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EPA's
Draft Report on the Environment
Technical Document

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This report is dedicated to the memory of our friend and colleague, Dr. Felicity (Kim) Devonald. Kim was a tireless advocate for the development and use of environmental indicators at EPA, pioneering our efforts to provide useful and reliable descriptions of environmental status and trends.

Kim joined EPA in1984. Since the early 1990s, she was instrumental in Agency explorations of the concept of environmental indicators. Her efforts led to the Agency's first published proposals of fully developed environmentally based indicators (from public workshops) in the mid-1990s. She was working on material related to the state of science of these indicators almost to the moment of her death, and much of that material has been incorporated into this Technical Document.

Without Kim's example and her early efforts, this report would be far less than it is.

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Preface

From EPA's Science Advisor and Chief Information Officer

The Environmental Protection Agency (EPA) has been a world leader in developing and implementing solutions to the environmental problems in our air, water and land. Through the years, working together with other Federal Agencies we have built a significant body of science and knowledge that has influenced national and international public policy, and has raised our awareness of the value of our environment. Yet, even with the enormous wealth of understanding and information that we have today, there are still gaps in our ability adequately monitor many key indicators in the cascades of events that link our efforts to protect the environment to the ultimate outcomes we seek: cleaner air, purer water, better protected land, and better human health or and ecological condition. To close that gap, we need both scientifically sound indicators and the national data to support them.

With the publication of the EPA Draft Report on the Environment, including this comprehensive Technical Document, EPA has launched a multi-year effort to improve the state of the science and our knowledge of the state of the environment. This effort addresses indicators, monitoring data and models for better tracking the impacts of our activities on the environment. This document includes indicators that EPA has monitored for many years, including ambient levels of pollutants in air, water and land. However, we recognize that protecting the environment ultimately is achieved in terms of human health and ecological condition, and these two chapters serve as anchors for the entire report.

The last sections of each chapter of this report describe challenges and data gaps associated with its particular subject area. Several general issues have emerged that we will address in the coming months and years.

Shifting to an "Outcomes" Framework

Identifying environmental "outcomes" such as better human health and ecological condition requires a significant shift in how the Agency frames questions and issues about environmental quality. The first three chapters of this report; Cleaner Air, Purer Water, and Better Protected Land, ask questions that tend to follow traditional Agency efforts to prevent, control, or remediate the effects of pollution. For example:

- What is the quality of outdoor air in the United States?
- What are pressures to water quality?
- What is the extent of developed land?

The final two chapters on human health and ecological condition, ask questions about outcomes, for example:

- What are the trends for cancer?
- What is the ecological condition of coasts and oceans?

To understand how EPA's mission affects these outcomes, both directly and indirectly, requires indicators not only of pollutant releases and ambient conditions, but indicators that span the chain of events between the release of a pollutant, exposure of people, plants and animals, and the chain of events from dose to effects. In the case of human health, factors such as level of health care, natural disease rates, and actual human exposures must be factored into an indicator strategy. For ecosystems, indicators are needed that track hydrology, features of the landscape, natural disturbances, ecological processes, and other factors that interact with pollutants to ultimately determine ecosystem condition.

Availability of Indicators

For a few of the questions in the report, indicators were identified that are available at the national level. More frequently, however, we found that promising indicators have been developed and measured for limited geographic areas, or for a part of the causal chain. Further exploration of the relationship between measurements used for assessments and measurements used for diagnosis of causal factors also is needed. Development and testing of national indicators has been a high research priority for EPA's Office of Research and Development.

Availability of Data

For each of the indicators, we attempted to gather data of sufficient quality and coverage to support national reporting, both within and outside the Agency. Generally, the available data were too limited in place and time to describe national trends, or even to provide a national snapshot of conditions. Because the data from different organizations often serve a broad range of purposes, even when data are available nationally, gaps remain in the spatial, temporal and phemonenological coverage needed to track the outcomes of many of EPA's programs. Monitoring networks established to address specific issues must be better integrated through common definitions, designs, methods, and information systems.

Collaborating for the Future

With this draft as a starting point, we look forward to collaborating with federal and state agencies to promote integrated and coherent approaches and mechanisms for reporting on the state of the environment. Following the release of this report, we will be working closely with scientists from other federal and state agencies and the academic community to explore how best to improve our ability to measure and assess environmental conditions.

We invite all of our stakeholders to lend their creativity and commitment in the months and years ahead as they join us in meeting Administrator Whitman's challenge to focus our resources on the areas of greatest concern and to manage our work to achieve measurable results.

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Introduction

"When I leave office, I want to be able to say that America's air is cleaner, its water is purer, and its land better protected than it was when I arrived. As we seek to achieve this goal, EPA needs to be accountable for our stewardship."
Christine Todd Whitman, Administrator, U.S. Environmental Protection Agency

In November 2001, EPA Administrator Christine Todd Whitman directed the Agency to bring together its national, regional and program office data to produce a report on the "state of the environment." The report would represent the first step of the Environmental Indicators Initiative, a multi-year process that would ultimately allow future EPA administrators to better measure and report on progress toward environmental and human health goals and to ensure the Agency's accountability to the public.

To produce this report, EPA's Office of Research and Development (ORD) and Office of Environmental Information (OEI) led a collaborative effort to identify the key questions to be answered by the report, to identify an initial set of indicators, and to develop a process for reviewing and selecting the indicators and supporting data to be included in the final report. This task was accomplished thanks to the efforts of numerous EPA staff, representatives from other federal agencies, representatives from the states and tribes, and external advisors and reviewers. The indicators and supporting data used in this report were generated by EPA and other federal, state, tribal, regional, local, and non-governmental organizations. The Council on Environmental Quality in the Executive Office of the President was helpful throughout in coordinating interagency contributions to the project.

EPA's *Draft Report on the Environment* (ROE) consists of this *Technical Document* and a version of the report for general reading. These reports pose national questions about the environment and human health and answer those questions wherever scientifically sound indicators and high-quality supporting data are available. The reports both pose questions and present indicators related to:

- Cleaner Air
- Purer Water
- Better Protected Land
- Human Health
- Ecological Condition

This *Draft Technical Document* discusses the limitations of the currently available indicators and data, and the gaps and challenges that must be overcome to provide better answers in the future.

For a few indicators, data are available that are truly representative of the entire nation. For other indicators, data currently are available for only one region (such as the East Coast or the Northwest), but the indicator could obviously be applied nationally if the data were available. Based on the availability of supporting data, indicators that were selected and included in this report were assigned to one of two categories:

- **Category 1** –The indicator has been peer reviewed and is supported by national level data coverage for more than one time period. The supporting data are comparable across the nation and are characterized by sound collection methodologies, data management systems, and quality assurance procedures.
- **Category 2** –The indicator has been peer reviewed, but the supporting data are available only for part of the nation (e.g., multi-state regions or ecoregions), or the indicator has not been measured for more than one time period, or not all the parameters of the indicator have been measured (e.g., data has been collected for birds, but not for plants or insects). The supporting data are comparable across the areas covered, and are characterized by sound collection methodologies, data management systems, and quality assurance procedures.

This report is part of EPA's continuing effort to identify, improve, and utilize environmental indicators in its planning, management, and public reporting. EPA's specific strategies and performance targets to protect human health and the environment are presented in the Agency's strategic and annual plans. These planning and performance documents, together with the questions, indicators and data presented in these reports, will allow EPA to better define and measure the status and trends in environment and health, and to better measure the effectiveness of its programs and activities.

This technical report is a draft, intended to elicit comments and suggestions on the approach and findings. To learn more about EPA's *Draft Report on the Environment* and the Environmental Indicators Initiative, and to provide comments and feedback, please visit http://www.epa.gov/indicators/.

Chapter 1:
Cleaner Air

Indicators that were selected and included in this chapter were assigned to one of two categories:

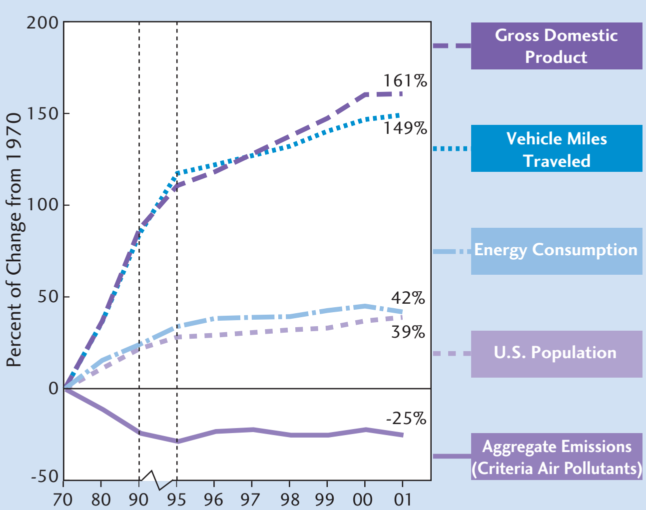
- **Category 1** –The indicator has been peer reviewed and is supported by national level data coverage for more than one time period. The supporting data are comparable across the nation and are characterized by sound collection methodologies, data management systems, and quality assurance procedures.
- **Category 2** –The indicator has been peer reviewed, but the supporting data are available only for part of the nation (e.g., multi-state regions or ecoregions), or the indicator has not been measured for more than one time period, or not all the parameters of the indicator have been measured (e.g., data has been collected for birds, but not for plants or insects). The supporting data are comparable across the areas covered, and are characterized by sound collection methodologies, data management systems, and quality assurance procedures.

1.0 Introduction

In 1970, Congress responded to concern over visible air pollution, irritating smog, and associated health and ecological effects by enacting the federal Clean Air Act (CAA). As a result, total national emissions of the six criteria air pollutants decreased by 25 percent between 1970 and 2001. Emissions of air toxics have declined as well, dropping 24 percent between 1990 and 1993 (the baseline period) and 1996. One of the major components of acid rain, wet sulfate deposition, has also decreased substantially (EPA, OAQPS, September 2002).

These improvements occurred during a time of significant growth in the nation's population and economy: from 1970 to 2001, the Gross Domestic Product (GDP) increased by 161 percent, the number of people increased from about 203 million to more than 280 million, energy consumption increased by 42 percent, and vehicle miles traveled increased by 149 percent (Exhibit 1-1) (EPA, OAQPS, September 2002).

Exhibit 1-1: Comparison of growth measures and emission trends, 1970-2001



Source: EPA, Office of Air Quality Planning and Standards. *Latest Findings on National Air Quality: 2001 Status and Trends.* September 2002.

Despite progress toward cleaner air, in 2001 more than 133 million people lived in counties where monitored air quality was unhealthy at times because of high levels of at least one criteria air pollutant (EPA, OAQPS, September 2002). Even after decades of regulation and emissions control, certain air quality problems persist. In particular, ozone and particulate matter are the criteria pollutants most often found at levels above national health-based standards.

Outdoor air is not the nation's only air quality concern. The levels of pollutants in the air inside homes, schools, and other buildings can be higher than in the outdoor air. Uncertainty remains about levels of indoor air pollutants, such as radon and environmental tobacco smoke.

Changes to stratospheric ozone levels are also concerns. The stratospheric ozone layer has become substantially thinner in recent decades, although scientists generally believe it will recover over the next several decades as a result of international controls (Scientific Assessment Panel, 2003).

This chapter summarizes the current status and trends in air quality, the pressures affecting air quality, and information regarding human health and ecological effects. It poses fundamental questions about air quality, contributors to pollution, and health and ecological effects, and it uses indicators drawn from well-reviewed data sources to help answer those questions. Exhibit 1-2 lists these questions and indicators, as well as the number of the chapter section where each indicator is presented.

The chapter is divided into six main sections:

- Section 1.1 discusses the quality of outdoor air.
- Section 1.2 provides information about acid deposition.
- Section 1.3 examines the quality of air inside homes, schools, and other buildings.
- Section 1.4 focuses on stratospheric ozone.
- Section 1.5 briefly addresses climate change research plans.
- Section 1.6 reviews the challenges and data gaps that remain in assessing the nation's air quality.

Exhibit 1-2: Air – Questions and Indicators

Outdoor Air Quality

Question	Indicator Name	Category	Section
What is the quality of outdoor air in the United States? (See also following four questions)	Number and percentage of days that metropolitan statistical areas (MSAs) have Air Quality Index (AQI) values greater than 100	2	1.1.1
– How many people are living in areas with particulate matter and ozone levels above the National Ambient Air Quality Standards (NAAQS)?	Number of people living in areas with air quality levels above the NAAQS for particulate matter (PM) and ozone	1	1.1.1.a
– What are the concentrations of some criteria air pollutants: $PM_{2.5}$, PM_{10}, ozone, and lead?	Ambient concentrations of particulate matter: $PM_{2.5}$ and PM_{10}	1	1.1.1.b
	Ambient concentrations of ozone: 8-hour and 1-hour	1	1.1.1.b
	Ambient concentrations of lead	1	1.1.1.b
– What are the impacts of air pollution on visibility in national parks and other protected lands?	Visibility	1	1.1.1.c
– What are the concentrations of toxic air pollutants in ambient air?	Ambient concentrations of selected air toxics	2	1.1.1.d
What contributes to outdoor air pollution? (See also following three questions)	See emissions indicators		1.1.2
– What are contributors to particulate matter, ozone, and lead in ambient air?	Emissions: particulate matter ($PM_{2.5}$ and PM_{10}) sulfur dioxide, nitrogen oxides, and volatile organic compounds	2	1.1.2.a
	Lead emissions	2	1.1.2.a
– What are contributors to toxic air pollutants in ambient air?	Air toxics emissions	2	1.1.2.b
– To what extent is U.S. air quality the result of pollution from other countries, and to what extent does U.S. air pollution affect other countries?	No Category 1 or 2 indicators identified		1.1.2.c
What human health effects are associated with outdoor air pollution?	No Category 1 or 2 indicators identified Also see Human Health chapter		1.1.3
What ecological effects are associated with outdoor air pollution?	No Category 1 or 2 indicators identified Also see Ecological Condition chapter		1.1.4

Acid Deposition

Question	Indicator Name	Category	Section
What are the deposition rates of pollutants that cause acid rain?	Deposition: wet sulfate and wet nitrogen	2	1.2.1
What are the emissions of pollutants that form acid rain?	Emissions (utility): sulfur dioxide and nitrogen oxides	2	1.2.2
What ecological effects are associated with acid deposition?	No Category 1 or 2 indicators identified Also see Ecological Condition chapter		1.2.3

Indoor Air Quality

Question	Indicator Name	Category	Section
What is the quality of the air in buildings in the United States?	U.S. homes above EPA's radon action levels	2	1.3.1
	Percentage of homes where young children are exposed to environmental tobacco smoke	2	1.3.1
What contributes to indoor air pollution?	No Category 1 or 2 indicators identified Also see Human Health chapter		1.3.2
What human health effects are associated with indoor air pollution?	No Category 1 or 2 indicators identified Also see Human Health chapter		1.3.3

Stratospheric Ozone

Question	Indicator Name	Category	Section
What are the trends in the Earth's ozone layer?	Ozone levels over North America	1	1.4.1
What is causing changes to the ozone layer?	Worldwide and U.S. production of ozone-depleting substances (ODSs)	2	1.4.2
	Concentrations of ozone-depleting substances (effective equivalent chlorine)	2	1.4.2
What human health effects are associated with stratospheric ozone depletion?	No Category 1 or 2 indicators identified		1.4.3
What ecological effects are associated with stratospheric ozone depletion?	No Category 1 or 2 indicators identified		1.4.4

1.1 Outdoor Air Quality

Among the pollutants affecting outdoor air quality are:

- Criteria pollutants–ozone (O_3), particulate matter (PM), sulfur dioxide (SO_2), nitrogen dioxide (NO_2), carbon monoxide (CO), and lead.
- Air toxics–pollutants such as mercury and benzene.

Under the Clean Air Act, EPA and states collect data on the six criteria air pollutants to measure compliance with National Ambient Air Quality Standards (NAAQS) (Exhibit 1-3). "Primary" NAAQS are set to protect public health with an adequate margin of safety, and "secondary" NAAQS protect against adverse welfare effects (e.g., effects on vegetation, ecosystems, visibility, manmade materials) (42 U.S.C. 7408 and 7409). After initially adopting NAAQS for each of the criteria air pollutants in the 1970s, EPA has periodically reviewed and sometimes revised the standards. EPA recently revised the health-based standard for ozone and added a new standard for fine $PM_{2.5}$ based on new health studies (EPA, 2003; EPA, 1997).

Criteria air pollutants are monitored through the National Air Monitoring Stations/State or Local Air Monitoring Stations network. This network consists of more than 5,000 monitors operating at 3,000 sites across the country, mostly in urban areas (EPA, OAQPS, September 2002). Measurements are taken on both a daily and continuous basis to assess both peak concentrations and overall trends, and are reported in the Air Quality Subsystem (AQS) database. In addition to other uses, EPA analyzes these air quality measurements to designate areas as either attainment or nonattainment for specific criteria air pollutants (i.e., determines if air quality levels in an area violate the NAAQS).

While air quality data on criteria air pollutants are ample, national data on air toxics concentrations are limited. Several metropolitan areas measure ambient air toxics concentrations, but there are few standards by which to evaluate levels of concern. In addition, cumulative or synergistic impacts of various air pollutants are not well understood.

Visibility is another outdoor air concern. Some data on this aspect of air quality are available from the Interagency Monitoring of Protected Visual Environments (IMPROVE) network, which collects data to characterize visibility at national parks and other protected areas.

This section addresses the following specific questions about outdoor air quality:

- What is the quality of outdoor air in the United States? (Section 1.1.1)
  - ▲ How many people are living in areas with particulate matter and ozone levels above the NAAQS?

Exhibit 1-3: National Ambient Air Quality Standards (NAAQS) in effect as of February 2003

Pollutant	Primary Standard (Health Related)		Secondary Standard (Welfare Related)	
	Type of Average	Standard Level Concentration[a]	Type of Average	Standard Level Concentration
CO	8-hour[b] 1-hour[b]	9 ppm (10 mg/m^3) 35 ppm (40 mg/m^3)	No Secondary Standard No Secondary Standard	
Pb	Maximum Quarterly Average	1.5 µg/m^3	Same as Primary Standard	
NO_2	Annual Arithmetic Mean	0.053 ppm (100 µg/m^3)	Same as Primary Standard	
O_3	Maximum Daily 1-hour Average[c] 4th Maximum Daily[d] 8-hour Average	0.12 ppm (235 µg/m^3) 0.08 ppm (157 µg/m^3)	Same as Primary Standard Same as Primary Standard	
PM_{10}	Annual Arithmetic Mean 24-hour[e]	50 µg/m^3 150 µg/m^3	Same as Primary Standard Same as Primary Standard	
$PM_{2.5}$	Annual Arithmetic Mean[f] 24-hour[g]	15 µg/m^3 65 µg/m^3	Same as Primary Standard Same as Primary Standard	
SO_2	Annual Arithmetic Mean 24-hour[b]	0.03 ppm (80 µg/m^3) 0.14 ppm (365 µg/m^3)	3-hour[b]	0.50 ppm (1,300 µg/m^3)

a Parenthetical value is an approximately equivalent concentration. (See 40 CFR Part 50).
b Not to be exceeded more than once per year.
c The standard is attained when the expected number of days per calendar year with maximum hourly average concentrations above 0.12 ppm is equal to or less than one, as determined according to Appendix H of the Ozone NAAQS.
d Three-year average of the annual 4th highest daily maximum 8-hour concentration.
e The short-term (24-hour) standard of 150 µg/m^3 is not to be exceeded more than once per year on average over three years.
f Spatially averaged over designated monitors.
g The form is the 98th percentile.

Source: Based on EPA, Office of Air Quality Planning and Standards. *National Air Quality and Emissions Trends Report, 1999*. March 2001.

- What are the concentrations of some criteria air pollutants: $PM_{2.5}$, PM_{10}, ozone, and lead?
- What are the impacts of air pollution on visibility in national parks and other protected lands?
- What are the concentrations of toxic air pollutants in ambient air?

■ What contributes to outdoor air pollution? (Section 1.1.2)
- What are contributors to particulate matter, ozone, and lead in ambient air?
- What are contributors to toxic air pollutants in ambient air?
- To what extent is U.S. air quality the result of pollution from other countries, and to what extent does U.S. air pollution affect other countries?

■ What human health effects are associated with outdoor air pollution? (Section 1.1.3)

■ What ecological effects are associated with outdoor air pollution? (Section 1.1.4)

1.1.1 What is the quality of outdoor air in the United States?

Indicator

Number and percentage of days that metropolitan statistical areas (MSAs) have Air Quality Index (AQI) values greater than 100

The nation's air quality has generally improved, as indicated by trends derived by averaging the direct measurements from the nation's criteria air pollutant monitoring stations on a yearly basis. In general, air pollution concentrations are declining, and overall air quality is improving (EPA, OAQPS, September 2002).

Most areas of the U.S. now have concentrations of NO_2, SO_2, CO, and lead that are below the level of the NAAQS (EPA, OAQPS, September 2002). However, ozone levels are above the level of the standard in many heavily populated areas, including many of the urban areas in the eastern half of the U.S. and in most of the urban areas in California (EPA, OAQPS, March 2001). Concentrations of $PM_{2.5}$—particles less than or equal to 2.5 micrometers in diameter—are above the level of the standard in much of the eastern U.S. and parts of California (EPA, OAQPS, September 2002).

It is important to recognize that while the national trend is toward cleaner air, regional and local conditions can vary quite greatly. This report focuses on national status and trends, but regional and local conditions should be evaluated as well, with the goal of understanding regional air quality conditions and trends and improving air quality in those areas where air quality does not meet the standards.

A number of indicators, described on the following pages, help to answer the questions posed in this section about outdoor air quality:

- Number and percentage of days that Metropolitan Statistical Areas (MSAs) have Air Quality Index (AQI) values greater than 100
- Number of people living in areas with air quality levels above the NAAQS for particulate matter and ozone
- Ambient concentrations of particulate matter: $PM_{2.5}$ and PM_{10}
- Ambient concentrations of ozone: 8-hour and 1-hour
- Ambient concentrations of lead
- Visibility
- Ambient concentrations of selected air toxics
- Emissions of particulate matter ($PM_{2.5}$ and PM_{10}), sulfur dioxide, nitrogen oxides, and volatile organic compounds
- Lead emissions
- Air toxics emissions

Indicator: Number and percentage of days that metropolitan statistical areas (MSAs) have Air Quality Index (AQI) values greater than 100 - Category 2

One measure of outdoor air quality is the daily AQI, which is based on concentrations of five of the criteria air pollutants: ozone, PM, CO, SO_2, and NO_2. The AQI indicates how clean or polluted the air is and the associated health concerns. It focuses on the health effects that can occur within a few hours or days after breathing polluted air. AQI data are compiled by state and local agencies and must be reported in metropolitan statistical areas (MSAs) with populations of more than 350,000 (EPA, OAQPS, March 2001).

AQI values range from 0 to 500, with higher numbers indicating more air pollution and more potential risk to public health. An AQI value of 100 generally corresponds to the short-term public health standard set by EPA for a particular pollutant. Values below 100 are generally thought of as satisfactory. However, unusually sensitive individuals may experience health effects when AQI values are between 50 and 100. Values above 100 suggest increasingly unhealthy air; sensitive population groups, such as children, the elderly, and those with respiratory illnesses, are likely to be among the first affected as the values increase.

The AQI scale is divided into six categories, each color-coded to correspond to a different level of health concern. For example,

- The color green is associated with "good" air quality or an AQI from 0 to 50.
- Yellow or "moderate"—51 to 100.
- Orange or "unhealthy for sensitive groups"—101 to 150.
- Red or "unhealthy"—151 to 200.
- Purple or "very unhealthy"—201 to 300.
- Maroon or "hazardous"—301 to 500. AQI values over 300 would trigger health warnings of emergency conditions for the entire population (EPA, OAQPS, March 2001).

The highest AQI value for an individual pollutant becomes the AQI value for that area for that particular day. For example, if on a day a certain area had AQI values of 150 for ozone and 120 for PM, the AQI value would be 150 for the pollutant ozone on that day. However, for all pollutants above 100, the appropriate sensitive groups would be cautioned. Ozone levels most often drive the AQI, but experts anticipate that $PM_{2.5}$ will also be a key driver of the AQI in coming years.

The AQI is useful in communicating to the public the air quality in a specific area on a given day and the potential health effects and actions to avoid exposure and reduce harmful impacts. Nationally, the number and percentage of days with AQI values of more than 100 gives a sense of the number of days that are potentially unhealthy for sensitive populations.

What the Data Show

This indicator is the annual sum of the number of days, and percentage of days, with AQI values above 100 across all MSAs with a population greater than 500,000. To assess trends, the number of days is adjusted to reflect changes in air quality standards or criteria for the number of MSAs reporting.

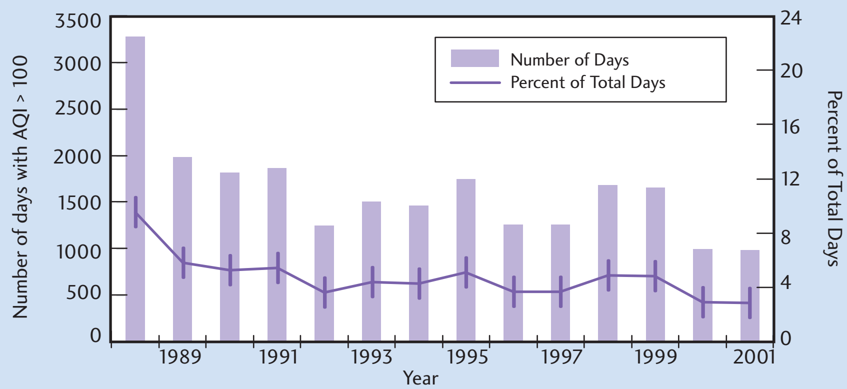
Between 1988 and 2001, the number of days with an AQI of 100 or greater decreased from approximately 3,300 days to approximately 1,000 days. In 1989 and after, the number of days with an AQI of 100 or greater ranged between 1,000 and 2,000. Based on EPA AQI data, the percentage of days across the country with AQI values above 100 dropped from almost 10 percent in 1988 to 3 percent in 2001 (Exhibit 1-4) (EPA, OAQPS, December 1998; EPA, OAQPS, 2001).

Indicator Gaps and Limitations

Limitations of this indicator include the following:

- The data for this indicator are associated with large MSAs only (500,000 people or more); therefore, the data tend to reflect urban air quality.

Exhibit 1-4: Number and percentage of days with Air Quality Index (AQI) greater than 100, 1988-2001



Note: Data are for MSAs > 500,000

Source: Data used to create graphic are drawn from EPA, Office of Air Quality Planning and Standards. *National Air Quality and Emissions Trends Report*, 1997. Table A-15. December, 1998; EPA, Office of Air Quality Planning and Standards. Air trends: Metropolitan area trends, Table A-17, 2001. (February 25, 2003; *http://www.epa.gov/airtrends/metro.html*).

Indicator: Number and percentage of days that metropolitan statistical areas (MSAs) have Air Quality Index (AQI) values greater than 100 - Category 2 (continued)

- This composite AQI indicator does not identify the pollutants of concern–that is, it does not show which pollutant(s) are causing the days with an AQI of more than 100, or which ones have decreased and are responsible for an improvement in the AQI.
- This composite AQI indicator does not show which areas, or how many areas, have problems–a specific number of days could reflect a few areas with persistent problems or many areas with occasional problems.

Data Source

The data sources for this indicator were "Air Trends: Metropolitan area trends," Table A-17, EPA, 2001, and *National Air Quality and Emissions Trends Report, 1997*, Table A-15, EPA, 1998. (See Appendix B, page B-2, for more information.)

1.1.1.a How many people are living in areas with particulate matter and ozone levels above the National Ambient Air Quality Standards (NAAQS)?

Indicator
Number of people living in areas with air quality levels above the NAAQS for particulate matter (PM) and ozone

In 2001, more than 133 million Americans (of a total population of 281 million) lived in counties where monitored outdoor air quality was unhealthy at times because of high levels (levels above the NAAQS) of at least one criteria air pollutant (EPA, OAQPS, September 2002). Ozone and PM remain the most persistent criteria pollutants.

Indicator: Number of people living in areas with air quality levels above the NAAQS for particulate matter (PM) and ozone - Category 1

The number of people living in areas above the level of the health-based NAAQS gives some indication of the number of people potentially exposed to unhealthy air.

What the Data Show

Despite trends of decreasing concentrations of criteria pollutants, many people still live in areas with air quality levels above the health-based standards for ozone and PM. In 2001, 11.1 million people lived in counties with air quality concentrations that at times were above the NAAQS for PM_{10}, and 72.7 million people lived in counties with air quality concentrations above the standard for $PM_{2.5}$. Some 40.2 million people lived in counties with concentrations that at times were above the 1-hour ozone standard, and 110.3 million people lived in counties with concentrations above the 8-hour ozone standard (Exhibit 1-5) (EPA, OAQPS, September 2002).

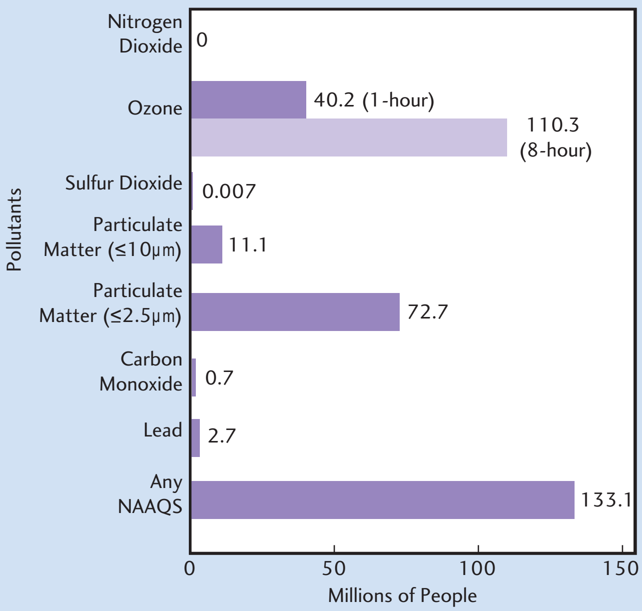
Indicator Gaps and Limitations

Limitations of this indicator include the following:

- The indicator helps in understanding the number of people potentially affected by air quality problems, but it does not tell the actual number of people exposed to unhealthy air. Not all counties have complete monitoring data, so some areas may be excluded. However, the areas of most concern are likely covered.

Indicator | Number of people living in areas with air quality levels above the NAAQS for particulate matter (PM) and ozone - Category I (continued)

Exhibit 1-5: People living in areas with air quality above the National Ambient Air Quality Standards (NAAQS) in 2001



Source: EPA, Office of Air Quality Planning and Standards. *Latest Findings on National Air Quality: 2001 Status and Trends*. September 2002.

- The indicator does not tell the amount or extent to which different areas exceed the standards, and so does not provide any specific exposure data.

Data Sources

The data source for this indicator was *Latest Findings on National Air Quality: 2001 Status and Trends*, EPA, 2002. (See Appendix B, page B-3, for more information.)

1.1.1.b What are the concentrations of some criteria air pollutants: $PM_{2.5}$, PM_{10}, ozone, and lead?

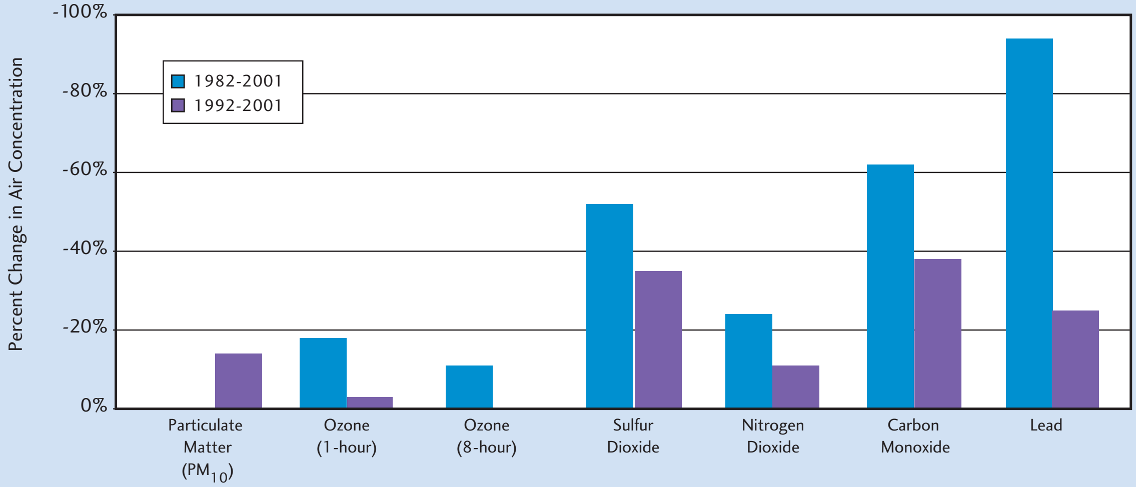
Indicators

Ambient concentrations of particulate matter: $PM_{2.5}$ and PM_{10}
Ambient concentrations of ozone: 8-hour and 1-hour
Ambient concentrations of lead

Three indicators, presented on the following pages, are available to help answer this question: ambient concentrations of particulate matter, ambient concentrations of ozone (8-hour and 1-hour), and ambient concentrations of lead. Concentrations of the criteria air pollutants have decreased over the past 2 decades, with substantial reductions in SO_2, CO, and lead levels (Exhibit 1-6) (EPA, OAQPS, September 2002). However, $PM_{2.5}$ and ozone concentrations are above the NAAQS in many areas, potentially exposing a significant percentage of the U.S. population to unhealthy air (EPA, OAQPS, September 2002).

The data for national levels of criteria pollutants tell only part of the story. Although significant improvements have been occurring nationally and regionally, some areas still have chronic air quality problems. The Northeast, for example, experiences frequent and widespread violations of the ozone health-based standard (Northeast States for Coordinated Air Use Management, 2002).

Exhibit 1-6: Percent reduction in concentration of six criteria air pollutants regulated under the Clean Air Act, 1982-2001



Note: Trend data for $PM_{2.5}$ are not available. Trend data for PM_{10} are only available for 1992-2001. Between 1992-2001, ozone (8-hour) concentrations remained level.

Source: EPA, Office of Air Quality Planning and Standards. *Latest Findings on National Air Quality: 2001 Status and Trends.* September 2002.

Indicator

Ambient concentrations of particulate matter: $PM_{2.5}$ and PM_{10}- Category 1

Particulate matter concentrations are a good indication of air quality health effects, because of concerns about associated respiratory effects. This indicator is based on the annual average concentrations, in micrograms per cubic meter (μg/m³) of $PM_{2.5}$ and PM_{10}. PM_{10} refers to particles 10 micrometers or less in diameter, and $PM_{2.5}$ refers to particles less than or equal to 2.5 micrometers in diameter.

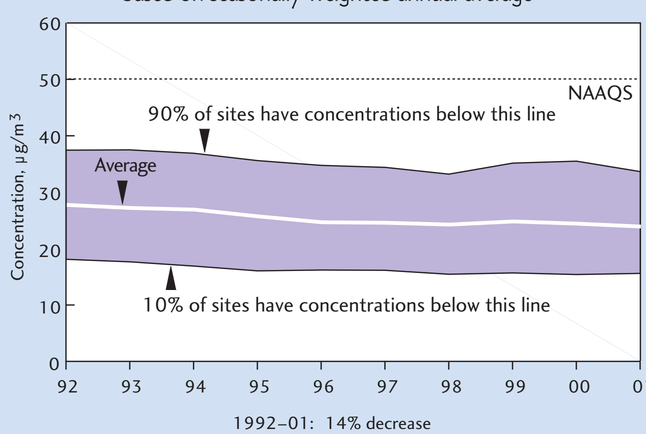
Trends in PM_{10} are presented from 1992 to 2001, and comparable $PM_{2.5}$ data have been collected since 1999 (EPA, OAQPS, September 2002).

What the Data Show

Concentrations of PM_{10} decreased by 14 percent between 1992 and 2001 (Exhibit 1-7), and are below the NAAQS standard concentration in most areas. Concentrations of $PM_{2.5}$ are above the level of the annual standard in much of the eastern U.S. and parts of California (Exhibit 1-8) (EPA, OAQPS, September 2002). Annual average $PM_{2.5}$ concentrations are generally higher in the eastern U.S. than in the West, mostly because sulfate concentrations are four to five times higher in the eastern U.S. (largely due to coal-fired power plants) (EPA, OAQPS, September 2001).

Exhibit 1-7: Particulate matter (PM_{10}) air quality, 1992-2001

based on seasonally weighted annual average



Coverage: 770 monitoring sites nationwide with sufficient data to assess trends.

