposal of High-level Radioactive Waste Generation and Disposal of Low-level Radioactive Waste Generation and Disposal of Municipal and Industrial Solid Waste Photochemical Smog Point Source Discharges to Surface Water and Groundwater	RCRA Hazardous Waste Storage Tanks	Abandoned/Superfund Sites Aggregated Drinking Water Aggregated Groundwater Airborne Lead Industrial Solid Waste Sites Industrial Wastewater Discharges Municipal Wastewater Discharges Particulate Matter PCB Worker Exposure—TSCA Storage Tanks
Medium	**Low**	**Low**
Accidental Releases and Responses Acid Deposition Criteria and Related Air Pollutants Electromagnetic Field Effects	Industrial Solid Waste Sites Municipal Solid Waste Sites	Municipal Solid Waste Sites Physical Degradation of Terrestrial Ecosystems RCRA Hazardous Waste

Future Work: Implementation Strategies

Now that major environmental issues have been identified and ranked, financial and human resources must be allocated to mitigate, remediate, or prevent environmental risks. For some issues, the next step is obvious. Legislation, executive orders, or similar measures can be implemented quickly. But these responses are not always the complete answer; and in many cases they are inadequate to resolve the most difficult problems.

Some issues, such as *energy production and consumption: practices and consequences,* will require comprehensive research and carefully designed public policies. Others may be addressed with a combination of executive orders, legislation, and additional research. In any case, the results of this project should be used to build public consensus for action.

In the course of developing solutions we must not forget direct and indirect costs. Some solutions, for example, may simply require additional funding in key areas. Others, however, may require new regulations that could lead to an increase in the cost of doing business in the state. These costs must be weighed against the benefits of protecting Michigan's environment.

Public policy is not driven by scientific knowledge alone. Public attitudes, economic reality, and the cooperation of the business community are among the factors affecting the state's ability to respond to environmental issues. A plan is required to identify and account for these factors in order to develop useful environmental strategies.

Appendix: Issue Summaries

Absence of Land Use Planning That Considers Resources and Integrity of Ecosystems

Land use, by and large, determines the future. The land in Michigan has a fundamental role in sustaining our state for the long haul. Despite this, Michigan lacks a statewide planning system that encourages appropriate land use with consideration for sustainable resources and long-term ecosystem health. This threatens Michigan's quality of life. The lack of integrated land-use planning is a broad issue with far-reaching effects.

In Michigan, and elsewhere, state and local agencies manage the resources under their statutory jurisdictions as individual commodities. For example, within the Michigan Department of Natural Resources (MDNR), the Wildlife Division focuses on deer, grouse, and pheasants, the Forest Management Division focuses on economic returns from the sale of fiber, the Fisheries Division focuses on fish species that support a strong recreational industry, the Surface Water Quality Division focuses on clean water, and so on. Other state agencies concern themselves with agriculture, urban development, human health, and transportation at various government levels. A multitude of land-use authorities and interests express their control and power at the local level. Little attention is paid to coordinating the goals of these various entities to lay the foundation for integrated land-use planning. Ramifications of this lack of coordination are numerous: The natural landscape pattern and its associated natural habitats and biota generally are unprotected and exposed to alteration; some renewable resources are not being managed in a sustainable fashion; a burgeoning deer herd threatens the regeneration of economically important tree species and many herbaceous plants in our forests; wetland degradation robs us of valuable ecosystem functions; urban sprawl supplants prime agricultural land; and the unnatural appearance of our landscape (including poorly planned residential and industrial parks) offends human sensibilities.

It should be a high priority for Michigan to develop a land-use plan that optimizes wood production, resource extraction, biological diversity, clean water, cultural cohesion, human health, housing, and other societal goals. Not adopting this priority poses a severe, long-term risk to the sustainability of resources, integrity of ecosystems, and human health and existence. Current science and technology is sufficient to allow us to undertake integrated land-use planning now.

In Michigan ad-hoc arrangements of government units cut across natural landscapes, and conflicting jurisdictions confound effective planning. Government agencies tend to manage the environment in a reactive, site-specific manner by making isolated decisions about individual activities. The process of making such decisions is encumbered by controversies about public versus private interests, conflicting goals among different segments of society, and inadequate information for making good decisions. Rarely is attention paid to proactive assessment of social goals for achieving balance between economic development and conservation of a healthy environment. Consequently, environmental management suffers from inadequate broad-based information and ineffective policies and procedures to address such concerns. For planning to be effective at the landscape level, all players (government entities; private, public, tribal, and corporate landholders; scientists; educators; and other

citizens) must discuss their long-term and short-term goals.

Michigan has the largest area of state-owned land of any state except Alaska. Many of these land holdings include substantial portions of watersheds. All of our rivers and streams flow into the Great Lakes, and many of the associated watersheds are small enough to be included within state-owned lands. Michigan has a unique opportunity to demonstrate that good land-use design and management can be both good ecologically and economically.

Accidental Releases and Responses

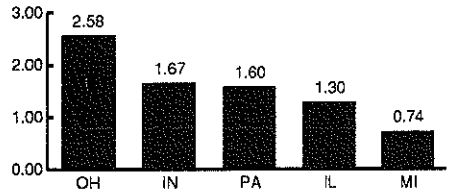
Given the statistical likelihood of accidental spills—and based on experience—federal, state, and local governments have developed rules to require mitigation of such spills as well as rules influencing the transport of potentially dangerous materials.

We live in a world of uncertainty that reflects circumstances and events that are a result of human behavior, design and operation of technology, and "acts of God" (climatic and geological changes that are unpredictable). It is not surprising then that unforeseen events and circumstances can combine to precipitate problems to human health and the environment. The frequency of such events, however, may be influenced by population density; both the incidence of an accidental release of toxic substances as well as the severity of the consequences may increase along with commercial activities. Damage to the environment, however, knows no urban boundaries, and therefore no location is immune to the problems associated with accidental spills or releases. This has been amply illustrated recently by the Exxon Valdez incident, in which a petroleum spill occurred in Alaska's Prince William Sound. More than 10 million gallons of oil spilled into the water, spread over an area the size of Delaware, and affected more than 300 miles of beach. The effects of the spill were apparent more than 250 miles from the spill site. On another occasion, here in Michigan a tanker ship exploded and caught on fire in the Saginaw River on September 16, 1990.

Within the state of Michigan and its boundary waters is included an array of potential problems that reflect our wide range of commercial activities and uniquely disparate ecological habitats. Commercial activities range from highly concentrated heavy industry, intensive agriculture, small manufacturing companies in rural areas, and petroleum production and processing to remote sparsely populated regions through which run major roadways associated with interstate commerce. The ecology of the state is equally diverse ranging from extensive coastlines bordered by large bodies of water and extensive wooded areas to densely populated environs both on shorelines and in the interior. This diversity requires a wide array of strategies in response to spills. There is no "standard solution" to an accidental release.

Risks from the accidental releases of toxic substances to the atmosphere may be both direct and indirect. In the former case, direct inhalation of pollutants may precipitate problems to human health and animal life. Such atmospheric pollutants may result from direct transfer from combustion or volatilization from chemicals in liquid or solid form. Longer term indirect effects may reflect deposition of atmospheric pollutants with moisture and dissolved particulates that may enter food chains or cause deleterious effects more directly on the viability of plant and aquatic life through the deposition of acid rains. These effects are similar to long-term releases

Annual Emissions of Sulfur Dioxide, 1984 (millions of tons)



at low concentrations but may require short-term solutions to minimize threats to human populations and the environment, since such indirect effects may occur quickly. Generally, such accidental releases of toxic substances may be associated with high concentrations of a particular agent and, therefore, there is the danger of exposure to high concentrations, albeit over a short period of time.

In the case of accidental releases of hazardous and toxic chemicals, many of the consequences to human health and the environment mirror those identified for the long-term release at low concentrations of the same materials. In the case of accidental releases, however, high concentrations of substances in transport or in storage may pose special problems. Not only may such materials be potentially toxic, but in many instances, such materials may be flammable and constitute a hazard of explosion or fire. Furthermore, such materials may quickly reach potable water supplies either by infiltration of aquifers used for adjacent domestic water supplies or transportation by lakes and rivers to population centers, where they may enter domestic water supplies. In addition, some materials when exposed to air or moisture may chemically react, leading to the formation of toxic fumes, which if inhaled may be life threatening.

If the response to an accidental spill is quick, much of the material can be contained or removed from the site, leaving lesser amounts to be removed or treated over a longer period of time, though probably from a larger area. The availability of either commercial sector or state personnel to accomplish the cleanup will influence directly the time required to mitigate the spill to acceptable levels. It follows that responsible and competent organizations should be identified who can perform such remedial cleanups on demand or within a short time. Information concerning capability and past performance should be readily available to responsible parties and concerned local officials. It seems reasonable to assume that the sooner the cleanup begins, the sooner the problems at hand will be reduced. This can be facilitated by prior knowledge of response capabilities available from the state and private sectors. The greatest risk is from highly toxic materials that can disperse very rapidly over wide areas prior to containment responses; for example, the explosion in Bopal, India, in 1984 in which an estimated 3,350 died as a result of exposure to methyl isocyanate.

Acid Deposition

Acid deposition is the process by which acidic material in the atmosphere from anthropogenic and biogenic sources is deposited onto the surface of the earth. Acid deposition includes acidic rain, snow, aerosols, fog, and gases. Wet acid deposition occurs through rain or snow, with H_2SO_4 and HNO_3 being the principal components dissolved. Dry deposition involves acidic gases, primarily HNO_3, or particles from the atmosphere, such as acid sulfate particles, being retained by the earth's surface. Dry deposition, while being more difficult to measure, is estimated to be of about the same magnitude as wet deposition.

The chemical precursors responsible for the production of acid deposition are sulfur dioxide (SO_2) and oxides of nitrogen (NO_X). It is worth noting that these are pollutants regulated by the Federal Clean Air Act. National Ambient Air Quality Standards (NAAQS) exist for these two pollutants, and they are among the success stories for the Federal Clean Air Act and federal and state regulators. Few nonattain-

ment areas in the United States exist for these two pollutants. No monitored nonattainment areas exist in Michigan. These precursors react with other compounds present in the atmosphere, and/or in the presence of sunlight, to form acids. The reaction rates vary depending upon the compound, weather, latitude, time of day, and presence of other compounds. Acidic deposition may take place near the source or can involve a receptor tens or hundreds of miles from the source.

In addressing earlier nonattainment problems concerning sulfur dioxide, Michigan indirectly took an initiative in dealing with acid deposition. A significant effort was made to limit the sulfur content of fossil fuels, such as coal or oil, burned in power-generating facilities. It was required that large coal-burning facilities use coal having a maximum sulfur content of one percent by July 1, 1978. While extensions were granted, all major power generating facilities in the state now meet this requirement.

Michigan's initiation and implementation of a one-percent maximum sulfur content in fuel is in sharp contrast to the neighboring industrial states: Illinois, Indiana, Ohio, and Pennsylvania. These states are major coal producers, with massive reserves of coal with sulfur content in excess of 2 percent. Michigan currently has no viable coal mining industry.

Most of the wet acid deposition in Michigan is imported from these states that use high sulfur coal. With the exception of part of the Upper Peninsula, however, Michigan's lakes and soils are adequately buffered so that adverse ecological effects of acid deposition do not appear to be occurring. In the eastern Upper Peninsula, about 9 percent of the lakes are naturally acidic, so acid deposition could enhance their acidification. It is not clear, however, whether this is occurring. Fish species are fewer in these lakes, but evidence for historical declines is limited.

Alteration of Surface Water and Groundwater Hydrology, Including the Great Lakes

Michigan's Great Lakes coastline is longer than 3,200 miles, including portions of lakes Michigan, Superior, Huron, and Erie. More than 36,000 miles of streams and rivers drain the watersheds of the state. Inland lakes number in excess of 11,000 and have a combined surface area of more than 1,000 square miles. The major uses of water in the state are: thermoelectric power generation (75 percent), self-supplied industry (12 percent), public supply (11 percent), and irrigation (approximately 2 percent). Approximately 90 percent of the total water use is drawn from the Great Lakes and connecting waterways. Groundwater resources provide the drinking water supply for more than 40 percent of the state's population and nearly all of the water used for irrigated agriculture. Use for irrigation, though only approximately 2 percent of the total, is a concern, since the practice has grown significantly in the past three decades.

Given that Michigan's boundaries account for more than 40 percent of the Great Lakes, and nearly half of all Great Lakes shorelines, the state has been challenged to maintain a leadership position in the protection and development of the Great Lakes ecosystem. The extent to which existing land and water contamination sources have been identified provides a perspective on the magnitude of the challenge to the state. It is clear, however, that

substantially more in-depth analysis and regulatory attention need to be focused on the direction of Michigan's leadership role in water resource management, remediation, and protection.

The quantity of Michigan's surface water and groundwater resources is significant, and the systems are very closely linked. Chemical stresses (contaminant release and transport, transformations, and so forth) and physical stresses (sedimentation, coastal erosion, and so forth) active within these hydrologic systems have continued to affect human and natural ecosystems.

Perhaps one of the most troublesome and ill-recognized problems in water resources management results from the "mining" of groundwater for consumptive uses (for instance, irrigation) that may have consequences far beyond immediate concerns of sustaining agricultural production or groundwater discharge. Incomplete understanding of shallow groundwater flow systems and their influence on the surface waters can result in drastic reductions in flow, lack of water availability for direct withdrawal, and habitat loss during drought periods. With regard to physical stresses on human and natural ecosystems, some attention also has been focused on the loss of coastal shoreline and wetlands, sedimentation and bank erosion in streams, runoff, and flood control.

Hydrologic alterations have been part of the state's water history. The consequences of these attempts to capitalize on or engineer relief from natural water occurrence, distribution, and flow dynamics cross-cut a number of areas of environmental concern and residual risk.

Many publications and datasets point out the critical hydraulic interactions between groundwater and surface water systems. This knowledge argues for a holistic approach to the management and use of Michigan's water resources. Since Michigan lies almost entirely within the Great Lakes Basin it should be evident that international, regional, and state water management efforts must work together, otherwise a high-quality water supply available for a variety of uses and the viability of both aquatic and terrestrial ecosystems cannot be guaranteed.

As a basis for action, the state should develop an overall water budget that, even if based initially on incomplete data on water flow, use, loss, storage, and so forth, would provide a reasonable framework for evaluating potential risks involved in new or continuing hydrologic alterations. The preliminary water budget would at least identify the most critical needs for information on which to base an accounting system that would be responsive to future state water planning efforts.

Atmospheric Transportation and Deposition of Air Toxics

There are thousands of commercial chemicals used in the United States. Hundreds of these substances are emitted into the atmosphere and may at certain concentrations have the potential to adversely affect human health or the health of certain ecosystems. Some are known or suspected carcinogens. The 1990 Clean Air Act Amendments identified 189 of these chemicals and classes of chemicals as air toxics, while the Michigan Department of Natural Resources lists 250 substances as air toxics and is in the process of developing emission limitations for them.

Little is known, however, about the concentrations of these substances in the ambient air and their effect on public health and the environment. In Michigan the main health risk from inhalation is thought to be from some of the carcinogens. A review of two preliminary air toxic studies in the Detroit Metropolitan area leads to the conclusion that even when the most conservative worst-case cancer risk estimates are used, the excess cancers due to exposure to air toxics would be indistinguishable from cancers caused by all other sources. As a result, it appears that inhalation of air toxics at the concentrations presently found in Michigan does not pose a significant public health risk.

However, there are a number of air toxics which, because of their stability in the environment, can be transported in the atmosphere for weeks or months before depositing on water or land. This persistence has made some of these compounds ubiquitous in Michigan's environment even though they may not be emitted in Michigan. The substances of greatest concern are those that bioaccumulate in the food chain and thus pose health risks to both wildlife and humans. Eleven of these substances have been identified to be of particular concern for the Great Lakes Basin; they are: polychlorinated biphenyls (PCBs); DDT and metabolites; dieldrin; toxaphene; 2,3,7,8-TCDD (dioxin); 2,3,7,8-TCDF (furan); mirex; hexachlorobenzene; mercury; alkylated lead; and benzo(a)pyrene (BaP). The first eight substances are chlorinated hydrocarbons that include a number of pesticides as well as PCBs, dioxins, and furans. Mercury and alkylated lead are metals. Benzo(a)pyrene (BaP) is a ubiquitous product of incomplete combustion.

Although there are a number of potential sources (point sources, runoff, contaminated sediments) from which these chemicals may enter Michigan's watersheds, a major source appears to be atmospheric deposition. Once deposited, the substances eventually will settle into the sediments and enter the food chain to some degree via bottom feeding organisms. High concentrations of mercury found in fish in inland lakes and high concentrations of PCBs found in fish in the Great Lakes are the primary reasons fish consumption advisories are presently in effect. Consumption of contaminated fish by wildlife has resulted in reproductive failures and deformities of predators such as herring gulls, cormorants, and mink. Tumors in fish have been related to the presence of BaP.

Data on sediments and fish tissue indicate that the concentrations of most of the toxics are decreasing because direct discharges were eliminated or the substances were banned from use. However, recent trends indicate that the concentrations of some of the toxics may be leveling off at concentrations above desired values. The remaining residuals are thought to be due largely to atmospheric deposition. One substance that has not exhibited a downward trend is mercury, and this problem is not unique to Michigan. Besides having natural sources, mercury is emitted from coal burning and incineration.

Biodiversity and Habitat Modification

Biodiversity can be defined as the variety and variability among living organisms and the habitats in which they live. In nature many species share common habitat requirements, and hundreds of species can coexist in close proximity. Habitats are degraded when they can no longer support associations of plants and animals in a natural condition. Erosion of native biodiversity is manifested as species

extinctions, restriction of geographic range, unusual population fluxes, reproductive failures, and depletion of genetic diversity. Lost are potentially valuable organisms and biological compounds for agriculture, silviculture, and medicine.

Habitat degradation and erosion of biodiversity are extremely difficult—if not impossible—to regain. Since all manner of human existence is dependent on environmental health, maintenance of natural habitats and native biodiversity are inexorably linked to human health and welfare.

The degradation of natural habitats and erosion of native biodiversity are caused directly or indirectly by humans and originates from both outside and inside Michigan. For example, global climate change and acid deposition result from national and global activities, yet their effects are felt by Michigan's native biota. Deforestation in the new world tropics may result in changes in our native biodiversity by causing a reduction of neotropical migrant birds that breed in Michigan.

Most sources of the problem, however, are in Michigan. Habitat degradation, and associated losses in biodiversity, result directly from such diverse stresses as recreational activity, impoundment of rivers, agriculture, forest practices, wildfire suppression, wildlife and fisheries management, urban sprawl, wetland dredging and filling, and construction of highways and transmission corridors. Sometimes natural habitats are degraded by overpopulation of native species or introduction of nonnative species (exotics). With each population loss, unique genetic diversity is lost. The ecological functions that these discrete populations perform are also lost.