Source: EPA, Office of Air Quality Planning and Standards. *Latest Findings on National Air Quality: 2001 Status and Trends*. September 2002.

Indicator

Ambient concentrations of particulate matter: $PM_{2.5}$ and PM_{10} - Category 1 (continued)

Indicator Gaps and Limitations

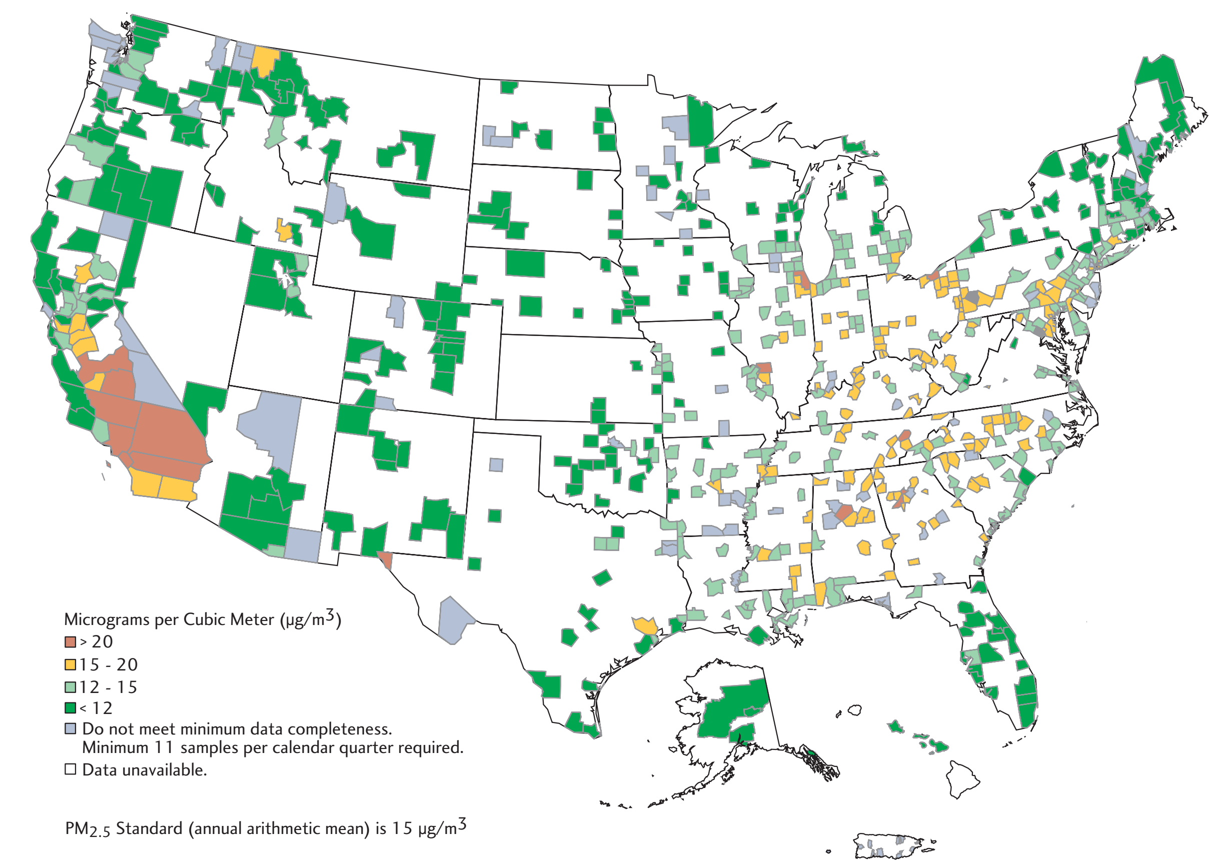
Limitations of this indicator include the following (EPA, OAQPS, September 2002):

- Ten-year trend data for PM10 are not available before 1990, because total suspended particulates, which include particle sizes larger than PM10, were monitored until 1990.
- The monitoring is conducted mostly in urban areas, although the PM2.5 data from the IMPROVE network support assessments of rural trends from 1992 to 1999.

Data Source

The data source for this indicator was *Latest Findings on National Air Quality: 2001 Status and Trends*, EPA, 2002. (See Appendix B, page B-3, for more information.)

Exhibit 1-8: 2001 annual average particulate matter ($PM_{2.5}$) concentrations



Source: EPA, Office of Air Quality Planning and Standards. *Latest Findings on National Air Quality: 2001 Status and Trends.* September 2002.

Indicator | Ambient concentrations of ozone: 8-hour and 1-hour - Category 1

Ozone is one of six criteria pollutants regularly monitored under the CAA to determine compliance with health-based standards. This indicator reflects ambient concentrations in parts per million (ppm) of ground- level ozone from 1982 to 2001, based on 1-hour and 8-hour measurements to gauge shorter-term and longer-term levels.

The 1-hour standard is useful in measuring potential effects during short-term "spikes" in concentrations. The longer 8-hour standard is used in evaluating exposures occurring over a more sustained period of time (e.g., an outdoor worker's exposure over the course of a work day).

What the Data Show

Although ozone concentrations are generally decreasing, they are higher than the NAAQS in many areas. Ground-level ozone concentrations fell by 11 percent between 1982 and 2001, based on the annual fourth highest daily maximum 8-hour average (Exhibit 1-9). Ozone levels based on the annual second highest daily maximum 1-hour standard fell by 18 percent during the same time (Exhibit 1-10). All regions experienced some improvement in 8-hour ozone levels during the past 20 years except the north central region (EPA Region 7), which showed little change (Exhibit 1-11) (EPA, OAQPS, September 2002).

Indicator Gaps and Limitations

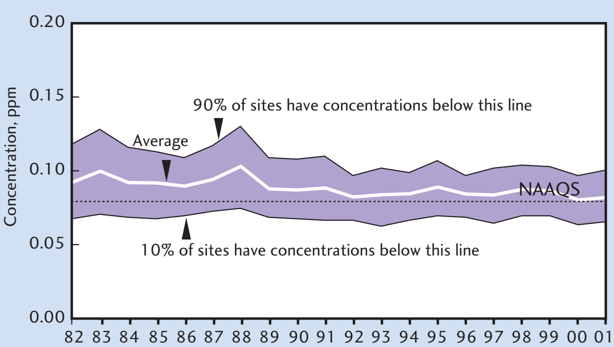
Limitations of this indicator include the following:

- Ground-level ozone is not emitted directly into the air, but is formed by the reaction of volatile organic compounds (VOCs) and nitrogen oxides (NO_X) in the presence of heat and sunlight, particularly in hot summer weather. To assess ozone trends, VOC and NO_X emissions and meteorological information are also evaluated.
- The monitoring is conducted mostly in urban areas; therefore, data may not accurately encompass rural impacts from ozone transport.

Data Source

The data source for this indicator was *Latest Findings on National Air Quality: 2001 Status and Trends*, EPA, 2002. (See Appendix B, page B-3, for more information.)

Exhibit 1-9: Ozone air quality, 1982-2001
based on annual 4th maximum 8-hour average

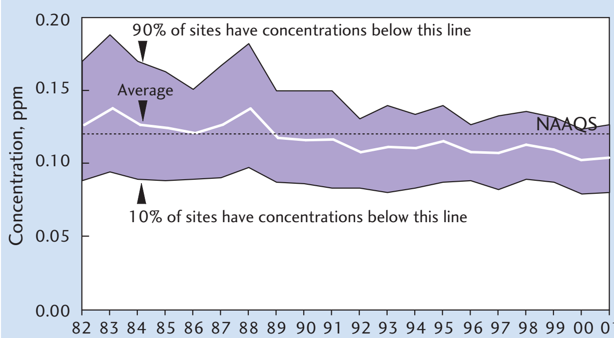


1982–01: 11% decrease
1992–01: 0% change

Coverage: 379 monitoring sites nationwide with sufficient data to assess trends.

Source: EPA, Office of Air Quality Planning and Standards. *Latest Findings on National Air Quality*: 2001 Status and Trends. September 2002.

Exhibit 1-10: Ozone air quality, 1982-2001
based on annual 2nd maximum 1-hour average



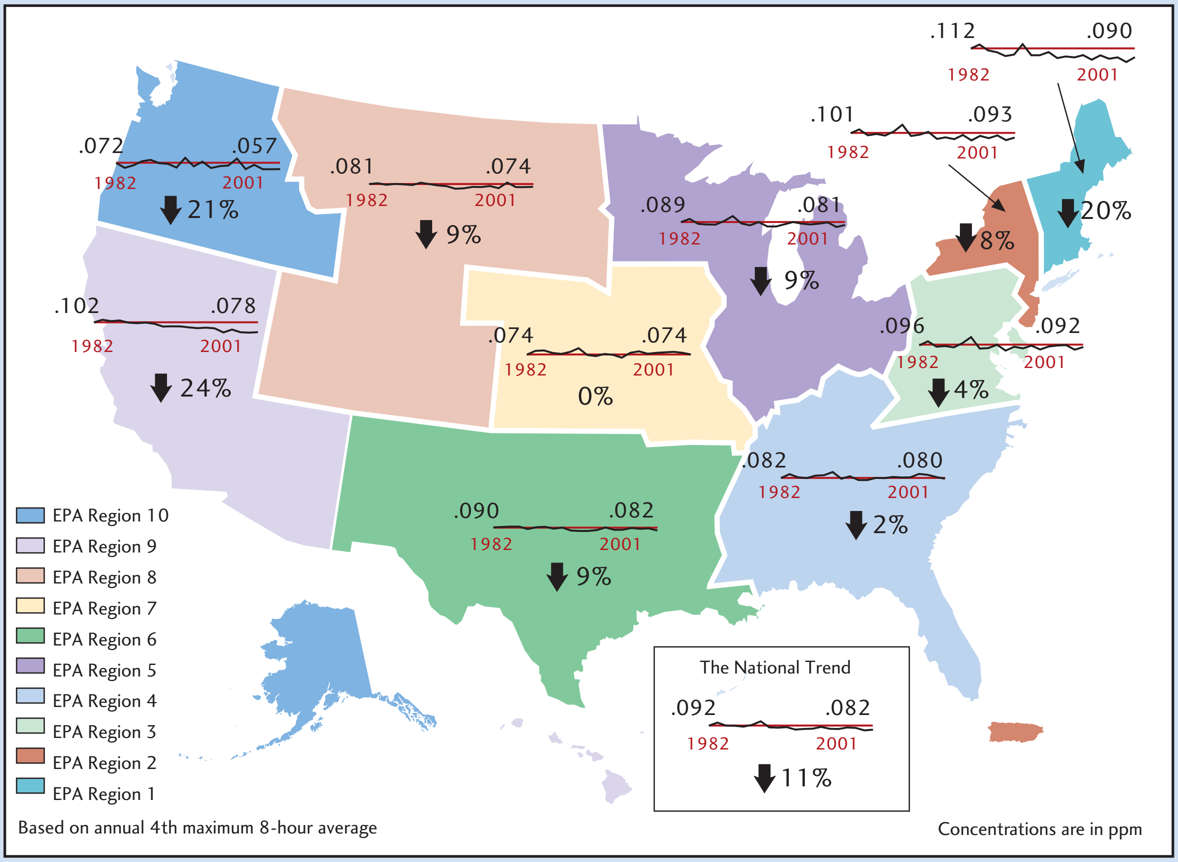
1982–01: 18% decrease
1992–01: 3% decrease

Coverage: 379 monitoring sites nationwide with sufficient data to assess trends.

Source: EPA, Office of Air Quality Planning and Standards. *Latest Findings on National Air Quality: 2001 Status and Trends.* September 2002.

Indicator | Ambient concentrations of ozone: 8-hour and 1-hour - Category 1 (continued)

Exhibit 1-11: Trends in ozone levels (8-hour), 1982-2001, averaged across EPA regions



Note: Alaska levels are included in EPA region 10 averages; Hawaii levels are included in EPA region 9 averages; and Puerto Rico levels are included in EPA region 2 averages.

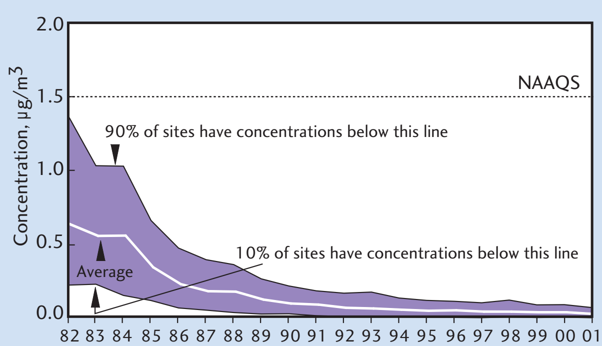
Source: EPA, Office of Air Quality Planning and Standards. *Latest Findings on National Air Quality: 2001 Status and Trends.* September 2002.

Indicator Ambient concentrations of lead - Category 1

Lead is a metal found naturally in the environment as well as in manufactured products. The major sources of lead emissions have historically been motor vehicles and industrial sources. Due to the phase-out of leaded gasoline, metals processing is the major source of lead emissions to the air today. The highest air concentrations of lead are usually found in the vicinity of smelters and battery manufacturers. Lead is a criteria and toxic air pollutant with significant health effects, as described in Chapter 4, Human Health.

Exhibit 1-12: Lead air quality, 1982-2001

Based on annual maximum quarterly average



1982–01: 94% decrease
1992–01: 25% decrease

Coverage: 39 monitoring sites nationwide with sufficient data to assess trends.

Source: EPA, Office of Air Quality Planning and Standards. *Latest Findings on National Air Quality: 2001 Status and Trends*. September 2002.

What the Data Show

This indicator shows ambient lead concentrations measured in µg/m³ per year from 1982 to 2001. Lead levels decreased by 94 percent in those years, largely because of regulations reducing the lead content in gasoline (Exhibit 1-12) (EPA, OAQPS, September 2002). The most significant decline in ambient lead levels began in the late 1970s and continued through the early 1980s. Outdoor lead levels are below the NAAQS for most areas of the U.S. (EPA, OAQPS, September 2002).

Indicator Gaps and Limitations

Limitations of this indicator include the following:

- Ambient lead monitoring is conducted mostly in urban areas, so it may not accurately encompass rural concentrations.
- This indicator would be very useful in conjunction with indicators of lead concentration in indoor air, drinking water, and soil to portray a broad picture of potential sources of lead exposure.

Data Source

The data source for this indicator was *Latest Findings on National Air Quality: 2001 Status and Trends*, EPA, 2002. (See Appendix B, page B-4, for more information.)

1.1.1.c What are the impacts of air pollution on visibility in national parks and other protected lands?

Indicator
Visibility

Visibility is a measure of aesthetic value and the ability to enjoy scenic vistas, but it also can be an indicator of general air quality. PM is the major contributor to reduced visibility, and high humidity levels worsen the effects of pollution on visibility. The Interagency Monitoring of Protected Visual Environments (IMPROVE) network collects data to characterize visibility in protected lands. IMPROVE was established in 1987 to:

- Determine the type of pollutants primarily responsible for reduced visibility in protected areas.
- Assess progress toward the Clean Air Act's national goal of remedying existing and preventing future visibility impairment.

The indicator below presents data from the IMPROVE network on visibility trends for national parks and other protected lands.

Indicator Visibility - Category I

This indicator presents visibility trends for U.S. national parks and wilderness areas in the eastern and western U.S. by mean visual range, as measured in km for 1992 to 1999 and 1990 to 1999, respectively, by worst, mid-range, and best visibility. Under the Clean Air Act, a Class I area is one in which visibility is protected more stringently than under the NAAQS, including national parks, wilderness areas, monuments, and other areas of special national and cultural significance.

What the Data Show

Data collected by the IMPROVE network show that visibility for the worst visibility days in the West is similar to days with the best visibility in the East (Exhibit 1-13). In 1999, the mean visual range for the worst days in the East was only 24 km (14.9 miles) compared to 84 km (52.2 miles) for the best visibility. In the West, visibility impairment for the worst days remained relatively unchanged over the 1990s, with the mean visual range for 1999 (80 km or 49.7 miles) nearly the same as the 1990 level (86 km or 53.4 miles). Without the effects of pollution, a natural visual range in the U.S. is approximately 75 to 150 km (47 to 93 miles) in the East and 200 to 300 km (124 to 186 miles) in the West (EPA, OAQPS, September 2002).

Indicator Gaps and Limitations

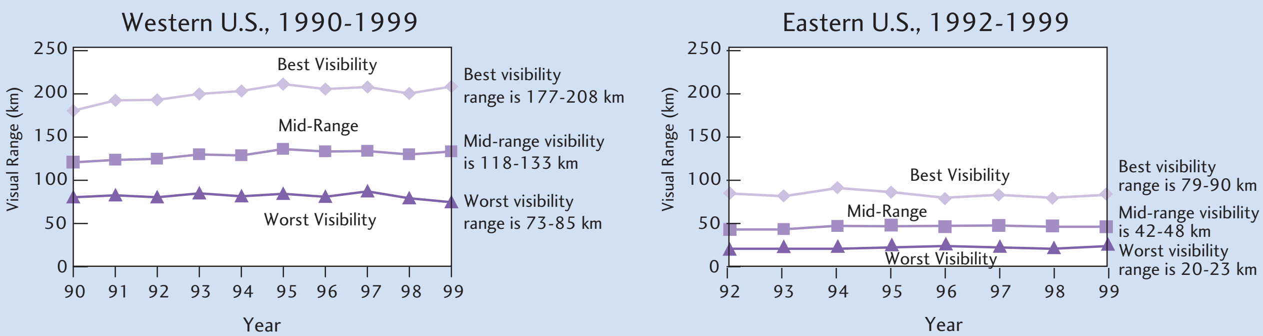
Limitations of this indicator include the following:

- The indicator compares trends within visibility range categories, but it would also be useful to indicate how often visibility falls into each range during a year.
- The data represent only a sampling of national park and wilderness areas; nevertheless, this indicator provides a good picture of the impact of air pollution on the nation's parks and protected areas. As of 2001, the network monitored 110 sites.

Data Source

The data source for this indicator was *Latest Findings on National Air Quality: 2001 Status and Trends,* EPA, 2002. (See Appendix B, page B-4, for more information.)

Exhibit 1-13: Visibility trends for U.S. Class I areas



Note: Under the Clean Air Act, a Class I area is one in which visibility is protected more stringently than under the National Air Quality Standards (NAAQS), including national parks, wilderness areas, monuments, and other areas of special national and cultural significance.

Source: EPA, Office of Air Quality Planning and Standards. *Latest Findings on National Air Quality: 2001 Status and Trends.* September 2002.

1.1.1.d What are the concentrations of toxic air pollutants in ambient air?

Indicator
Ambient concentrations of selected air toxics

Air toxics, also known as hazardous air pollutants, are pollutants that may cause cancer or other serious health effects, such as reproductive effects or birth defects, or adverse environmental and ecological effects. The Clean Air Act identifies 188 air toxics; some common ones are perchloroethylene (from dry cleaners), mercury (from coal combustion), methylene chloride (from consumer products such as paint strippers), and benzene and 1,3-butadiene (from gasoline). EPA does not set health-based standards for these pollutants; instead, the Clean Air Act mandates a two-phased approach. In the first phase, EPA establishes standards for source categories (major sources, area sources, and mobile sources). In the second phase, EPA assesses how well the standards are reducing health and environmental risks, and based on these assessments, determines what further actions are necessary to address any significant remaining, or residual, health or environmental risks.

No formal monitoring network for air toxics currently exists, but several metropolitan areas do maintain monitoring programs. Data from these areas provide the basis for an air toxics indicator. Metropolitan areas with air toxics data generally show downward trends (EPA, OAQPS, September 2002). However, although data and tools for assessing risks from air toxics are limited, available evidence suggests that emissions of air toxics may still pose significant health risks in many areas throughout the U.S. (EPA, OAR, September 2002). In addition to ambient concentrations of air toxics, an issue of particular concern is the deposition of toxic air pollutants to surface waterbodies. A pollutant of particular concern is mercury, which accumulates in fish tissue and in humans after they ingest contaminated fish (see Chapter 2, Purer Water; and Chapter 5, Ecological Condition).

Indicator Ambient concentrations of selected air toxics - Category 2

This indicator reflects data about annual average ambient concentrations of four selected air toxics, in µg/m^3, derived from monitoring sites with sufficient trend data from 1994 to 1999. Selected air toxics are benzene, 1,3-butadiene, total suspended lead, and perchloroethylene (EPA, OAQPS, March 2001).

What the Data Show

Ambient concentrations of the selected air toxics—benzene, 1,3-butadiene, total suspended lead, and perchlorethylene—generally declined between 1994 and 1999, based on the annual average from the reporting sites (EPA, OAQPS, March 2001). The lead concentration level is well below the NAAQS standard (see Section 1.1.1.b in this chapter). Benzene levels, measured at 95 urban monitoring sites, decreased 47 percent from 1994 to 2000 (Exhibit 1-14) (EPA, OAQPS, September 2002).

Indicator Gaps and Limitations

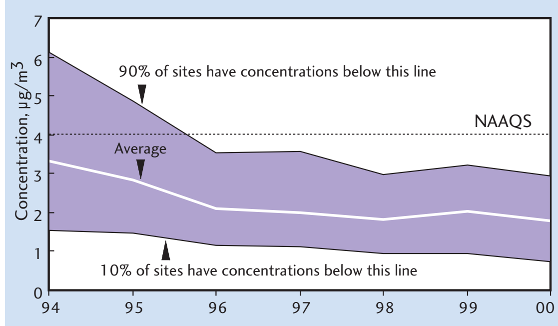
Limitations of this indicator include the following:

- Information is limited because no formal network is currently in place for monitoring ambient concentrations of air toxics; however, EPA and states are working to establish a national toxics monitoring network.
- The indicator reflects trends for selected air toxics, but not for all 188 toxic air pollutants identified under the CAA.
- More information is available for lead than for the other three selected air toxics. Monitoring stations with sufficient trend data for the other three compounds tend to be concentrated in California, the Great Lakes, southern Texas, and the Northeast.

Data Sources

The data sources for this indicator were *Latest Findings on National Air Quality: 2001 Status and Trends*, EPA, 2002, and *National Air Quality and Emissions Trends Report, 1999*, EPA, 2001. (See Appendix B, page B-4, for more information.)

Exhibit 1-14: Ambient benzene, annual average urban concentrations, nationwide, 1994-2000



Coverage: 95 monitoring sites nationwide with sufficient data to assess trends.

Source: EPA, Office of Air Quality Planning and Standards. *Latest Findings on National Air Quality: 2001 Status and Trends*. September 2002.

1.1.2 What contributes to outdoor air pollution?

Anthropogenic sources of air pollution range from "stationary sources" such as factories, power plants, agricultural facilities, and smelters, to smaller "area sources" such as dry cleaners and degreasing operations, to "mobile sources" such as cars, buses, planes, trucks, trains, construction equipment, and lawn mowers. Naturally occurring sources such as wind-blown dust, volcanoes, and wildfires add to the total air pollution burden and may be significant on local and regional scales.

Most of the six criteria air pollutants show declining emissions since 1982. But as reported in *Latest Findings on National Air Quality: 2001 Status and Trends*, emissions of NO_X, a contributor to ozone, PM, and acid rain formation, increased by nine percent between 1982 and 2001, with a slight decrease (three percent) between 1992 and 2001 (EPA, OAQPS, September 2002). A significant amount of that increase is attributed to growth in emissions from non-road engines, including construction and recreation equipment and diesel vehicles. EPA continuously reviews and improves estimates of pollutant emissions. Emissions estimates for criteria pollutants are currently under such evaluation and may be updated.

1.1.2.a What are contributors to particulate matter, ozone, and lead in ambient air?

Indicators

Emissions: particulate matter ($PM_{2.5}$ and PM_{10}), sulfur dioxide, nitrogen oxides, and volatile organic compounds

Lead emissions

Two indicators are available to help answer this question:

- Emissions of particulate matter, sulfur dioxide, nitrogen oxide, and volatile organic compounds.
- Emissions of lead.

Particulate matter can be emitted directly or formed in the atmosphere. "Primary" particles, such as dust from roads and elemental carbon (soot) from wood combustion, are emitted directly into the atmosphere. "Secondary" particles are formed in the atmosphere from primary gaseous emissions. Examples include sulfates, formed from SO_2 emissions from power plants and industrial facilities, and nitrates, formed from NO_X emissions from power plants, automobiles, and other types of combustion sources. The chemical composition of particles depends on factors such as location, time of year, and weather.

The VOCs contributing to ozone formation are emitted from motor vehicles, chemical plants, refineries, factories, consumer and commercial products such as paints and strippers, and other industrial sources. Nitrogen oxides, also an ozone precursor, are emitted primarily from vehicles, power plants, and other combustion sources. Smelters and battery manufacturers are the largest sources of lead in outdoor air.

Indicator

Emissions: particulate matter ($PM_{2.5}$ and PM_{10}), sulfur dioxide, nitrogen oxides, and volatile organic compounds - Category 2

This indicator includes the following data:

- Direct PM emissions are measured in thousands of short tons per year. PM_{10} emissions are presented from 1985 to 2001; emissions of $PM_{2.5}$ from 1992 to 2001.
- Emissions of NO_X, and SO_2 presented from 1982 to 2001. Emissions of NO_X, contribute to nitrogen loading on land and in water directly and as runoff from land. NO_X, is also a precursor of ground-level ozone. Sulfates and nitrates, formed by emissions of SO_2 and NO_X, contribute to acid deposition, which can have significant impacts on aquatic life (see Chapter 2, Purer Water).
- Emissions of VOCs, also precursors of ground-level ozone. These emissions, presented from 1982 to 2001, are measured in thousands of short tons per year.

What the Data Show

Direct emissions of PM_{10} fell by 13 percent between 1992 and 2001 (Exhibit 1-15). Emissions of direct $PM_{2.5}$ also fell, decreasing by 10 percent between 1992 and 2001 (Exhibit 1-16). Sulfur dioxide emissions also decreased by 25 percent between 1982 and 2001 and by 24 percent between 1992 and 2001 (Exhibit 1-17). However, emissions of NO_X increased by 9 percent between 1982 and 2001 and decreased by 3 percent between 1992 and 2001 (Exhibit 1-18) (EPA, OAQPS, September 2002). VOC emissions decreased by 16 percent from 1982 to 2001 and by 8 percent from 1992 to 2001 (Exhibit 1-19) (EPA, OAQPS, September 2002).

Indicator Gaps and Limitations

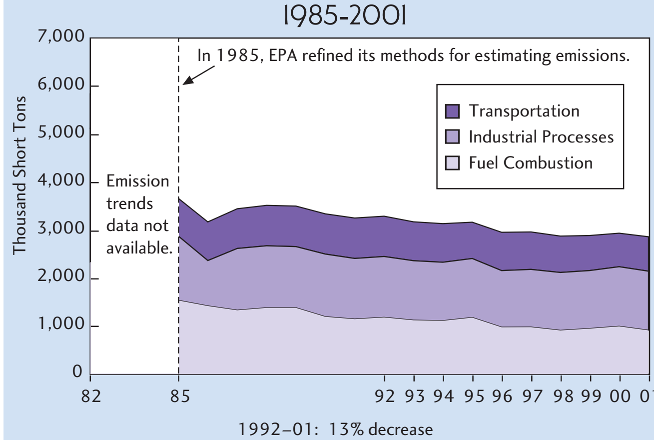
Limitations of this indicator include the following:

- The emissions indicators are estimates; however, consistent estimation methods can provide useful trend data.
- The methodology for estimating emissions is continually reviewed and is subject to revision. EPA is currently conducting such an evaluation of emissions data, and emissions estimates may be updated. Trend data prior to these revisions must be considered in the context of those changes.

Data Source

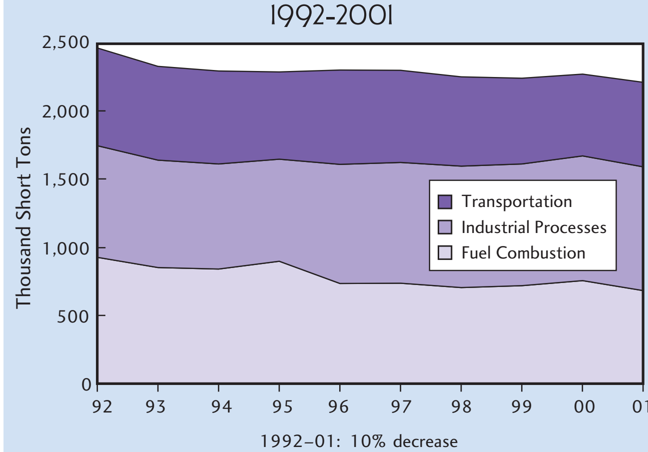
The data source for this indicator was *Latest Findings on National Air Quality: 2001 Status and Trends*, EPA, 2002. (See Appendix B, page B-5 for more information.)

Exhibit 1-15: Direct particulate matter (PM_{10}) emissions, 1985-2001



Source: EPA, Office of Air Quality Planning and Standards. *Latest Findings on National Air Quality: 2001 Status and Trends*. September 2002.

Exhibit 1-16: Direct particulate matter ($PM_{2.5}$) emissions, 1992-2001

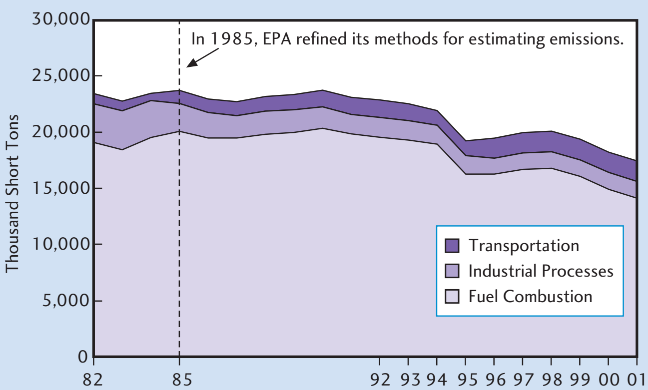


Source: EPA, Office of Air Quality Planning and Standards. *Latest Findings on National Air Quality: 2001 Status and Trends*. September 2002.

Indicator

Emissions: particulate matter ($PM_{2.5}$ and PM_{10}), sulfur dioxide, nitrogen oxides, and volatile organic compounds - Category 2 (continued)

Exhibit 1-17: Sulfur dioxide (SO_2) emissions, 1982-2001

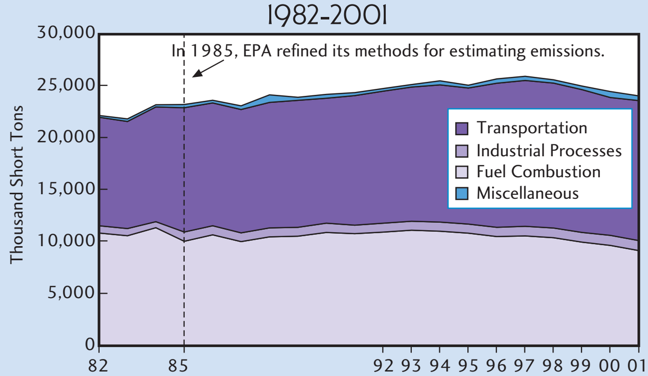


1982–01: 25% decrease

1992–01: 24% decrease

Source: EPA, Office of Air Quality Planning and Standards. *Latest Findings on National Air Quality: 2001 Status and Trends*. September 2002.

Exhibit 1-18: Nitrogen oxides (NO_x) emissions, 1982-2001

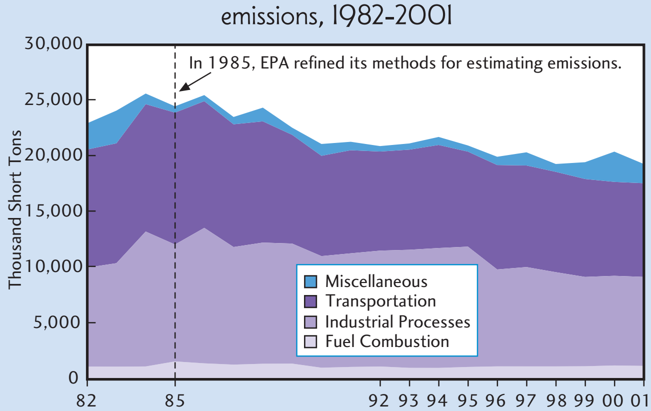


1982–01: 9% increase

1992–01: 3% decrease

Source: EPA, Office of Air Quality Planning and Standards. *Latest Findings on National Air Quality: 2001 Status and Trends*. September 2002.

Exhibit 1-19: Volatile organic compounds (VOCs) emissions, 1982-2001



1982–01: 16% decrease

1992–01: 8% decrease

Source: EPA, Office of Air Quality Planning and Standards. *Latest Findings on National Air Quality: 2001 Status and Trends*. September 2002.

Indicator

Lead Emissions - Category 2

This indicator is lead emissions from 1982 to 2001, measured in short tons per year.

What the Data Show

Lead emissions decreased by 93 percent from 1982 to 2001 and by 5 percent from 1992 to 2001 (Exhibit 1-20) (EPA, OAQPS, September 2002). The transportation sector, particularly automotive sources, used to be the major source of lead emissions. The phase-out of lead in gasoline resulted in great declines in lead emissions from the transportation sector over the past 2 decades. Today, industrial processes, primarily metals processing, are the major source of lead emissions to the atmosphere.

Indicator Gaps and Limitations

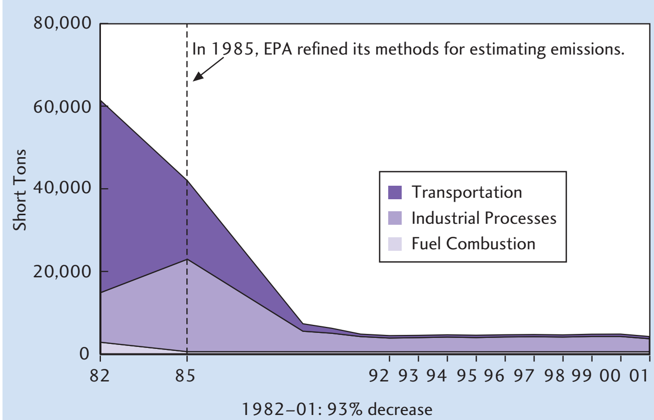
Limitations of this indicator include the following:

- The indicator does not present actual emissions data; thus, it has the inherent limitations of estimates. However, consistent estimation methods can provide useful trend data.
- Estimation is necessary for mobile sources and several area-wide sources.
- The methodology for estimating emissions is continually reviewed and is subject to revision. Trend data for years prior to revisions must be considered in the context of those changes.

Data Source

The data source for this indicator was *Latest Findings on National Air Quality: 2001 Status and Trends*, EPA, 2002. (See Appendix B, page B-5, for more information.)

Exhibit 1-20: Lead emissions, 1982-2001



Source: EPA, Office of Air Quality Planning and Standards. *Latest Findings on National Air Quality: 2001 Status and Trends*. September 2002.

1.1.2.b What are contributors to toxic air pollutants in ambient air?

Indicator
Air toxics emissions

An indicator for air toxics emissions is available to help address this question. The Clean Air Act identifies 188 air toxics. EPA estimates that more than 50 percent of air toxics emissions come from vehicles and other mobile sources such as aircraft, locomotives, and construction equipment (EPA, OAQPS, September 2002). Other major sources include industrial facilities and area sources such as small dry cleaners and gas stations. Emissions of benzene, come from cars, trucks, oil refineries, and chemical processes. Mercury emissions come from coal combustion and waste incineration and can travel thousands of miles before being deposited in water or on land (see Chapter 2, Purer Water). Some air toxics are also released from natural sources such as volcanic eruptions and forest fires.

Indicator Air toxics emissions - Category 2

This indicator is national air toxics emissions, in million of tons per year, between the 1990-1993 baseline period and 1996. EPA compiles an air toxics inventory as part of the National Emissions Inventory, which focuses on four sectors—large industrial sources, smaller industrial and natural sources, on-road mobile sources, and non-road mobile sources.

What the Data Show

Estimates show a 24 percent reduction in nationwide air toxics emissions between the baseline period (1990-1993) and 1996—a reduction from 6.11 million to 4.67 million tons per year (Exhibit 1-21) (EPA, OAQPS, September 2002).

Indicator Gaps and Limitations

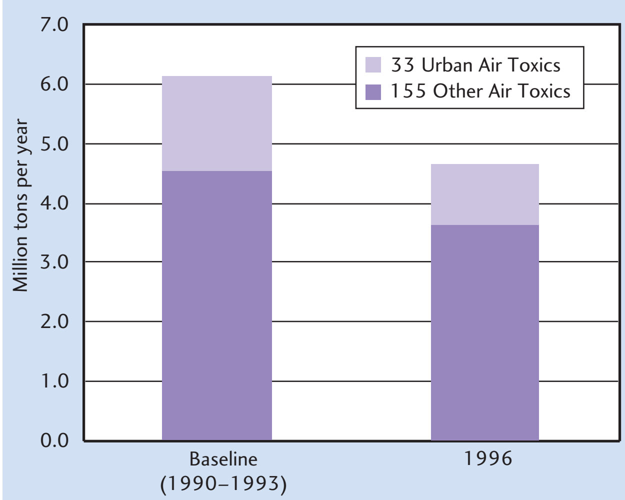
Limitations of this indicator include the following:

- Air toxics emissions estimates are currently available for only 1990 to 1993 (a mix of years depending on data availability on various source types) and 1996.
- The emissions data are based on estimates that are not available on an annual basis.
- The indicator is an aggregate number; actual changes vary among the toxic air pollutants and also vary from one part of the country to another.

Data Source

The data source for this indicator was *Latest Findings on National Air Quality: 2001 Status and Trends,* EPA, 2002. (See Appendix B, page B-6, for more information.)

Exhibit 1-21: National air toxics emissions, 1990-1993, 1996 (total for 188 toxic air pollutants)



Source: EPA, Office of Air Quality Planning and Standards. *Latest Findings on National Air Quality: 2001 Status and Trends.* September 2002.

1.1.2.c To what extent is U.S. air quality the result of pollution from other countries, and to what extent does U.S. air pollution affect other countries?

Air pollution does not recognize political boundaries: ozone and PM, for example, can be transported hundreds or thousands of miles, depending on weather conditions, including wind speeds. Canada and the U.S. have jointly studied ground-level ozone occurrence and transport in eastern North America. Eight-hour ozone measurements for 1988 and 1995 from eastern Canada and the eastern U.S. demonstrate how ozone travels in both directions across the U.S.-Canadian border. The data suggested that ozone was being transported from urban to non-urban areas.

The U.S.-Canada Air Quality Committee studied the relative contribution of sources in each country to the ozone precursors–NO_X and VOCs. According to the report, "anthropogenic sources of NO_X emissions in the U.S. are ten times larger, and VOC emissions are 7 times larger in magnitude than in Canada, paralleling the relative population ratio between the 2countries." The study also showed that wind speed can significantly affect ozone transport between the two countries. At low wind speed (<3 meters per second), ozone concentrations were high over major metropolitan areas or close to the sources. At intermediate wind speeds (3 to 6 meters per second), overall concentrations were lower and ozone was transported up to 500 km downwind. At higher wind speeds, higher concentrations were in downwind corners up to 1,000 km away (U.S.-Canada Air Quality Committee, March 1999).

Transboundary air pollution issues are not limited to North America, as demonstrated in the discussion of stratospheric ozone depletion (see Section 1.4 in this chapter). More recently, the U.N. Environment Programme suggested that the so-called Asian Brown Cloud, a 2-mile-thick blanket of pollution over part of South Asia, could travel halfway around the globe in a week (CNN, 2002).

No specific indicators have been identified at this time to address the issue of transboundary air pollution.

1.1.3 What human health effects are associated with outdoor air pollution?

Outdoor air pollution can cause a variety of adverse health effects. Exposure to air pollution can result in short-term health effects and can also contribute to or aggravate chronic conditions. One such condition is asthma, the leading chronic illness of children in the U.S. and a leading cause of school absenteeism. In 2000, asthma caused 465,000 hospitalizations and about 4,500 deaths in the U.S. (CDC, 2003). Other chronic conditions to which air pollution can contribute include lung cancer, asthma, respiratory disease, and cardiovascular disease.

Some of the criteria pollutants, including ozone, NO_2, and SO_2, are associated primarily with respiratory-related effects, including aggravation of asthma and other respiratory diseases and irritation of the lung and respiratory symptoms (e.g., cough, chest pain, difficulty breathing) (EPA, ORD, 1982,1986, August 1993, 1994). Carbon monoxide, on the other hand, primarily affects people with cardiovascular disease by reducing oxygen in the blood, leading to aggravation of angina (EPA, ORD, NCEA, 2000).

Short-term exposure to ozone has been linked to lung inflammation and increased hospital admissions and emergency room visits (EPA, ORD, NCEA, July 1996). Repeated short-term exposures to ozone may damage children's developing lungs and may lead to reduced lung function later in life; long-term exposures to high ozone levels are a possible cause of increased incidence of asthma in children engaged in outdoor sports (McConnell, et al., 2002). Efforts to control automobile traffic in Atlanta during the 1996 Summer Olympic Games were associated with a 28 percent reduction in peak daily ozone concentrations during the Games and a significantly lower rate of childhood asthma events (Friedman, et al., 2001).

When EPA introduced a new 8-hour ozone ambient standard in 1997, it estimated that meeting the standard would reduce the risk of significant decreases in children's lung functions (such as difficulty in breathing or shortness of breath) by about 1 million incidences per year and would result in thousands of fewer hospital admissions and visits for people with asthma (EPA, OAQPS, July 1997).

Exposure to airborne particulate matter is associated with a broader range of health problems, including respiratory-related and cardiovascular effects. For example, short-term exposures to PM may aggravate asthma and bronchitis and have been associated with heartbeat irregularities and heart attacks. PM exposures have been linked to increased school absences and lost work days, hospital admissions and emergency room visits, and even death from heart and lung diseases (EPA, ORD, NCEA, April 1996). Long-term exposures have also been linked to deaths from heart and lung diseases, including lung cancer (EPA, ORD, NCEA, 2002; Pope, et al., 2002).

When EPA established new $PM_{2.5}$ standards in 1997, it estimated that meeting the standard would save about 15,000 lives each year, especially among the elderly and those with existing heart and lung diseases. The Agency said the new standard would reduce hospital admissions by thousands each year; reduce risk of symptoms associated with chronic bronchitis by tens of thousands each year; and avoid hundreds of thousands of incidences of asthma each year (EPA, OAQPS, July 1997).

Lead, both a criteria pollutant and a toxic air pollutant, has significant health effects. Elevated blood lead levels are associated with behavioral problems, neurological effects, and lowered IQ (EPA, OAQPS, September 2002), The decrease in the average level of lead in children's blood reflects declines in ambient lead levels by 93 percent from 1982 to 2001—largely the result of regulations reducing lead content in gasoline (EPA, OAQPS, September 2002).

Toxic or hazardous air pollutants may cause many other less common but potentially hazardous health effects, including cancer and damage to the immune system, and neurological, reproductive, and developmental problems. Acute exposure to some air toxics can cause immediate death. Many of these pollutants can cause serious health damages even at relatively low concentrations. National emission standards have been established for eight of the 188 listed hazardous air pollutants: asbestos, mercury, beryllium, benzene, vinyl chloride, arsenic, radionuclides, and coke oven emissions.

The National-Scale Air Toxics Assessment, a nationwide analysis of air toxics, develops health risk estimates for 33 toxic air pollutants using computer modeling of the 1996 National Emissions Inventory air toxics data. Based on the assessment, chromium, benzene, and formaldehyde appear to pose the greatest nationwide carcinogenic risk (EPA, OAR, September 2002). Benzene exposure has been linked to increases in the risk of leukemia and multiple myeloma (EPA, OAQPS, July 1995).

No specific indicators have been identified at this time to address the health effects associated with outdoor air pollution. For additional discussion of air pollution and associated health effects, see Chapter 4, Human Health.

1.1.4 What ecological effects are associated with outdoor air pollution?

Outdoor air not only has the potential to affect human health, but also transports pollutants and deposits them onto soils or surface waters. There, the pollutants can cause ecological effects and damage to property. Ground-level ozone damages plants and crops. It interferes with the ability of plants to produce and store food, reducing overall plant health and the ability to grow and reproduce. The weakened plants are more susceptible to harsh weather, disease, and pests. Through its effects on plants, ozone also can pose risks to ecological functions such as water movement, mineral nutrient cycling, and habitats for various animal and plant species (see Chapter 5, Ecological Condition).

Airborne nitrogen species (including the criteria pollutants NO_2 and particulate nitrate) can contribute to excess nitrogen levels in ecosystems. These excess nitrogen levels can result in:

- Changes in plant and soil community species diversity.
- Altered community structure.
- Eutrophication in surface and coastal waters.
- Acidified soils and waters (see Chapter 2, Purer Water).

Airborne sulfur species (including the criteria pollutants SO_2 and particulate sulfate) can also contribute excess sulfur to ecosystems, which can lead to acidification of the soils and related effects. When deposited together, airborne nitrogen and sulfur species are known as acid deposition. (See the discussion of acid deposition in Section 1.2 of this chapter.)

Land and water can be contaminated by deposition of air toxics, leading to contamination of plants and animals and, eventually, of humans further up the food chain. Airborne mercury from incineration, for example, can settle in water and contaminate fish (see Chapter 2, Purer Water). People who eat fish are then exposed to mercury, which is known to be harmful to the nervous system.

No specific indicators have been identified at this time to address the ecological effects associated with outdoor air pollution. Additional discussion of the ecological effects associated with outdoor air pollution is found in Chapter 5, Ecological Condition.

1.2 Acid Deposition

Sulfur dioxide and NO_X emissions in the atmosphere react with water, oxygen, and oxidants to form acidic components, also referred to as acid deposition or "acid rain." Air contaminants can be deposited on land or water through precipitation (wet deposition) or directly by dry deposition. Wet acid deposition is monitored by the National Atmospheric Deposition Program/National Trends Network, a cooperative program of federal and state agencies, universities, electric utilities, and other industries. Dry deposition is measured by the Clean Air Status and Trends Network (CASTNET), operated by EPA and the National Park Service.

The acidity in precipitation in the eastern U.S. is at least twice as high as in pre-industrial times (EPA, ORD, January 2003). To reduce emissions of SO_2 and NO_X, EPA established the Acid Rain Program under the Clean Air Act. This program focuses on the largest and highest-emitting coal-fired power plants, which are significant contributors to acid deposition.

This section addresses the following questions:

- What are the deposition rates of pollutants that cause acid rain? (Section 1.2.1)
- What are the emissions of pollutants that form acid rain? (Section 1.2.2)
- What ecological effects are associated with acid deposition? (Section 1.2.3)

1.2.1 What are the deposition rates of pollutants that cause acid rain?

Indicators

Deposition: wet sulfate and wet nitrogen

Efforts to reduce sulfur dioxide and nitrogen oxides emissions from power plants have helped to significantly reduce wet sulfate deposition and to contain increases in nitrogen deposition. Wet sulfate deposition levels for 1999 to 2001 showed reductions of 20 to 30 percent compared to levels for 1989 to 1991 over widespread areas in the Midwest and the Northeast, where acid rain has had its greatest impact. Nitrogen deposition levels showed no major changes. Although NO_X emissions from power plants decreased, nitrogen emissions from sources other than power plants (e.g., motor vehicles, non-road vehicles, and agricultural activities) increased between 1990 and 2001 (EPA, OAR, November 2002).

Deposition of wet sulfate and wet nitrogen is the indicator used to address this question.

Indicator Deposition: wet sulfate and wet nitrogen - Category 2

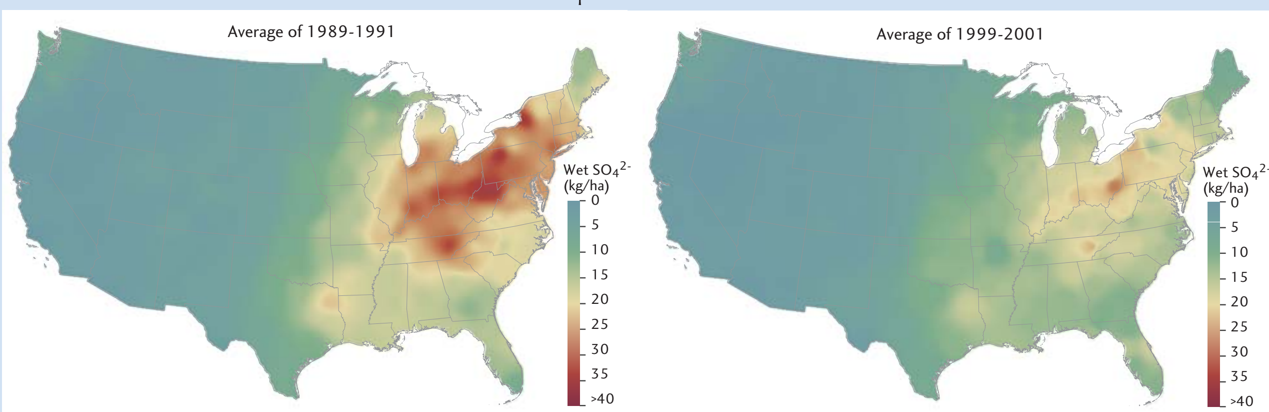
Measures of wet sulfate and wet nitrogen deposition in kilograms per hectare (kg/ha), are a key indicator of acid deposition.

What the Data Show

Wet sulfate decreased substantially throughout the Midwest and Northeast between 1989-1991 and 1999-2001 (Exhibit 1-22). By 2001, wet sulfate deposition had decreased more than 8 kilograms per hectare (kg/ha) from 30-40 kg/ha/year in 1990 in much of the Ohio River Valley and northeastern U.S. The greatest reductions occurred in the mid-Appalachian region (EPA, OAR, November 2002).

There were no dramatic regional changes in wet nitrogen deposition between 1989-1991 and 1999-2001 (Exhibit 1-23). Since 1990, nitrogen deposition decreased slightly in areas of the eastern U.S., while increases occurred in some areas with significant agricultural activity (e.g., the Plains and coastal North Carolina) or substantial mobile source emissions (e.g., southern California). (EPA, OAR, November 2002).

Exhibit 1-22: Wet sulfate deposition, 1989-1991 vs. 1999-2001

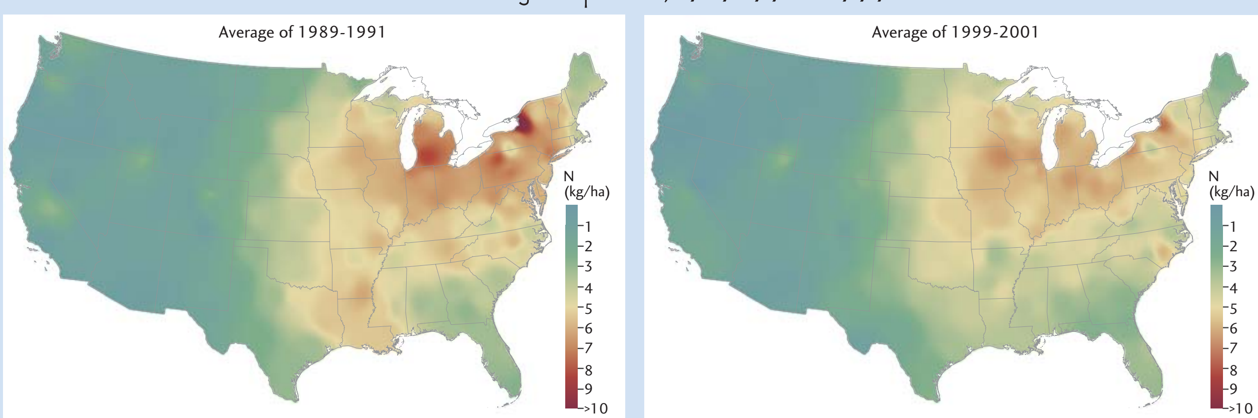


Coverage : 250 National Atmospheric Deposition Program National Trends Network (NADP/NTN) monitoring stations located throughout the lower 48 states.

Note: Map colors represent relative concentrations and do not imply ecological or human health status

Source: EPA, Office of Air and Radiation, Clean Air Markets Program. *EPA Acid Rain Program: 2001 Progress Report*. November 2002.

Exhibit 1-23: Wet nitrogen deposition, 1989-1991 vs. 1999-2001



Coverage : 250 National Atmospheric Deposition Program National Trends Network (NADP/NTN) monitoring stations located throughout the lower 48 states.

Note: Map colors represent relative concentrations and do not imply ecological or human health status

Source: EPA, Office of Air and Radiation, Clean Air Markets Program. *EPA Acid Rain Program: 2001 Progress Report.* November 2002.

Indicator

Deposition: wet sulfate and wet nitrogen - Category 2 (continued)

Wet and dry sulfur deposition make up roughly the same percentages of total sulfur deposition in the Midwest, whereas, in most other areas, wet deposition makes up a greater percentage of the total. Wet deposition also makes up most of the total nitrogen deposition load at the majority of the monitoring sites in the eastern U.S. In southern California, dry deposition makes up a greater percentage of the total (Exhibit 1-24).

Using National Atmospheric Deposition Program data, a U.S. Department of Agriculture (USDA) report on sustainable forests observed that annual wet sulfate deposition decreased significantly between 1994 and 2000, especially in the North and South Resource Planning Act regions, where deposition was the highest. Nitrate deposition rates were lowest in the Pacific and Rocky Mountain regions, where approximately 84 percent of the regions experienced deposition rates of less than 4.2 pounds per acre (4.8kg/ha) per year. Only 2 percent of the sites in the eastern U.S. received less than that amount (USDA, FS, 2002).

Indicator Gaps and Limitations

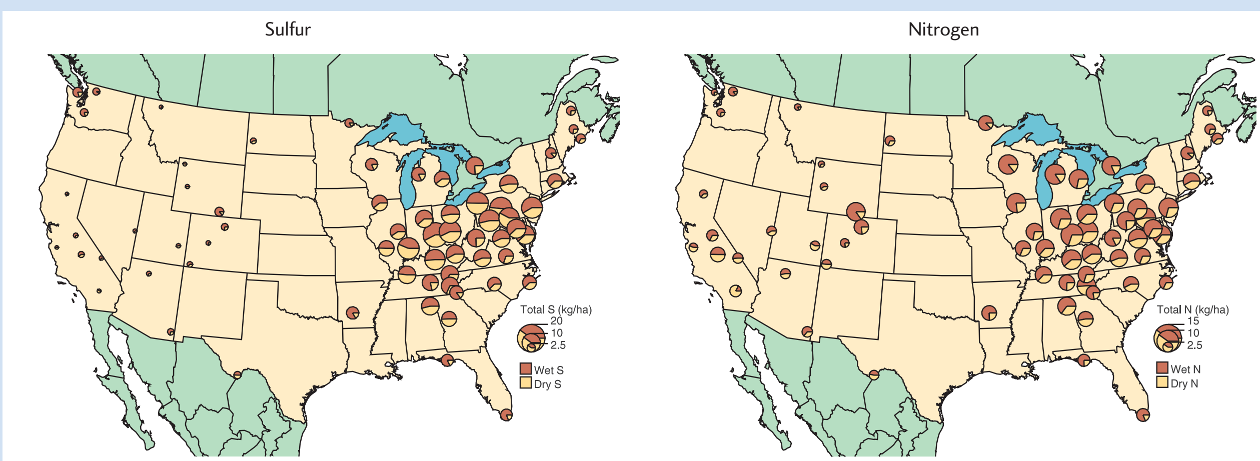
Limitations of this indicator include the following:

- Geographic coverage is limited for measuring wet deposition and even more so for measuring dry deposition. Additional monitoring sites for both in coastal areas in the Southeast would support improved measurement of nitrogen deposition to estuaries. Additional dry deposition monitoring would provide a better understanding of acid deposition in the Ohio Valley and Central and Rocky Mountain areas.
- Measurement techniques for dry deposition have improved substantially, but still lag behind operational wet deposition techniques.

Data Source

The data source for this indicator was *EPA Acid Rain Program: 2001 Progress Report*, EPA, 2002. (See Appendix B, page B-6, for more information.)

Exhibit 1-24: Total sulfur and total nitrogen deposition, 2001



Coverage: 70 Clean Air Status and Trends Network (CASTNet) monitoring stations concentrated in the eastern half of the lower 48 states.

Note: The size of the "pies" indicates the total magnitude of deposition; the colors indicate the percentage of wet and dry deposition.

Source: EPA, Office of Air and Radiation, Clean Air Markets Program. *EPA Acid Rain Program: 2001 Progress Report.* November 2002.

1.2.2 What are the emissions of pollutants that form acid rain?

Indicators
Emissions (utility): sulfur dioxide and nitrogen oxides

Acid deposition occurs when emissions of SO_2 and NO_X in the atmosphere react with water, oxygen, and oxidants to form acidic compounds. Electric utility plants that burn fossil fuels are a significant source of SO_2 and NO_X and monitor their emissions continuously. NO_X is also emitted from other high-temperature combustion sources, including automobiles.

The indicator used to address this question is emissions of sulfur dioxide and nitrogen oxides from utilities.

Indicator Emissions (utility): sulfur dioxide and nitrogen oxides - Category 2

This indicator is millions of tons of NO_X and SO_2 emissions from sources covered under the Acid Rain Program from 1990 to 2001 and 1980 to 2001, respectively. These emissions data are an important component of a market-based trading program to reduce emissions and consequent impacts on the environment.

What the Data Show

SO_2 emissions from sources covered under the Acid Rain Program were 10.6 million tons in 2001, compared to 15.7 million tons in 1990. Emissions of NO_X from these sources declined from 6.7 million tons in 1990 to 4.7 million tons in 2001 (Exhibit 1-25) (EPA, OAR, June 2002).

Indicator Gaps and Limitations

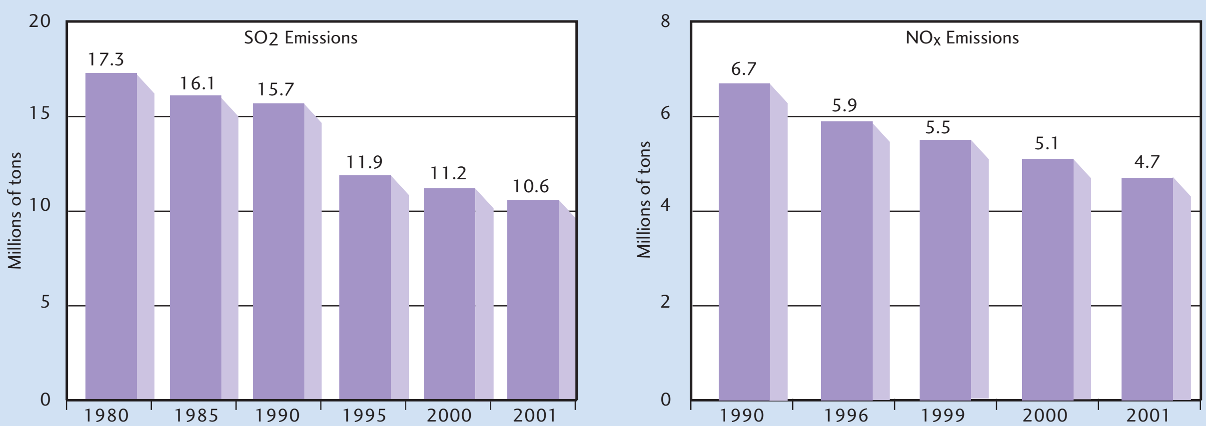
Limitations of this indicator include the following:

- Although electric utilities and large boilers are key sources of SO_2 and NO_X, they are not the only sources. It is estimated that about 64 percent of annual SO_2 emissions and 26 percent of NO_X emissions are produced by electric utility plants that burn fossil fuels (EPA, OAQPS, September 2002).
- Information on mobile source emissions is particularly useful for completing the picture of NO_X contributions to acid deposition.

Data Source

The data source for this indicator was *EPA Acid Rain Program: 2001 Progress Report*, Appendices A and B1, EPA, 2002. (See Appendix B, page B-6, for more information.)

Exhibit 1-25: Power plant sulfur dioxide (SO_2), 1980-2001, and nitrogen oxides (NO_x), 1990-2001, emissions



Source: EPA, Office of Air and Radiation, Clean Air Markets Program. *EPA Acid Rain Program: 2001 Progress Report*. November 2002. Appendix A: Acid Rain Program - Year 2001 SO2 Allowance Holdings and Deductions. (April 8, 2003; *http://www.epa.gov/airmarkets/cmprpt/arp01/appendixa.pdf*) and Appendix B1: 2001 Compliance Results for NOx Affected Units. (April 8, 2003; *http://www.epa.gov/airmarkets/cmprpt/arp01/appendixb1.pdf*).

1.2.3 What ecological effects are associated with acid deposition?

Increased acid levels damage soils, lakes, and streams, rendering some waterbodies unfit for certain fish and wildlife species. Indirect effects of acid deposition are also responsible for damage to forest ecosystems (see Chapter 5, Ecological Condition). Acidic ions in the soil displace calcium and other nutrients from plant roots, inhibiting growth. Acidic deposition can also mobilize toxic amounts of aluminum, increasing its availability for uptake by plants and by fish and other aquatic life (EPA, OAR, November 2002).

The nitrogen in acid rain adds to the total loading of nitrogen in waterbodies. As coastal ecosystems become overly rich in nitrogen, conditions favor more frequent and more severe emergence of algal blooms, which deplete oxygen, harming fish and reducing plant and animal diversity (see Chapter 2, Purer Water).

A recent report assessing deposition-related changes in surface water chemistry in the northern and eastern U.S. found that the Clean Air Act has resulted in a large and widespread decrease in the deposition of sulfur by approximately 40 percent in the 1990s. In the same period, surface water sulfate concentrations declined in all regions except the Ridge and Blue Ridge provinces (Virginia). Acid neutralizing capacity (ANC), a key indicator of recovery, increased in three of the regions (Adirondacks, Northern Appalachian Plateau and Upper Midwest) and was unchanged in the New England and the Ridge/Blue Ridge region. Modest increases in ANC have reduced the number of acidic lakes and stream segments in some regions:

- In the Adirondacks, 8.1 percent of lakes (150 lakes) were acidic in 2000. In the early 1990s, 13 percent (240 lakes) were acidic.
- In the Upper Midwest, an estimated 80 of 250 lakes that were acidic in the mid-1980s are no longer acidic.
- In the Northern Appalachian Plateau region in 2000, there were an estimated 3,393 kilometers (2,104 miles) of acidic streams in the region, or 7.9 percent of the total population; this compares to 5,014 kilometers (3,109 miles) of acidic streams (12 percent) in 1993-94.
- There was no evidence of recovery in New England, or in the Ridge and Blue Ridge Provinces; the latter region is not expected to recover immediately, due to the nature of forest soils in the province.
- In the three regions showing recovery, approximately one-third of formerly acidic surface waters are no longer acidic, although still subject to episodes of acidification.
- Nitrogen deposition levels changed little between 1989 and 2001, and surface water nitrate concentrations are largely unchanged as well. Nitrogen deposition remains a concern, because future increases in surface water nitrate concentrations could retard surface water recovery (EPA, ORD, January 2003).

No specific indicators have been identified at this time to address the ecological effects associated with acid deposition.

1.3 Indoor Air Quality

People in the U.S. spend 90 percent of their time indoors, and indoor air pollutant levels may exceed those allowable outside. Radon and environmental tobacco smoke (ETS) are the two indoor air pollutants of greatest concern from a health perspective (EPA, ORD, December 1992; NRC, 1988).

Although methods to monitor and measure indoor air quality (IAQ) exist, there is no practical way to assess the general quality of indoor air nationwide. There are millions of residences, thousands of workplaces, and more than a hundred thousand schools in the U.S., and representative samples are not practical because of cost and access issues. This section, therefore, presents indoor air quality data from limited studies, not from ongoing monitoring efforts.

This section addresses the following questions:
- What is the quality of the air in buildings in the United States? (Section 1.3.1)
- What contributes to indoor air pollution? (Section 1.3.2)
- What human health effects are associated with indoor air pollution? (Section 1.3.3)

1.3.1 What is the quality of the air in buildings in the United States?

Indicators
U.S. homes above EPA's radon action levels
Percentage of homes where young children are exposed to environmental tobacco smoke

While it is difficult to make general statements about the quality of indoor air nationwide, two studies–the National Residential Radon Survey and an analysis of ETS exposure based on data from the National Health Interview Survey–offer important insights. These studies provide data about residential levels of radon and ETS, presented in the description of two indicators on the following pages.

In addition, several studies have attempted to characterize environmental issues inside office buildings and schools. The Building Assessment Survey and Evaluation (BASE) study, conducted from 1994 to 1998, is a study of office IAQ. The study was designed with input from more than 40 national IAQ experts and reviewed by the EPA Science Advisory Board. The consensus of these national experts was that a sample of 100 to 200 office buildings would be sufficient to characterize the central tendency of IAQ in office buildings nationwide.

Limited information about IAQ in schools is available from a 1999 survey of about 900 public schools by the National Center for Education Statistics. This survey addressed concerns related to environmental conditions, defined as lighting, heating, ventilation, IAQ, acoustics or noise control, and physical security of buildings. In all, 43 percent of schools responded that at least one environmental condition was unsatisfactory. Ventilation was the most often cited environmental issue of concern (DOE, NCES, 2000).

In addition to the indoor pollutants discussed above, pesticides also may pose IAQ concerns. Approximately three-quarters of U.S. households use at least one pesticide product indoors during the course of a year. Products used most often are insecticides and disinfectants. The EPA Nonoccupational Pesticide Exposure Study (NOPES), published in 1990, assessed exposure to airborne pesticides in Jacksonville, Florida, and in Springfield and Chicopee, Massachusetts. Indoor sources accounted for 90 percent or more of the total airborne exposure to most of these pesticides. NOPES found that tested households had at least 5 pesticides in indoor air, at levels often 10 times greater than levels measured in outdoor air (EPA, AREAL, January 1990). Some of the pesticides had been banned or otherwise regulated by EPA (e.g., aldrin, dieldrin, heptachlor, and chlordane), but continued to be found in the homes. Since these pesticides previously were widely used to prevent termites, they are believed to have entered the homes via diffusion of soil gas into basements, similar to the way radon enters homes. Another pesticide, DDT, banned for nearly 20 years, was found in house dust in five out of eight homes (EPA, AREAL, January 1990). Later studies, including measurements in soil just outside the home, suggested that DDT and other long-lasting pesticides can be tracked in from soil clinging to shoes.

No comprehensive nationwide information is available on the amount of pesticides used in the nation's 11,000 public schools. The federal government has not collected such data, and only one state, Louisiana, requires its school districts to specifically report the amount of pesticides used (GAO, 1999).

This report uses two indicators, discussed below, to address the question, "What is the quality of air in the buildings in the United States?":

- U.S. homes above EPA radon action levels.
- Percentage of homes where young children are exposed to ETS.

Indicator U.S. homes above EPA's radon action levels - Category 2

Naturally occurring radon gas is formed by the decay of uranium in rock, soil, and water. Radon enters a home by moving up from rock and soil and into the building through cracks or other holes in the foundation.

The amount of radon gas in the air is measured in picocuries per liter of air or pCi/L. EPA has set a recommended "action level" of four pCi/L for homes and schools to reduce the risk of lung cancer.

What the Data Show

A 1991 representative survey of all housing units in the United States estimated that six percent of U.S. homes (5.8 million in 1990) had an annual average radon level of more than four picocuries per liter (pCi/L) in indoor air. Also, about 56 percent of Americans' exposure to radon occurs in homes with two pCi/L or more. Single-family detached homes were four times more likely to require mitigation than multi-family homes. The survey's findings were used in constructing EPA's estimate of U.S. lung cancer risks from radon, in setting the four pCi/L action level, and in crafting testing and mitigation guidance for the American public (EPA, OAR, October 1992).

Indicator Data Gaps and Limitations

The study is several years old and may not reflect changes brought about as a result of significant EPA radon public education campaigns since that time. Since the mid-1980s, about 18 million homes have been tested for radon and about 700,000 of them have been mitigated. In addition, since 1990 approximately one million new homes have been built with radon-resistant features.

Data Source

The data source for this indicator was *National Radon Residential Survey: Summary Report EPA*, 1992. (See Appendix B, page B-7, for more information.)

Indicator

Percentage of homes where young children are exposed to environmental tobacco smoke – Category 2

Environmental tobacco smoke (ETS)—smoke emitted from the burning end of a cigarette, pipe, or cigar, and smoke exhaled by a smoker—is a complex mix of more than 4,000 chemical compounds, containing many known or suspected carcinogens and toxic agents, including particles, carbon monoxide, and formaldehyde.

What the Data Show

The National Center for Health Statistics has conducted a major nationwide survey, known as the National Health Interview Survey, continuously since 1957. The survey estimated that in 1998, young children were exposed to ETS in 20 percent of homes in the U.S.—down from approximately 39 percent in 1986. About 43,000 households and 106,000 people participated in the survey (DHHS, NCHS, 2001).

Indicator Data Gaps and Limitations

The estimate is not based on a specific question about children's exposure to ETS, but rather is calculated based on the number of houses with smokers and with children.

Data Source

The data source for this indicator was *Healthy People 2000 Final Review,* Department of Health and Human Services, National Center for Health Statistics, 2001. (See Appendix B, page B-7, for more information.)

1.3.2 What contributes to indoor air pollution?

Indoor air pollutants come from a wide array of sources. In considering the potential impact of these sources on indoor air quality, it is vital to recognize the exchange between indoor and outdoor air. Exchange rates vary considerably from building to building, from one part of the country to another, and by seasons. Tight building construction improves energy efficiency but reduces indoor-outdoor air exchange and may contribute to indoor air pollution.

Among the sources of indoor air pollution are:

- Combustion of fuel used for heating and cooking, including oil, gas, kerosene, coal, and wood.
- Environmental tobacco smoke.
- Some adhesives, paints, and coatings (building materials).
- Furniture made of certain pressed wood products.
- Deteriorated, asbestos-containing insulation.
- Some products for household cleaning and maintenance, personal care, or hobbies.
- Inadequate maintenance of central heating and cooling systems.
- Radon, pesticides, and outdoor air pollution.
- Biological sources, including animal dander, cockroaches, dust mites, molds, and fungi.

1.3.3 What human health effects are associated with indoor air pollution?

In general, indoor air pollution can cause headaches, tiredness, dizziness, nausea, and throat irritation. More serious effects include cancer and exacerbation of chronic respiratory diseases, such as asthma. The most sensitive and vulnerable population groups—the elderly, the young, and the infirm—tend to spend the most time indoors; therefore, they may face higher than usual exposures.

Radon is estimated to be the second leading cause of lung cancer in the U.S. In an EPA-sponsored study, the National Research Council (NRC) found between 15,000 and 22,000 radon-related lung cancer deaths annually in the U.S. (NRC, 1998).

Environmental tobacco smoke causes eye, nose, and throat irritation, and is a carcinogen. Children exposed to ETS are at increased risk for respiratory problems and experience increased episodes of asthma (Mannino, et al., 2001). In studies of lifelong nonsmoking women, there was a 24 percent excess risk of lung cancer as a result of ETS exposures from a spouse's smoking (Hackshaw, 1998).

Asthma, particularly in children, is associated with poor indoor air quality. Dust mite proliferation in moist indoor environments can lead to asthma attacks. Other allergens and irritants such as animal dander, ETS, pesticide sprays, cockroach particles, and chemical fumes from household products have also been shown to increase asthma attack rates (IOM, 2000).

Fungal spores from mold growth in moist areas in homes have been associated with health effects in occupants, including allergies and asthma (IOM, 1993). Headaches, respiratory distress, and cardiovascular effects are also associated with exposure to molds.

No specific indicators have been identified at this time to address the human health effects associated with indoor air pollution.

1.4 Stratospheric Ozone

Although ozone is a harmful pollutant at ground level, it plays a valuable role in the stratosphere–the part of the atmosphere at an altitude of 10 to 30 km–by filtering harmful radiation from the sun. The sun's radiation bathes the Earth in ultraviolet (UV) wavelengths of 150 to 400 nanometers (nm). Ultraviolet radiation in the band between 280 and 320 nm, known as UV-B, is harmful to most organisms.

About 90 percent of the planet's ozone at a given time is in a thin layer of the lower stratosphere called the ozone layer, which also includes other gases. Ozone is constantly being created and destroyed by UV radiation. About 95 to 99 percent of UV-B radiation that reaches the Earth's surface is absorbed by ozone and oxygen in the ozone layer (NASA, 2002).

The ozone layer varies in space and time and is highly susceptible to changes in atmospheric chemical reactions by which it is created and destroyed. Scientists in the 1970s and 1980s discovered that human-caused changes to the composition of the atmosphere were leading to depletion of stratospheric ozone (NASA, 2002). They initially identified chlorofluorocarbons (CFCs) as being particularly significant stratospheric ozone depleters. Scientists subsequently identified additional human-produced ozone-depleting substances (ODSs).