Aquatic, wetland, and terrestrial habitats are intricately intermeshed. Stresses on one habitat inevitably result in stresses on another. The effects of single activities may be local in nature and apparently of little consequence. When taken collectively, however, the cumulative effect may be large with the irreversible loss of natural habitats or ecosystems and a concomitant loss in biodiversity. Wetlands are extremely important ecosystems. In Michigan we have lost more than half of our original wetlands due to a variety of human activities. Unfortunately, no-net-loss policies for wetlands focus attention on total wetland acreage and divert attention from important issues of individual wetland size, configuration, location in the watershed, connections to other wetlands, and habitat heterogeneity. These attributes often impart a large portion of the functions and value of a wetland.

Habitat modification of terrestrial systems is also a significant problem in Michigan. Our current landscape is comprised of mixed ownerships and supports multiple uses that include wilderness, natural preserves, working (managed) forests, farmlands, urban and rural residential areas, and paved surfaces. As an example, the northern Michigan landscape is dominated by working forests in corporate, state, tribal, and federal ownership. Much forest management occurs without a landscape perspective, resulting in degraded habitats, poor spatial positioning of habitat blocks, few corridors appropriate for movement of organisms, and inadequate buffer zones between areas of intensive human activity and adjacent natural habitats.

In Michigan, overpopulation of some native species contribute to the erosion of native biodiversity.

These instances of overpopulation result directly from intentional game management and indirectly from forestry and agricultural practices. An obvious example is the overabundance of white-tailed deer. Currently, high deer populations threaten biodiversity of both plant and animal communities in Michigan. Overbrowsing by deer harms native flora (including economically important tree species and rare plants) and the thousands of animals that depend on this flora. Extraordinarily high deer populations also pose direct threats to human health (car-deer collisions and Lyme disease) and agricultural crops. In other landscapes, beavers, grackles, crows, and brown-headed cowbirds have deleterious effects on the overall biodiversity. Examples of native plants that have proliferated because of human activities and now threaten native biodiversity are quack grass and witch grass.

Introductions of exotic species of animals and plants also pose extreme threats to native biodiversity. These introductions can be intentional (as is the case with ring-necked pheasants and chinook salmon) or inadvertent (as with the zebra mussel, rusty crayfish, European starling, ragweed, Norway rat, purple loosestrife, buckthorne, European hawkweeds, spotted knapweed, and Russian thistle). Ecological communities are associations of biotic species that have co-evolved and interact by way of predation, competition, mutualism, symbiosis, and obligatory physical associations. Some of these associations are so interdependent that the fates of entire groups of species are inseparably bound. In addition to the direct ecological impact, management for exotic game and fish species (i.e., fish stocking) frequently takes an inordinate proportion of the effort and money available for natural resource management.

Within Michigan, state and federal resource agencies devote much management attention (and money) either to those organisms that we intend to harvest directly through activities such as fishing, hunting, lumbering, or agriculture or to organisms that are on the brink of extinction (threatened and endangered species). All other plants and animals are managed by default as corollaries to game, fish, forest, and agriculture management. As a result of the limited attention that these "in-between" organisms receive, very little is known about their habitat requirements, distribution, and population levels.

Populations of rare species are generally given expensive, emergency management attention. Unfortunately, many endangered species recovery plans deal with captive breeding, stocking, and handling of individual organisms. This very costly "last resort" management is avoidable by maintaining intact natural habitats in the landscape.

Contaminated Sites

There are currently 3,396 sites included on the list of sites of environmental contamination that is prepared annually by the DNR under the Michigan Environmental Response Act (1982 PA 307, as amended; hereafter called Act 307). In addition, there are more than 6,600 confirmed releases from leaking underground storage tanks that are not included on the Act 307 site list. The site counts have increased approximately 30 percent per year in recent years. Contamination sites are found in every county in Michigan.

Hazardous substances present at contamination sites can pose risks to the public health and environment through a number of exposure pathways. Ap-

proximately 50 percent of Michigan's residents use groundwater as their source of drinking water; hazardous substances have been found in groundwater at thousands of sites. Hazardous substances in surface water and sediments can result in contamination of biota and impairment of other surface water uses. (See "Contaminated Surface Water Sediments" issue.) Some materials pose health risks primarily through inhalation; sites where these hazardous substances are uncontrolled can threaten nearby residents. An important exposure pathway for many contamination sites is direct contact with hazardous substances (i.e., dermal absorption or ingestion). This is an issue at sites where access is unrestricted and hazardous substances are present in soil, in leaking containers, or in waste pits. Finally, hazardous substances sometimes pose fire and explosion hazards. This is a problem commonly associated with leaks from underground storage tanks that result in flammable vapors entering nearby basements or utility trenches.

Some of the hazardous substances most commonly found at contamination sites are benzene, ethylbenzene, toluene, xylenes, and polynuclear aromatic hydrocarbons (PAHs). These contaminants are often found at leaking underground storage tank sites and other sites where petroleum has been released. Industrial solvents such as trichloroethylene, dichloroethane, and vinyl chloride are associated with many industrial contamination sites. PCBs and heavy metals (e.g., lead, cadmium, and chromium) are other categories of hazardous substances. Acute and chronic human health effects associated with these materials span a broad range from cancer (benzene) to impaired neurological function (childhood exposure to lead).

The DNR uses public funding, made available through the $425 million Environmental Protection Bond program approved by Michigan voters in 1988, to address approximately 20 percent of the known contamination sites. State-funded efforts have focused on actions that address immediate threats to human health or the environment. This includes providing 455 water supply replacements and conducting "surface cleanups" at 247 sites. Surface cleanups can include removal of drums of waste or restricting access to hazardous substances. Responsible parties (e.g., site owners and operators) are providing for response activity at approximately 60 percent of the remaining sites. Approximately 20 percent of the total number of sites are not currently being addressed. Funding for cleanup of many leaking underground storage tank sites is provided by a 7/8-cent-per-gallon tax on refined petroleum products. Estimates of the cost for remedial action at the nearly 10,000 contamination sites approach $8 billion.

Eighty-three Michigan sites are on the National Priorities List, making them eligible for funding under the federal Comprehensive Environmental Response, Compensation and Liability Act (CERCLA or "Superfund"). Congress created Superfund in 1980 to deal with the most serious sites across the nation. There are currently about 1,200 sites on the National Priorities List.

In contrast to some other issues evaluated in the relative risk project, contaminated sites may pose relatively high risks to individuals or the local environment while posing a lesser risk to the population as a whole. Because of this characteristic, risk should be evaluated on a case-by-case basis.

Contaminated Surface Water Sediments

Sediments usually have been thought of as contaminated when naturally occurring substances are markedly elevated above background concentrations or when synthetic substances are detected by chemical analysis. Unacceptable biological effects are not the primary basis for determining contamination of sediments and remedial actions. Sediment contaminants can be placed in the following groups: metals (including heavy metals and metalloids), nutrients, petroleum products, polynuclear aromatic hydrocarbons (PAHs), and synthetic organic compounds (pesticides, polychlorinated biphenyl (PCBs), dioxins, and furans).

Atmospheric transport and deposition is probably the most important loading source for many sediment contaminants of concern in the Great Lakes basin at this time. Many sediment contaminants have increased markedly in lake sediment core profiles over the past 75 years in the region. Recently, some sediment contaminants have begun to decrease, most notably in areas where point-source discharges have been controlled or use of certain products has been curtailed or eliminated.

Some Michigan harbors, connecting channels, and boundary waters and several inland lakes and rivers have high concentrations of contaminants in sediments due to past discharges. About a million cubic meters of material are dredged in Michigan's Great Lakes connecting channels and harbors annually. Fortunately, pollution control programs over the past two decades have resulted in significant decreases in sediment contaminant concentrations in navigation channels near discharges.

An array of physical, chemical, and biological conditions influence the fate of sediment contaminants in lakes and streams, including: water turbulence and sediment particle size; sediment biota, which play a major role in transferring sediment contaminants; and sediment contaminants, which also can be released directly to the overlying water as a result of changing conditions at the sediment/water interface.

The primary effect of sediment contaminants is on the biotic community living in or on the sediments. Under highly contaminated conditions, sediment dwelling animals and plants cannot exist, and the biota is composed of microorganisms at best. This loss of species diversity exemplifies an unstable and unhealthy ecosystem. Some sediment contaminants, both natural and synthetic, can also induce growth anomalies, reduce growth, and cause reproductive problems in sediment dwelling animals.

Important secondary effects of contaminants released from sediments occur at higher trophic levels in food webs. The greatest risks to humans and other animals at higher trophic levels occurs through consumption of organisms that have biomagnified chlorinated organic compounds (some PCBs, furans, pesticides, and dioxins), other persistent organic compounds, and mercury. In addition to acute or chronic toxic effects to both micro- and macroinvertebrate biota, some sediment contaminants have been found to cause thyroid dysfunction, decreased fertility, decreased hatching success, gross birth deformities, metabolic abnormalities, behavioral abnormalities, changes in sex ratios, compromised immune systems, tumor induction, kidney and liver failure, and growth anomalies in vertebrates. Humans would be expected to exhibit similar

effects if exposure via food was sufficient, especially in the embryonic or fetal stages of development.

The greatest risks from sediment contaminants exist where sediment concentrations are high and biologically available. Dredging and disposal of sediments has occurred over many years in some of our most highly contaminated areas. Some sediment-bound contaminants are released to the water column during dredging and disposal operations but readily settle near the dredging site or in the disposal facility. Where dredging exposes highly contaminated sediments to the water column, releases of contaminants may occur for an extended period following dredging. Since almost all of the contaminant load remains bound to sediments, risks associated with dredging and proper disposal would be much lower than risks from leaving highly contaminated sediments in areas where shipping or high flow events and strong currents could redistribute and expose contaminants to the water column. In areas where contaminated sediments would remain undisturbed, leaving them in place for final burial would pose the least risk.