This section poses four questions about stratospheric ozone:
- What are the trends in the Earth's ozone layer? (Section 1.4.1)
- What is causing changes to the ozone layer? (Section 1.4.2)
- What human health effects are associated with stratospheric ozone depletion? (Section 1.4.3)
- What ecological effects are associated with stratospheric ozone depletion? (Section 1.4.4)

1.4.1 What are the trends in the Earth's ozone layer?

Indicators

Ozone levels over North America

The most recent authoritative assessment of the Earth's stratospheric ozone is the *Scientific Assessment of Ozone Depletion: 2002* (Scientific Assessment Panel, 2003), conducted under the auspices of the United Nations Environment Programme (UNEP) and the World Meteorological Organization (WMO). The study found an average decrease of about 6 percent in average ozone concentrations between 35 and 60 degrees South for the period 1997 to 2001, compared with pre-1980 average values. It also found an average decrease of 3 percent between 35 and 60 degrees North for the same period (Scientific Assessment Panel, 2003).

It is generally believed that, after years of continuing thinning of the stratospheric ozone layer, the ozone layer will recover over the next several years as a result of international controls of ODSs. The Montreal Protocol on Substances that Deplete the Ozone Layer (Montreal Protocol), for example, restricts global manufacturing of CFCs (Scientific Assessment Panel, 2003).

Scientists largely agree that a thinning of the stratospheric ozone layer causes an increase in the amount of UV radiation, especially UV-B, that reaches the Earth's surface. This outcome is consistent with theories about the physical processes involved, measurable locally by ground-based and satellite-based instruments.

While acknowledging high uncertainty in the estimates, it is estimated that UV irradiance has increased since the early 1980s by 6 to 14 percent at more than ten sites distributed over mid and high latitudes of both hemispheres. Over the past two decades, UV increases are believed to have been considerably greater at higher latitudes. In the Northern Hemisphere, they are believed to be greater in the winter/spring than in the summer/fall (Scientific Assessment Panel, 2003). The estimates of increasing UV-B levels are based on indirect methods and models rather than direct measurements.

Because of the phase-out of ODS, total stratospheric concentrations of ODS seem to have peaked; it is believed that stratospheric ozone concentrations, near the lowest point since systematic measurements began, will not decrease any further and will eventually recover. These developments lead to the conclusion that UV radiation levels reaching the Earth's surface are close to the maximum they will reach as a result of human-induced stratospheric ozone depletion (Scientific Assessment Panel, 2003).

Obtaining reliable measurements of broad trends in levels of UV radiation reaching ground level in North America, however, is a complex task. It is particularly challenging to measure in ways that highlight the relationship between ozone depletion and UV radiation. The amount of incoming UV radiation is affected by several variables, including latitude, season, time of day, snow cover, sea ice cover, surface reflectivity, altitude, clouds, and aerosols. Determining which portion of any change is attributable to ozone depletion is difficult.

The indicator used to address the extent of change to the ozone layer is ozone levels over North America.

Indicator Ozone levels over North America, - Category 1

Data mapped for this indicator are derived from the Total Ozone Mapping Spectrometer (TOMS), flown on NASA's Nimbus-7 satellite. The TOMS measures amounts of backscattered UV radiation at various wavelengths. Backscattered radiation levels at wavelengths where ozone absorption does and does not take place are compared with radiation directly from the sun at the same wavelengths, allowing scientists to derive a "total ozone" amount in the Earth's atmosphere.

The data for this indicator are presented in Dobson Units (DU) which measure how thick the ozone layer would be if compressed in the Earth's atmosphere (at sea level and at 0°C.) One DU is defined to be 0.01 mm thickness at standard temperature and pressure.

What the Data Show

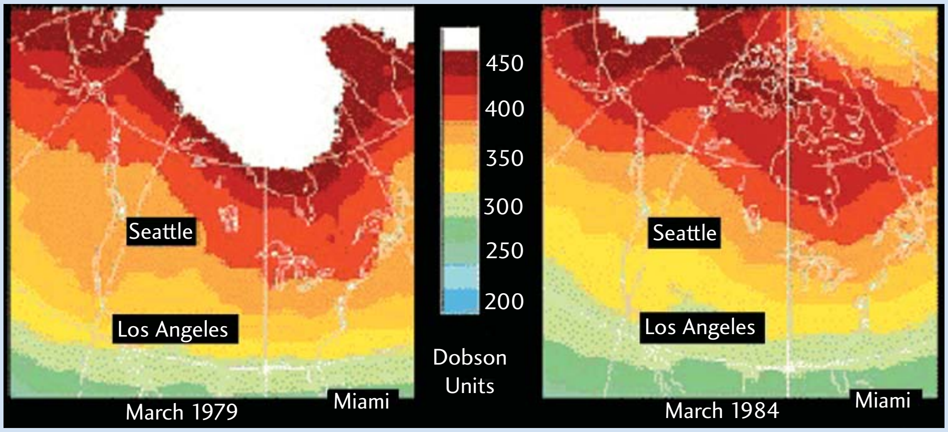
The ozone maps illustrate graphically and quantitatively the thinning of total column ozone over North America during a 15-year period. For example, in 1979, the ozone column over the Seattle area was 391 Dobson Units (DU), but in 1994 it had dropped to 360 DU. Over Los Angeles, the ozone column during that time dropped from 368 DU to 330 DU, and over Miami from 303 DU to 296 DU (Exhibit 1-26) (NASA, March 1979 and March 1994). Although exact calculations cannot be made from Exhibit 1-26, the graph demonstrates thinning of the ozone layer over much of the globe.

In general, ozone depletion is greater at higher latitudes. Therefore, it is predictable that the decrease in the ozone layer over Seattle is greater than over Los Angeles, with the ozone layer over Miami experiencing the lowest depletion among the three cities. However, southern cities also have higher levels of UV-B, so even with less depletion, the net increase in UV-B can exceed that over northern latitudes.

According to the latest estimates in the *Scientific Assessment*, the global-average total column ozone during 1997 to 2001 was about 3 percent below average pre-1980 values (Scientific

Indicator | Ozone levels over North America, March 1979 and March 1994 - Category 1 (continued)

Exhibit 1-26: Ozone levels over North America, 1979 and 1994



Source: NASA, Goddard Space Flight Center. Total Ozone Mapping Spectrometer (TOMS), flown on Nimbus-7 satellite. (January 24, 2003; Available: http://www.epa.gov/ozone/science/glob_dep.html).

Assessment Panel, 2003). Trends over North America reflect this global phenomenon.

Indicator Gaps and Limitations

TOMS provides no data during nighttime or during the longer periods of darkness in polar regions.

Data Source

The data source for this indicator was NASA, Total Ozone Mapping Spectrometer, flown on the Nimbus-7 satellite. March 1979 and March 1994. (See Appendix B, page B-7, for more information.)

1.4.2 What is causing changes to the ozone layer?

Indicators

Worldwide and U.S. production of ozone-depleting substances (ODSs)

Concentrations of ozone-depleting substances (effective equivalent chlorine)

Analyses have shown that the presence of CFCs and other ODSs was negligible before commercial production of CFCs and other ODSs began in the 1930s and 1940s (Scientific Assessment Panel, 2003).

The adoption of the 1987 Montreal Protocol significantly affected production levels, resulting in reduced concentrations of ODSs.

Worldwide emissions are estimated to have been reduced significantly, since peaking in 1993 (Scientific Assessment Panel, 2003). Likewise, there have been marked decreases in U.S. emissions of ODSs over the past decade, resulting in a 79 percent decrease in total ODP-weighted emissions from 1990 to 2000 (EPA, OAP, April 2002).

Two indicators are used to address this question:

- Worldwide and U.S. production of ODSs.
- Concentration of ODSs (effective equivalent stratospheric chlorine).

Indicator: Worldwide and U.S. production of ozone-depleting substances (ODSs) - Category 2

Worldwide ODS production estimates are derived from reports produced by each nation, as required under the Montreal Protocol and subsequent amendments.

Production, consumption, and emissions of ODSs are not identical; even though the ultimate destiny of a given pound of CFCs might be release to the atmosphere, a time lag is involved. ODSs initially are contained—and isolated from the atmosphere—after they are produced. They are likely to stay contained until they are consumed—for example, used as coolant in a refrigerator or as a foaming agent in polystyrene-foam hot cups. Once they are consumed, the ODSs still might not be released to the atmosphere until years later, such as when the cup degrades in a landfill, or when the refrigerator is disposed of or recycled (at which time the ODS may actually be reclaimed for further use).

Because of these complexities, consumption and emissions figures involve significant uncertainties—they are estimated based on rates of conversion. Production figures may be more meaningful, because they are compiled from data which a relatively small number of producing companies must report by law.

Exhibit 1-27: Worldwide ODS production and consumption (ODP-weighted tons), 1986 and 1999

Year	Production	Consumption
1986	1,768,789	1,784,015
1999	312,731	275,382

Source: United Nations Environment Programme, Ozone Secretariat. *Production and Consumption of Ozone Depleting Substances under the Montreal Protocol: 1986-2000*. April 2002.

What the Data Show

There have been marked decreases in worldwide production, and consumption of ODSs over the past 2 decades (Exhibit 1-27). Worldwide ODS production declined from approximately 1.8 million tons in 1986 to 313,000 tons in 1999 (UNEP, 2002). Worldwide measures are presented in ozone depletion potential (ODP)-weighted tons. Each ODS is weighted based on its damage to the stratospheric ozone; this is its ODP. U.S. production of selected ODSs peaked in 1988 and declined by nearly 65 percent in 5 years (Exhibit 1- 28) (USITC, 1994).

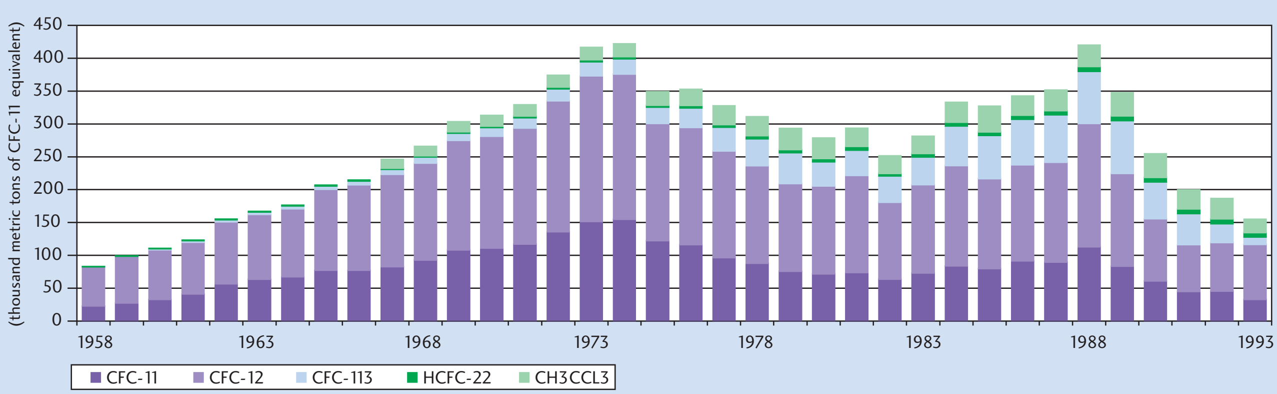
Indicator Gaps and Limitations

In some cases ODS production data are reliable because laws require that they be reported. Coverage from nation to nation is incomplete, however, and sometimes methods are inconsistent. Production estimates for the U.S. are generally reliable as a result of the legal reporting requirement for production figures and the small number of producers involved.

Data Sources

The data sources for this indicator were *Worldwide Estimates: Production and Consumption of Ozone Depleting Substances* 1986-2000, Ozone Secretariat/UNEP, 2002, and *1993 Synthetic Organic Chemicals; U.S. Production and Sales*, U.S. International Trade Commission, 1994. (See Appendix B, page B-7, for more information.)

Exhibit 1-28: U.S. production of selected ozone-depleting chemicals, 1958-1993



Source: U.S. International Trade Commission. *1993 Synthetic Organic Chemicals; U.S. Production and Sales. 1994* (July 3, 2002; *http://www.epa.gov/ozone/science/indicat/index.html*).

Indicator

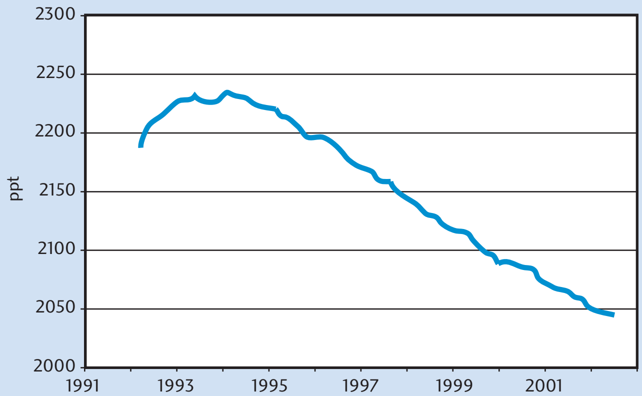
Concentrations of ozone-depleting substances (effective equivalent chlorine) - Category 2

Effective equivalent chlorine (EECl), the amount of chlorine and bromine in the lower atmosphere, is used to represent concentrations of ozone-depleting substances. It is a convenient parameter for measuring with a single number the overall potential human effect on stratospheric ozone. EECl is derived by considering the changing concentrations of about a dozen gases that can affect the stratospheric ozone concentration. An index is then developed based on the ability of those gases to catalyze the destruction of ozone relative to the ability of chlorine to do so. The units of EECl are parts per trillion by volume.

What the Data Show

The *Scientific Assessment* states that the total effect of all ozone-depleting halogens in the atmosphere, estimated by calculating chlorine equivalents from atmospheric measurements of chlorine- and bromine- containing gases, continues to decrease. As of mid-2000, equivalent organic chlorine in the troposphere was nearly five percent below the peak value in 1992 to 1994 (Exhibit 1-29). The recent decrease is slightly slower than in the mid-1990s due to the reduced influence of methyl chloroform on this decline (Scientific Assessment Panel, 2003).

Exhibit 1-29: Global total effective equivalent chlorine (EECl), 1992-2002



Source: Updated from Montzka, Stephen A., et al. *Present and future trends in the atmospheric burden of ozone-depleting halogens*. April 1999;
NOAA, Climate Monitoring & Diagnostics Laboratory. Halocarbons and other Atmospheric Trace Species (HATS). 2002. March 18, 2003; *http://www.cmdl.noaa.gov/hats/graphs/graphs.html*).

In 1996, EPA measurements indicated that concentrations of methyl chloroform had started to fall, indicating that emissions had been reduced. Concentrations of other ozone-depleting substances in the upper layers of the atmosphere, like CFCs, are also beginning to decrease. Stratospheric chlorine levels have apparently peaked and are expected to slowly decline in coming years (EPA, OAQPS, September 2002). The best current estimate from computer models is that the atmospheric burden of halogens will return to 1980 levels (pre-Antarctic ozone hole) around the middle of this century if the Montreal Protocol and its Amendments are fully adhered to (Scientific Assessment Panel, 2003).

Indicator Gaps and Limitations

The precision of this indicator depends on understanding the chemistry and behavior of the many different gases involved. For example, accurate estimates of the atmospheric lifetime of a gas are essential to assigning it the proper weight relative to other gases. As scientific understanding of atmospheric chemistry improves, calculations continue to be refined.

Data Source

The data source for this indicator was *Scientific Assessment of Ozone Depletion: 2002*, Scientific Assessment Panel of the Montreal Protocol on Substances that Deplete the Ozone Layer, WMO, 2003. (See Appendix B, page B-8, for more information.)

1.4.3 What human health effects are associated with stratospheric ozone depletion?

The increased ground-level UV radiation that can result from stratospheric ozone depletion is expected to have significant adverse human health effects. UV-B radiation is linked to skin cancer, increased incidence of cataracts, and suppression of the immune system (EPA, OAQPS, September 2002). Approximately 1.3 million new cases of skin cancer are diagnosed every year in the U.S., according to the Centers for Disease Control and Prevention (CDC) and the American Cancer Society. Malignant melanoma accounts for about 75 percent of the approximately 9,800 skin cancer deaths in the U.S. annually. The incidence rate of malignant melanoma is increasing by about 3 percent annually, although death rates have remained constant (Wingo, et al., 1999).

Possible increased UV radiation levels is only one of many factors that could affect skin cancer incidence. Others include behavioral changes (people spending more time at the beach or outdoors) and changes in screening for, diagnosis of, and reporting of the disease.

Data on UV-B radiation and tropospheric ozone are used to calculate benefits from accelerated phase-out schedules for ODSs. EPA

Exhibit 1-30: Estimated benefits of phaseout of ozone-depleting substances (sections 604, 606, and 609 of the Clean Air Act)

Health Effects - Quantified	Estimate	Basis for Estimate
■ Melanoma and nonmelanoma skin cancer (fatal)	6.3 million lives saved from skin cancer in the U.S. between 1990 and 2165	Dose-response function based on UV exposure and demographics of exposed populations[1]
■ Melanoma and nonmelanoma skin cancer (non-fatal)	299 million avoided cases of non-fatal skin cancers in the U.S. between 1990 and 2165	Dose-response function based on UV exposure and demographics of exposed populations[1]
■ Cataracts	27.5 million avoided cases in the U.S. between 1990 and 2165	Dose-response function uses a multivariate logistic risk function based on demographic characteristics and medical history[1]
Ecological Effects - Quantified	**Estimate**	**Basis for Estimate**
■ American crop harvests	Avoided 7.5 percent decrease from UV-b radiation by 2075	Dose-response sources: Teramura and Murali (1986), Rowe and Adams (1987)
■ American crops	Avoided decrease from tropospheric ozone	Estimate of increase in troposhpheric ozone: Whitten and Gery (1986). Dose-response source: Rowe and Adams (1987)
■ Polymers	Avoided damage to materials from UV-b radiation	Source of UV-b/stabilizer relationship; Horst (1986)
Health Effects - Unquantified		
Skin cancer: reduced pain and suffering		
Reduced morbidity effects of increased UV. For example: ■ reduced actinic keratosis (pre-cancerous lesions resulting from excessive sun exposure) ■ reduced immune system suppression		
Ecological Effects - Unquantified		
Ecological effects of UV. For example, benefits relating to the following: ■ recreational fishing ■ forests ■ overall marine ecosystem ■ avoided sea level rise, including avoided beach erosion, loss of coastal wetlands, salinity of estuaries and aquifers	■ other crops ■ other plant species ■ fish harvests	
Ecological benefits of reduced trophospheric ozone relating to the overall marine ecosystem, forests, mand-made materials, crops, other plant species, and fish harvests		
Benefits to people and the environment outside the U.S.		
Effects, both ecological and human health, associated with global warming		

Notes:
1) For more detail see EPA's *Regulatory Impact Analysis: Protection of Stratospheric Ozone* (1988).
2) Note that the ecological effects, unlike the health effects, do not reflect the accelerated reduction and phaseout schedule of section 606.
3) Benefits due to the section 606 methyl bromide phaseout are not included in the benefits total because EPA provides neither annual incidence estimates nor a monetary value. The EPA does provide, however, a total estimate of 2,800 avoided skin cancer fatalities in the U.S.

Source: EPA, Office of Air and Radiation. *The Benefits and Costs of the Clean Air Act 1990 to 2010. EPA Report to Congress.* November 1999.

estimates that between 1990 and 2165, in the U.S. alone 6.3 million fatal skin cancers, 299 million cases of non-fatal skin cancers, and 27.5 million cases of cataracts will be prevented because of the worldwide phase-out of ODSs. (EPA, OAR, November 1999) (Exhibit 1-30). These are estimated cumulative effects, so there are no data series or trends to evaluate.

No specific indicators have been identified at this time for human health effects of stratospheric ozone depletion.

1.4.4 What ecological effects are associated with stratospheric ozone depletion?

UV radiation in sunlight affects the physiological and developmental processes of plants. Even though plants have mechanisms to reduce or repair these effects and some ability to adapt to increased UV-B levels, UV radiation can still directly affect plant growth. It can also produce indirect effects such as changes in plant form, distribution of nutrients within the plant, timing of developmental phases, and secondary metabolism. These changes can be even more important than direct damage because of their implications for plant competitive balance, herbivory, plant diseases, and biogeochemical cycles (UNEP, 1994).

UV radiation can also affect aquatic life. UV exposure affects both orientation mechanisms and motility in phytoplankton, resulting in reduced survival rates for these organisms. Scientists have demonstrated a direct reduction in phytoplankton production as a result of ozone depletion-related increases in UV-B (DeMora, et al., 2000). Small increases in UV-B radiation have been found to cause damage in the early developmental stages of fish, shrimp, crab, amphibians, and other animals, the most severe effects being decreased reproductive capacity and impaired larval development. Animals higher on the food chain that depend on these organisms for food could, in turn, be affected (UNEP, 1994).

Increases in UV radiation could also affect terrestrial and aquatic biogeochemical cycles, and, as a result, alter both sources and sinks of greenhouse and chemically important trace gases. These potential changes would contribute to biosphere-atmosphere feedback that attenuates or reinforces the atmospheric buildup of these gases (UNEP, 1994). Synthetic polymers, naturally occurring biopolymers, and some other materials of commercial interest also are adversely affected by UV radiation, but special additives somewhat protect some modern materials from UV-B. Increases in UV-B levels nonetheless will likely accelerate their breakdown, limiting their usefulness outdoors (UNEP, 1994).

No specific indicators have been identified at this time to address the ecological effects associated with stratospheric ozone depletion.

1.5 Climate Change

The issue of global climate change involves changes in the radiative balance of the Earth—the balance between energy received from the sun and emitted from the Earth. This report does not attempt to address the complexities of this issue. For information on the $1.7 billion annual U.S. Global Climate Research Program and Climate Change Research Initiative, please find *Our Changing Planet: The Fiscal Year 2003 U.S. Global Climate Research Program* (November 2002) at www.usgcrp.gov and the *Draft Ten-Year Strategic Plan for the Climate Change Science Program* at www.climatescience.gov.

1.6 Challenges and Data Gaps

Outdoor Air Quality and Acid Deposition

In general, some very good indicators of outdoor air quality exist. The national air monitoring network for the six criteria air pollutants is extensive; however, there are far more monitors in urban areas than in rural areas. Monitoring in urban areas helps to characterize population exposures, because population tends to be concentrated in urban areas. More rural monitoring might help scientists assess transport and ecological effects, although EPA uses additional tools and techniques (e.g., models and spatial analyses) to augment limited monitoring in some areas and to better characterize pressures on ecological condition. EPA is currently conducting a national assessment of the existing ambient monitoring networks and is analyzing, among other issues, the need for and appropriateness of each of the nation's urban monitors.

Many major metropolitan areas monitor air quality for the presence of selected air toxics. However, there is no national monitoring network with standard data collection guidance for air toxics; therefore, numerous air toxics are not being measured. National assessments of levels of air toxics would benefit from a more extensive ambient monitoring network for toxics. EPA is currently working with state and local partners to design and deploy such a network.

Questions still exist about how indicators of concentrations and emissions relate to exposure and human health effects. The use of one approach to determining how various air pollution levels affect health would be to use established and quantified effects and surrogates for air pollution health impacts from epidemiology studies, such as asthma hospitalizations and childhood school absences. Research needs to be conducted that will develop these health endpoints into useful indicators.

As highlighted in Chapter 4, Human Health, for most health outcomes other than mortality, no national systems for data collection currently exist. With regard to criteria air pollutants, it would be useful to track asthma and chronic respiratory diseases, cardiovascular diseases, and adverse birth outcomes. For air pollutants in general, including air toxics and indoor pollutants, the list can also include neurological diseases, developmental disabilities, reproductive disorders, and endocrine/metabolic disorders.

As described in Chapter 5, Ecological Condition, there are large gaps in our ability to report on the condition of ecological systems and linkages between indicators of atmospheric stressors and specific ecological effects. There is a need for improved monitoring information for deposition and concentrations of both criteria and toxic air pollutants to ecosystems. Data on exposure of high-elevation forests and their watersheds to ozone and acid deposition are especially sparse, relative to data on lower elevations. And exposure patterns are likely to be significantly different at higher elevations because of higher acid deposition rates due to higher rainfall and fog, and less diurnal variation in ozone concentrations due to less nighttime scavenging (NAPAP, 1991). Furthermore, despite considerable progress, there is still no index of ozone exposure that relates optimally to plant response (EPA, NCEA, July 1996). Although mercury monitoring has begun as part of the National Atmospheric Deposition Program, the availability of data is inadequate to assess national trends (EPA, OAQPS, ORD, December 1997). There are inadequate data on indicators of actual UV exposures of ecosystems of all types.

Indoor Air Quality

While environmental indicators have been developed for some aspects of indoor air, significant gaps exist in our knowledge about the conditions inside the nation's buildings. For schools and residences, a large amount of information on IAQ is available, but it is composed primarily of case studies and, at best, small regional studies. Exposure studies on a national scale would help better characterize IAQ of schools and residential indoor environments, including multiple family residences. Ideally, these studies would collect exposure data on air toxics and PM in these indoor environments, and data for the various biological contaminants found in indoor air.

Stratospheric Ozone

In general, high quality data exists with which to predict the human health effects of increased ultraviolet exposure resulting from depletion of the stratospheric ozone. These include robust satellite data on stratospheric ozone concentrations and UV-B levels, comprehensive and well documented incidence and mortality rates for cutaneous melanoma, and well characterized action spectra for skin cancers and cataracts. However, there are areas where additional data would be useful. First, no national system exists that collects incidence data for squamous cell carcinoma and basal cell carcinoma, the non-melanoma skin-cancers caused by increased UV-B exposure. Thus, our incidence estimates are modeled using data from a nation-wide survey of non-melanoma skin cancer incidence and mortality, and may not represent the most current non-melanoma skin cancer rates. Second, there is a lack of adequate ground level UV monitoring with which to compare the satellite data. Satellites cannot directly measure ground level UV, and are sensitive to pollution. Therefore, while satellite data compare fairly well to ground level UV measurements in clean locations, this is not the case in polluted areas. Additional UV monitoring in cities is crucial to support future epidemiological research on the human health effects of UV-B exposure. Third, increased UV-B levels have been associated with other human and non-human endpoints including immune suppression and effects on aquatic ecosystems and agricultural crops. However, additional research on these topics is necessary before these effects can be modelled or quantified. Finally, the future behavior of the ozone layer will be affected by changing atmospheric abundances of various atmospheric gases. It remains unclear how these changes will affect the predicted recovery of the ozone layer. Additional research on the interaction between climate and stratospheric ozone could provide more accurate predictions of ozone recovery and the human health effects resulting from ozone depletion.

Chapter 2: Purer Water

Indicators that were selected and included in this chapter were assigned to one of two categories:

- **Category 1** –The indicator has been peer reviewed and is supported by national level data coverage for more than one time period. The supporting data are comparable across the nation and are characterized by sound collection methodologies, data management systems, and quality assurance procedures.
- **Category 2** –The indicator has been peer reviewed, but the supporting data are available only for part of the nation (e.g., multi-state regions or ecoregions), or the indicator has not been measured for more than one time period, or not all the parameters of the indicator have been measured (e.g., data has been collected for birds, but not for plants or insects). The supporting data are comparable across the areas covered, and are characterized by sound collection methodologies, data management systems, and quality assurance procedures.

2.0 Introduction

Our nation's water resources have immeasurable value. Animals, plants, and ecosystems depend on clean and abundant water, without which they could not exist. Humans, too, need clean water to drink, to grow food, and to produce goods and services. Clean water generates billions of dollars for the economy each year. Water resources provide opportunities for families to swim and fish, and wetlands protect homes and property against floods. Rivers, lakes, wetlands, and coastal waters provide critical habitats for many species and serve as nurseries for many of the valued commercial and recreational fisheries. Water beneath the water table in fully saturated soils and geological formations, known as ground water, provides half the nation with drinking water.

An increasing tide of pressures has compromised the health of many waterbodies. In the early 20th century, industrial growth and an expanding population left behind a legacy of pollution. After the burning of Ohio's Cuyahoga River—so polluted with oil and debris that it caught fire—Congress passed the landmark Clean Water Act (CWA) and Safe Drinking Water Act (SDWA). These acts and other laws brought to bear strong regulatory and financial tools to clean up polluted surface waters and ensure that public water systems provide safe drinking water.

Thanks to these significant investments, pollutant discharges into our nation's waters have been substantially reduced and the safety of public water supplies has improved (EPA, OW, December 1999). Nevertheless, significant water pollution problems persist and threats to drinking water remain. Today, discharges from industry and sewage treatment plants, together with pollution from many other sources—including, agricultural lands, residential areas, city streets, forestry operations, and pollutants settling out of the air—continue to degrade our nation's waters. Other stresses also threaten water quality. These include landscape modification, introduction of invasive species, changes in flow patterns, and over-harvesting of fish and other aquatic organisms.

Adequately maintained water infrastructure will be essential to sustain the water quality gains of the past 30 years and to address challenges to water quality and delivery of safe drinking water in the coming years. By achieving a better understanding of the condition of our nation's waters, we will be able to make informed decisions about how to protect and preserve our water infrastructure.

This chapter summarizes what is generally understood about the current status and trends in water quality, the pressures affecting water quality, and information regarding associated human health and ecological effects. It poses fundamental questions about water quality, sources of pollution, and health and ecological effects, and it uses indicators drawn from well-reviewed data sources to help answer those questions. Exhibit 2-1 lists these questions and indicators, as well as the number of the chapter section where each indicator is presented.

The questions addressed in this chapter are divided into four categories:

- Waters and watersheds, discussed in Section 2.2.
- Drinking water, discussed in Section 2.3.
- Recreation in and on the water, discussed in Section 2.4.
- Consumption of fish and shellfish, discussed in Section 2.5.

Section 2.1 provides information on the extent and use of our nation's water resources. Section 2.6 reviews the challenges and data gaps that remain in assessing the condition of our nation's water resources.

The key sources of data used to support these indicators vary and are described in each section. Some of the primary data sources that contribute directly or indirectly to indicators throughout this chapter include data from EPA and other federal agencies. Predominant EPA programs or data sets supporting the indicators in this chapter include the Environmental Monitoring and Assessment Program (EMAP); the National Sediment Quality Inventory; the Toxics Release Inventory (TRI); the Safe Drinking Water Information System (SDWIS); the National Health Protection Survey of Beaches; and the National Listing of Fish and Wildlife Advisories (NLFWA). Other national programs that provide data for the indicators described in this chapter include the:

- *U.S. Geological Survey's* National Water Quality Assessment (NAWQA) program.
- *U.S. Fish and Wildlife Service's* (USFWS's) National Wetlands Inventory (NWI) studies of the status and trends of wetlands resources.
- *U.S. Department of Agriculture* (USDA) Natural Resources Conservation Service's (NRCS's) National Resources Inventory (NRI).
- *National Atmospheric Deposition Program* (NADP).
- *National Oceanic and Atmospheric Administration* (NOAA) programs.

Many of these data sets have been compiled and summarized in a report titled *The State of the Nation's Ecosystems*, developed by the H. John Heinz III Center for Science, Economics and the Environment (The Heinz Center, 2002). Gaps in the data exist that make it difficult or impossible to answer some of the questions posed about the condition of our nation's waters. Data gaps and limitations are described under each question and at the end of this chapter.

Exhibit 2-1: Water - Questions and Indicators

Waters and Watersheds

Question	Indicator Name	Category	Section
What is the condition of fresh surface waters and watersheds in the U.S.?	Altered fresh water ecosystems	2	2.2.1
	Lake Trophic State Index	2	2.2.1
What are the extent and condition of wetlands?	Wetland extent and change	1	2.2.2
	Sources of wetland change/loss	2	2.2.2
What is the condition of coastal waters?	Water clarity in coastal waters	2	2.2.3
	Dissolved oxygen in coastal waters	2	2.2.3
	Total organic carbon in sediments	2	2.2.3
	Chlorophyll concentrations	2	2.2.3
What are pressures to water quality?	General pressures		
	Percent urban land cover in riparian areas	2	2.2.4.a
	Agricultural lands in riparian areas	2	2.2.4.a
	Population density in coastal areas	2	2.2.4.a
	Changing stream flows	1	2.2.4.a
	Number/duration of dry stream flow periods in grassland/shrublands	2	2.2.4.a
	Sedimentation index	2	2.2.4.a
	Nutrient pressures		
	Atmospheric deposition of nitrogen	2	2.2.4.b
	Nitrate in farmland, forested, and urban streams and ground water	2	2.2.4.b
	Total nitrogen in coastal waters	2	2.2.4.b
	Phosphorus in farmland, forested, and urban streams	2	2.2.4.b
	Phosphorus in large rivers	2	2.2.4.b
	Total phosphorus in coastal waters	2	2.2.4.b
	Chemical Pressures		
	Atmospheric deposition of mercury	2	2.2.4.c
	Chemical contamination in streams and ground water	2	2.2.4.c
	Pesticides in farmland streams and ground water	2	2.2.4.c
	Acid sensitivity in lakes and streams	2	2.2.4.c
	Toxic releases to water of mercury, dioxin, lead, PCBs, and PBTs	2	2.2.4.c
	Sediment contamination of inland waters	2	2.2.4.c
	Sediment contamination of coastal waters	2	2.2.4.c
	Sediment toxicity in estuaries	2	2.2.4.c
What ecological effects are associated with impaired waters?	Fish Index of Biotic Integrity in streams Also see Ecological Condition chapter	2	2.2.5
	Macroinvertebrate Biotic Integrity index for streams Also see Ecological Condition chapter	2	2.2.5
	Benthic Community Index for coastal waters Also see Ecological Condition chapter	2	2.2.5

Drinking Water

Question	Indicator Name	Category	Section
What is the quality of drinking water?	Population served by community water systems that meets all health-based standards	1	2.3.1
What are sources of drinking water contamination?	No Category 1 or 2 indicators identified		2.3.2
What human health effects are associated with drinking contaminated water?	No Category 1 or 2 indicators identified Also see Human Health chapter		2.3.3

Recreation in and on the Water

Question	Indicator Name	Category	Section
What is the condition of waters supporting recreational use?	Number of beach days that beaches are closed or under advisory	2	2.4.1
What are sources of recreational water pollution?	No Category 1 or 2 indicators identified		2.4.2
What human health effects are associated with recreation in contaminated waters?	No Category 1 or 2 indicators identified Also see Human Health chapter		2.4.3

Consumption of Fish and Shellfish

Question	Indicator Name	Category	Section
What is the condition of waters that support consumption of fish and shellfish?	Percent of river miles and lake acres under fish consumption advisories	2	2.5.1
	Contaminants in fresh water fish	2	2.5.1
	Number of watersheds exceeding health-based national water quality criteria for mercury and PCBs in fish tissue	2	2.5.1
What are contaminants in fish and shellfish, and where do they originate?	No Category 1 or 2 indicators identified		2.5.2
What human health effects are associated with consuming contaminated fish and shellfish?	No Category 1 or 2 indicators identified Also see Human Health chapter		2.5.3

2.1 Extent and Use of Water Resources

Our nation's water resources, which consist of both surface waters and ground water, are critical to both human activities and the functioning of ecological systems:

- Surface waters, such as rivers, lakes, ponds, reservoirs, wetlands, riparian (river and stream) areas, and estuarine areas, are fundamental components of ecological systems described in this report. They are also important sources of fresh water for human use, including drinking water, recreation, wastewater treatment, industrial usage, livestock, and irrigation. Wetlands and riparian areas help provide clean water, reduce flooding, and support critical fish and wildlife habitat.
- Ground water, one of our nation's most important natural resources, provides about 40 percent of the U.S. public water supply and much of the rural water supply, which comes primarily from domestic wells. Ground water also is the source of much of the water used for irrigation, is the principal reserve of fresh water, and represents much of our nation's potential future water supply. Ground water may contribute as much as 40 percent of all stream flow in the eastern U.S. (Alley, et al., 1999).

Extent of Ground Water and Fresh Water Resources

Ground water comprises about 25 percent of all fresh water on Earth. By contrast, surface water and soil moisture constitute less than one percent of the world's fresh water (Alley, et al., 1999) (the remaining 75 percent is stored in polar ice and glaciers). The Great Lakes, which cover 60.2 million acres, hold about 18 percent of the globe's fresh surface water (Environment Canada and EPA, 1995).

The lower 48 states (conterminous U.S.) contain:

- About half of our nation's 41.6 million acres of lakes, ponds, and reservoirs.
- About 3.7 million miles of streams and rivers (EPA, OW, June 2000).
- An estimated 105.5 million acres of wetlands as of the mid-1990s (Dahl, 2000).

Alaska has an estimated 170 million acres of wetlands, which cover approximately 45 percent of the state. Hawaii has nearly 52,000 acres of wetlands (Dahl, 1990). U.S. coastal waters include 66,645 miles of coastline and 57.9 million acres of estuarine surface area (EPA, OW, June 2000).

Ground water and surface water are closely related and, in many areas, constitute a singe resource. Both are recharged through precipitation. The U.S. receives enough annual precipitation to cover the entire country to a depth of 30 inches (known as the U.S. water budget), though the eastern U.S. receives more rainfall than the western part of the country. Over two-thirds (21 inches) of this precipitation returns to the water cycle through evapotranspiration. The rest becomes surface water, ground water, or soil moisture.

Water use is an important dynamic that can impact both the quantity and quality of available fresh water resources. Accurate information about water use helps planners and managers make informed decisions about our nation's water resources. With this information, they can project future water demand and better assess the effectiveness of alternative water-management policies, regulations, and conservation activities.

States report their water use to the U.S. Geological Survey (USGS) in five mutually exclusive categories:

- *Public water supply use*—water withdrawn by public and private water suppliers and delivered to homes and businesses for drinking, commercial, and industrial uses.
- *Self-supplied water*—water for domestic use and for livestock that is not drawn from the public supply.
- *Irrigation*—this includes application to crops, pastures, and recreational lands such as parks and golf courses.
- *Thermoelectric use*—that is, water used for cooling during electric power generation.
- *Industrial use*—this includes self-supplied water for fabrication, processing, cooling, and washing (including commercial and mining uses).

The USGS coordinates the national water-use compilation effort and publishes the results every five years in the circular series *Estimated Use of Water in the U.S.* Withdrawals are reported in billions of gallons of water per day for the five use categories. Sources of information and accuracy of water-use data vary by state and by water-use category (The Heinz Center, 2002).

The USGS (Solley, et al., 1998) estimated that:

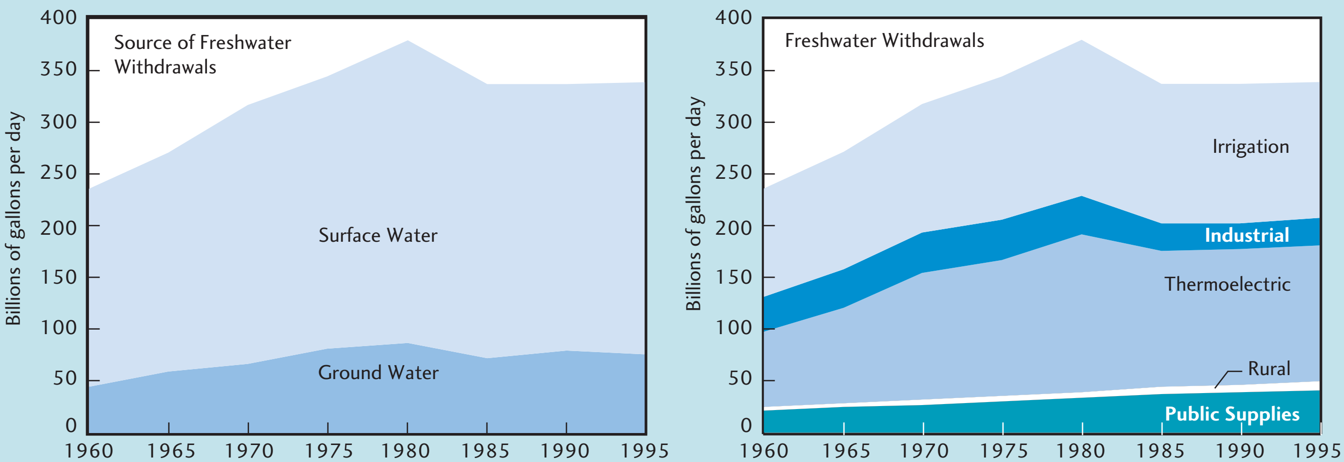
- Total withdrawals of fresh water and saline water during 1995 were 402,000 million gallons per day (Mgal/d) for all water-use categories (public supply, domestic, commercial, irrigation, livestock, industrial, mining, and thermoelectric power).
- Total fresh water withdrawals were an estimated 341,000 Mgal/d. About 100,000 Mgal/d (29.3 percent) of this was consumed, and the rest (241,000 Mgal/d, or 70.7 percent) was returned.

From 1960 to 1980, total water use, as well as the water use for each major use category, increased. However, from 1980 to 1995, total water use, as well as usage in several individual categories declined, though water used for public supply continued to grow (Exhibit 2-2). The two largest uses of water in the U.S.—irrigation and cooling (during electric power generation)—were responsible for much of the decline in total use between 1980 and 1995.

Decreases in withdrawals by self-supplied industrial users also contributed to the overall decline.

In many areas of the U.S., withdrawal of ground water has significantly depleted ground water reserves. Since ground water and surface water are closely related, this depletion can reduce river flows, lower lake levels, and reduce discharges to wetlands and springs. These reductions may, in turn, affect drinking water supplies, riparian areas, and critical aquatic habitats (Alley, et al., 1999). In the southwestern U.S., for example, the High Plains aquifer covers 174,000 square miles under eight states stretching from South Dakota to Texas. By 1999, an estimated 220 million acre-feet (270 cubic kilometers, or something over half the amount of water contained in Lake Erie) had been removed (USGS, 2002), primarily for irrigation.

Exhibit 2-2: Sources of fresh water withdrawals, 1960-1995



Coverage: all 50 states

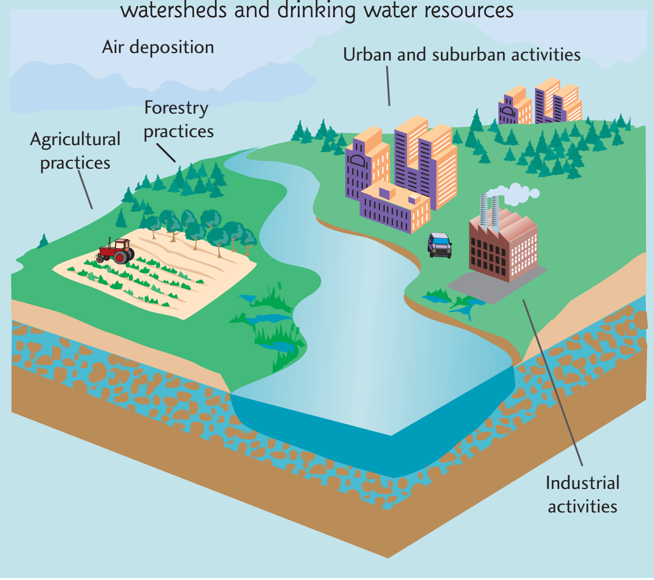
Source: Solley et al. *Estimated Use of Water in the United States in 1995*. 1998.

2.2 Waters and Watersheds

A watershed is the area that drains to a common waterway, such as a stream, lake, estuary, wetland, or ultimately the ocean. It is a land feature that is identified by tracing a line along the highest elevations (often a ridge) between two areas on a map. Watersheds come in all shapes and sizes, and smaller watersheds drain into larger watersheds which may cross county, state, and national boundaries. For example, a small stream running through a farmer's field in Pennsylvania may drain only a few acres within the larger Susquehanna River watershed, which in turn is a portion of the Chesapeake Bay watershed, which extends across six states and the District of Columbia. The watershed's natural processes (e.g., rainfall runoff, ground water recharge, sediment transport, plant succession) provide beneficial services when functioning properly, but may cause ecological and physical (flooding) disasters when misunderstood and disrupted. Watersheds are subject to many different pressures (or "stressors"), including pollution and human activities (see Exhibit 2-3).

Because of their many influences on water quality, watersheds are often the focus of efforts to manage water use and reduce pollution. Traditionally, managers have focused on reducing pollution from specific sources (such as sewage discharges) or within specific water resources (such as river segments or wetlands). This approach successfully reduces pollutant loads, but often does not adequately address the combined concentration of multiple sources that contribute to a watershed's decline. For example, pollution from a sewage treatment plant might be reduced significantly after a new technology is installed, and yet the local river may still suffer if other factors in the watershed, such as habitat destruction or non-point source pollution, are not addressed. Watershed management can offer a stronger foundation than more traditional segmented approaches for elucidating the many stressors that affect a watershed and for developing effective management strategies to protect water resources.

Exhibit 2-3: Selected activities affecting water, watersheds and drinking water resources



Section 2.2 addresses five questions about our nation's waters and watersheds:

- What is the condition of fresh surface waters and watersheds in the U.S.?
- What are the extent and condition of wetlands?
- What is the condition of coastal waters?
- What are pressures to water quality?
- What ecological affects are associated with impaired waters?

Loss of wetlands and the diversion of stream flows are important to understand and quantify condition. Condition, which is addressed in the first three questions, is a function of the quality, extent, and location of the water and how that water quality affects the condition of the biotic resources that depend on that water. To answer questions about condition, a watershed's extent, as well as its chemical, physical, and biological attributes, must be defined. Section 2.2 addresses extent and chemical and physical attributes. Chapter 5, Ecological Condition, describes the biotic condition of waters and watersheds.

2.2.1 What is the condition of fresh surface waters and watersheds in the U.S.?

Indicators

Altered fresh water ecosystems
Lake Trophic State Index

Because the components of condition vary naturally, condition is most often defined as a trend in concentrations or as concentrations relative to standards adopted by state agencies or set by EPA. Only a few programs collect information on the condition of waters at a national scale. One of the most widespread among these programs is EPA's state data collection and reporting program, mandated under Section 305(b) of the Clean Water Act (CWA), and the associated biennial National Water Quality Inventory (NWQI). At this time, however, these data cannot be used to produce a national indicator that can answer this question with sufficient confidence and scientific credibility because the programs vary greatly from state to state in the:

- Percentage of waters assessed.
- Monitoring approaches used.

- Water quality standards upon which the assessments are based.
- Water quality characteristics measured in those assessments.

The CWA vests responsibility in states, territories, and tribes to assess the health of their waters at least every two years. The purpose of these assessments is to determine if the water quality in different areas is supporting "designated uses," which are defined under state procedures and approved by EPA. Typical state designated uses include aquatic life protection, drinking water supplies, fish and shellfish consumption, recreation, and agricultural, industrial, and domestic uses. Because of the high cost of monitoring, states, territories, and tribes typically collect data and information for only a portion of their waterbodies. Their programs and sampling techniques differ. Compounding these differences is the fact that states also have the responsibility to set water quality standards, many of which differ between states. States monitor water quality to identify and address problems, and they often place a higher priority on immediate management concerns than on characterizing all their water resources. These issues limit the ability to use CWA-mandated state data to describe water quality conditions at the national level.

Two indicators, "altered fresh water ecosystems" and "lake trophic state," partially address the question of the quality of the nation's waters. These indicators are somewhat limited at this time, but they do show that 23 percent of fresh water resources have been altered physically to some degree and that 22 percent of northeastern U.S. lakes exhibit eutrophic conditions.

In addition to the CWA 305(b) reporting program, several other existing programs also contribute to our understanding of the condition of aquatic resources:

The U.S. Geological Survey's (USGS's) National Water Quality Assessment (NAWQA) program is a perennial program designed to provide consistent descriptions of the status and trends of some of the largest and most important streams and aquifer systems of the nation and to link the status and trends to the natural and human factors that affect water quality. The program involves physical, chemical, and biological assessments of 42 large hydrologic systems, which are conducted on staggered 10-year cycles. These assessments include targeted sampling designs to measure stream flow, habitat, water, sediment, and tissue chemistry, and to characterize algae, invertebrate, and fish communities. NAWQA studies cover watersheds and aquifers contributing a high percentage of the water used in the U.S. The NAWQA program has made valuable contributions in documenting the close relationship between land use, chemicals used in watersheds (e.g., for urban/industrial or agricultural activities), and the presence and concentrations of chemicals found in streams and ground water.

EPA's Environmental Monitoring and Assessment Program (EMAP) conducts representative sampling of estuarine and stream resources and incorporates biological measures in condition estimates. Geographic coverage for fresh water resources is limited to the mid-Atlantic region and the western states. Coverage of estuarine resources has been primarily limited to coastal areas on the East Coast south of Cape Cod, in the Gulf of Mexico, and in some western states. EMAP data on biological condition have been reported for fish and macroinvertebrates in Mid-Atlantic Highland streams and for macrobenthos in East Coast and Gulf of Mexico estuaries.

The National Oceanic and Atmospheric Administration's (NOAA's) National Status and Trends program (NS&T) collects information on the chemical contamination of sediments and organisms and potential biological effects in the nation's coastal areas. Sampling of sediments and bivalves was initiated in the mid-1980s from over 250 sites along the U.S. coast in areas not considered to be heavily polluted. On a national scale, the higher levels of contamination in sediments are clearly associated with the urbanized areas of the northeast states and with areas near San Diego, Los Angeles, and Seattle on the West Coast. Except at a few sites, higher levels of sediment contamination are relatively rare in the Southeast and along the Gulf of Mexico coast.

The Natural Resources Conservation Service's (NRCS's) National Resources Inventory (NRI) is a statistically-based sample of land use and natural resource conditions and trends on U.S. non-federal lands. NRI collects data on land cover and use, soil erosion, prime farmland soils, wetlands, habitat diversity, selected conservation practices, and related resource attributes. Many of the resource inventories have recognized relationships to water quality. The NRI provides comprehensive data on land use on the 1.5 billion acres of non-federal lands which are made up of roughly equal parts of rangeland (27 percent), forest land (27 percent), and cropland (25 percent).

The U.S. Fish and Wildlife Service's (USFWS's) National Wetlands Inventory (NWI) project produces information on the characteristics and extent of the nation's wetlands that is used by the USFWS to produce status and trends reports. The Emergency Wetlands Resources Act requires USFWS to update this information at 10-year intervals. Data collected from over 4,300 randomly selected sample plots provide important long-term trend information about specific changes in wetland extent, where those changes take place, and the overall status of wetlands in the U.S.. Data are produced by the USFWS National Wetlands Inventory, which has mapped 89 percent of the conterminous U.S. USFWS results are discussed further in Section 2.2.2 of this chapter.

These programs portray a general picture of widespread fresh water and coastal wetland loss, of water quality widely impacted by stream bank habitat loss, and of chemical contamination as urban land uses and agriculture encroach into riparian areas. They show that the abundance of nutrients from agriculture and atmospheric sources impacts coastal areas, with 40 percent of estuaries exhibiting eutrophic conditions (high nutrient concentrations and algae production), and some estuaries also experiencing hypoxia (insufficient oxygen levels to support marine life) and reduced water clarity.

Pesticides from agricultural and urban areas are found widely in surface waters, and residues from past chemical uses are found in sediments and fish tissue. Mercury and mercury compounds are foremost among pollutants contaminating fish. Bacterial contamination is found throughout surface waters used for drinking, although treatment of public water supplies is an effective barrier to protect human health. Contamination of swimming beaches by bacteria, however, continues to be a concern.

An improved ability to report on the condition of surface waters will require a collaboration of states, tribal authorities, and federal agencies. This may involve a nationally coordinated program. Under Section 305(b) of the Clean Water Act, states are required to report on the condition of their waterways. This requirement could serve as a platform upon which national condition estimates could be compiled using a consistent sample design approach and comparable data collection and analysis procedures.

EPA has long sought to increase the coverage of water quality assessments made and submitted biannually in conformance with Section 305(b) of the CWA. Historically, states have employed monitoring programs with sampling methods targeted to known problem areas that exhibit well-defined point and non-point pollution sources. While these approaches are effective in relating pollution sources to water quality conditions, they cannot accurately represent both the extent and condition of water quality problems and resources. EPA issued guidance on water quality assessments in 1997 (EPA, OW, September 1997), and produced a major supplement to this guidance in 2002 (EPA, OW, July 2002). These documents describe a comprehensive assessment as an evaluation of water resources that covers a complete geographic area or resource; provides information on the resource condition and spatial and temporal trends in the resource condition; and identifies the stressors (causes) and sources of pollution. The approach to these assessments is defined as either a complete survey (census), a judgmental or targeted design, or a statistical survey (probability-based) using randomly selected sample locations that allow researchers to make valid inferences about the condition of the water resource. The targeted approach is effective for relating specific pollution sources to water condition and is used in guiding pollution abatement, whereas the statistical/census survey approaches provide a complete or representative assessment of the entire resource.

In 2000, 14 states reported that they had monitored and assessed more than 95 percent of their lakes, and 10 states reported that they had assessed at least 98 percent of their rivers. Two years. later, in 2002, three states reported that they had made these assessments using a statistically valid sampling design. Several states are engaged in multi-year studies that are adding probabilistic surveys to their assessments. Examples of states that are collecting data from statistically-based monitoring networks are described in the sidebar.

Statistically-based water quality monitoring in states: Two examples

Indiana

In its 2002 State of the Environment Report, the Indiana Department of Environmental Management (IDEM) used a statistical survey to assess stream water quality by major watersheds. Historically, IDEM assessed 6,000 to 8,000 miles of stream every two years. Beginning in 1996, 20 percent of the state's streams were sampled each year in its watershed monitoring program and then assessed for the ability to support aquatic life. The results allowed IDEM to estimate the water quality within each major water basin in the state. IDEM reports its data with 95 percent confidence. Accuracy varies between basins, but is between 11 and 16 percent.

Of the 35,430 stream miles assessed over the past five years, approximately 64.5 percent were estimated to fully support the maintenance of well-balanced aquatic communities. Fish and benthic macroinvertebrate community assessments provided a measurement of adverse response to stressors. Some of the community responses included loss of sensitive species, lack of diversity, and increase in tolerant species. As a result, several hundred stream miles were classified as not fully supporting aquatic life based on the fish and macroinvertebrate community surveyed.

Maryland

The Maryland Biological Stream Survey (MBSS) uses a probability-based survey design to assess the status of biological resources in Maryland's non-tidal streams. The state intends to:

- Characterize biological resources and ecological conditions.
- Assess the condition of these resources.
- Identify the likely sources of degradation.

The state has developed an interim framework for applying biocriteria in the state's water quality inventory (305[b] report) and list of impaired waters (303[d] list). To date, the proposed biocriteria for wadeable, non-tidal (first- to fourth-order) streams rely on two biological indicators from the MBSS; the fish and benthic indices of biotic integrity (IBIs). The approach centers on identifying impaired waterbodies at the Maryland 8-digit watershed and 12-digit subwatershed levels.

A preliminary evaluation using MBSS 2000 data was conducted to identify watersheds failing to meet the requirements of the interim biocriteria framework. For a portion of the state, three 8-digit watersheds that were assessed passed, and six were inconclusive. Of the 123 watersheds sampled at the 12-digit subwatershed level, 69 failed, 32 passed, and 22 were inconclusive.

Indicator

Altered fresh water ecosystems - Category 2

Physically altering a fresh waterbody can change its character and the benefits it provides local communities and land owners. Fresh waterbodies may be altered to increase some other benefit— for example, to control floods; improve navigation; reduce erosion; increase the available area for farming, livestock grazing, or development; and increase the amount of water available for drinking and industrial purposes. However, these alterations also change fish and wildlife habitat, disrupt patterns and timing of waterflows, serve as barriers to animal movement, and reduce or eliminate the natural filtering of sediment and pollutants. In addition, water usage, particularly in the arid West, but also in suburban areas that rely on wells, may deplete aquifers and thus cause permanent damage to the physical characteristics of surface water resources, including reduced base flows.

The altered fresh water ecosystems indicator reports the percentage of each of the major fresh water ecosystems (rivers and streams, riparian areas, wetlands, lakes, ponds, and reservoirs) that are altered. "Altered" is defined differently for each of these ecosystems:

- Streams and rivers (all flowing surface waters) are altered if they are leveed or channelized or impounded behind a dam.
- Riparian zones along rivers and streams are considered altered if they are used for urban or agricultural purposes.
- Lakes and reservoirs are considered altered if any portion of the area immediately adjacent to the shoreline is either urban or agricultural land. Since there is no agreed-upon proportion of shoreline that must be in these land use categories to classify an individual lake as "altered," this indicator simply reports the overall percentage of lake or reservoir shoreline with agricultural or urban land use in the shoreline zone. (Note that, at present, data for lakes and reservoirs are aggregated, even though a reservoir is a man-made structure or seriously altered habitat. If, in the future, natural lakes can be distinguished from reservoirs, these may be reported separately. In this case, the number or percent of natural lakes whose waterflow has been altered by damming would also be reported.)
- Wetlands are considered altered if they are excavated, impounded, diked, partially drained, or farmed (Cowardin, et al., 1979).

What the Data Show

Data reported for this indicator were produced using remote sensing imagery and the USGS stream/lake database (National Hydrography Data Set). These data characterize areas adjacent to a waterbody at a resolution of about 100 feet across. Thus, they present the general land cover surrounding a lake or stream, rather than a fine-scale picture of the exact composition of a shoreline or bank.

The available data indicate that 23 percent of the banks of both rivers and streams (riparian areas) and lakes and reservoirs have either croplands or urban development in the narrow area immediately adjacent to them. Data on the degree to which streams and rivers are channelized, leveed, or impounded are not available.

Dahl (2000) does provide some information on the extent to which wetlands are altered. For example, from 1986 to 1997:

- A total of 78,100 acres (31,600 hectares) of forested wetlands were converted to fresh water ponds.
- Human activities, such as creating new impoundments or raising the water levels on existing impoundments (thus killing the trees), created conversions to deep water lakes.
- Additionally, fresh water unconsolidated shores exhibited an 8 percent gain in acreage or about 32,000 acres (13,000 hectares). This was due, in part, to peat mining operations that removed the wetland vegetation and exposed the substrate. Because these areas were not drained, they remained wetland, but their classification was changed from "fresh water shrub bogs" to "fresh water unconsolidated shores."

Indicator Gaps and Limitations

There is no nationally aggregated database that records the number of impounded or leveed river miles. As noted above, there is also no method for calculating the extent of downstream effects of dams, other than by conducting site-specific investigations for each dam.

At present, there are no nationally aggregated databases that list whether natural lakes are dammed at their outlets. It is possible that existing databases on dam locations, such as those maintained by the U.S. Army Corps of Engineers, could be merged with other datasets, such as the National Hydrography Data Set (NHD), to derive this information.

Data on the alteration of rivers and streams are not collected in a manner that allows for aggregation to provide a national perspective.

Data Source

Data on altered wetlands are available only in paper form on a quad-sheet by quad-sheet basis. The data sources for this indicator were the:

- Multi-Resolution Land Characterization Consortium and U.S. Geological Survey National Hydrography Dataset, processed by

Indicator Altered fresh water ecosystems - Category 2 (continued)

the EPA's Office of Research and Development (National Exposure Research Laboratory).

- Department of the Interior, U.S. Fish and Wildlife Service, National Wetlands Inventory (See Appendix B, page B-9, for more information.).

Indicator Lake Trophic State Index - Category 2

Lakes can be divided into three categories based on trophic state: oligotrophic, mesotrophic, and eutrophic. These categories reflect a lake's nutrient and clarity levels.

- *Oligotrophic lakes* are generally clear, deep, and free of weeds or large algae blooms. They are low in nutrients and do not support large numbers of fish. Oligotrophic lakes often develop a food chain capable of sustaining a very desirable fishery of large game fish.
- *Eutrophic lakes* are high in nutrients and support a large biomass (all the plants and animals living in a lake). They are usually either weedy, or subject to frequent algae blooms, or both. Eutrophic lakes often support large fish populations, but are also susceptible to oxygen depletion. A subcategory, *hypertrophic lakes*, is used below to describe lakes that are extremely eutrophic (i.e., very nutrient-enriched), resulting in particularly high productivity (Peterson, et al., 1999).
- *Mesotrophic lakes* lie between the oligotrophic and eutrophic stages.

A natural aging process occurs in all lakes, causing them to change from oligotrophic to eutrophic over time. This process is accelerated by nutrient enrichment from agriculture, lawn fertilizers, streets, septic systems, and urban storm drains.

Various methods are used to calculate the trophic state of lakes. Common characteristics used to determine trophic state are: total phosphorus concentration (important for algae growth); concentration of chlorophyll *a* (a measure of the amount of algae present); and secchi disc readings (an indicator of water clarity).

No national data regarding the trophic state of lakes are available. However, regional patterns of lake trophic condition were assessed for a target population of 11,076 northeast lakes, which were sampled during the summers of 1991 to 1994 using a trophic state index based primarily on their nutrient or total phosphorus (TP) concentrations (Peterson, et al., 1999). A total of 344 lakes were sampled once.

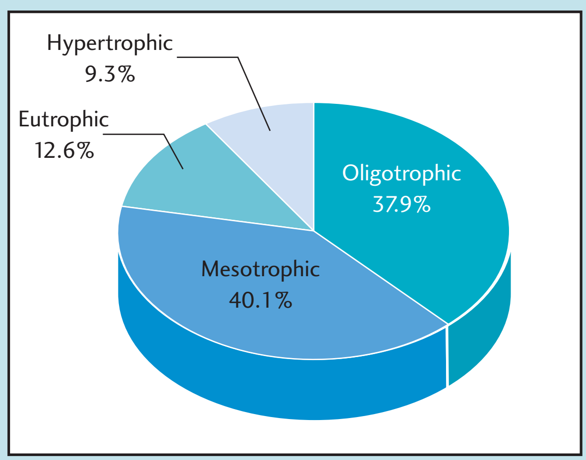
The following trophic state categories were established based on total phosphorus concentrations:

- *Oligotrophic* for nutrient poor (less than 10 parts per billion [ppb]).
- *Mesotrophic* to denote nutrient concentrations sufficient to support natural algal communities (from 10 to 30 ppb).
- *Eutrophic* for enriched nutrient conditions (from 30 to 60 ppb).
- *Hypertrophic* for very nutrient-enriched (greater than 60 ppb).

What the Data Show

The trophic state analysis (Exhibit 2-4) showed that 37.9 percent of the northeast lakes were oligotrophic, 40.1 percent were mesotrophic, 12.6 percent were eutrophic, and 9.3 percent were hypertrophic (Peterson, et al., 1999).

Exhibit 2-4: Trophic State Index for northeast lakes, 1991-1994



Source: Peterson S.A., et al. *Sample Representativeness: A Must for Reliable Regional Lake Condition Estimates.* 1999.

Indicator | Lake Trophic State Index - Category 2 (continued)

Indicator Gaps and Limitations

These data reflect a one-time sample of lakes in one region, the Northeast, and cannot be extrapolated to the national scale or provide trends data. Also, trophic status in and of itself does not necessarily imply that water quality problems exist (i.e., that oligotrophy is a common natural state).

Data Source

The data source for this indicator was the Environmental Monitoring and Assessment Program Lakes Data Set. (See Appendix B, page B-9, for more information.)

2.2.2 What are the extent and condition of wetlands?

Indicators

Wetland extent and change
Sources of wetland change/loss

When European settlers first arrived, wetland acreage in the area that would become the 48 states was more than 220 million acres, or about five percent of the total area of the conterminous U.S. More than one-half of the wetlands in the conterminous U.S. have been lost or converted to other uses since pre-colonial times. However, in as little as four recent decades, the rate of wetland loss has declined dramatically, from about 500,000 acres per year to less than 100,000 acres per year (Dahl, 2000). By 1997, total wetland acreage was estimated to be 105.5 million acres (Dahl, 2000). Almost 50 percent of wetland loss occurring in the 1990s was due to conversion to urban and suburban development.

Wetland ecosystems are areas that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support (and that under normal circumstances do support) a prevalence of vegetation typically adapted for life in saturated soil conditions. There are different types of wetlands, including: fresh water wetlands, inland wetlands, and coastal wetlands (see glossary for definitions). These habitats provide many benefits to humans and ecological systems. For example, wetland habitats are critical to the life cycles of many plants and fish, shellfish, migratory birds, and other wildlife. They provide essential breeding habitat for roughly one-quarter of all North American breeding bird species (Davis, 2000). In 1997, it was estimated that 81 percent (72 species) of the U.S. bird species on the Endangered Species List were dependent on or associated with wetlands (Day Boylan and MacLean, 1997).

An estimated 95 percent of commercial fish and 85 percent of sport fish spend a portion of their life cycles in coastal wetland and estuarine habitats. Adult stocks of commercially harvested shrimp, blue crab, oysters, and many other species throughout the U.S. (EPA, ORD, OW, September 2001) are directly related to wetland quality and quantity (EPA, OW, OWOW, March 2002). More than half of all U.S. adults (98 million people) hunt, fish, birdwatch, or photograph wildlife (USFWS, 2002). Many of these activities are associated with healthy wetlands.

Wetlands also filter residential, agricultural, and industrial wastes, thereby improving surface water quality. They buffer coastal areas against storm and wave damage. Wetlands function as natural sponges that trap and slowly release surface water, rain, snowmelt, ground water, and flood waters. Trees, root mats, and other wetland vegetation also slow the speed of flood waters and distribute them more slowly over the floodplain. This combined water storage and braking action lowers flood heights and reduces erosion. Wetlands within and downstream of urban areas are particularly valuable, counteracting the greatly increased rate and volume of surface water runoff from pavement and buildings. The holding capacity of wetlands helps control floods and prevents water logging of crops. Preserving and restoring wetlands can often provide the level of flood control otherwise provided by expensive dredge operations and levees. For example, the bottomland hardwood-riparian wetlands along the Mississippi River once stored at least 60 days of flood water. Now these wetlands store only 12 days of flood water because most have been filled or drained (EPA, OW, December 1995).

Wetlands are diverse. Inland wetlands are most common on floodplains along rivers and streams (riparian wetlands), in isolated depressions surrounded by dry land (e.g., playas, basins, and "potholes"), along the margins of lakes and ponds, and in other low-lying areas where the ground water intercepts the soil surface or where precipitation sufficiently saturates the soil (e.g., vernal pools and bogs). Inland wetlands include marshes and wet meadows dominated by herbaceous plants, swamps dominated by shrubs, and wooded swamps dominated by trees. Many wetlands are seasonal (i.e., they are dry one or more seasons every year). In fact, particularly in the arid and semiarid West, wetlands may be wet only periodically. The quantity of water present and the timing of its presence in part determine the functions of a wetland and its role in the environment. Even wetlands that appear dry at times for significant parts of the year, such as vernal pools, often provide critical habitat for wildlife adapted to breeding exclusively in these areas.

Coastal wetlands in the U.S. are found along the Atlantic, Pacific, Alaskan, and Gulf coasts. They are closely linked to our nation's estuaries, where sea water mixes with fresh water to form an environment of varying salinities. Certain grasses and grasslike plants that adapt to the saline conditions form the tidal salt marshes that are found along the Atlantic, Gulf, and Pacific coasts. Mangrove swamps, with salt-loving shrubs or trees, are common in tropical climates, such as in southern Florida and Puerto Rico. Some tidal fresh water wetlands form beyond the upper edges of tidal salt marshes where the influence of salt water ends.

An indicator related to wetland extent has been identified to address the question "What are the extent and condition of wetlands?" This indicator is discussed on the following pages. No indicators for the biological condition of wetlands are being implemented nationally or regionally at this time, and none were recommended for inclusion in this report. However, wetland extent can partially serve as a surrogate to address wetland condition. This is because the loss of wetlands in the landscape negatively impacts the condition of the remaining wetlands by decreasing both the connectivity among aquatic resources and the landscape heterogenity.

Indicators of wetland condition are being developed and implemented by some states, but not on a broad-scale basis. States have been developing assessment methods for a variety of organisms in multiple wetland types, including macroinvertebrates, algae, amphibians, and vegetation (Danielson, 1998). These indicators and an assessment process will be necessary to ensure that both wetland extent and condition can be properly described in the future.

Indicator Wetland extent and change - Category 1

Two programs, the USFWS NWI status and trends studies and the NRCS NRI, estimate wetland extent. The USFWS surveys all wetlands in the conterminous U.S. The NRI surveys wetlands on non-federal lands, which make up approximately 75 percent of the nation's land base. The methods employed differ, but the statistical results from the most recent survey period were not significantly different. USFWS data are used for the "wetland extent and change" indicator due to their broader coverage. This indicator is derived from three separate analyses: one covering the 1950s to the 1970s; one covering the 1970s to 1980s, and one covering the 1980s to the 1990s.

The USFWS counts all wetlands every 10 years, regardless of land ownership, but only recognizes wetlands that are at least three acres. A permanent study design is used, based initially on stratification of the 48 conterminous states by state boundaries and 35 physiographic subdivisions. Within these subdivisions are 4,375 randomly selected, four-square-mile (2,560 acres) sample plots. These plots were examined with the use of aerial imagery, ranging in scale and type; most were 1:40,000 scale, color infrared, from the National Aerial Photography Program.

Field verification was conducted to address questions of image interpretation, land use coding, and attribution of wetland gains or losses; plot delineations were also completed. For example, for the 1980s to 1990s analysis, 21 percent of the sample plots were verified.

What the Data Show

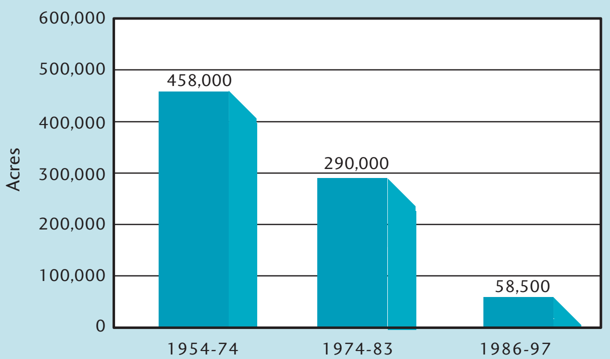
When European settlers first arrived, wetland acreage in the area that would become the 48 states was more than 220 million acres, or about five percent of the total area of the conterminous U.S. Since then, extensive losses have occurred, and over half of our original wetlands have been drained and filled. By 1997, total wetland acreage was estimated to be 105.5 million acres (Dahl, 2000). Of that total, nearly 95 percent or 100.2 million acres were fresh water and about five percent or 5.3 million acres were intertidal marine and estuarine. Between 1986 and 1997, 98 percent of all wetland losses in the conterminous U.S. were fresh water wetlands.

Rates of annual wetland losses have been decreasing from almost 500,000 acres a year three decades ago to less than 100,000 acres, averaged annually since 1986 (Exhibit 2-5). The USFWS estimated the annual rate of loss at 58,500 acres per year between 1986 and 1997. This represents an 80 percent reduction compared to the previous decade's rate of loss. The slower rate of wetland loss is due to several factors, including:

- Federal farm policies that discourage drainage and encourage restoration.
- More effective government regulation.
- Better land stewardship.
- Acquisition and protection of sensitive environmental areas.
- More state, tribal, and local involvement in wetland protection programs.

Indicator Wetland extent and change - Category 1 (continued)

Exhibit 2-5: Average annual wetland loss, 1954-1974, 1974-1983, 1986-1997



Coverage: Conterminous United States

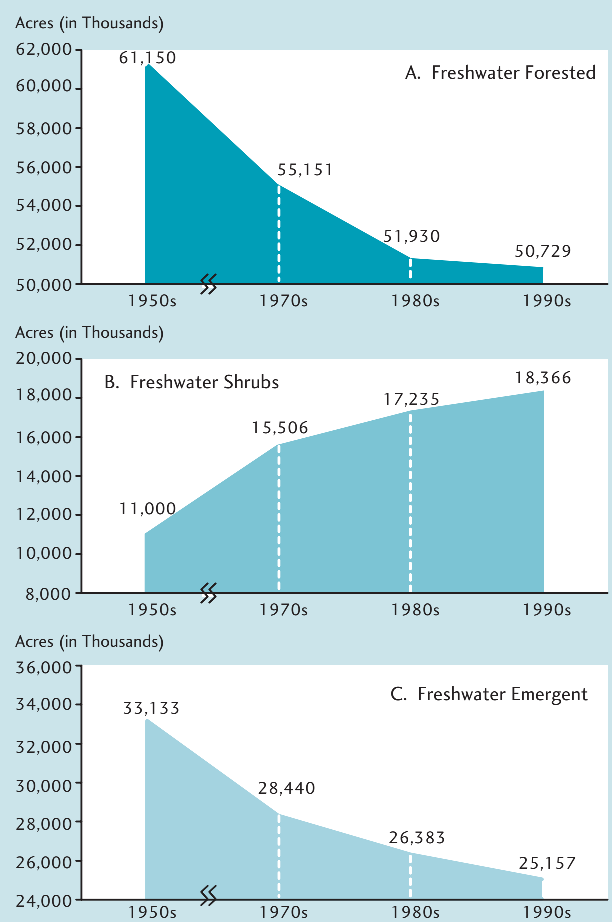
Source: Frayer et al. *Status and Trends of Wetlands and Deepwater Habitats in the Conterminous United States, 1950s to 1970s*. 1983; Dahl, T.E. and C. E. Johnson. *Wetlands Status and Trends in the Conterminous United States: 1970s to 1980s*. 1991; Dahl, T. E. *Status and Trends of Wetlands in the Conterminous United States 1986 to 1997*. 2000.

In addition to loss of wetland acreage, a major ecological impact has been the conversion of one wetland type to another, such as clearing trees from a forested wetland or excavating a shallow marsh to create an open water pond. Open water ponds have more than doubled in area since the 1950s and are not the ecological equivalent of fresh water emergent marshes. These types of conversions change habitat types and community structure in watersheds and impact the animal communities that depend on them.