Due to pollution control programs, contaminant levels have decreased in sediments over the past decade, although in some areas not to acceptable levels. Decreases in sediment contaminants and fish contamination occurs within a few years after loadings cease and in most cases a decade or two of natural deposition would bury or dilute most contaminated sediments. While some risk is involved in doing nothing other than reducing contaminant loads, history suggests this is a reasonable way to proceed. Natural processes of transport and deposition, degradation, binding, and burial deeper in sediments may be the only thing that can be done at this time for moderately contaminated but widely distributed sediments.

Criteria and Related Air Pollutants

In the early 1970s the U.S. Environmental Protection Agency (EPA) established National Ambient Air Quality Standards (NAAQS) for "criteria" pollutants. These were the first air pollutants to attract the attention of regulators because they were ubiquitous, there was evidence linking them to health effects at high concentrations, and some of them were known phytotoxicants. The criteria pollutants include sulfur dioxide (SO_2), nitrogen dioxide (NO_2), carbon monoxide (CO), PM_{10} (particulate matter with a diameter less than or equal to 10 um), ozone (O_3), and lead (Pb). Because of the known risks presented by these pollutants at high concentrations, extensive resources have been committed to controlling and measuring these pollutants in Michigan. This issue focuses on the criteria pollutants except for O_3 and lead, which are covered separately in the issues of *photochemical smog* and *trace metals*, respectively. In addition, this issue includes pollutant issues related to the criteria pollutants—acid aerosols and visual air quality. A third related issue, acid deposition, is considered separately.

In Michigan concentrations of SO_2, NO_2, CO, and PM_{10} are below the NAAQS. Because of existing regulations, future concentrations are expected to be even lower.

SO_2—At high concentrations SO_2 has been associated with the aggravation of existing respiratory and cardiovascular disease and increased mortality, especially in the presence of elevated concentrations of particulate matter.

NO_2—In high concentrations NO_2 has been linked to impaired respiratory defense mechanisms and increased susceptibility to infection.

CO—The concern with CO is its ability to combine with the hemoglobin in the blood stream. At high concentrations it can interfere with mental judgement, cause fatigue and headaches, and aggravate symptoms in individuals with heart or circulatory disorders. The largest source of CO is motor vehicles. Since the 1960s, however, CO emission rates from passenger cars have been reduced by 96 percent, and this has dramatically reduced concentrations of CO in the ambient air despite an increase in the vehicle miles traveled.

PM_{10}—Epidemiologic studies have associated high concentrations of particulate matter with aggravation of asthma and chronic lung disease, chest discomfort, and even increased mortality. **Related Air Pollution Issues**—There is some information that suggests that some of the adverse effects attributed to exposure to high concentrations of ambient PM_{10} or total suspended particulates (TSP) might be due to the acid aerosol component of the particulates. Very limited acid aerosol data suggest that the levels observed in Michigan do not merit concern. However, this issue should be revisited in the future when studies now under way have been completed.

The sulfate haze that frequents southeastern Michigan is formed primarily from the oxidation of SO_2 emissions in the high emissions areas in the lower Midwest. There is strong evidence that this haze has significantly deteriorated visual air quality in Michigan in recent decades. Reductions in SO_2 emissions mandated by the 1990 Clean Air Act Amendments should reduce both the concentrations of acid sulfates, the predominant contributor to aerosol acidity, and visibility-reducing haze, although the degree of the reduction cannot be quantified.

Degradation of Urban Environments

Most Michigan residents live in cities. A variety of utilities, products, and services are required to support densely populated areas, and as a result there is a concentration of consumption in urban areas. Many environmental problems are caused or exacerbated by this intense consumption, which includes a variety of materials and energy. The concentration of stressors in the urban environment is also a function of industrial and commercial activities in urban areas.

Although social, economic, racial, housing, and other issues are related to urban environmental quality, they are beyond the scope of this project. It is important to remember, however, that these factors affect all or parts of the issues identified. Thus, the urban environment is unique in that it is affected by all of these problems and, in many cases, the effect is greater because of urban conditions.

One must consider how certain environmental issues are related to the urban environment in order to understand the importance of recognizing urban areas as a special component of Michigan's environment. For example, air quality problems are frequently most intense in urban areas where incinerators, power plants, and factories are located. Lead emissions from automobiles that burned leaded fuel are believed to be the source of high lead levels in urban soils, and water quality is affected by the nonpoint-source runoff from streets, parking lots, combined sewer overflows, and changes in water courses.

Degradation of urban environments also includes problems related to the aging of drinking and waste water systems, urban sprawl, abandoned and contaminated industrial sites, and the failure to protect natural features such as wetlands, woodlots, and green belts.

Problems of particular importance, and unique to urban areas, include preschool children's exposure to lead, problems associated with using otherwise valuable land for industrial development because of contamination, and the household use of pesticides.

These factors make Michigan's urban residents more susceptible to many environmental problems. Risk reduction, therefore, has the potential to benefit especially these residents just as inattention to environmental problems could pose greater risks.

Electromagnetic Field Effects

The first epidemiological report about the possible increased risk of leukemia in children living near high voltage power lines appeared in 1979. The authors concluded that the increased incidence resulted from exposure to electromagnetic fields (EMFs) produced as electricity surged through the wires. Since that time more than three dozen epidemiologic reports concerning EMFs have been published. Biological studies, however, have yet to prove a cause-and-effect relationship.

The report engendered a controversy over whether electric power lines, electric switch boxes, electric blankets, microwave ovens, hair dryers, black and white television, or household appliances might be related to increased leukemia in children, high levels of breast cancer in males, brain tumors, lymphoma, or cancer in general.

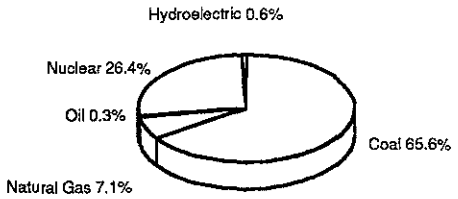
A major difficulty in interpreting the epidemiological data has been the absence of simple, objective, and reliable measures of exposure. Some indirect measures have been applied, such as for occupational exposures. Studies have not been able to link the dosage of EMFs directly to their effect on the subjects.

Until scientific research provides some explanation of how EMFs can affect biological systems, the epidemiologic data will be subject to challenge. Some scientists also contend that conventional physics is unable to explain any mechanism of EMF effect on the body.

In Michigan and Wisconsin over the past 25 years there has been a running battle between citizen's groups opposing EMFs and the U.S. Navy over the installation of project ELF, a $400-million web of antennae for communicating with submarines around the world. This extremely low frequency system is in two locations—one part in upper Michigan and the other in Wisconsin. Along the way there have been protests. There were many revisions of plans and reductions of the size of the project. What was originally planned as an underground grid of about 3,000 miles of cable ended up as 56 miles on telephone poles in Michigan and 10 miles in Wisconsin. ELF is 75 Hz frequency modulated to 72–78 Hz; power lines are 60 Hz. The Navy renamed the project Naval Communications Unit, headquartered outside Marquette, and activated it in 1989.

Marginal relationships of EMFs to certain kinds of cancer, which in most cases are statistically weak, tentative, or the subject of controversy among scien-

Fuel Sources of Power Generated in Michigan



tists, make the data insufficient as a basis for decisions about power lines. Many skeptics remain unswayed. If, however, it is proven with subsequent research that there is a definite effect on the health of the population, especially children, measures must be taken to modify the exposure of our citizens to EMFs.

Energy Production and Consumption: Practices and Consequences

Michigan is primarily an energy consuming state. Michigan imports approximately 89 percent of its petroleum supplies, 80 percent of its natural gas, and 100 percent of its coal. In the state petroleum supplies approximately 35 percent of our energy needs; natural gas, 28 percent; and coal, 30 percent. The remaining 7 percent is supplied by nuclear, hydroelectric, and wood. Michigan does have limited energy production—approximately 5,000 producing oil and natural gas wells. These wells represent an ongoing risk to the environment. Michigan's reliance on durable goods manufacturing, tourism, and agriculture all place Michigan in a relatively vulnerable position with respect to the economic effects of the cost of energy.

Energy resources can be divided into three categories: electric power, transportation, and other nonelectric uses.

Electric Power—Many of Michigan's existing electric generating plants were built in the 1950s and early 1960s. Approximately 28 percent of the state's generating capacity is more than 30 years old. New electric generation being built differs from existing generation in two significant ways: (1) It is almost entirely based on natural gas rather than coal and nuclear power, and (2) it is generated by nonutility companies rather than as part of the utility's integrated system. Each of these differences presents potential difficulties. Although utilities have not been building new generating plants in recent years, they have been playing a greater role in assisting customers in meeting their needs by using energy more efficiently. There can be little doubt that improved energy efficiency is essential if we expect to compete effectively in the global economy. Whether measured in terms of consumption per capita or per dollar of gross domestic product, the United States consumes almost twice the electricity as Japan or most European countries. Because of the changing structure of electric power generation, aging generating plants, and the reliability of new generation, the role of conservation should be considered in evaluating Michigan's electric future.

Transportation—In Michigan approximately 25 percent of all energy consumed is used for transportation. In addition, as the major automobile manufacturing state, Michigan is acutely affected by this industry. The automobile has been almost totally powered by gasoline refined from crude oil. Approximately 63 percent of the oil consumed in the United States is used for transportation.

Other Nonelectric Uses—Natural gas is by far the largest source of heat for residential and commercial buildings—more than 80 percent of Michigan homes use natural gas.

The threats posed by potential global climate change, air pollution, and dependence on oil imports are intimately linked to energy use, mainly fossil fuel combustion. Burning fossil fuels (coal, oil, and natural gas) releases carbon dioxide, which represents 55 percent of the total greenhouse gases that many believe will lead to global climate change.