Wetland types include fresh water forested, shrub, and emergent wetlands, plus open water ponds. Forested and emergent wetlands make up over 75 percent of all fresh water wetlands. Since the 1950s, fresh water emergent wetlands have declined by nearly 24 percent—more than any other fresh water wetland type. Fresh water forested wetlands have sustained the greatest overall losses—10.4 million acres since the 1950s (Exhibit 2-6).

Coastal wetlands are the vegetated interface between aquatic and terrestrial components of estuarine ecosystems. Estuarine emergent wetlands account for nearly 75 percent of coastal wetlands. The loss of coastal wetland habitats in the U.S. is significant (Exhibit 2-7). Since the 1950s, coastal and estuarine losses were about 1.4 million acres–a nearly 12 percent decline. Emergent and forested intertidal wetlands experienced the greatest absolute and proportional losses during this four-decade measurement period. Proportional losses along the West Coast have been the largest (68 percent), although the actual number of acres lost there is among the smallest. Absolute and proportional acreages lost in the Great Lakes and Gulf of Mexico are also high (about 50 percent of wetlands that existed in pre-colonial times). Even in more recent years (mid- to late 1990s), wetland losses in southeastern and Gulf of Mexico states continue at a high rate—more than one percent per year.

Exhibit 2-6: Long-term trends in selected freshwater wetlands, 1954-1997

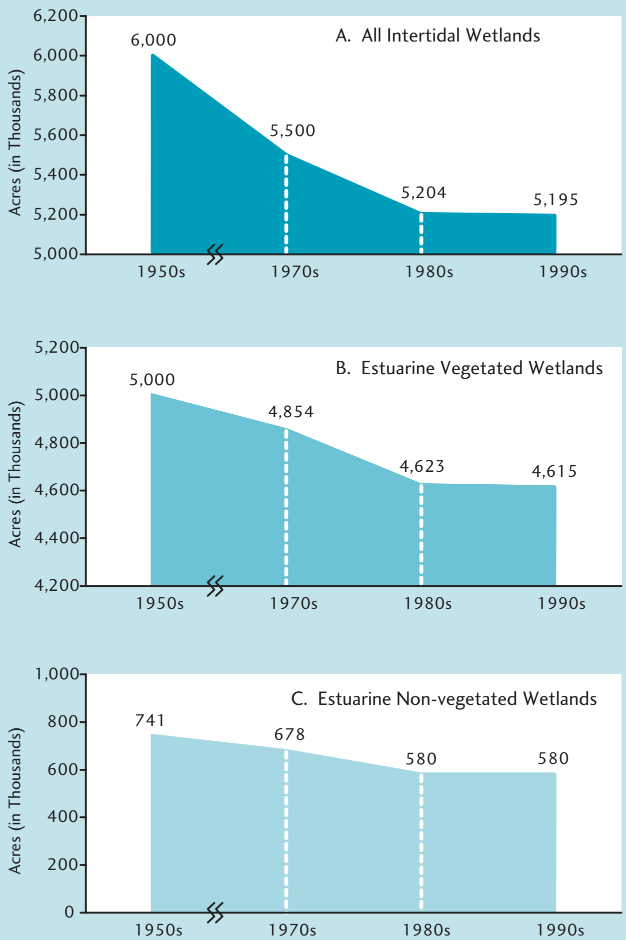


Coverage: Conterminous United States

Source: Frayer et al. *Status and Trends of Wetlands and Deepwater Habitats in the Conterminous United States, 1950s to 1970s*. 1983; Dahl, T.E. and C. E. Johnson. *Wetlands Status and Trends in the Conterminous United States: 1970s to 1980s*. 1991; Dahl, T. E. *Status and Trends of Wetlands in the Conterminous United States 1986 to 1997*. 2000.

Indicator | Wetland extent and change - Category I (continued)

Exhibit 2-7: Long-term trends in selected estuarine wetlands, 1954-1997



Coverage: Conterminous United States

Source: Frayer et al. *Status and Trends of Wetlands and Deepwater Habitats in the Conterminous United States, 1950s to 1970s*. 1983; Dahl, T.E. and C. E. Johnson. *Wetlands Status and Trends in the Conterminous United States: 1970s to 1980s*. 1991; Dahl, T. E. *Status and Trends of Wetlands in the Conterminous United States 1986 to 1997*. 2000.

Indicator Gaps and Limitations

This indicator does not effectively address the question of wetland condition. While it is possible to inventory wetlands that have been lost, many wetlands have suffered degradation of condition and functions, which cannot be quantified nationally.

Different methods were used in some of the early classification schemes to classify wetland types. The currently used classification system was not applied to some of the earlier (1970s) maps. As methods and spatial resolution have improved over time, acreage data were adjusted, resulting in changes in the overall wetland base over time. Thus, the evaluation process is evolving, which contributes to reducing the accuracy of the trends observed.

Forested wetlands are difficult to photointerpret and are generally underestimated by the USFWS. Ephemeral wetlands and effectively drained palustrine wetlands observed in farm production are not recognized as a wetland type by the USFWS and, therefore, are not included. Also, USFWS does not survey wetlands under 3 acres in size; therefore, no record exists of the extent and change in these valuable resources. Pacific coast estuarine wetlands are not surveyed due to the discontinuity in their patch sizes. The temporal coverage of the coastal wetland loss indicator (length of record) is not consistent across the U.S.

Data Source

The data for this indicator are from the Department of the Interior, U.S. Fish and Wildlife Service, Status and Trends Report. (See Appendix B, page B-9 for more information.)

Indicator | Sources of wetland change/loss - Category 2

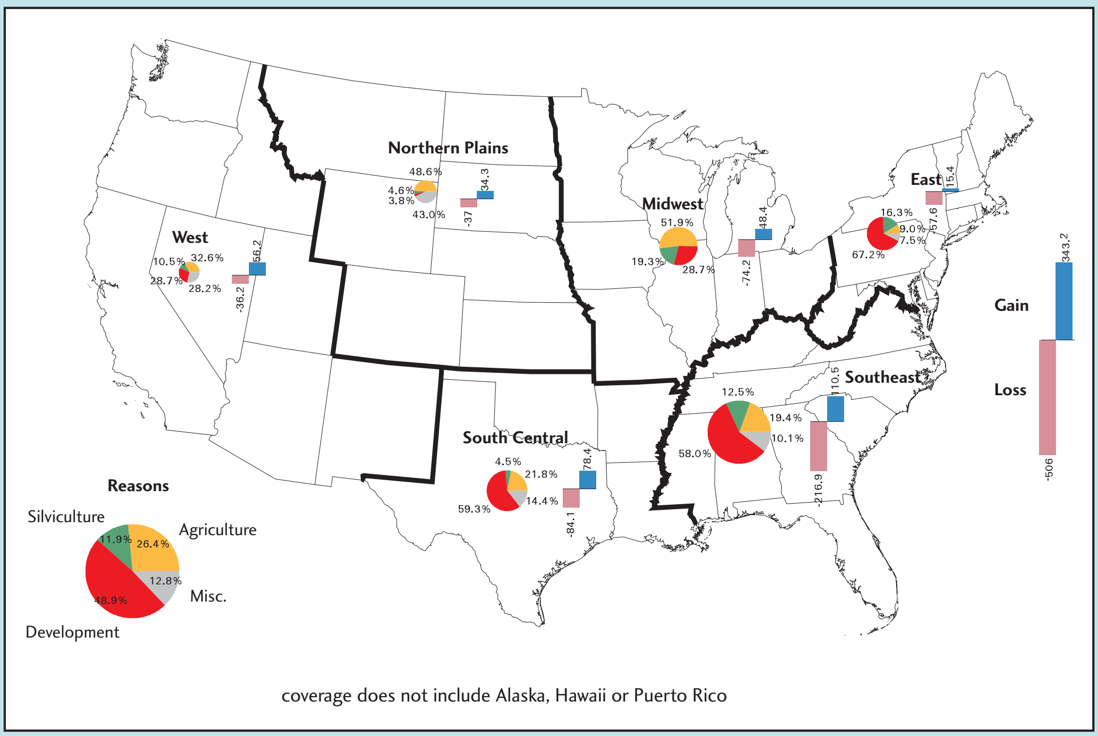
This indicator attempts to estimate the causes or sources of wetland losses. The extensive survey data collected in the NRI by the USDA's Natural Resources Conservation Service in cooperation with the Iowa State University Statistical Laboratory provides land use information that can be associated with estimates of wetland extent. This database is a compilation of natural resource information on non-federal land, which comprises nearly 75 percent of the nation's total land area. The 1997 NRI captures data on land cover and use, soil erosion, prime farmland soils, wetlands, habitat diversity, selected conservation practices, and related resource attributes at over 300,000 primary sample units (nominally 160 acres each) containing over 800,000 sample points.

Data used for the NRI were collected using a variety of imagery, field office records, historical records and data, ancillary materials, and a limited number of on-site visits. The data have been compiled, verified, and analyzed to provide a comprehensive look at the state of the nation's non-federal lands.

What the Data Show

According to the USDA Agricultural Research Service, between 1954 and 1974, agriculture accounted for 81 percent of all wetlands conversions. As a result of changing federal agricultural policies that emphasize wetlands conservation, agriculture accounted for only 20 percent of national wetlands conversion between 1982 and 1992 (USDA, 2000). In surveys conducted between 1992 and 1997, NRI determined that 506,000 acres of wetlands on non-federal lands were lost, while 343,000 were gained, for a net loss of 163,000 acres. Agriculture accounted for 26 percent of the net national wetlands loss for this survey period, although this varies by region. For example, in the Midwest and northern plains, about 50 percent of the losses were from agriculture (Exhibit 2-8). Since the mid–to late 1980s, urban, suburban, and commercial development have been the major contributors to net losses of wetland resources and were responsible for 49 percent of those losses. The East, Southeast, and South Central states had the highest percentages of wetland losses due to development. In the East, 67 percent of the wetland losses were a result of development (USDA, 2000). Timber harvesting practices and conversion of land to silvicultural uses

Exhibit 2-8: Non-Federal wetland losses and gains and reasons for conversion, 1992-1997



Source: *Summary Report: 1997 National Resources Inventory (Revised December 2000)*. 2000.

Indicator Sources of wetland change/loss - Category 2 (continued)

have also contributed to losses in wetland resources. The NRI analysis attributed 12 percent of the wetland losses between 1992 and 1997 to silviculture.

Using different methods, the USFWS reported a similar result from 1986 to 1997: 30 percent of wetland losses were attributed to urban development; 21 percent to rural development; 23 percent to silviculture; and 26 percent to agriculture (Dahl, 2000).

Indicator Gaps and Limitations

The differences in survey design between NRI and USFWS will continue to cause difficulties in assessing the effectiveness of current wetlands policies. The USFWS data are gathered from interpretation of aerial imagery and remotely sensed data, and are repeated every 10 years. The NRI data are based on statistical sampling, but do not include an adequate sample of coastal resources. They provide information at a coarse scale, summarized by state, and are useful for national reporting. The NRI does not collect data on federal lands or for the state of Alaska.

Data Source

Data for this indicator come from the U.S. Department of Agriculture, National Resources Inventory (2000).
(See Appendix B, page B-10, for more information.)

2.2.3 What is the condition of coastal waters?

Indicators

Water clarity in coastal waters
Dissolved oxygen in coastal waters
Total organic carbon in sediments
Chlorophyll concentrations

Coastal waters—the interface between the land and the sea—provide a wide range of habitats for animals and plants essential to global ecosystems, and they support the majority of commercial and recreational fisheries in the U.S. Coastal waters also contain significant energy and mineral reserves, travel lanes for shipping, and a base for outdoor recreation and tourism industries (EPA, ORD, OW, September 2001).

Coastal waters include estuaries—bodies of water that are balanced by fresh water and sediment influx from rivers and tidal action of the oceans. They provide a transition zone between fresh water and saline water. Estuaries are unique environments that support wildlife and fisheries and contribute substantially to the economy of coastal areas. These natural areas are under the most intense development pressure in the nation. This narrow fringe accounts for only 17 percent of the total conterminous U.S. land area, but is home to more than 53 percent of the population. Today, that proportion is growing faster than in any other area of the U.S. (NRC, 2000).

Four indicators have been selected to address the condition of coastal waters: water clarity, dissolved oxygen content, organic carbon content of sediments, and chlorophyll concentrations. The first three—water clarity, dissolved oxygen, and organic carbon content—are derived from EPA's EMAP, which samples estuaries using a probability- based design.

For water clarity and dissolved oxygen, estuaries in the East, West, and Gulf of Mexico coast are well represented. These two indicators, as reported in EPA's Coastal Condition Report (EPA, ORD, OW, September 2001), show that water clarity and oxygen conditions are good. Organic carbon data indicate that 16 percent of the area of mid-Atlantic estuaries have enriched carbon levels. About 33 percent of the mid-Atlantic estuarine area had chlorophyll concentrations exceeding the Chesapeake Bay restoration goal for survival of submerged aquatic vegetation. Coastal waters overall exhibited much lower chlorophyll concentrations. Chlorophyll concentrations were the most pronounced in the Gulf of Mexico.

Eutrophication is also an important parameter for understanding the condition of coastal waters; however, insufficient data were available to develop a scientifically robust indicator for this parameter at the national level. Eutrophication is discussed following the indicator descriptions.

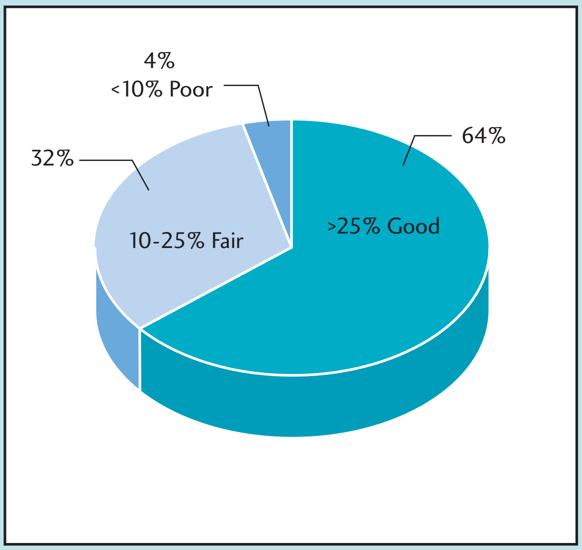
Indicator

Water clarity in coastal waters - Category 2

Light penetration is an important characteristic of many estuarine and coastal habitats. Reduced penetration is often associated with eutrophic conditions, algal blooms, and erosional events. Reduced clarity can impair the normal algal growth that contributes to oligotrophy and the extent and vitality of submerged aquatic vegetation. This is a critical habitat component for many aquatic animals.

For purposes of this indicator, water clarity is defined as a measure of light penetration (i.e., the amount and type of light reaching a one - meter water depth compared to the amount and type of light at the water's surface). Data were collected using a point-in-time measurement with a transmissometer, which estimates light transmission. Measurements were made at one meter below the water's surface. EPA in its Coastal Condition Report describes light penetration less than 10 percent of the amount of light incident at the surface is considered to represent poor conditions. Light penetration greater than 25 percent of that at the surface is deemed good.

Exhibit 2-9: Estuarine area with good (>25% of light incident at the surface), fair (between 25 and 10% of incident light), and poor (<10% of incident light) light penetration, 1990 – 1997



Coverage: United States east coast (excluding waters north of Cape Cod), west coast, and Gulf of Mexico

Source: EPA, Office of Research and Development and Office of Water. *National Coastal Condition Report.* September 2001.

What the Data Show

The overall water clarity of the nation's estuaries is rated as good (EPA, ORD, OW, September 2001). That is, 25 percent of light incident at the surface penetrates to a depth of one meter. That condition existed at 64 percent of the estuarine areas assessed. Poor light penetration is a problem in only about four percent of estuarine waters (Exhibit 2-9).

Indicator Gaps and Limitations

Sampling generally occurred during an EMAP-defined index period (summer months) as a point-in- time measure. While eutrophic stress is expected to be highest during warmer months, episodic algal blooms or runoff/erosional events would likely not occur during this timeframe.

Turbid waters are a natural characteristic of many estuaries (e.g., upper Chesapeake Bay, Albermarle-Pamlico Sound), and low light penetration conditions are not necessarily associated with impaired aquatic health. This indicator does not account for naturally turbid conditions and will rate those areas as "poor," reflecting degraded water quality.

Data Source

Water clarity data are from EPA's Environmental Monitoring and Assessment Program Estuaries database. (See Appendix B, page B-10, for more information.)

Indicator Dissolved oxygen in coastal waters - Category 2

Dissolved oxygen (DO) is a fundamental requirement for all estuarine life. Low levels of oxygen often accompany the onset of severe bacterial degradation, sometimes resulting in algal scums, fish kills, and noxious odors, as well as loss of habitat and aesthetic values. Often, low dissolved oxygen occurs as a result of the process of decay of large algal blooms whose remnants sink to the bottom. Concentrations of oxygen below about 2 parts per million are thought to be stressful to estuarine organisms (Diaz and Rosenberg, 1995; EPA, OW, October 2000).

Under EPA's EMAP, data were collected generally at one-meter above the bottom using electronic DO meters. In some cases, data were point-in-time measurements taken once during the summer months (e.g., in the Virginian Province), while in other cases data were predominantly collected by continuous readings over a multiple day/time period (e.g., in the Louisianian Province). Values of dissolved oxygen were classified into three condition categories:

- Poor: less than 2 parts per million (ppm)
- Fair: between 2 and 5 ppm
- Good: greater than 5 ppm

What the Data Show

Dissolved oxygen conditions in the nation's estuaries are reported by EPA, ORD, OW (September 2001) in its Coastal Condition Report as "good" because 80 percent of the estuarine waters assessed exhibited dissolved oxygen at concentrations greater than five ppm. Both EMAP and NOAA's National Eutrophication Assessment examined the extent of estuarine waters with low dissolved oxygen. EMAP estimates that only about four percent of bottom waters have low dissolved oxygen (Exhibit 2- 10). However, low dissolved oxygen is a problem in some individual estuarine systems like the Neuse River Estuary and parts of the Chesapeake Bay.

Hypoxia resulting from anthropogenic activities is a relatively local occurrence in Gulf of Mexico estuaries, accounting for about 4 percent of the total area, however, hypoxia in the shelf waters of the Gulf of Mexico is more significant. The Gulf of Mexico hypoxia zone is the largest anthropogenic coastal hypoxic area in the western hemisphere (CAST, 1999). Since 1993, mid-summer bottom water hypoxia in the northern Gulf of Mexico has been larger than 3,860 square miles (except in 2000). In 1999, it reached over 7, 700 square miles (CENR, 2000).

Indicator Gaps and Limitations

Coverage of the nation's coastline is limited. Probabilistic surveys like those in the Northeast, the Southeast, and the Gulf Coast do not exist for areas north of Cape Cod or for the Great Lakes. Similar probabilistic data do not exist for Puget Sound or San Francisco Bay.

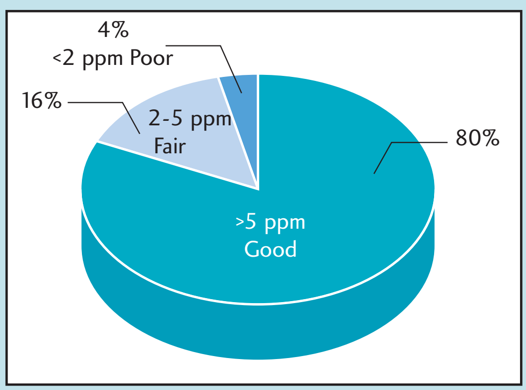
The relationship between threshold values and effects on aquatic life is neither well established nor expected to be consistent across all regions. For example, warm water environments would be naturally lower in DO. The criteria of two ppm might not be sufficiently protective in cold water environments. Much of the data apparently represent point-in-time measures. If so, the data contain limitations, and the length of time that dissolved oxygen concentrations were below two ppm would not have been considered.

The data set incorporates a mix of time series and point-in-time measures based on historical data sets collected. Where time series data are available and used, better estimates of oxygen conditions would be achieved. Point-in-time measures are weaker. Since only one season, the summer, was generally represented, oxygen stress in other seasons would be missed.

Data Source

Dissolved oxygen data used for this indicator are from the EPA's Environmental Monitoring and Assessment Program Estuaries database. (See Appendix B, page B-10, for more information.)

Exhibit 2-10: Estuarine area with poor (<2 ppm), fair (between 2 and 5 ppm), and good (>5 ppm) dissolved oxygen conditions, 2000



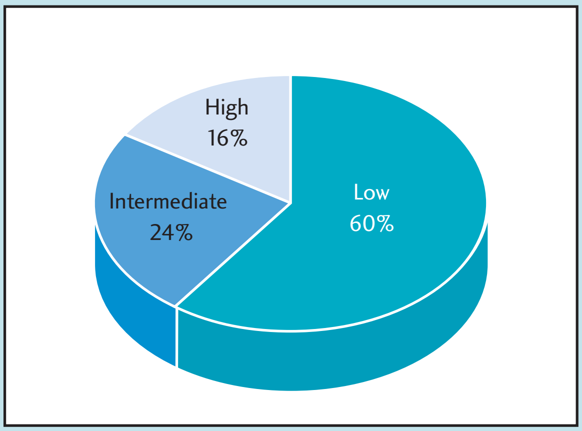
Coverage: United States east coast (excluding waters north of Cape Cod), west coast, and Gulf of Mexico

Source: EPA, Office of Research and Development and Office of Water. *National Coastal Condition Report.* September 2001.

Indicator Total organic carbon in sediments - Category 2

Total organic carbon (TOC) is a measure of the concentration of organic matter in sediments. It represents the long-term, average burial rate of organic matter in the sediments. High TOC values can arise from frequent algal blooms in the overlying waters or transport of sewage or high organic waste from point sources. TOC can also sequester or chelate organic compounds and some metals and make them less biologically available for uptake.

Exhibit 2-11: Percentages of Mid-Atlantic estuarine area with low, intermediate, and high total organic carbon content in sediments, 1997-1998



Note: High is > 3%; Intermediate is >1 to 3%; Low is ≤1%

Source: EPA, Office of Research and Development. *Mid-Atlantic Integrated Assessment, MAIA - Estuaries 1997-98, Summary Report.* May 2003.

TOC values are calculated as percent carbon in dried sediments. Assessment categories for the Mid-Atlantic estuaries were:

- Low: 1 percent
- Intermediate: >1 to 3 percent
- High: >3 percent

What the Data Show

Carbon values ranged from 0.02 to 13 percent throughout the mid-Atlantic estuaries (Paul, et al., 1999). For the mid-Atlantic region, about 60 percent of the estuarine sediments had low TOC values, about 24 percent had intermediate TOC values, and 16 percent had high TOC sediment values (EPA, ORD, May 2003); (Exhibit 2-11). Values ranged from Delaware Bay with about 95 percent of its sediments having low TOC values to the Chowan River in the Albemarle-Pamlico Estuary with 65 percent of its sediments having high TOC values (EPA, ORD, May 2003). The Chesapeake Bay mainstem had about 65 percent of its sediments with low TOC values and about 15 percent with high TOC values.

Indicator Gaps and Limitations

These data are from a survey of mid-Atlantic estuaries and cannot be extrapolated to national-scale estimates. Samples were collected during an EMAP-defined index period of summer months.

Data Source

The total organic carbon data for this indicator come from EPA's Environmental Monitoring and Assessment Program, Mid-Atlantic Integrated Assessment (MAIA) Estuaries Program. (See Appendix B, page B-10, for more information.)

Indicator Chlorophyll concentrations - Category 2

Chlorophyll concentrations are a measure of the abundance of phytoplankton. Phytoplankton account for most of the plant production in the ocean. Excessive growth of phytoplankton, as measured through chlorophyll concentrations, can lead to degraded water quality, such as noxious odors, decreased water clarity, oxygen depletion, and harmful algal blooms. Excess phytoplankton growth is usually associated with increased nutrient inputs (e.g., watershed or atmospheric transport, upwelling) or a decline in filtering organisms such as clams, mussels, or oysters (The Heinz Center, 2002).

Indicator Chlorophyll concentrations - Category 2 (continued)

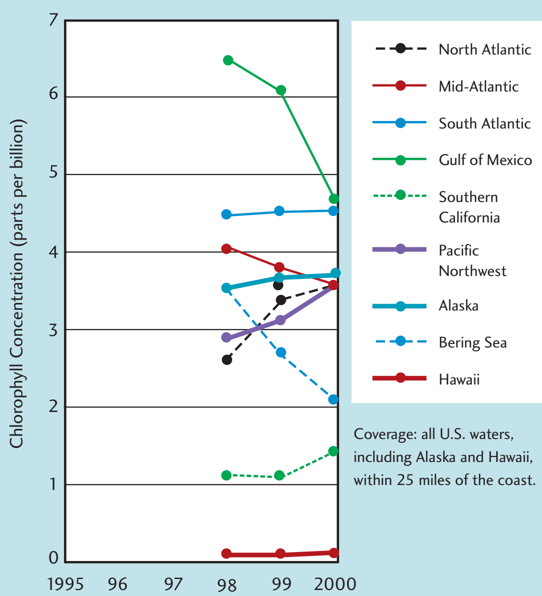
Chlorophyll concentrations were considered for both estuarine and ocean waters within 25 miles of the coast (The Heinz Center, 2002). Three categories of concentrations were established by EPA for mid-Atlantic estuaries:

- Good: 15 ppb
- Fair: 15-30 ppb
- Poor: > 30 ppb

The lower threshold of 15 ppb chlorophyll is equal to the restoration goal recommended for the survival of submerged aquatic vegetation (SAV) in Chesapeake Bay (Batiuk, et al., 2000).

For ocean waters, the indicator reports the average value for the season, displaying the highest concentrations for each region. Estuarine chlorophyll concentrations are not available for national reporting. Ocean data, based on surface reflectance, were inferred from National Aeronautics and Space Administration's (NASA's) Sea-viewing Wide Field-of-View-Sensor. Data were analyzed for nine ocean regions by NOAA's National Ocean Service. The estuarine chlorophyll concentrations were obtained from field measurements as part of the EPA EMAP Mid-Atlantic Estuaries Program.

Exhibit 2-12: Chlorophyll concentrations in U.S. coastal waters, 1998-2000



Source: Modified from The Heinz Center. *The State of the Nation's Ecosystems. 2002.* Data from National Oceanic and Atmospheric Administration, National Ocean Service.

What the Data Show

Analysis of the data showed that:

- Ocean chlorophyll concentrations ranged from average seasonal concentrations of 0.1 to 6.5 ppb (Exhibit 2-12) (The Heinz Center, 2002).
- The highest ocean chlorophyll concentrations (4.8 to 6.5 ppb) occurred in the Gulf of Mexico, with the lowest concentrations (0.1 ppb) in Hawaiian waters (Exhibit 2-12).
- Southern California had the next lowest chlorophyll concentrations—between 1.1 and 1.5 ppb (Exhibit 2-12).
- Other ocean waters (e.g, north, mid-, and south Atlantic, and the Pacific Northwest) had chlorophyll concentrations ranging from 2 to 4.5 ppb (Exhibit 2-12).
- Chlorophyll concentrations in the mid-Atlantic estuaries ranged from 0.7 to 95 ppb in 1997 and 1998 (EPA, ORD, May 2003).
- About 33 percent of the mid-Atlantic estuarine area had chlorophyll concentrations exceeding 15 ppb.
- The Delaware Estuary showed a wide range of chlorophyll concentrations, from a low (< 15 ppb) in the Delaware Bay, to intermediate (15-30 ppb) in the Delaware River, to very high (> 80 ppb) in the Salem river.
- The western tributaries to the Chesapeake Bay were consistently high in chlorophyll *a*, with more than 25 percent of the area showing > 30 ppb chlorophyll concentrations.
- Chlorophyll concentrations in the coastal bays were generally low (< 15 ppb), even though nutrients were elevated because of increased turbidity and low light penetration.

Indicator Gaps and Limitations

Algorithms used to translate spectral reflectance data into chlorophyll concentrations currently provide only rough estimates of concentrations in those waters where concentrations of suspended sediments and colored dissolved organic matter are high (e.g., near-shore waters influenced by surface and ground water discharges, coastal erosion, and sediment resuspension).

The data presented here are based on a fairly coarse scale (six-mile resolution). Currently, data showing relative changes in chlorophyll within a region can be reliable; however, data showing actual concentrations for any given region might vary by a factor of two. Thus, unless differences are large, meaningful comparisons between regions are not yet possible.

The mid-Atlantic estuary data are one-time estimates of chlorophyll content in mid-Atlantic estuaries only, so these data cannot be projected to the national scale or to different time periods. Samples were

Indicator Chlorophyll concentrations - Category 2 (continued)

collected during an EMAP-defined index period of summer months and do not represent conditions at different times.

Data Source

Ocean data are found in the National Aeronautics and Space Administration's Sea-Viewing Wide Field-of-View Sensor. Estuarine chlorophyll concentrations are found in the EPA's Environmental Monitoring and Assessment Program, Mid-Atlantic Integrated Assessment (MAIA) Estuaries Program. (See Appendix B, page B-11, for more information.)

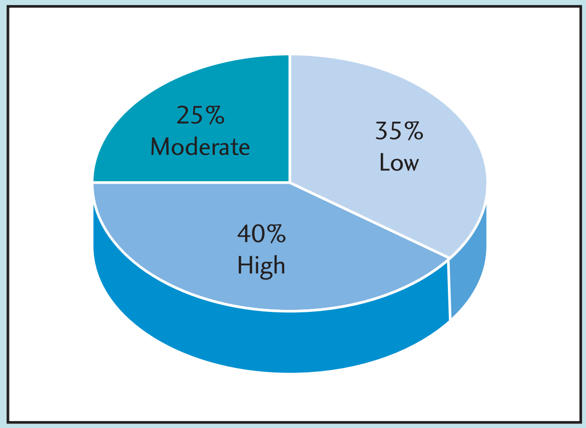
Additional Consideration: Eutrophication

Another key issue relevant to understanding the condition of coastal waters is eutrophication. Eutrophication is a natural process, through which there is "an increase in the rate of supply of organic matter" to a waterbody (Nixon, 1995). This process usually represents an increase in the rate of algal production. Under natural conditions, algal production is influenced by a gradual buildup of plant nutrients in ecosystems over long periods of time and generally leads to productive and healthy estuarine and marine environments. However, in recent years, human activities have substantially increased the rate of delivery of plant nutrients to many estuarine and marine areas (NRC, 2000; Peierls, et al., 1991; Turner and Rabalais, 1991). As a result, algal production in many estuaries has increased much faster than would occur under natural circumstances. This accelerated algal production is referred to as "cultural" or "anthropogenic" eutrophication and often results in a host of undesirable conditions in estuarine and marine environments.

These conditions, which include low dissolved oxygen concentrations, declining sea grasses, and harmful algal blooms, might impact the uses of estuarine and coastal resources by reducing the success of commercial and sport fisheries, fouling swimming beaches, and causing odor problems from the decay of excess amounts of algae (NRC, 2000; Duda, 1982). Despite much research, however, the link between coastal eutrophication and effects on living marine resources and fisheries is not well understood or quantified (NRC, 2000; Boesch, et al., 2001).

Between 1992 and 1998, NOAA conducted a survey and series of regional workshops to synthesize the best available information on eutrophication-related symptoms in 138 estuaries. Data from these surveys are presented in NOAA 's National Estuarine Eutrophication Assessment (Bricker, et al., 1999). They indicate that the nation's estuaries exhibit strong symptoms of eutrophication, which were reported by EPA to be "poor" (EPA, ORD, OW, September 2001). When data on the symptoms of eutrophication are combined, they suggest that 40 percent of the surface area of the nation's estuarine waters exhibit high levels of eutrophic condition (Exhibit 2-13).

Exhibit 2-13: Percent of estuaries with high, moderate, and low levels of eutrophic condition, 1998



Coverage: United States, excluding the Great Lakes

Source: Bricker *et al. National Estuarine Eutrophication Assessment: Effects of Nutrient Enrichment in the Nation's Estuaries*. 1999; EPA, Office of Research and Development and Office of Water. *National Coastal Condition Report*. September 2001.

Many of these waters are in the mid-Atlantic and gulf regions of the U.S. Moreover, based on expert opinion, eutrophic conditions are expected to worsen in 70 percent of U.S. estuaries by 2020 (Bricker, et al., 1999).

These eutrophication estimates are largely based upon best professional judgement. They do not adequately reflect regional differences that may occur naturally, so high scores may not be a true measure of eutrophication. Also, there are no strong scientific data to indicate that the thresholds used are indeed indicative of eutrophic conditions on a region-by-region basis. Use of SAV loss, macroalgae, and epiphytic growth is not appropriate for regions/areas where SAV beds or macroalgae are not present (e.g., South Carolina, Georgia). Standard methods do not appear to have been used among states. For all these reasons, these data were judged not to be sufficiently robust to qualify as an indicator for purposes of this report. Nevertheless, accelerated eutrophication can be an important symptom of environmental decline in estuarine and marine areas.

Therefore, eutrophication should be reconsidered as an indicator in the future if and when scientifically sound data become available.

2.2.4 What are pressures to water quality?

Indicators

Percent urban land cover in riparian areas
Agricultural lands in riparian areas
Population density in coastal areas
Changing stream flows
Number/duration of dry stream flow periods in grassland/shrublands
Sedimentation index
Atmospheric deposition of nitrogen
Nitrate in farmland, forested, and urban streams and ground water
Total nitrogen in coastal waters
Phosphorus in farmland, forested and urban streams
Phosphorus in large rivers
Total phosphorus in coastal waters
Atmospheric deposition of mercury
Chemical contamination in streams and ground water
Pesticides in farmland streams and ground water
Acid sensitivity in lakes and streams
Toxic releases to water of mercury, dioxin, lead, PCBs, and PBTs
Sediment contamination of inland waters
Sediment contamination of coastal waters
Sediment toxicity in estuaries

A complex suite of pressures weighs on surface water resources. EPA data on water quality provide some measure of the major stressors. Under the Clean Water Act, EPA requires states to define and list waters under their jurisdiction that are impaired, and to identify the causes of those impairments and develop a program to manage and control the causes. In 1998, more than 21,000 waterways were identified as impaired under the provisions of Section 303(d) of the CWA (EPA, OW, March 2003). The following top five causes of impairment accounted for 60 percent of the cases:

- Sediment/siltation
- Pathogens
- Metals
- Nutrients
- Organic enrichment/low dissolved oxygen

The next five causes account for additional 21 percent of impairment:

- Habitat alteration
- Thermal modifications
- Low or high pH
- Pesticides
- Fish consumption advisories

Twenty indicators have been identified to help answer the question "What are the pressures to water quality?" These indicators have been divided into three categories:

General pressures—Section 2.2.4.a presents six indicators of general pressures that relate in some way to habitat quality but do not fall into a specific stressor category.

Nutrient pressures—Section 2.2.4.b presents six indicators that relate specifically to nutrient enrichment.

Chemical contaminant pressures—Section 2.2.4.c discusses eight indicators that describe chemical contamination.

These indicators do not address sediment/siltation or pathogens (the two most important causes of water quality impairment as identified under Section 303[d] of the Clean Water Act), nor do they address another key concern—the impact of invasive species. Additional pressures to water quality are discussed in the Ecological Condition, Better Protected Land, and Cleaner Air chapters.

2.2.4.a General Pressures

General pressures that alter aquatic ecosystems and for which indicators are available include (1) the extent of urban land cover and agricultural lands in stream riparian areas, and (2) the extent of coastal development, as represented by population density. Additional indicators of pressures on streams relate to changes in stream flow and altered in-stream habitat. These six indicators, discussed in this section, address pressures directly on stream ecosystems and coastal areas, but they do not attempt to define pressures on lakes, ponds, reservoirs, or wetland resources, even though the pressures are likely comparable.

The difference in pressures related to urban development versus pressures from agricultural activities generally are a function of the location of, extent of, and change in urban and agricultural areas. Coastal development data, in the form of population density, suggest strong pressures on coastal systems today and in the future. Data on stream flow indicate that changes in minimum and maximum flow have increased slightly over the last three decades and that maximum flows in some areas have increased significantly. Zero (no) flow data for grassland and shrubland streams are consistent with these observations in that the percent of streams with no- flow periods has decreased.

Indicator

Percent urban land cover in riparian areas - Category 2

This indicator provides a snapshot in time of the potential stress to stream ecosystems across the nation due to urban development. Specifically, the indicator examines the extent of land cover within riparian zones, which are defined as the 30-meter buffer on each side of a stream or river. The indicator focuses on land cover along streams or rivers within watersheds categorized by the U.S. Geological Survey (USGS) as eight-digit HUCs under its hydrologic unit code (HUC) categorization system.

To calculate the extent of urban land cover, each of these buffer zones was divided into grid cells (of 15 minute latitude by 15 minute longitude dimensions). The extent of urban land cover was calculated as the percent of grid cells with land cover, divided by the total number of grid cells. To make this calculation:

- Stream map sets were derived from remote sensing techniques, generally aerial photography and satellite imagery.
- The land cover data sets were collected using remote sensing techniques, generally satellite imagery, with ground truth fieldwork.
- Stream extent and locations were defined as any line or polygon feature attributed as "stream/river." This is consistent with the definition in the USGS's National Hydrography Dataset (NHD), a key data source for this indicator.
- Urban land cover was defined as (1) the sum of low-intensity residential, high-intensity residential, and commercial/industrial/transportation land cover types in the National Land Cover Database (NLCD) and (2) the sum of both high-intensity and low-intensity developed land cover types in the Coastal Change Analysis Program (C-CAP).

What the Data Show

The analysis indicates that nearly 80 percent of the watersheds (8-digit HUCs) in the continental U.S. have less than 2 percent urban land uses within 30 meters of streams. Five percent of watersheds (8-digit HUCs) have urban land uses of greater than 8 percent within 30 meters of streams. Less than 1 percent of the nation's watersheds (8-digit HUCs) have more than 25 percent urban uses within stream riparian areas. Watersheds with streamside urban development tend to be concentrated in certain parts of the country (e.g., the Midwest, Southeast, and Northeast).

Indicator Gaps and Limitations

The streams data set is known to contain both systematic and random errors. Many of these errors, such as positional accuracy of stream segments due to digitizing accuracy, are minimized due to the scale of this analysis (i.e., at the 8-digit HUC level). But stream omission, the degree of which varies between different scale maps (i.e., 30- by 60-minute quadrangle maps), has a higher impact on potential error. In addition, the accuracy of whether or not a stream was perennial also varied between quadrangle maps, preventing a more accurate representation of riparian areas.

This indicator only examines urban land within 30 meters of streams and rivers, which means that more significant urban development at distances beyond 30 meters is not evaluated. The analysis is not a standardized ongoing assessment. Because the land cover data sets exists only for a single year, changes in the amount of urban land cover over time are not addressed by this indicator at present.

Data Source

Information is available from the specific program datasets (National Land Cover Database, Coastal Change Analysis Program, National Hydrography Dataset, and Hydrologic Unit Code). Data were summarized by the EPA. (See Appendix B, page B-11, for more information.)

Indicator Agricultural lands in riparian areas - Category 2

Agricultural land uses in riparian areas may have environmental effects, due to erosion and disturbance of riparian habitat. When land immediately adjacent to streams is used for agricultural purpose, this may affect water quality in a number of ways:

- Runoff from plowed fields can potentially become a source of stream sediment.
- Fertilizers and pesticides are often conveyed to streams by runoff or by drainage.
- Grazing animals may contaminate streams with coliform bacteria.

Results for this indicator are expressed in bank miles, calculated as the percent of agricultural land cover within the stream corridor, multiplied by the total length of stream bank within the 8- digit HUC. The data sets and analytical procedures are the same as those for the urban land in riparian areas indicator described above.

What the Data Show

The major areas of high agricultural activities in riparian areas of the U.S. are found in the Midwest, in the Southeast, east of the Cascade Mountains in Washington state, and in the inland valleys of California. The arid Southwest has very few stream miles in agriculture, due both to a low stream density and limited agriculture. Conversely, areas with the highest number of stream miles in agriculture are in watersheds that have extensive agriculture and high stream density. Only one percent of the watersheds (8-digit HUCs) in the conterminous U.S. have no stream miles in agriculture. Ten percent of the watersheds (8-digit HUCs) in the conterminous U.S. have more than 1,500 miles of streams in agriculture. About half of the watersheds (8-digit HUCs) in the conterminous U.S. have less than 250 miles of streams in agriculture.

Indicator Gaps and Limitations

The issues associated with this indicator are the same as those described for the previous indicator "percent urban land cover in riparian areas." Because the classified land cover data sets were only produced once, changes in the amount of agricultural land cover over time are not addressed by this indicator at present. Refer to the "Indicator Gaps and Limitations" section in the discussion of the previous indicator for details.

Data Source

EPA's Office of Research and Development analyzed and summarized data from the National Land Cover Database for stream miles with agricultural uses. Information is available from the specific program datasets (NLCD, C-CAP, NHD, and HUC). (See Appendix B, page B-11 for more information.)

Indicator Population density in coastal areas - Category 2

Land along the U.S. coastline is experiencing more acute pressure from population growth than other areas. Using primarily census data, NOAA has produced several reports on population distribution, density, and growth in coastal areas. These reports describe the pressure on coastal environments from land development.

What the Data Show

The NOAA reports find that coastal areas are the most developed in the nation. The narrow fringe of coastline, comprising 17 percent of our nation's total land area, contains 53 percent of the nation's population. The rate of population growth along the coast is faster than for the nation as a whole. At an average growth rate of 3,600 people per day, coastal population is expected to reach 165 million by 2015 (NOAA, 1998).

Indicator Gaps and Limitations

The NOAA estimates of coastal population and pressures are likely to be an overestimate, as data are aggregated by counties, which have extensive inland areas in addition to coastal shoreline.

Data Source

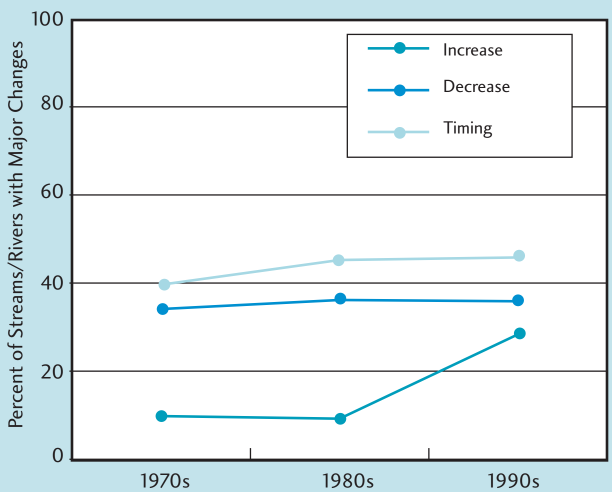
Data for this indicator are from a report on urban development in coastal areas by the U.S. Department of Commerce, National Oceanic and Atmospheric Administration. (See Appendix B, page B-11, for more information.)

Indicator Changing stream flows - Category 1

Flow is a critical aspect of hydrology in streams. Low flows define the smallest area available to stream biota during the year; high flows shape the stream channel and clear silt and debris from the stream. Also, some fish depend on high flows for spawning (The Heinz Center, 2002). The timing of a stream's high and low flows can influence many ecological processes. Changes in flow can be caused by dams, water withdrawal, changes in land use, and climate trends. This indicator reports the percentage of streams or rivers with major changes in the magnitude or timing of their high or low flows over three decades (1970s, 1980s, 1990s) compared to a reference period from 1930 to 1949.

The USGS stream gauge database, which served as the data source for this indicator, contains 867 gauging sites with at least 20 years of discharge records within the target dates 1930 to 1949, and 10 years of records for the 1970s, 1980s, and 1990s. The measures were 7-day low flow and the corresponding Julian days and the average 1-day high flow and Julian day.

Exhibit 2-14: Percent of streams with changes in high flows (1970s-1990s) compared to baseline high flow data (1930-1949)



Coverage: lower 48 states

Note: Totals may add to more than 100%, because both the timing and magnitude may change in a single stream or river.

Source: The Heinz Center. *The State of the Nation's Ecosystems.* 2002. Data from the U.S. Geological Survey.

What the Data Show

The percentage of streams and rivers with major changes in their high or low flows or the timing of those flows (i.e., compared to the same data for those streams or rivers as recorded between 1930 and 1949) increased slightly from the 1970s to the 1990s (The Heinz Center, 2002). The number whose high flows were well above the flows in those same streams and rivers between 1930 and 1949 increased by approximately 30 percent in the 1990s (Exhibit 2-14). The baseline period of 1930 to 1949 included some droughts, which may partially explain the increase in high flows in subsequent decades. However, much of this baseline period also preceded widespread irrigation projects, which means that fewer high flows would be expected in subsequent decades.

Indicator Gaps and Limitations

Data from the period 1930 to 1949 are being used here as a practical baseline for historical comparison, even though many dams and other waterworks had already been constructed by this time, and even though this period was characterized by low rainfall in some parts of the country. For this reason, it may be more useful to compare changes in stream flows on a decade-by-decade basis rather than to the 1930 to 1949 baseline period selected here.

Although the sites analyzed here are spread widely throughout the U.S., gauge placement by the USGS is not a random process. Gauges are generally placed on larger, perennial streams and rivers, and changes seen in these larger systems may differ from those seen in smaller streams and rivers. In addition, the USGS gauge network does not represent the full set of operating stream flow gauges in the U.S. The U.S. Army Corps of Engineers, for example, operates gauges, and those data are not available through the USGS; they were not used in this analysis.

Data Source

Data for this indicator came from the U.S. Geological Survey gauging station network, compiled for The Heinz Center (2002). (See Appendix B, page B-12, for more information.)

Indicator Number/duration of dry stream flow periods in grassland/shrublands - Category 2

Many grassland/shrublands are located in arid climates where water availability is critical. The number and duration of dry periods in streams and rivers is used as a hydrology/geomorphology indicator in the Heinz report (The Heinz Center, 2002). Changes in the number and/or duration of no-flow periods can significantly stress aquatic plants and animals. These alterations can result from changes in agricultural management or irrigation practices, development, change in flow regulation below dams, or depletion of shallow ground water. Riparian condition is critical for grassland and shrubland streams. Because most of the streams are ephemeral, aquatic organisms have evolved to complete their life histories during periods when water is available (Fisher, 1995). Increasing the percentage of no-flow periods can significantly stress riparian and aquatic communities.

Gauging sites with at least 50 percent grassland/shrubland were identified for 4-digit HUC watersheds. The NLCD coverage was used to identify these areas as grassland/shrubland. The number of sites with at least one no-flow day in a year was determined for each year from 1950 to 1999. The corresponding percentage of area as grassland/shrubland for that year was also calculated. To analyze the duration of no-flow, only sites with at least one no-flow day in each decade between October 1, 1949, and September 30, 1999, were considered. This analysis considered whether there was an increase, decrease, or minimal change in the number of no-flow days, compared to the long-term (50-year) average for each stream.

What the Data Show

The percentage of no-flow periods has decreased in all grassland/shrubland regions of the West (The Heinz Center, 2002). The percentage of no-flow periods was similar in the 1950s and 1960s and then generally decreased in the 1970s, 1980s, and 1990s (Exhibit 2-15) (The Heinz Center, 2002). The 1980s was a relatively wet period, during which some of the smallest percentages of no-flow periods existed in a 50-year period of record (The Heinz Center, 2002). The duration of no-flow periods also decreased during the 1970s through the 1990s, compared to the 1950s and 1960s (The Heinz Center, 2002).

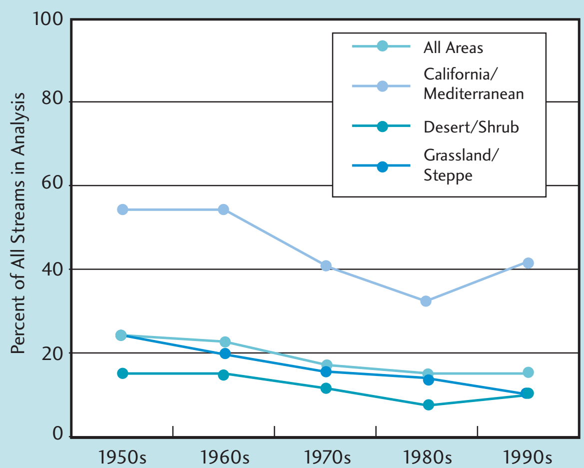
Indicator Gaps and Limitations

These data are from USGS gauging stations, which may be found on larger, perennial streams; thus, these data may not reflect conditions on very small streams. Data limitations, generally, are similar to those described for the "number/duration of dry stream flow periods in grasslands/shrublands" indicator described on the previous page.

Data Source

The data source for this indicator was the U.S. Geological Survey gauging stations, analyzed by Colorado State University for The Heinz Center. (See Appendix B, page B-12, for more information.)

Exhibit 2-15: Percent of streams that have zero-flow periods, 1950s-1990s



Coverage: grassland/shrubland regions in lower 48 states.

Source: The Heinz Center. *The State of the Nation's Ecosystems.* 2002. Data from the U.S. Geological Survey.

Indicator Sedimentation index - Category 2

Stream channels undergo a long-term adjustment to a region-specific rate of sediment supply that is delivered by erosion processes from natural disturbance. The size distribution of streambed particles is dependent upon the relationship between sediment supply and stream sediment transport capability. Under a natural disturbance regime, sediment supply in watersheds that are not altered by human disturbances may be roughly in long-term equilibrium with stream sediment transport. In watersheds that are relatively undisturbed by humans, the relationship between bed particle size and stream transport capability should tend toward a characteristic value that is typical to the region. Human activities may increase sediment input rates to streams, resulting in higher amounts of fine substrates in sediments than the predicted regional value.

Higher sedimentation rates can significantly alter instream habitat. These alterations are the greatest stressor to mid-Atlantic streams and many other streams throughout the U.S. For example, change in channel morphology can affect stream biota and ecological condition. Thrush, et al. (2000) provide 10 geomorphic attributes that are needed for suitable stream habitat, in addition to critical channel morphological indicators.

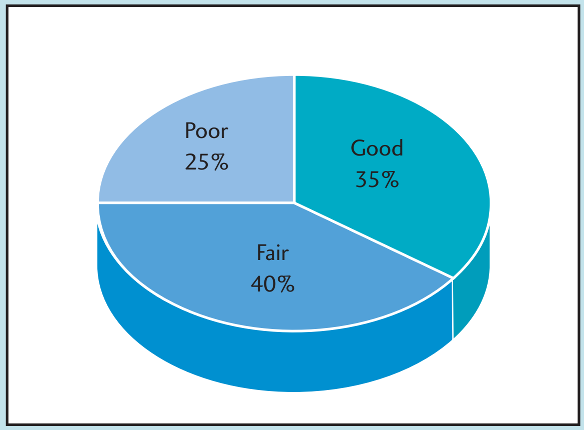
A sedimentation index was developed for Mid-Atlantic Highland streams to assess the quality of instream habitat to support aquatic communities (Kaufmann, et al., 1999). Stream sedimentation was defined as an increase or excess in the amount of fine substrate particles (smaller than 16-mm diameter) relative to an expected reference value that is based on the region and the sediment transport capability of each sample stream reach. Streams were given the following ratings with respect to sedimentation:

- "Good" when the proportion of fine particles was at least 10 percent below the predicted value.
- "Fair" when the population of fine particles ranged from 10 percent below to 20 percent above the predicted value.
- "Poor" when the proportion of fine particles was more than 20 percent above regional mean expectations.

What the Data Show

Based on the sedimentation index, about 35 percent of the Mid-Atlantic Highland stream miles had good instream habitat, 40 percent had fair instream habitat, and 25 percent of the stream miles had poor instream habitat (Exhibit 2-16) (EPA, ORD, Region 3, August 2000).

Exhibit 2-16: Percent of Mid-Atlantic highland streams exhibiting good, fair, and poor habitat condition based upon a sedimentation index, 1993-1994



Source: EPA Region 3 and the Office of Research and Development. *Mid-Atlantic Highlands Streams Assessment.* August 2000.

Indicator Gaps and Limitations

This sedimentation index has been applied only in the context of the mid-Atlantic region and cannot be used for a national assessment. The index itself may not apply equally to other regions of the nation.

Data Source

The data source for this indicator was EPA's Mid-Atlantic Highlands Streams Assessment, part of the Environmental Monitoring and Assessment Program. (See Appendix B, page B-12, for more information.)

2.2.4.b Nutrient Pressures

Nutrient enrichment by nitrogen and phosphorus is one of the leading causes of water quality impairment in the nation's rivers, lakes, and estuaries. In a 1998 water quality report to Congress, nutrients were listed as a leading cause of water pollution. About half of the nation's waters surveyed by states do not adequately support aquatic life because of excess nutrients. In 1998, states reported that excessive nutrients have degraded almost 2.5 million acres of lakes and reservoirs and over 84,000 miles of rivers and streams to the extent that they no longer meet basic uses such as supporting healthy aquatic life. Nutrients have also been associated with both the large hypoxic zone in the Gulf of Mexico, the hypoxia observed in several East Coast states, and *Pfisteria*-induced fish kills and human health problems in the coastal waters of several East Coast and Gulf states.

Many of the nutrients used in chemical fertilizers are water soluble. Consequently, one of the major potential environmental effects of fertilizer usage is the nitrogen or phosphorus that may find its way into water systems, affecting water quality and aquatic habitats. Another major source of nutrients from agricultural lands are those related to animal feed operations. Nutrients, particularly nitrogen and phosphorus, increase the levels of algae in receiving waterbodies.

Most of the streams that are enriched with nutrients lie in drainage areas for agricultural and/or urban land. Forested landscapes rarely contribute to heightened water concentrations of these nutrients. Ground water from more than half the sites sampled in a nationwide study contained nutrients at concentrations higher than natural background levels. Data presented in Chapter 3, Better Protected Land, describe a USGS risk analysis that evaluated the likelihood of ground water contamination from nitrate resulting from a combination of well-drained soils and a high proportion of cropland to woodland. The data illustrate a clear relationship between potential ground water contamination and predominantly agricultural areas of the country (see Chapter 3–Better Protected Land).

"Nitrogen export" is the annual quantity of total nitrogen produced by nitrogen sources in a watershed that leaves the watershed through a river or stream that connects to other watersheds downstream. Estimates of total nitrogen (TN) export were developed by Smith, et al. (1997) through analysis of data from monitoring stations in the USGS's National Stream Quality Accounting Network (NASQAN) SPARROW (SPAtially-Referenced Regressions On Watershed attributes). This model relates in-stream measurements of TN export to point and non-point sources of pollution, and to land-surface and stream-channel characteristics in the watersheds that contain the monitoring stations. This modeling was performed using data from approximately 400 long-term stream monitoring sites. Using these data, the model empirically estimated the delivery of nutrients to streams and the outlets of watersheds from point and non-point sources.

This section presents six indicators of pressures on water quality related to nutrient enrichment:

- Atmospheric deposition of nitrogen
- Nitrates in farmland, forested, and urban streams and ground water
- Total nitrogen in coastal waters
- Phosphorus in farmland, forested, and urban streams
- Phosphorus in large rivers
- Phosphorus in coastal waters

Chapter 3–Better Protected Land, discusses the potential for nutrient runoff from farmlands.

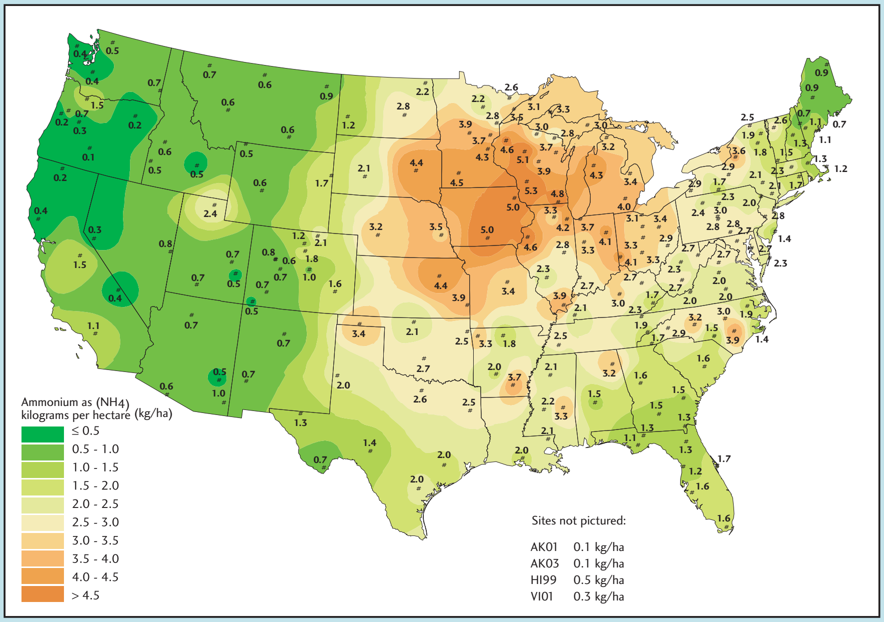
Indicator Atmospheric deposition of nitrogen - Category 2

Nitrogen, essential to life, is a component of proteins and nucleic acids. Natural and human processes convert nitrogen gas to a variety of usable forms, including nitrogen oxides, ammonia, and organic nitrogen. Natural sources of nitrogen oxides and ammonia include volcanic eruptions, lightning, forest fires, and certain microbial processes. Anthropogenic sources contribute about the same amount of nitrogen oxides and ammonia to the environment as do natural sources. The largest single source of nitrogen oxides to the atmosphere is the combustion of fossil fuels (such as coal, oil, and gas) by automobiles and electric power plants (Schlesinger, 1997). The largest sources of ammonia emissions are fertilizers and domesticated animals (such as hogs, chickens, and cows).

In some places, nitrogen deposited from the atmosphere is a large percentage of the total nitrogen load. For instance, Albemarle-Pamlico Sound in North Carolina receives 38 percent of its nitrogen from the atmosphere (EPA, OAQPS, June 2000). As human sources of nitrogen compounds to the atmosphere increase, the importance of atmospheric deposition of nitrogen to bodies of water will increase as well.

Indicator | Atmospheric deposition of nitrogen - Category 2 (continued)

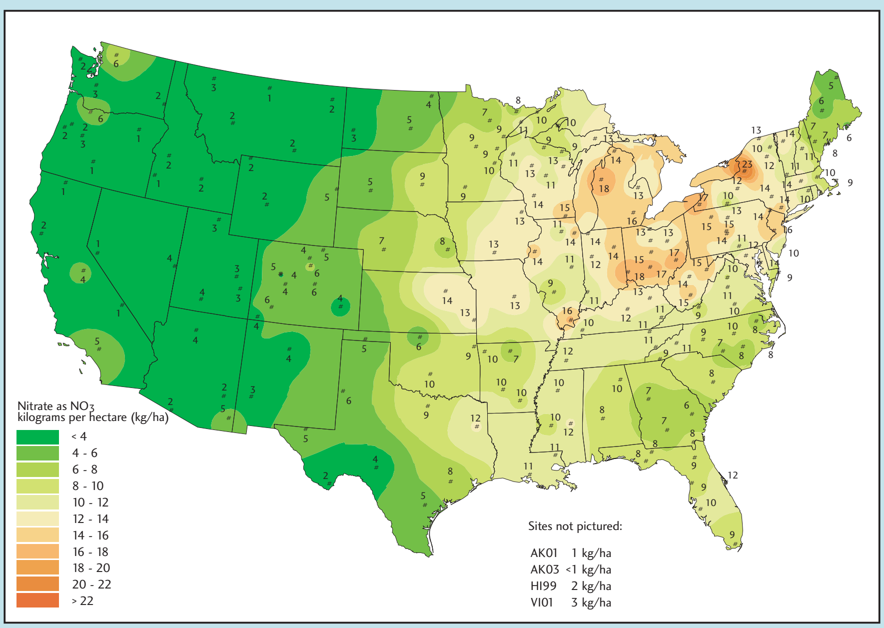
Exhibit 2-17: Ammonium wet deposition, 2001



Coverage: lower 48 states

Source: National Atmospheric Deposition Program, National Trends Network. 2001. (March 25, 2003; *http:..nadp.sws.uiuc.edu/isopleths/maps2001/nh4dep.pdf*).

Exhibit 2-18: Nitrate wet deposition, 2001



Coverage: lower 48 states

Source: National Atmospheric Deposition Program, National Trends Network. 2001. (March 25, 2003; *http://nadp.sws.uiuc.edu/isopleths/maps2001/no3dep.pdf*).

The deposition of nitrogen compounds on land or water can take several forms. Wet deposition occurs when air pollutants fall with rain, snow, or fog. Dry deposition is the deposition of pollutants as dry particles or gases. In either form, the pollutants can reach bodies of water as direct deposition falling directly into the water or as indirect deposition—falling onto land and passing into a body of water as runoff. In either case, atmospheric deposition is often one of the major sources of nitrogen in surface waters.

This indicator focuses on atmospheric deposition of inorganic nitrogen, as it is the most immediately available form of nitrogen in the environment. Its components, nitrate and ammonium, are presented using the National Atmospheric Deposition Program/National Trends Network (NADP/NTN) data collected in 2001.

What the Data Show

Ammonium deposition is lowest in the western states, where it is generally less than 1 kg/ha. Highest rates occur in the upper midwestern states in the upper Mississippi River watershed (Exhibit 2-17). Nitrate deposition also is low in the western states (< 4 kg/ha). Highest deposition rates occur in the upper Midwest and in the eastern states (Exhibit 2-18). High ammonium values are associated with wastes from animal agriculture, while nitrates are largely from fertilizers used in row crop agriculture.

Indicator Gaps and Limitations

This indicator measures wet deposition, not dry deposition. Total nitrogen deposition is not measured.

Indicator Atmospheric deposition of nitrogen - Category 2 (continued)

Additionally, the indicator estimates deposition only to the surface areas, not directly to the water, except where large waterbodies are present.

Data Source

The data source for this indicator was the interagency National Atmospheric Deposition Program. (See Appendix B, page B-12 for more information.)

Indicator Nitrate in farmland, forested, and urban streams and ground water - Category 2

Nitrogen is a critical plant nutrient, and most nitrogen is used and reused by plants within an ecosystem. Thus, in undisturbed ecosystems, minimal "leakage" occurs into either surface runoff or ground water, and concentrations are very low. However, when amounts of nitrate in streams and ground water are elevated, this generally indicates that inputs from human sources have increased or that plants in the system are under stress. Elevated nitrogen levels might come from fertilizer use, disposal of animal waste, onsite septic systems, sewage treatment plants, or rain and snowfall (in the form of atmospheric deposition).

This indicator reports on the concentration of nitrate in streams and ground water in farmland, forested, and urban areas. Specifically, the indicator reports the percent of streams with average nitrate concentrations in one of four ranges: less than two ppm; two-six ppm; six-10 ppm; and 10 ppm or more. The data, comprised of samples collected at over 100 stream sites in farmland areas, were collected and analyzed by the NAWQA program in 36 large watersheds across the U.S. during 1993 to1998. Thirty-six forested streams and 21 urban/suburban streams also were evaluated. Ground water samples were collected from 20 to 30 private wells in each of 36 agricultural study areas and 13 urban study areas.

What the Data Show

USGS data, compiled for The Heinz Center (2002), indicate that:

- Nitrate concentrations were above two ppm (mg/L) in about half of the stream sites and 55 percent of ground water wells sampled in areas where agriculture is the primary land use (Exhibit 2-19).
- Most nitrate concentrations in forested streams were less than 0.5 ppm (50 percent had concentrations of nitrate less than 0.1 ppm, 75 percent had concentrations of less than 0.5 ppm, and only one had a concentration of more than 1.0 ppm).
- Forty percent of urban/suburban streams had nitrate concentrations above 1.0 ppm (25 percent had concentrations below 0.5 ppm, and three percent had concentrations below 0.1 ppm).

About 20 percent of the ground water wells and about 10 percent of stream sites had concentrations that exceeded the federal drinking water standard (10 mg/L). Only three percent of urban ground water wells had nitrate concentrations exceeding the standard. Samples of ground water in agricultural areas have nitrate concentrations higher than ground waters of forested or urban areas.

In four of 33 major drinking water aquifers sampled, the federal drinking water standard for nitrate was exceeded in more than 15 percent of samples collected. In these aquifers, all of which underlie intensive agricultural areas, nitrate most often is elevated in karst (carbonate) areas or where soils and aquifers consist of sand and gravel. These natural features enable rapid infiltration and downward movement of water and chemicals. Some of the more vulnerable areas of the nation are the Central Valley of California, and parts of the Pacific Northwest, the Great Plains, and the Mid-Atlantic region. In contrast, contaminants are barely detectable in ground water underlying farmland in parts of the upper Midwest, despite similar high rates of chemical use. In these areas, ground water contamination may be limited, because of the relatively impermeable, poorly drained soils and glacial till that cover much of the region, and because tile drains provide quick pathways for runoff to streams (Gilliom, et al., 2002).

Nitrate contamination in shallow ground water (less than 100 feet below land surface) raises potential concerns for human health,

Indicator Nitrate in farmland, forested, and urban streams and ground water - Category 2 (continued)

particularly in rural agricultural areas where shallow ground water is used for domestic water supply. Furthermore, high levels of nitrate in shallow ground water may serve as an early warning of possible future contamination of older underlying ground water, which is a common source for public water supplies (USGS, 1999).

Indicator Gaps and Limitations

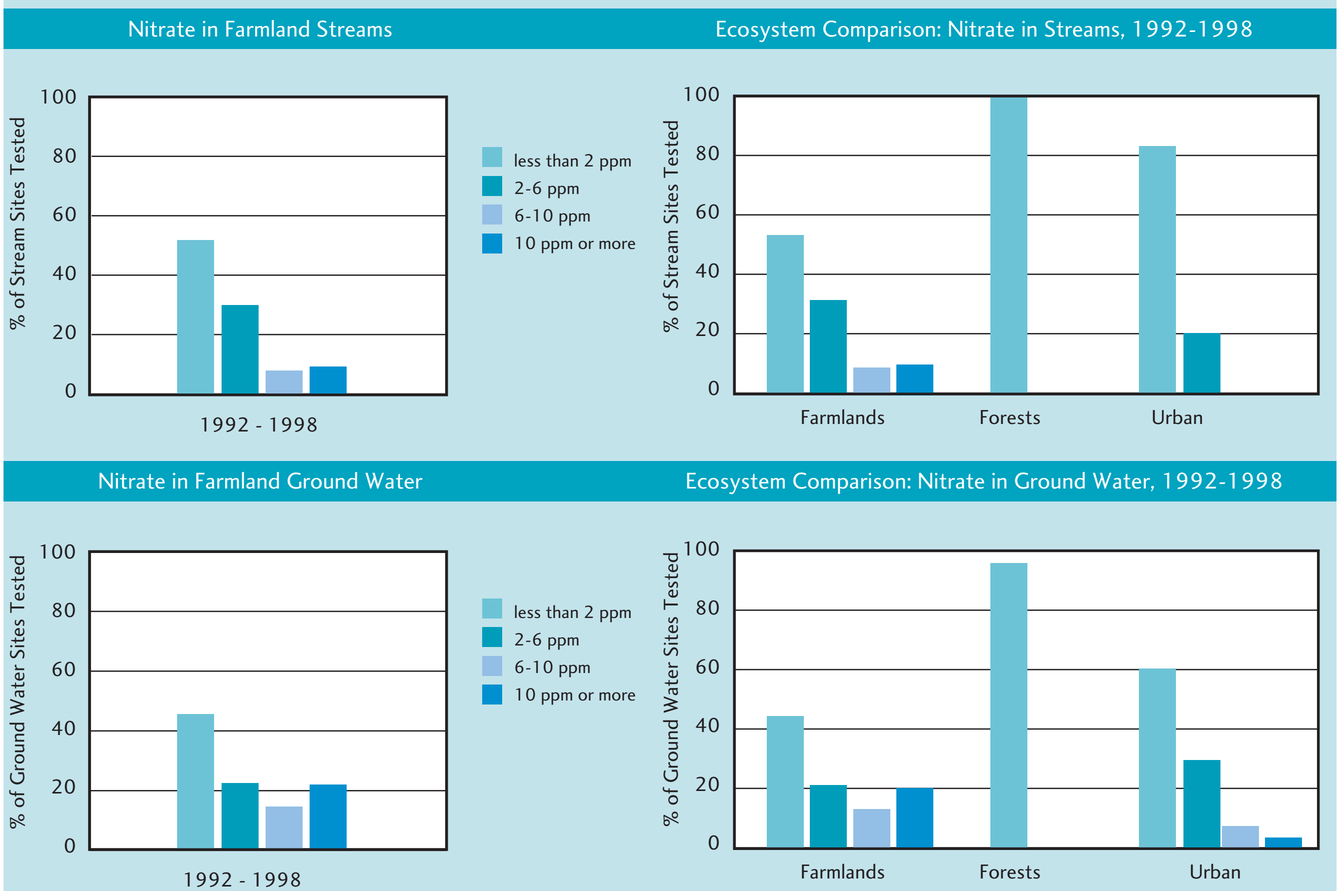
These data only represent conditions in the 36 major river basins and aquifers sampled by the NAWQA program. While they were subjectively chosen to be representative of watersheds across the U.S., they are the result of a targeted sample design.

The data also are highly aggregated and should only be interpreted as an indication of national patterns. For example, the definition of agricultural land included land use by cropland or pasture. The percentage of land used for agricultural purposes within specific watersheds varied from 10 to 99 percent of the land cover, so the characterization of lands as agricultural is subject to this degree of variation in land use.

Data Source

Data for this indicator were compiled for The Heinz Center (2002) from the U.S. Geological Survey's National Water Quality Assessment Program. (See Appendix B, page B-13 for more information.)

Exhibit 2-19: Nitrates in farmland streams and ground water, 1992-1998



Coverage: lower 48 states. Each sampling area was sampled intensively for approximately 2 years during 1992–1998.
Source: The Heinz Center. *The State of the Nation's Ecosystems. 2002.* Data from the U.S. Geological Survey.

Indicator Total nitrogen in coastal waters - Category 2

Nitrogen in estuaries is commonly regarded as the most important limiting nutrient. Nutrients can originate at either point sources (e.g., sewage treatment plants and industries) or non-point sources (e.g., farmlands, lawns, leaking septic systems, and the atmosphere). Excess nutrients can lead to eutrophication.

Total nitrogen (TN) in the mid-Atlantic estuaries was calculated by summing the concentrations of total dissolved nitrogen and particulate organic nitrogen (EPA, ORD, May 2003). Assessment categories were determined based on the 25th and 75th percentiles. The categories are (EPA, ORD, May 2003):

- Low: < 0.5 ppm nitrogen
- Intermediate: 0.5 to 1.0 ppm nitrogen
- High: > 1.0 ppm nitrogen

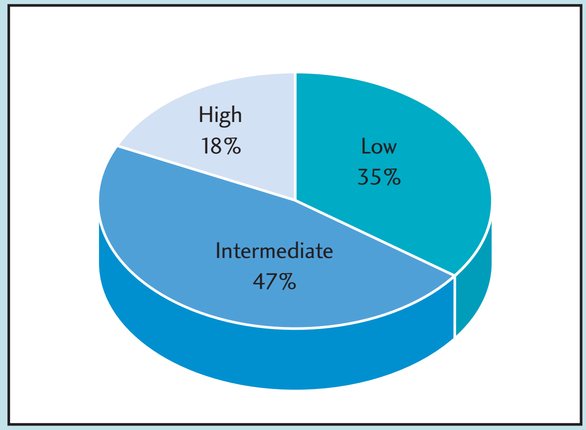
Currently there are no national-level water quality criteria for total nitrogen in estuaries, but states are in the process of determining nutrient criteria for their waters.

What the Data Show

This analysis yielded the following results:

- For the mid-Atlantic region, about 35 percent of the estuarine area had low TN concentrations, 47 percent had intermediate TN concentrations, and 18 percent had high TN concentrations (Exhibit 2-20).
- About 50 percent of the mainstem area of the Chesapeake Bay had low TN concentrations, with only about five percent having high TN concentrations.
- In contrast, about fives percent of coastal bays had low TN concentrations, and about 35 percent had high TN concentrations.
- The entire Delaware River estuary portion of Delaware Bay had high TN concentrations.

Exhibit 2-20: Extent of Mid-Atlantic estuaries with low, intermediate, and high total nitrogen concentrations, 1997-1998



Source: EPA, Office of Research and Development. *Mid-Atlantic Integrated Assessment, MAIA - Estuaries 1997-98, Summary Report.* May 2003.

Indicator Gaps and Limitations

These TN estimations for estuaries apply only to the mid-Atlantic region and cannot be used to make national estimates of nitrogen concentrations.

Data Source

The data source for this indicator was EPA's Mid-Atlantic Integrated Assessment (MAIA) Estuaries Program, part of EPA's Environmental Monitoring and Assessment Program. (See Appendix B, page B-13, for more information.)

Indicator Phosphorus in farmland, forested, and urban streams - Category 2

Phosphorus, an essential nutrient for all life forms, occurs naturally in soils and aquatic systems. However, at high concentrations, phosphates, the most biologically active form of phosphorus, can cause significant water quality problems by overstimulating algae growth. This is both aesthetically unappealing and can contribute to the loss of oxygen needed by fish and other animals. Human activity can increase phosphorus levels through fertilizer use, disposal of animal waste, sewage treatment, and use of some detergents.