Fuel burning also releases pollutants that lead to acid rain and photochemical smog (urban smog). The United States is importing a growing portion of its oil supply—a pattern that poses long-term financial and national security risks.

As long as electricity use continues to increase in the United States and Michigan and is generated mainly from fossil fuel, and as long as oil consumption for transportation grows in the absence of practical alternatives to the oil-based internal combustion engine, electric power production and transportation will remain the most important U.S. source of environmental degradation (carbon dioxide emissions, other air pollutants, and groundwater and land pollution through resource extraction). It is particularly important that state and federal energy policies appropriately consider environmental effects of energy production and consumption.

Generation and Disposal of Hazardous Waste

Hazardous wastes are generated abundantly in Michigan (and in every other state as well). However, they are generated as part of processes that usually have significant value for the personal and economic well-being of all residents of the state. Many types of hazardous waste are actually residuals from waste treatment operations.

Under completely uncontrolled conditions these wastes have the potential for producing adverse effects in humans and the environment, and therefore, they need to be properly managed in order to limit potential risks. The general management procedures are well understood and driven by both economics and regulatory pressures. They range from process control leading to waste avoidance or waste reduction, to reuse and recycling, to waste treatment or destruction, to the containment of residual waste. It should be clear that these processes apply in varying degrees to hazardous waste. Wastes that have been generated in the past and are still present in the environment pose significant challenges to currently available management options.

There is an extensive legal, administrative, and enforcement framework that governs the generation, transport, storage, treatment, and disposal of presently produced hazardous wastes. There also is a framework for dealing with emergencies arising from spilled hazardous wastes, and for managing hazardous wastes that had been generated and disposed of improperly or before our present requirements for waste storage were developed.

In most states the management of hazardous wastes falls under the control of the U.S. EPA. Four states, including Michigan, have been authorized by the EPA to substitute their own programs, which must incorporate the major features of the national program and can be no less stringent than the national program. The management of hazardous wastes that are presently being produced are primarily controlled through the Resource Conservation and Recovery Act (RCRA), and the Hazardous Waste Management Act (Act 64).

The Federal Hazardous and Solid Waste Amendments of 1984 clarified issues related to the protection of groundwater, specified the engineering requirements for land disposal, extended regulation to include some small quantity generators, regulated underground storage tanks, and banned certain chemicals completely from land disposal.

Certain wastes are specifically excluded from consideration, sometimes because they are already regulated under other authority. Examples of excluded wastes are: waste water discharges, nuclear wastes, ordinary household waste, coal combustion waste, fertilizers, drilling fluids and brines, mining wastes (overburden), and agricultural waste used as fertilizer.

The process for managing hazardous wastes is extremely complex. It is characterized by extensive paper work and a very high price tag. The real risks associated with hazardous waste are poorly defined, because the process of waste management is not driven by risk analysis, but rather by administrative procedures. Cleanups under Superfund are driven by the aspiration to remove every vestige of real or potential risk, which has resulted in a continuing controversy over "how clean is clean." Because of the extensive use of worst-case exposure analyses, the risk assessments associated with Superfund sites may overstate the real risks.

Generation and Disposal of High-level Radioactive Waste

In producing electric power, nuclear plants also generate radioactive waste. Because it requires different care and disposal, this waste is generally classified as high-level (spent nuclear reactor fuel) and low-level (all other). It has been estimated that it will require between 1,000 and 10,000 years for the radioactive biological effects of spent nuclear fuel, high-level radioactive waste, to decline to that of the uranium ore from which it was made.

Approximately 26 percent of electricity used Michigan is generated by nuclear power plants at four locations:

(a) Big Rock Point (Consumers Power Co.) near Charlevoix;

(b) Palisades (Consumers Power Co.) near South Haven;

(c) Fermi 2 (Detroit Edison Co.) near Monroe; and

(d) Cook Units 1 & 2 (Indiana Michigan Power Co.) near Bridgeman.

High-level radioactive waste is currently being stored at four nuclear power plant locations in Michigan. While this storage has been adequate to date, the existing facilities are reaching their capacity and new storage will be needed in the near future. Existing nuclear plants in Michigan are aging—Big Rock is due to be decommissioned in 2000, Palisades in 2007, the Cook units in 2014 and 2017, respectively, and Fermi in 2025.

Nearly all spent nuclear fuel is stored at the reactor site in water pools. Pool storage has been used for two reasons: (1) it provides a cooling medium for removing the high radioactive heat output in the initial period after the fuel is removed from the reactor; and (2) it provides a convenient temporary storage medium if the fuel is to be reprocessed, as was originally intended by the nuclear power industry. When pool storage is filled, additional spent fuel is expected to be stored in above-ground dry casks located at the reactor site.

The federal government is scheduled to construct a temporary national storage facility by 1998

and complete a permanent facility by 2010 at the Yucca Mountain, Nevada, site. However, these schedules have repeatedly slipped in the past. Since high-level nuclear waste presents health and environmental risks, there are significant questions regarding the advisability of long-term storage of these wastes at facilities that were intended for only short-term use. All 34 states utilizing nuclear power face this problem along with Michigan.

The U.S. Department of Energy (DOE) has made little progress in the characterization of the Yucca Mountain site to determine if it is geologically suitable as a permanent repository. Even if the Yucca Mountain site survives this process, the DOE must still obtain an operating license from the Nuclear Regulatory Commission (NRC), which is not assured. The potential for delays associated with this site are magnified by the failure to pursue alternatives. The process of designating the Yucca Mountain site has resulted in at least temporary elimination of all other sites and options before they were evaluated. Although the Yucca Mountain site is the only permanent repository currently under consideration, the U.S. Office of the Nuclear Waste Negotiator is actively soliciting states and Indian tribes to accept a radioactive waste facility.

Risks to Michigan are due to delays in the development of a permanent repository and result from the continued storage of high-level waste at operating nuclear plants. Existing on-site storage was intended to be of short-term duration.

The merits of on-site storage as a short-term remedy to the nuclear waste problem have been demonstrated, but these facilities cannot be relied upon to serve adequately for the 10,000 year period required for high-level wastes to become harmless. No one suggests using on-site pool or cask storage as permanent repositories for this waste. Yet it is possible that this unacceptable "solution" may be the one ultimately derived by default rather than by any conscious national decision.

Permanent on-site storage would have none of the safeguards built into the process for citing the permanent national repository. The risks associated with this scenario are clearly greater than with the first option but are difficult to quantify due to the unknowable safety threats related to maintaining hazardous waste in short-term storage indefinitely. It would appear that some significant mobilizing event would be necessary, since once the impetus to find a permanent repository is lost, it would require a major adverse development to galvanize public opinion to develop an alternative.

Generation and Disposal of Low-level Radioactive Waste

Low-level radioactive wastes are generated abundantly in Michigan (and in every other state as well). However, they are generated as part of processes that usually have significant value for the personal and economic well-being of all citizens of the state.

Under completely uncontrolled conditions these wastes have the potential for producing adverse effects in humans and the environment, and therefore, they need to be properly managed in order to limit potential risks.

The disposal of low-level radioactive waste is governed by the Low-level Radioactive Waste Policy Act (1980) and the Low-level Radioactive Wastes

Policy Amendment Act (1986), which require the states or state compacts to establish their waste disposal capacity for commercially generated low-level radioactive waste that has been produced within their boundaries. The methods for managing low-level radioactive wastes are prescribed in procedures and rules that have been developed by the U.S. Nuclear Regulatory Commission, the U.S. Department of Energy, and the U.S. EPA and reviews by the National Academy of Science and the Science Advisory Board of the U.S. EPA. Separate rules are applicable to mixed hazardous and radioactive waste, which is regulated under the RCRA.

In contrast to the procedures for some types of hazardous wastes, low-level radioactive wastes cannot be destroyed, and therefore the major management options are storage and containment. The supporting sciences in dealing with containment designs incorporate hydrogeological models, environmental transport and fate models, and risk assessments. In the case of radioactive materials the measurement of the radiation is exceedingly simple, when compared with the difficulties involved in measuring large quantities of organic and inorganic chemicals found in the usual type of hazardous waste site.

Most of the information used for the risk assessments for radioactivity is based on information derived from human exposures. The migration patterns of radioactive materials have been studied based on actual experience at sites such as Oak Ridge, Tennessee, and Hanford, Washington. Consequently, the foundations for modeling environmental transport of radioactive materials, the potential doses, and the potential effects in humans are better established for radioactive materials than for any other contaminant. The dose and risk projections approximate worst-case conditions and are thought by some to be highly conservative. The projected risks are dependent upon the siting and the engineering features incorporated into the site. Furthermore, the physical, chemical, biological, and engineering issues related to maintaining the risks well within the limits that are accepted for other agents are better understood for radioactive waste than for any other class of waste.

The State of Michigan is not participating in any multistate compact for the disposal of low-level radioactive waste. There are no concrete plans to develop a disposal site in the state. Low-level radioactive wastes continue to accumulate in cellars and sheds in hospitals, universities, and other institutions.

Generation and Disposal of Municipal and Industrial Solid Waste

Americans produce more than 170 million tons of municipal solid waste every year—more than three pounds per person each day—the highest per capita rate among industrial nations. About 70 percent is currently being landfilled, 17 percent incinerated, and 13 percent recycled. In Michigan approximately 12 million tons of solid waste is produced each year, approximately 50 percent of which originates from households. The majority of the solid waste generated in Michigan is landfilled. It is important to recognize that residential and municipal waste streams contain some hazardous materials.

Some believe that options for safe and efficient waste management are vanishing. It is also believed that landfill space will soon run out and that disposal options such as new landfills and incineration are not safe alternatives. Among the concerns about solid

waste management are the lack of physical space for new landfills, the actual composition of these wastes, and the risks associated with current disposal options such as air emissions from incineration; leachates, soil, and groundwater contamination associated with landfill disposal; and residues from treatment processes.

The remaining available space in Michigan landfills should last about six years, at the current rate of waste generation and due to plans to close out-of-compliance landfills. Anticipated reductions in this rate through aggressive recycling and composting programs may postpone the crisis but will not provide the needed long-term solutions.

Comprehensive management of land disposal units and the surrounding soil and water environments needs to be considered. Michigan depends heavily on shallow groundwater resources for domestic drinking water (approximately 50 percent of domestic supplies). In larger municipalities the proximity of waste disposal units to residences or public water supply well fields poses immediate challenges to county or regional waste management strategies. The state must be prepared to lead the way to long-term risk management. The state's regional master planning process should be conducted with the goals of minimizing the further contamination of soil and water. The utilization of appropriate, existing, or past sites of land disposal for future waste management operations should be evaluated.

On October 29, 1990, a draft waste prevention strategy proposed a goal of 30 percent reduction in overall solid waste generated by the year 2000. Most of that goal would be achieved through composting yard wastes and removal of recyclable materials from the waste stream.

On December 7, 1991, the DNR prepared a Solid Waste Management Planning Program that calls for a comprehensive, statewide plan based on regional (multicounty) rather than county-by-county plans. This could lead to improved strategies, siting, and sizing of new facilities. Regional resource recovery, waste-to-energy, and landfill facilities could be located away from high population areas.

Although some communities have been willing to support an additional $2 to $4 per week for curbside collection of recyclables, the economics of reprocessed goods does not support these programs. The average cost to collect recyclables is $40 per ton versus $28 per ton to put the same materials in landfills. The primary reason for recycling, however, is to achieve *more efficient use of resources*, such as with reprocessed versus virgin aluminum, *rather than health-risk reductions or economics.*

Recent experience with community programs involving curbside collection of recyclables suggests that from 5 percent to 10 percent of the solid waste stream can be deflected from landfills. These programs collect glass, cans, plastics, newspapers, and cardboard. Some economic incentives, such as "buck-a-bag" for nonrecyclables and free collection for recyclables, have the potential to improve the percentage of the waste stream deflected from landfills or incinerators, although not very much.

The nationwide characterizations of the solid waste stream also suggest that community recycling programs should be expected to yield at least a 30 percent deflection from landfills and incinerators as seen in the following table.

Composition of Solid Waste, 1988	
Paper and paperboard	41.0%
Yard wastes	17.6
Metals	9.0
Rubber, wood, textiles, and leather	8.0
Plastics	8.0
Food waste	7.0
Glass	7.0
Miscellaneous wastes	2.4

Source: Based on 1988 information by Franklin Associates.

Global Climate Change

The greenhouse effect is a natural phenomenon by which the atmosphere holds heat. Sunlight strikes the earth and is converted to heat. The earth then re-emits the heat, which would be lost to space if it were not for the presence of greenhouse gases that absorb some of the heat. Thus, the earth's atmosphere acts as the glass on a greenhouse. Without this atmospheric greenhouse effect, life on earth would not exist. The annual additions of anthropogenic carbon dioxide (CO_2), methane, nitrous oxide, and chlorofluorocarbons (CFCs), however, has caused an enhanced greenhouse effect, increasing the heat retention capabilities of the atmosphere. The results of global climate models indicate that this will result in a global warming trend—a condition that could have serious consequences by changing the distribution of rainfall, increasing evaporation, expanding deserts, melting polar ice, and flooding coastlines. In terms of human economics, these changes could have disastrous effects on production of food and timber and on fresh water supplies. Such climate changes also would result in the dislocation of many ecosystems.

The United States contributes 21 percent of the world's greenhouse gases. Michigan, as an industrial and agricultural state, with 9.3 million people and a high rate of resource use, likely contributes proportionately more to the greenhouse effect than most areas of equivalent size. The amount of CO_2 in the atmosphere has increased by more than 25 percent in the past 200 years, and the sources are primarily anthropogenic; atmospheric concentration of methane (CH_4) has doubled in the last century.

There remains considerable uncertainty about the potential climatic effects of greenhouse gases. The global climate models do not include many processes (such as cloud formation, ocean dynamics, and so forth) that could act to mitigate or enhance global warming. Also, the global climate models indicate that the earth should have warmed already by about 10 degrees Celsius (C), but the temperature records do not support that. Although there are large uncertainties, the potential consequences of significant alterations in the global climate are enormous. Computer models indicate that if current trends continue, CO_2 concentrations will double by the year 2075, causing global temperatures to rise 1.5–4.5 degrees C. The warming will not be evenly distributed; some areas will warm more, others less. The effects of other greenhouse gases could hasten and intensify that effect.

The accumulation of most greenhouse gases is irreversible in the short term because the atmosphere residence time of CO_2 and some of the other greenhouse gases is on the order of hundreds of years. The effects of global warming are not totally predictable; if nothing is done, however, and warming does occur, it would probably be too late to plan for changes or to reverse the process. The result of tak-

ing no action could seriously affect resource production on earth for centuries.

In Michigan a likely effect would be hotter and possibly drier summers. Dryness and heat would render the state's main agricultural region in the southern Lower Peninsula less productive. If the current climatic conditions were shifted northward 100–200 miles, the northern Lower Peninsula and Upper Peninsula might have longer and warmer growing seasons, but the sandy and rocky soils that prevail throughout that region would be unlikely to match crop yields now obtained in the southern Lower Peninsula.

Indoor Pollutants

When one considers that most people spend nearly 90 percent of their time indoors, it becomes evident that we should pay careful attention to the pollutants that may affect our health during this large amount of time spent inside the home and the workplace. There are nine major source-specific air contaminants:

- radon
- environmental tobacco smoke
- biological contaminants—including bacteria, fungi, viruses, animal dander, cat saliva, rat and mouse urine, mites, cockroaches, and pollen
- gases from stoves, heaters, fireplaces, and chimneys—mainly carbon monoxide, nitrogen dioxide, and particulate matter
- household products—including widely used organic chemicals such as cleaning fluids, paints, varnishes, wax, disinfectants, cosmetics, and degreasing and hobby products
- formaldehyde
- pesticides
- asbestos
- lead

There is no comprehensive plan or act in Michigan governing indoor air pollution, although specific rules have been promulgated concerning restaurants and certain public buildings. Also, individual companies and institutions have issued rules, particularly addressing the problem of tobacco smoke. The Michigan Relative Risk Analysis Project considered only indoor pollutants in the home and non-Occupation Safety and Health Administration (OSHA) regulated buildings.

The Clean Air Act and a network of federal and state regulations have strengthened air pollution controls for outside air. Indoor air pollution, however, has not received much attention until recently, and increasing energy-saving measures have resulted in limited air turnover between indoor and outdoor air. In Michigan the temperate-to-cool climate in the winter results in an increase in energy-saving building practices that further reduce the exchange of air from inside to outside. As a result, levels of several potentially harmful indoor air pollutants have risen, both in homes and in offices. Concentrations of most air toxics, for example, benzene and other volatile organic solvents, are higher in indoor than outdoor air.

Lack of Environmental Awareness

Survival of the planet depends on whether present and future generations can become ecologically literate—gain an awareness of the interconnectedness of all life. It is increasingly difficult for people to keep abreast of new scientific informa-

tion about environmental issues; fewer and fewer have the opportunity for regular experience with nature. Compounding the problem is an uninformed press that sometimes focuses attention away from key issues. Without a broad understanding of the links between human welfare and the environment, environmental protection initiatives will face a host of challenges. With popular support, however, these challenges could be reduced or could be more easily overcome. Few educational institutions have integrated the concept of building a sustainable society into the learning process. Such an education requires fundamental changes in many of our present assumptions about schooling; the model of humans *and* nature needs to be replaced by the alternative model of humans *in* nature.

Preserving the ability of future generations to meet their needs will require a citizenry with an awareness and ethic for environmental protection. A sustainable future depends on a healthy environment. To protect the environment we must change the mindset of individuals, institutions, communities, and industry with respect to their surroundings.

Public concern about environmental problems is high and rising. In 1990 the Roper Organization, Inc., conducted a survey about public attitudes and individual behavior as it relates to the environment. In this and other surveys, more than 90 percent of Americans described themselves as environmentalists. Nevertheless, public involvement remains relatively low. There is a clear gap between what American people are saying and doing. This gap stems from the belief that an individual has a very limited effect on environmental problems.

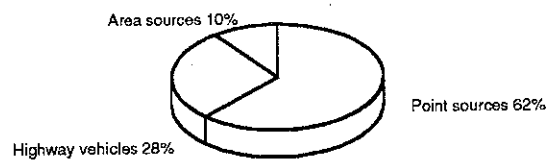
The first difficulty with environmental education in Michigan is that it is fragmented. There is no state leadership in environmental education, and there are many endeavors. The difficulty arises in trying to ascertain exactly what is happening in the state. Often the environmental education efforts of one group are not known to others. There is no easy way to get information about environmental education opportunities statewide, no coordinating agency, no umbrella organization, no central clearinghouse, no phone number to call. There are substantial materials and programs that small groups, large groups, and individuals have put together but little or no connection between such groups. There are many committed and interested people, but they have a difficult time finding out all the environmental education opportunities in Michigan. Also, there is no long-term state commitment to funding environmental education.

In 1988, in an effort to tackle the gaps in environmental education in Michigan, the departments of Natural Resources and Education signed a Memorandum of Understanding identifying several elements of cooperation between the two departments, including the establishment of an Interagency Task Force (MDE-MDNR) and a Citizens Advisory Committee and the development of a state environmental education policy. The Environmental Education Citizens' Advisory Committee draft report is currently under review.

Nonpoint-source Discharges to Surface Water and Groundwater, Including the Great Lakes

Diffuse (nonpoint) pollution is increasingly recognized as the primary source of surface water degradation. Groundwater also has been shown to be vulnerable to nonpoint-source pollution (NPS). Many

Sources of NO_X in Michigan



Michigan water bodies do not meet designated uses or are degraded because of NPS. In general, nonpoint pollutants enter surface water and groundwater as a result of precipitation that leads to land runoff or percolation through soils. Specific contaminants include sediment, nutrients, pathogenic microorganisms, and chemicals (including pesticides).

In an 1988 survey the MDNR found the major rural sources of nonpoint-source pollution were septic systems, streambank erosion, and agricultural practices. Major urban sources included construction site erosion and urban runoff. The effects of these sources were seen primarily as added sediment deposits, turbidity, excessive aquatic plants, nuisance algae blooms, and oxygen depletion.

The following land use categories were considered by the DNR to pose the greatest threats of groundwater contamination: petroleum product manufacturing (including coal); junk yards and salvage yards; vehicle maintenance services, including public and private garages; chemical paint and allied products manufacturing; laundries and dry cleaners; and electronic and other equipment, including plating and chemical coating. In addition, more than fifty land use categories were identified as posing a medium-high risk of groundwater contamination, including golf courses, unsewered residential development, household hazardous wastes, bulk storage of agrichemicals, agricultural practices, lawn care businesses, municipal and state garages, lumber and wood production, paper and allied products, printing and publishing, leather and leather products, roads and airports (deicing salts and liquids), and wastewater treatment facilities.

Nonpoint source pollution is by its very nature a problem that requires an integrated approach to management. Nonpoint pollution is produced by diverse land use activities that cut across agencies and organizations as well as program areas within these groups. Prior to 1988 there was no coordinated effort in Michigan to assess the scope and extent of NPS pollution much less control it. The state addressed nonpoint-source pollution primarily through a loose network of existing conservation programs and projects.

Efforts to control NPS pollution became better defined and more comprehensive with the 1987 amendments to the Clean Water Act. These amendments required states to identify watersheds affected by nonpoint sources and to develop a plan to manage these sources. The DNR management plan was submitted to the U.S. EPA in the fall of 1988 and subsequently approved. Since approval of the DNR (Nonpoint Source Advisory Committee and Nonpoint Source Technical Committees) plan, several of the recommendations have been implemented, including the development of best management practices (BMP) for various land use activities. BMPs are methods, measures, or practices to prevent or reduce water pollution, including structural and nonstructural controls, operations, and maintenance procedures and scheduling and distribution of activities. Currently, BMPs exist for construction sites, golf courses, and forestry. Urban and agricultural BMPs are in draft form and will soon be available for public review.

Photochemical Smog

Photochemical smog is a complex mixture of constituents formed when volatile organic compounds (VOCs) and nitrogen oxides (NO_X) are irradiated by sunlight. Ozone (O_3) is the primary concern

and the most abundant compound formed in photochemical smog.

Photochemical smog is a summertime phenomenon in Michigan. Temperatures are too low and sunlight is insufficient during the other seasons. Despite almost two decades of reducing VOC emissions from stationary and mobile sources and NO_X emissions from mobile sources, progress in reducing O_3 in Michigan has fallen short of expectations as two regions of the state, the western shore of Lake Michigan and southeast Michigan, continue to have nonattainment status for O_3.

There are numerous reasons why Michigan's and the nation's progress in reducing O_3 has fallen far short of expectations: Models were flawed; anthropogenic sources were grossly underestimated; the importance of biogenic VOC emissions were not realized; control programs were assumed to be 100 percent effective in reducing VOC emissions but were not; as well as others.

The standards for O_3 were established by federal National Ambient Air Quality Standards (NAAQS) for a one-hour period. This standard is not to be exceeded more than once per year or the area is classified to be in nonattainment status. The one-hour NAAQS level was chosen because decrements in lung function tests were observed in heavily exercising adults at concentrations higher than the standard. In addition, numerous studies at high O_3 concentrations have shown that the decrements in the lung function tests are transient; the subjects' test performance returns, in most cases within hours, to their preexposure levels without any long-term consequences. Other data suggest that repeated exposure, rather than individual peaks or chronic exposure, may be of concern.

The ecological concerns of O_3 exposure focus on decreased agricultural crop yields and damage to forests. In high concentrations O_3 is a phytotoxicant that produces visible injury to the foliage as well as growth and yield reductions. In addition, O_3 is suspected of being a contributor to forest damage in Europe and in parts of the United States.

On a few days every summer, a number of ozone monitoring sites near Lake Michigan and in the Detroit metropolitan area record ozone concentrations in excess of the NAAQS for an hour or two. Near Lake Michigan, the ozone is formed primarily from emissions in the Chicago and/or Milwaukee areas and is imported across the lake. In the Detroit area a significant fraction of the observed ozone can be imported from upwind areas, but a fraction is also produced from local emissions. At the concentrations experienced in Michigan, only the very small fraction of the population that is engaged in prolonged vigorous outdoor activity at the time the ozone standard is exceeded is exposed to ozone levels that may pose a measurable health risk. Agricultural crop yield losses in Michigan appear to be statistically insignificant.

Point-source Discharges to Surface Water and Groundwater, Including the Great Lakes

Passage of the Clean Water Act in 1972 funded and set in motion a mostly successful national effort to clean the nation's waters. Discharges of untreated sanitary and industrial wastewater and stormwater during decades of increasing urbanization and industrialization had resulted in substantial degradation in many of Michigan's water bodies.

Beach closings, threatened drinking water supplies, increased eutrophication, and fish kills were common. After twenty years of extensive construction of wastewater treatment facilities and regulation to meet established effluent levels and treatment requirements many successes have been realized. Reductions of conventional pollutants such as nutrients, microorganisms, chlorides, heat, oil and grease, biological oxygen demand, and suspended solids in many surface waters have been documented. Eutrophication problems in many inland lakes, including Lake Erie, have declined primarily because of reductions in phosphorus and organic material loads. Concentrations of phosphorus in the Grand, Saginaw, and Kalamazoo rivers have fallen an average of 70 percent since 1970, principally due to the phosphorus detergent ban and wastewater treatment plant upgrade and construction. The Tittabawassee and Saginaw rivers at one time would not freeze because of the heat and dissolved solids load. Now they provide a healthy walleye population for ice fishers.

Although dramatic improvements in water quality have occurred, the goal of the Clean Water Act has not been totally achieved. The national goal set by the act was for the elimination of all discharges of pollutants into navigable waters by 1985. Point-source pollution problems that need to be addressed in the future are combined sewer overflows (CSOs), urban stormwater, persistent toxics both from historical and present discharges, aging municipal wastewater treatment plants (WWTPs), and sewer systems.

The control of water pollution by conventional treatment of most point-source discharges of wastewater from industry and municipalities over the last twenty years has greatly improved surface waters in Michigan. Intermittent discharges of untreated wastes via CSOs persist in many urbanized areas of Michigan and are in violation of water quality standards. Stormsewer discharges and urban runoff degrade aquatic resources in many areas. Discharges of trace levels of persistent toxic substances exist and may be untreatable by means of conventional technology.

Wastewater treatment systems are aging and in need of substantial maintenance, upgrading, or replacement to meet more stringent discharge limits and increased waste volumes. Treatment of CSOs will be required and stormwater discharges will be addressed under the National Pollutant Elimination Discharge System (NPDES). Industrial wastewater treatment facilities also must be maintained in order to meet discharge limits. The public expenditures over the next twenty years for the construction of wastewater treatment facilities via grants, bonding, and tax exemptions for sanitary and industrial wastewater, as well as CSOs and stormwater, will easily exceed the more than $4 billion expended for water pollution abatement over the past twenty years. Under the present system of funding for municipal treatment facilities, the local match for construction will be 65 percent and not 20 percent, as it was in the past.

Stratospheric Ozone Depletion

Ozone is the dominant gas in the upper atmosphere that prevents harmful solar ultraviolet radiation from reaching the surface of the earth. Recent scientific studies have documented decreases in the average ozone concentration worldwide, with a dramatic decrease recorded over the Antarctic in the spring and as much as 70 percent of the ozone destroyed in some areas. It has been estimated that

for every one percent decrease in stratospheric ozone there is a 2 percent increase in ultraviolet-B (uv-B) radiation, the ultraviolet wavelengths of most concern, penetrating the atmosphere.

This loss of upper atmospheric ozone and subsequent increase in uv-B radiation at the earth's surface can cause undesirable effects on humans such as increased rates of skin cancer, cataracts, and possibly suppression of the immune system. U.S. EPA scientists estimate that for every one percent depletion in ozone, one can expect 20,000 additional skin cancer deaths in the United States. The EPA also has estimated "that ozone depletion will lead to an additional 31,000 to 126,000 cases of melanoma among U.S. whites born before the year 2075 and an additional 7,000 to 30,000 fatalities." In the same predictions they estimated that "an additional 550,000 to 2,800,000 Americans born before the year 2075 will have cataracts."

It is believed that many biological species other than humans can have susceptibility to increased uv-B radiation. Stratospheric ozone depletion also can result in crop damage; damage to aquatic ecosystems, particularly phytoplankton, zooplankton, and the larval stage of certain fish; increased smog; and increased damage to materials such as making plastics more brittle and fading paint. A very rapid change in the amount of ultraviolet radiation reaching the earth's surface also may negate the ability of plants and animals to adapt naturally, through genetic development, to increased uv-B radiation.

In addition to biological effects, there is also concern that the global declines in temperature in the stratosphere at about 50km that have been documented during the past ten years may be due to the decline in ozone. This could be caused by less absorption of solar ultraviolet radiation at this level, which, in turn, could affect stratospheric wind patterns and global climate. Such effects have worldwide implications.

Current science shows that chlorine and bromine compounds are primarily responsible for the destruction of stratospheric ozone. The principal source of chlorine is chlorofluorocarbons (CFCs), while bromine originates from halons. CFCs are synthetic, stable, volatile compounds not normally present in the atmosphere. They are important commercially and widely used as refrigerants, solvents, cleaners, aerosol propellants, medical sterilants, and blowing agents in rigid and soft foams. Approximately 30 percent of the world CFC total is produced in the United States. When released to the open atmosphere they do not break down but migrate upward, over a period of six to eight years, to the stratosphere where they can be broken down by ultraviolet light, releasing chlorine that is capable of destroying ozone. Even with the present scheduled phase-out of these chemicals, it is predicted that chlorine concentrations will continue to increase due to past CFC releases, with a peak level being reached in about the year 2010. These chemicals can survive in the upper atmosphere for more than 100 years and can recycle many times before being removed. It has been estimated that on average, one chlorine atom may destroy 100,000 ozone molecules before it is removed from the stratosphere.

Michigan contributes to the stratospheric ozone depletion problem in several ways. The state is heavily industrialized and has a number of companies that directly release ozone depleting chemicals to the atmosphere as a result of their manufacturing activities. In 1989, 145 companies released at least 6.5 million pounds of the three ozone depleting chemi-

cals (CFC-113, methyl chloroform, and carbon tetrachloride) that they are required to report under the federal Community Right-to-Know Law. Reporting compliance under this law is low; moreover, reporting of other ozone depleting chemicals, such as the CFCs with higher usage, has only recently been required (in 1992). Also, general consumers use many products that either contain ozone-depleting chemicals or were made using them. It can be assumed that Michigan's per capita use/consumption of these chemicals is around the United States average, which is about 1.5 kg per capita annually.

Once the problem of stratospheric ozone depletion was recognized, governments and the scientific community mobilized to mediate it. A major world conference was held, and in 1987 the Montreal Protocol to control CFCs and other ozone depleting chemicals was agreed to by most of the world's industrialized nations. It was ratified by the U.S. Congress in 1988. Based on new scientific evidence and increasing concern, the Protocol was revised in 1990 to call for a complete phase-out of the production of CFCs, halons, and carbon tetrachloride by the year 2000 and methyl chloroform by the year 2005.

More significant from Michigan's standpoint are the new amendments to the federal Clean Air Act passed in November 1990. These established a completely new federal regulatory framework for the control and phase-out of production and use of ozone-depleting chemicals.

After the National Aeronautics and Space Administration (NASA) indicated it had new information on high levels of ClO in the stratosphere on February 3, 1992, President Bush announced that the United States would take unilateral action to phase out the production and use of CFCs by the end of 1995.

Trace Metals in the Ecosystem

Trace metals are metals and metalloids (e.g., lead and arsenic, respectively) that typically occur in low concentrations in the major elemental reservoirs of the earth: sediment, soil, rocks and minerals, water, air, and biota. Health problems associated with trace metals in the environment have occurred since ancient times. Metals cannot be destroyed, are hard to remove from the environment, and can be concentrated in biota. Not addressing the trace metal issue (in part because of a lack of knowledge) could result in serious consequences.

Some of these metals, such as the "heavy" metals arsenic (As), cadmium (Cd), mercury (Hg), and lead (Pb), are toxic even at low concentrations. Hence, the International Joint Commission (U.S. and Canada) has targeted these four metals as critical contaminants in the Great Lakes region. However, with increasing concentration in the environment, metals not normally toxic, and even essential to life at low concentrations, become toxic. Thus, there are potentially more trace metals (both heavy and transition) and forms (oxidation state, methylated, and so forth) of the metals that may be of concern in the Great Lakes region than the four "critical" contaminants.

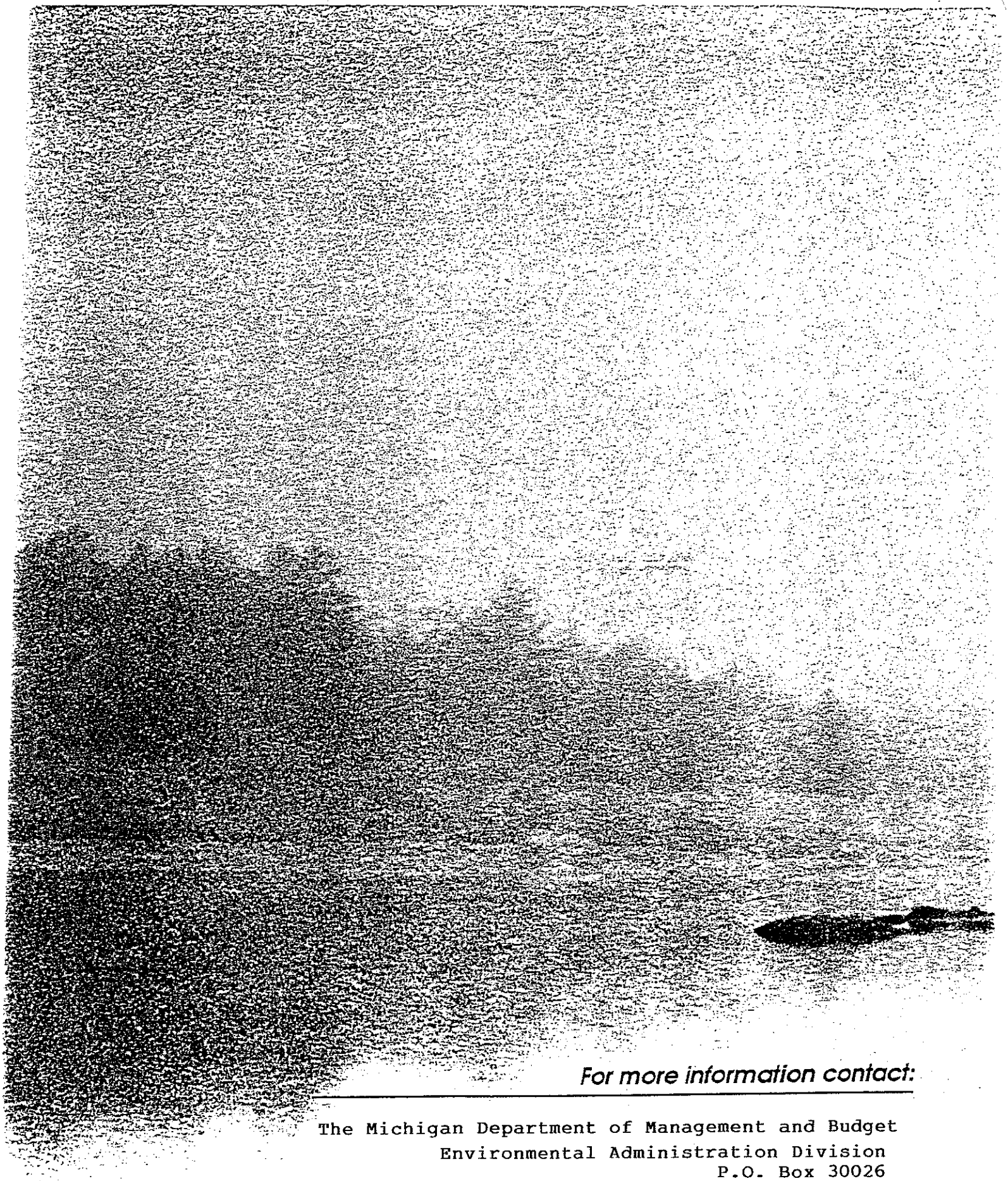
Assessments of metal pollution based on total concentrations in soils, sediments, and so forth may be misleading because metals have natural sources and different toxicities as a function of their form in the environment. Of major concern is the build-up of metals in the environment due to anthropogenic emissions, mainly from fossil-fuel combustion, waste incineration, manufacturing processes, mining, and smelting. The relative importance of these sources varies for each metal. The major anthropogenic

sources for As, Cd, Hg, and Pb are historical pesticide use, coal burning, iron/steel production, and motor fuel/industry, respectively.

The east-north central states (Michigan, Wisconsin, Illinois, Indiana, and Ohio) are a major source for and recipient of trace metals. Trace metals enter the Michigan ecosystem both from within the state and from outside Michigan borders (transboundary effect). Pathways for trace metals in Michigan (and the Great Lakes region in general) are: from atmosphere to land and water (Great Lakes, inland lakes, rivers); from land (added from the atmosphere and from the weathering of minerals) to groundwater and rivers; and from groundwater and rivers to the Great Lakes (as well as inland lakes).

Some of the problems with trace metals in the Michigan ecosystem are obvious. Ingestion of leaded paint by children, mercury in fish throughout the inland lakes, and arsenic in groundwater in the Bad Axe area are a few examples. Other problems, such as the continual build-up of metals in soil, are not as obvious. The geochemistry of trace metals (and other elements as well) in the Michigan environment and how this geochemistry relates to health and disease is poorly understood.

As the heavy metal burden in the environment (air, soil, and water) increases, the threshold level at which "safe" environments become poisonous is approached. This threshold level for most metal-environment-biologic interactions is poorly understood, has already been surpassed (and may be unrecognized) in some environments, and could be lowered suddenly by changes in the environment due to such factors as acid rain and global climate change.



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