This indicator reports on the concentration of phosphorus in streams that drain watersheds comprised primarily of farmland, forested, or urban land use. Specifically, the indicator reports the percent of these streams that have average annual phosphorus concentrations in one of four ranges: less than 0.l ppm; 0.1 to 0.3 ppm; 0.3 to 0.5 ppm; and 0.5 ppm or more. Thirty-six forested streams and 21 urban/suburban streams also were evaluated.

What the Data Show

Data compiled by the USGS indicate that:

- About three-fourths of farmland stream sites had concentrations of phosphorus above 0.1 parts per million (mg/L) (Exhibit 2-21).
- About 15 percent of farmland stream sites had phosphorus concentrations greater than 0.5 ppm of phosphorus.
- Phosphorus concentrations in streams of agricultural lands were similar to but slightly higher than those in urban streams and much greater than those in forest streams.

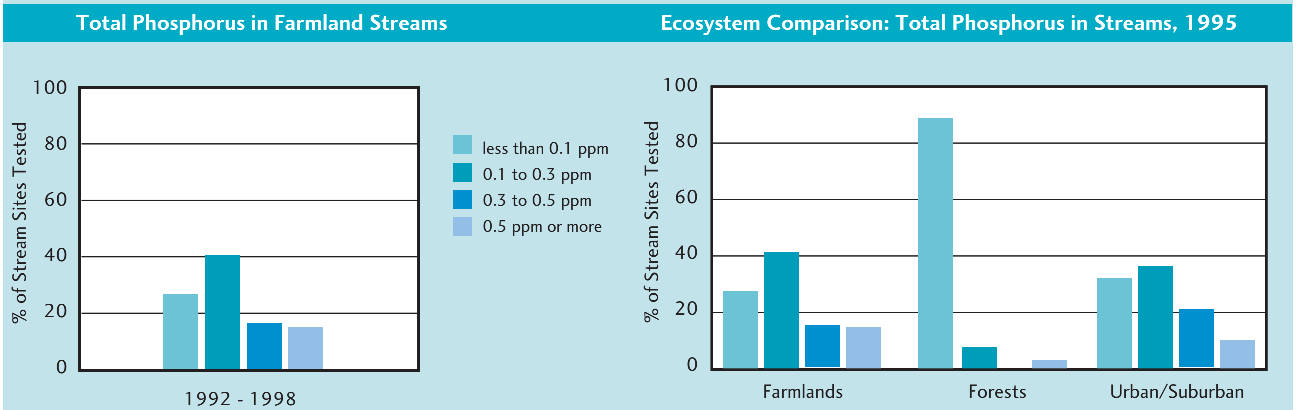
EPA has recently set new regional water quality criteria for phosphorus levels in streams in agricultural ecosystems. These criteria range from 0.023 to 0.076 ppm and vary according to differences in ecoregions, soil types, climate, and land use.

Compared to nitrogen, a smaller proportion of phosphorus (originating mostly from livestock wastes or fertilizers) was lost from watersheds to streams. The annual amounts of total phosphorus measured in agricultural streams were equivalent to less than 20 percent of the phosphorus that was applied annually to the land. This is consistent with the general tendency of phosphorus to attach to soil particles that move more slowly with runoff to surface water. Even though less phosphorus is transported from land than nitrogen, phosphorus is more likely to reach concentrations that can cause excessive aquatic plant growth. Nitrogen concentrations are rarely low enough to limit aquatic plant growth in fresh water, whereas phosphorus concentrations can be low enough to limit such growth. Thus, adding phosphorus to an aquatic system can have a greater impact than adding nitrogen. Hence, excessive aquatic plant growth and eutrophication in fresh water generally result from elevated phosphorus concentrations (typically greater than 0.1 ppm) (EPA, OW, June 1998). In contrast, nitrogen typically is the limiting nutrient for aquatic plant growth in saltwater and coastal waters.

Indicator Gaps and Limitations

These data only represent conditions in the 36 major river basins and aquifers sampled by NAWQA. While they were subjectively

Exhibit 2-21: Phosphorus in farmland streams and ground water, 1992-1998



Coverage: lower 48 states. Each sampling area was sampled intensively for approximately 2 years during 1992–1998.

Source: The Heinz Center. *The State of the Nation's Ecosystems.* 2002. Data from the U.S. Geological Survey.

Indicator Phosphorus in farmland, forested, and urban streams - Category 2 (continued)

chosen to represent watersheds across the U.S., they are the result of a targeted sample design.

The data also are highly aggregated and should only be interpreted as an indication of national patterns. For example, watersheds dominated by agricultural land included land use by cropland or pasture. The percentage of land used for these purposes varied from 10 to 99 percent, so the characterization of lands as agricultural is subject to this degree of variation in land use.

Data Source

Data used for this indicator were compiled for The Heinz Center (2002) from the U.S. Geological Survey's National Water Quality Assessment Program. (See Appendix B, page B-13, for more information.)

Indicator Phosphorus in large rivers - Category 2

Increased phosphorus in large rivers and other waterbodies leads to an increase in growth of algae. While small amounts of algae provide the critical base of the food chains in these waterbodies, larger amounts lead to eutrophication. As discussed in Section 2.2.3, eutrophication can lead to loss of oxygen, shifts in fish population, and "nuisance blooms" of algal species. Algal blooms generally degrade aesthetic and recreational values.

Data on phosphorus were collected from 140 sites in large rivers (i.e., rivers with flows exceeding 1,000 cubic feet per second) at least 30 times over a 2-year period between 1992 and 1998 by the USGS (The Heinz Center, 2002).

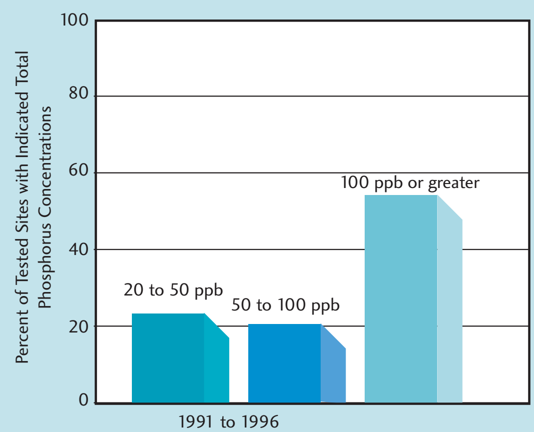
What the Data Show

Half of the rivers tested had total phosphorus concentrations equaling or exceeding 100 parts per billion (The Heinz Center, 2002) (Exhibit 2-22), which is EPA's recommended goal for preventing excess algal growth in streams that do not flow directly into lakes. None of the rivers had concentrations below 20 parts per billion, a level generally held to be free of negative effects (EPA, OW, November 1986).

Indicator Gaps and Limitations

Phosphorus measurements in rivers were restricted to those large rivers with flows exceeding 1,000 cubic feet per second. To ensure proper characterization of average values for each river, only sites that had at least 30 samples over the course of 2 years were included. Thus, only large rivers with adequate sampling are represented.

Exhibit 2-22: Distribution of phosphorus concentrations in large rivers, 1991-1996



Coverage: lower 48 states

Note: 140 sites were tested. (ppb = parts per billion)

Source: The Heinz Center. *The State of the Nation's Ecosystems.* 2002. Data from the U.S. Geological Survey.

The data used for this indicator are from larger rivers. Larger rivers typically have both larger discharge volumes and watersheds with more diverse land uses. These samples, therefore, represent the integrating influences of many different land uses. Also, they were the result of a targeted sample design, and may not be representative of large rivers across the U.S.

Data Source

The data used for this indicator were from the U.S. Geological Survey as compiled for The Heinz Center (2002). (See Appendix B, page B-14, for more information.)

Indicator Total phosphorus in coastal waters - Category 2

Phosphorus is an essential plant nutrient. It is derived from weathering and erosion of natural mineral deposits, runoff of fertilizers applied to agricultural and urban areas, and point source discharges of sewage, detergents, pharmaceuticals, and other phosphorus-containing products. Phosphorus is generally considered the limiting nutrient in fresh water systems (Schindler, 1977), but it can also become limiting in estuarine areas if total nitrogen becomes abundant (EPA, ORD, May 2003).

Total phosphorus data were collected in the mid-Atlantic estuaries (EPA, ORD, May 2003) during 1997 and 1998. TP assessment categories were based on the 25th and 75th percentile concentrations measured throughout the mid-Atlantic region. These categories are:

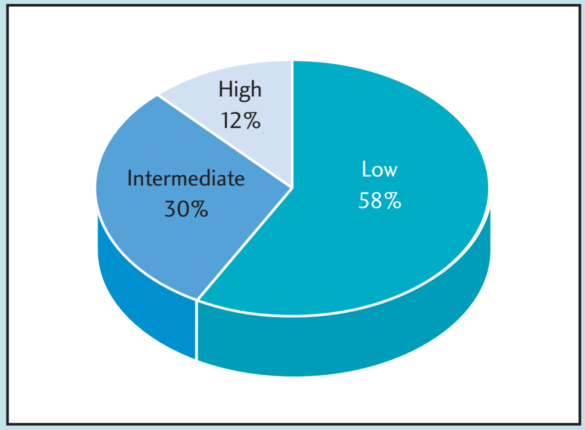
- Low: <0.05 to 0.1 ppm
- Intermediate: 0.05 to 0.1 ppm
- High: >0.1 ppm

What the Data Show

Analysis of the data showed that:

- TP concentrations in mid-Atlantic estuaries ranged from 0 to 0.34 ppm.
- For the mid-Atlantic region, about 58 percent of the estuarine area had low TP concentrations, 30 percent had intermediate TP concentrations, and 12 percent had high TP concentrations (Exhibit 2- 23).
- About 85 percent of the mainstem area of Chesapeake Bay had low TP concentration with no areas having high TP concentrations.
- The coastal bays, in contrast, had no areas with low TP concentrations and about 35 percent with high TP concentrations.
- The Delaware River estuary portion of Delaware Bay had 100 percent of its area with high TP concentrations.

Exhibit 2-23: Extent of Mid-Atlantic estuaries with low, intermediate, and high total phosphorus concentrations, 1997-1998



Source: EPA, Office of Research and Development. *Mid-Atlantic Integrated Assessment, MAIA - Estuaries 1997-98, Summary Report.* May 2003.

Indicator Gaps and Limitations

These TP estimations apply only to estuaries of the mid-Atlantic region and cannot be used to make national estimates of phosphorus concentrations.

Data Source

Data for this indicator came from EPA's Environmental Monitoring and Assessment Program, Mid-Atlantic Integrated Assessment (MAIA) Estuaries Program. (See Appendix B, page B-14, for more information.)

2.2.4.c Chemical Contaminant Pressures

The waters of our rivers, lakes, and oceans have been contaminated by pollutants. Some of these pollutants, such as the pesticide DDT and the industrial chemicals known as PCBs, were released into the environment long ago. The use of DDT and PCBs in the U.S. was banned in the 1970s, but these chemicals persist for many years. Other contaminants enter our waters every day. Some flow directly from industrial and municipal waste dischargers, while others come from non-point source pollution in urban and agricultural areas. Additionally, other contaminants are carried through the air and eventually are deposited on lands and in lakes and streams far from the facilities that produced them. When this happens, sediments in waterbodies may serve as a reservoir for these contaminants and, ultimately, as a source of contamination.

The USGS has compiled contaminant data for waterbodies as part of its National Water Quality Assessment Program. Gilliom, et al. (2002) summarized some of major NAWQA findings as follows:

- Detectable concentrations of pesticides were widespread in agricultural area streams. DDT was the most commonly detected organochlorine compound, followed by dieldrin and chlordane.
- Water in urban areas has a characteristic "signature" that is reflective of the chemicals used in the watersheds. Insecticides—such as diazinon, carbaryl, cholorpyrifos, and malathion—were detected more frequently and usually at higher concentrations in urban streams than in agricultural streams.
- Concentrations of selected trace elements, such as cadmium, lead, zinc, and mercury, are elevated above background levels in heavily populated urban settings.
- Volatile organic compounds (VOCs), which are used in plastics, cleaning solvents, gasoline, and industrial operations, are prevalent in shallow urban ground water.

Eight indicators have been chosen to describe chemical contaminant pressures on water resources:

- Atmospheric deposition of mercury.
- Chemical contamination in streams and ground water.
- Pesticides in farmland streams and ground water.
- Acid sensitivity in lakes and streams.
- Toxic releases to water of mercury, dioxin, lead, PCBs, and persistent bioaccumulative toxic chemicals (PBTs).
- Sediment contamination of inland waters.
- Sediment contamination of coastal waters.
- Sediment toxicity in estuaries.

Mercury contamination of waters and sediments is one of the leading causes of closed fisheries and fish consumption advisories in the U.S. (see Section 2.5). Atmospheric deposition in the Great Lakes and northeastern area of the U.S. is the primary source of this contaminant. Discharges to waterways as indicated by data from EPA's Toxics Release Inventory (TRI) are a relatively small source of mercury contamination.

The EPA National Sediment Inventory (NSI) has extensively reviewed sediment quality data collected predominantly from sampling programs targeted at sites of known contamination (see <*http://www.epa.gov/waterscience/basins/metadata/nsi.htm*>). NSI classifies these sites as demonstrating, by association or otherwise, probable biological effects related to the contamination. Not surprisingly, the most contaminated watersheds are found in the Great Lakes region and northeast corridor in areas of dense populations and industrial development. Data show that a small proportion (1 percent or less) of the sampled estuarine areas of the eastern U.S. and Gulf of Mexico coasts contain chemicals at concentrations high enough to be associated with biological effects.

Indicator Atmospheric deposition of mercury - Category 2

The primary sources of mercury emissions on a national level are coal-fired power plants (33 percent), municipal waste incinerators (18 percent), and medical waste incinerators (10 percent) (EPA, OW, December 1997). Coal-fired power plants produce mercury by burning coal, which contains trace amounts of mercury that are released during combustion. Incinerators emit mercury when they burn wastes containing mercury. For medical waste incinerators, mercury waste comes from medical devices like thermometers and blood pressure cuffs. For municipal waste incinerators, mercury comes from discarded appliances, such as thermostats and fluorescent lights and lamps.

Mercury deposition was estimated from measurements made by the Mercury Deposition Network (MDN), which is part of the National Atmospheric Deposition Program. Precipitation samples were collected weekly and analyzed for total mercury and methylmercury. The MDN began a transition network of 13 sites in 1995 and, in the next year, became an official network in the NADP with 26 sites. During 2000, more than 50 sites were in operation.

Indicator | Atmospheric deposition of mercury - Category 2 (continued)

What the Data Show

Estimates of annual mercury wet deposition in 2001 are presented in Exhibit 2-24. Mercury deposition ranges from a low of 2.4 micrograms per square meter (µg/m²) measured at a California site to over 14 µg/m² at sites in eastern Texas, south Florida, and eastern Wisconsin. The Great Lakes and southeastern states are those most greatly affected by mercury deposition.

Indicator Gaps and Limitations

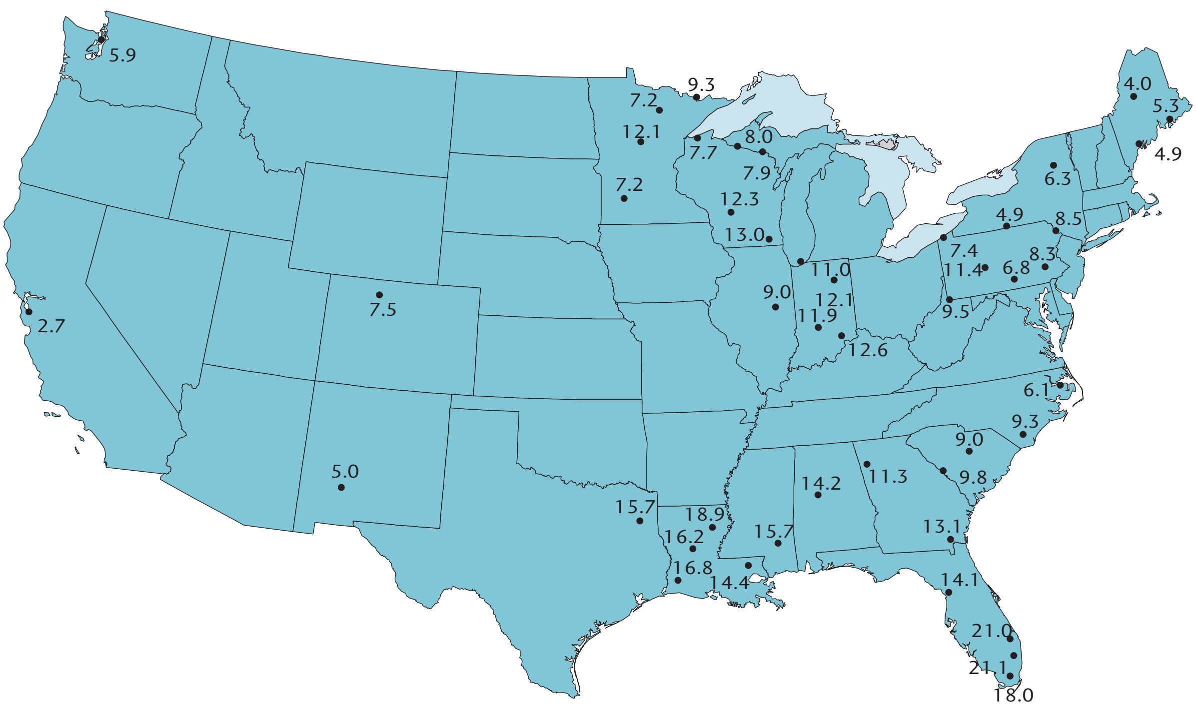
Limitations for this indicator include:

- The spatial coverage provided by the Mercury Deposition Network is somewhat limited, though the measurement sites have been distributed relative to major mercury emission sources.
- Only wet deposition of mercury was measured.

Data Source

The interagency National Atmospheric Deposition Program served as the data source for this indicator. (See Appendix B, page B-14, for more information.)

Exhibit 2-24: Annual mercury wet deposition in 2001 per square meter (µg/m²)



Note: Coverage does include Alaska, Hawaii, or Puerto Rico

Source: National Atmospheric Deposition Program, Mercury Deposition Network. 2001. March 25, 2003; (*http://nadp.sws.uiuc.edu/mdn/maps/2001/01MDNdepo.pdf*).

Indicator Chemical contamination in streams and ground water - Category 2

The U.S. Geological Survey reported on contaminants in stream waters and streambed sediment for the entire U.S. (see The Heinz Center, 2002). The contaminants reported include many pesticides, selected pesticide degradation products, PCBs, polyaromatic hydrocarbons (PAHs), volatile organic compounds, other industrial contaminants, and trace elements. In sufficient concentrations, any of these chemicals can harm wildlife, but for many of these compounds, there are no standards or guidelines for acceptable levels in aquatic systems.

In the USGS analysis, water contaminant data were derived from 36 major river basins, which included 109 stream sites with data sufficient to calculate annual averages. Stream water samples generally were collected on 20 to 40 occasions over a one-year period (Gilliom, et al., 2002) during 1992 to 1998. Ground water data were collected from 3,549 wells in these major river basins and aquifers.

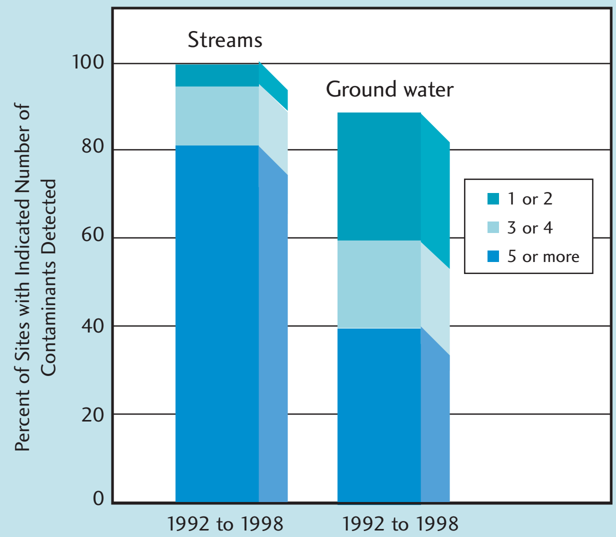
What the Data Show

All stream waters averaged one or more contaminants at detectable levels throughout the year. More than 80 percent averaged five or more (Exhibit 2-25). About 90 percent of ground water sites averaged one or more detectable contaminants. 40 percent contained five or more contaminants.

Indicator Gaps and Limitations

The sites sampled are representative of a wide range of stream sizes, types, and land uses broadly distributed across the U.S. (Gilliom, et al., 2002; The Heinz Center, 2002).

Exhibit 2-25: Occurrence of contaminants in streams and ground water, 1992-1998



Coverage: lower 48 states.

Source: The Heinz Center. *The State of the Nation's Ecosystems.* 2002. Data from the U.S. Geological Survey.

Data Source

Date for this indicator came from U.S. Geological Survey, as compiled for The Heinz Center (2002). (See Appendix B, page B-15, for more information.)

Indicator Pesticides in farmland streams and ground water - Category 2

Nearly one billion pounds of pesticides are used in the U.S. each year to control weeds, insects, and other organisms that threaten or undermine human activities such as agriculture. The vast majority of pesticides—about 80 percent—are used for agricultural purposes. Although pesticide use has resulted in increased crop production and other benefits, it has also raised concerns about potential adverse effects on the environment and human health. Pesticide contamination of streams, rivers, lakes, reservoirs, coastal areas, and ground water may cause unintended adverse effects. These water resources support aquatic life and related food chains and are used for recreation, drinking water, irrigation, and many other purposes. In addition, water is one of the primary pathways by which pesticides are transported from their application areas to other parts of the environment.

Indicator Pesticides in farmland streams and ground water - Category 2 (continued)

From 1992 to 1998, the USGS, under its National Water Quality Assessment Program, conducted the largest data collection effort ever performed for pesticides (including insecticides and herbicides) in ground and surface waters. This effort involved analysis for 76 pesticides and seven selected pesticide degradation products in 8,200 samples of ground water/surface water in 20 of the nation's major hydrologic basins. Sampling sites included streams and ground water in both agricultural areas and urban areas.

What the Data Show

In all streams, at least one pesticide was present at detectable levels throughout the year. Data were analyzed separately for agricultural and urban areas:

- *Agricultural areas.* About 75 percent of monitored farmland streams had an average of five or more pesticides at detectable levels, and over 80 percent had at least one pesticide that exceeded aquatic life guidelines. About 60 percent of ground water sites in agricultural areas had a least one detectable pesticide, and seven percent had an average of five or more compounds at detectable levels. A very small proportion (less than one percent) of ground water sites in farmland areas had one or more pesticides in concentrations that exceeded human health standards or guidelines (The Heinz Center, 2002). A relatively small number of these chemicals—specifically the herbicides atrazine (and its breakdown product desethylatrazine), metolachlor, cyanazine, and alachlor—accounted for most detections in ground water. The high detection frequency for these pesticides is related to their use. All are among the top five herbicides used in agriculture across the nation (Gilliom, et al., 2002).
- *Urban areas.* Water in urban areas has a characteristic "signature" that is reflective of the chemicals used in the watersheds serving those areas. Insecticides such as diazinon, carbaryl, chlorpyrifos, and malathion were detected more frequently, and usually at higher concentrations, in urban streams than in agricultural streams. Herbicides were detected in 99 percent of urban stream samples and in more than 50 percent of sampled wells. The most common herbicides in urban streams and ground water were simazine and prometon.

Frequency of detection, expressed as a percentage of pesticides in water samples, serves as a basic indicator (Exhibit 2-26):

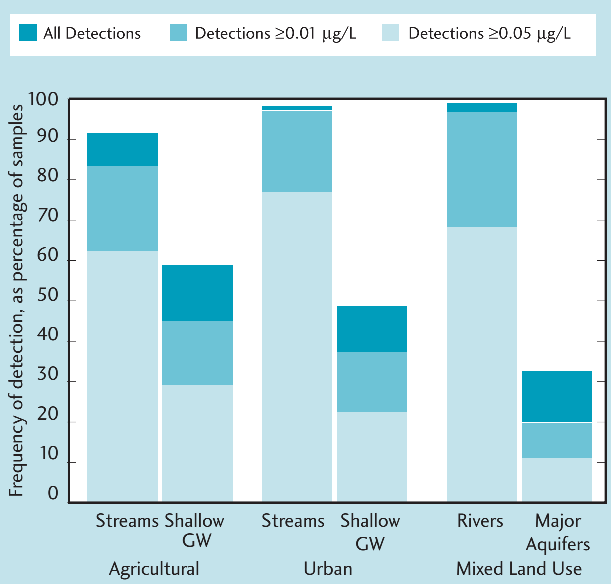
- *Streams*. The data suggest that pesticides are fairly ubiquitous in both farmland and urban streams and rivers. As noted above, at least one pesticide was present at detectable levels throughout the year in all monitored streams. Most pesticide detections were found in rivers associated with mixed land uses, followed by streams associated with urban land use, then streams associated with agricultural land uses.
- *Ground water*. Significantly fewer detections of pesticides were found in shallow ground water, and the least detections were found in major aquifers.

For the 21 most detected pesticides, data suggest that their occurrence, in both streams and ground water, closely mirrors their use. Surprisingly, pesticides were detected as frequently, or sometimes more frequently, in urban streams than in streams associated with agricultural lands. The NAWQA data indicate that, in urban and agricultural streams and shallow ground water, pesticides most often occur in mixtures (i.e., more than one compound is present in the sample). The human health and environmental impacts of pesticide contamination, particularly when the pesticides occur as mixtures, are not well understood.

Data Gaps and Limitations

Knowing how many pesticides are detected and at what concentrations provides basic information on the extent to which these compounds are found in streams and ground water. However, the presences of pesticides does not necessarily mean that the levels

Exhibit 2-26: Summary of detections of one or more pesticides in streams and ground water, 1992-1998



Coverage: lower 48 states

Source: Modified from The Heinz Center. *The State of the Nation's Ecosystems.* 2002. Data from the U.S. Geological Survey.

Indicator Pesticides in farmland streams and ground water - Category 2 (continued)

are high enough to cause problems. Comparison to standards and guidelines provides a useful reference to help judge the significance of contamination.

Drinking water standards or guidelines do not exist for 43 percent (33 of 76) of the pesticides analyzed, and aquatic life guidelines do not exist for 63 percent (48 of 76) of the pesticides analyzed. Current standards and guidelines do not account for mixtures of chemicals and seasonal pulses of high concentrations. In addition, potential effects on reproductive, nervous, and immune systems, as well as on chemically sensitive individuals, are not yet well understood.

Data Sources

The data sources for this indicator were The U.S. Geological Survey's National Water Quality Assessment Program, as compiled for The Heinz Center (2002), and The EPA's Office of Prevention, Pesticides, and Toxic Substances.(See Appendix B, page B-15, for more information.)

Indicator Acid sensitivity in lakes and streams - Category 2

Airborne nitrogen and sulfur gases (i.e., nitrogen oxides and sulfur oxides) are referred to as acid precursors because they react with water, oxygen, and other compounds to form sulfuric acid and nitric acid. For example:

- They combine with water vapor and oxygen in the atmosphere to form acids that fall to earth as a component of snow, fog, dry particles, gases, or acid rain.
- When they reach a waterbody through dry deposition, they combine with surface water to form nitric acid and sulfuric acid.
- Indirect deposition can occur when these precursors are deposited on land and then washed into a waterbody by storm water runoff. The effects of indirect deposition are particularly serious if the storm deposits acid rain.

Acidification is common in waterbodies in the eastern U.S., where weather patterns deposit acids made from air pollutants generated in the Midwest and points further west. Also, many eastern waterbodies are naturally acidic, making them more susceptible to the effects of acid deposition because their underlying soils and rock are not able to buffer incoming acids. This is particularly true for many lakes in the Adirondack Park, located in upstate New York.

Acidification affects ecosystems in many ways. For example:

- Aquatic organisms in acidified waters often suffer from calcium deficiencies that can weaken bones and exoskeletons and can cause eggs to be weak or brittle.
- It affects the permeability of fish membranes and, particularly, the ability of gills to take in oxygen from water.
- Increasing amounts of acid in a waterbody change the mobility of certain trace metals like aluminum, cadmium, manganese, iron, arsenic, and mercury. Species that are sensitive to these metals, particularly fish, can suffer as a result.

Acid sensitivity in lakes and streams is determined based on a suite of chemical measurements, including pH, conductivity, dissolved organic carbon (DOC), cations, anions, and acid-neutralizing capacity (ANC). Using data for these parameters, it is possible to distinguish, on a national scale, natural sources of acidity such as wetlands, from anthropogenic sources such as acid deposition and mine drainage (Baker, et al., 1991). For example, in low pH waters:

- High conductivity and high sulfate concentrations indicate acid-mine drainage.
- High DOC concentrations with low conductivity indicate acid contributions from wetlands.
- Low conductivity, moderate sulfate concentrations, and low DOC concentrations indicate acid deposition.

What the Data Show

EPA's 1984 to 1986 National Surface Water Survey (NSWS) estimated that, in acid-sensitive regions of the northern and eastern

Indicator Acid sensitivity in lakes and streams - Category 2 (continued)

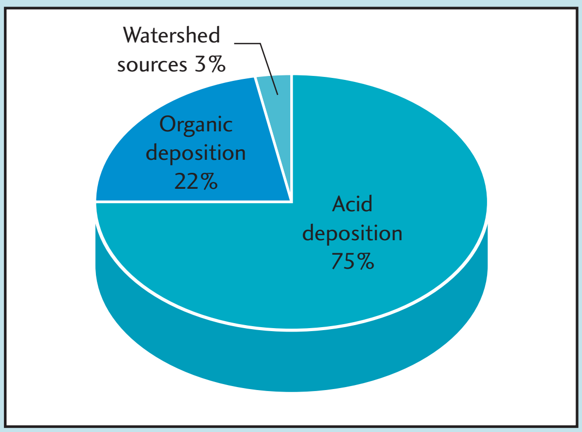
U.S., 4.2 percent of lakes and 2.7 percent of streams were acidic. Of those acidic lakes and streams, 75 percent were acidic due to acid deposition, 22 percent were acidic due to organic sources, and three percent were acidic due to acid-mine drainage (Exhibit 2-27).

These surveys have been repeated periodically for smaller probability samples of lakes in the Northeast, the Adirondacks and streams in the Appalachians (Stoddard, et al., 1996). More intensive monitoring also has been conducted on lakes in the Northeast, the Appalachians, and the Midwest, and on streams in the Appalachian Plateau and Blue Ridge to assess long-term acidification trends (Stoddard, et al., 1998). Based on these programs, EPA estimated that in three regions, one-quarter to one-third of lakes and streams previously affected by acid rain were no longer acidic, although they were still highly sensitive to future changes in deposition (EPA, ORD, January 2003). EPA has concluded that the decrease in acidity is a result of reduced sulfate emissions under its acid rain programs. Specifically:

- Eight percent of lakes in the Adirondacks are currently acidic, down from 13 percent in the early 1990s.
- Less than two percent of lakes in the upper Midwest are currently acidic, down from three percent in the early 1980s.
- Nine percent of the stream length in the northern Appalachian plateau region is currently acidic, down from 12 percent in the early 1990s.

Lakes in New England did not show decreases in acidity, and streams in the Ridge and Blue Ridge regions of Virginia were unchanged. Even though acid deposition has been decreasing in the Ridge and Blue Ridge regions, waterbodies in these areas are expected to show a lag time in their recovery due to the nature of the soils in those regions. Immediate responses to decreasing deposition were neither seen nor expected in these two regions.

Exhibit 2-27: Sources of acidity in acid-sensitive lakes and streams, 1984-1986



Coverage: Acid sensitive regions of the United States north and east, inclusive of the upper midwest, New England, Adirondack Mountains in New York, the northern Appalachian Plateau, and the Ridge and Blue Ridge Provinces of Virginia

Source: Baker et al. *Acid Lakes and Streams in the United States: The Role of Acidic Deposition.* (1991).

Indicator Gaps and Limitations

The NSWS has not been repeated nationwide since the mid-1980s, so there are no data to assess trends in surface water acidification in other sensitive areas of the country.

Data Source

The data source for this indicator was EPA's National Surface Water Survey. (See Appendix B, page B-15, for more information.)

Indicator: Toxic releases to water of mercury, dioxin, lead, PCBs, and PBTs - Category 2

The Toxics Release Inventory (TRI) contains information on toxic chemical releases and other waste management activities reported annually by certain industries as well as by federal facilities. This inventory was established under the Emergency Planning and Community Right-to-Know Act of 1986 (EPCRA), which requires facilities to use their best readily available data to calculate their releases and other waste management estimates. This indicator is based on reported TRI releases of mercury, dioxins, PCBs, sum of all persistent bioaccumulative toxic chemicals (PBTs), and lead to water in calendar year 2000 (EPA, OEI, May 2002).

PBT chemicals include dioxins, mercury, PCBs, PAHs, and pesticides (but not lead). PBT pollutants are chemicals that are toxic, persist in the environment, and bioaccumulate in food chains, thus posing risks to human health and ecosystems. They transfer easily across and among ecological systems.

Under EPCRA, most dischargers must report releases of toxic chemicals. Specifically, a facility must report to TRI if it meets all of the following criteria:

- Conducts manufacturing operations within Standard Industrial Classification (SIC) codes 20 through 39 or, beginning in the 1998 reporting year, is in one of the following industry categories: metal mining, coal mining, electric utilities that combust coal and/or oil, chemical wholesale distributors, petroleum terminals, bulk storage facilities, Resource Conservation and Recovery Act (RCRA) subtitle C hazardous waste treatment and disposal facilities, and solvent recovery services. Also, federal facilities must report to TRI regardless of their SIC code classification.
- Has 10 or more full-time employee equivalents.
- For all but certain PBT chemicals, manufacturers or processes more than 25,000 pounds or otherwise uses more than 10,000 pounds of any listed chemical during the calendar year.

What the Data Show

During 2000, facilities reporting to the TRI released over 7 billion pounds of chemicals (EPA, OEI, May 2002). Of that total, nearly 261 million pounds (3.7 percent) were discharged to water, including 21,318 pounds of PBTs, 29 pounds of PCBs, 5 pounds of dioxin compounds, and 2,302 pounds of mercury compounds. (Note that the total for PBTs includes all PBT compounds reported under TRI. Total releases for specific types of PBT compounds, such as PCBs and mercury compounds, are also aggregated and reported separately.)

Indicator Gaps and Limitations

The TRI data have several limitations:

- The TRI program only accounts for direct releases to water (i.e., it does not include releases from non-point sources). However, it does identify releases of metal and metal compounds from publicly owned treatment works (POTWs).
- It does not include releases below the reporting thresholds.
- Reporting is made by the releasing facilities, and no standard estimation procedure is employed (see Chapter 3–Better Protected Land).

Data Source

The data source for this indicator is EPA's Toxics Release Inventory program. (See Appendix B, page B-15, for more information.)

Indicator Sediment contamination of inland waters - Category 2

Contaminated sediments generally have localized impacts, with the severity of impact depending on the degree of chemical contamination. Contaminated sediments affect benthic organisms, such as worms, crustaceans, and insect larvae that inhabit the bottom of waterbodies. In some cases, toxic sediments kill these benthic organisms, reducing the food available to larger animals such as fish. Also, some contaminants in sediments may be taken up by benthic organisms and passed onto larger animals that feed on these contaminated organisms. In this way, toxins in sediment move up the food chain in increasing concentrations. As a result, fish and shellfish, waterfowl, and fresh water and marine animals, as well as benthic organisms, may be affected by contaminated sediments.

As part of EPA's National Sediment Inventory (described in the introduction to Section 2.2.4c), sediment chemical concentrations were evaluated in over 19,000 samples in the U.S. and categorized into three groups:

- Tier 1 (associated adverse effects on aquatic life or human health are probable).
- Tier 2 (associated adverse effects on aquatic life or human health are possible).
- Tier 3 (no indication of associated adverse effects on aquatic life or human health).

Tier 1 sampling stations were distinguished from Tier 2 sampling stations based on the magnitude of a contaminant concentration in sediment, or the degree of corroboration among the different types of sediment quality measures.

What the Data Show

Of the sampling stations evaluated, 8,348 stations (43 percent) were classified as Tier 1, 5,846 (30.1 percent) were classified as Tier 2, and 5,204 (26.8 percent) were classified as Tier 3. The sampling stations were located in 5,695 individual river reaches (or waterbody segments) across the conterminous U.S., which constitute approximately 8.8 percent of all river reaches in the country (based on EPA's River Reach File 1).

- Approximately 3.6 percent of all river reaches in the conterminous U.S. had at least one station categorized as Tier 1.
- Approximately 3 percent of reaches had at least one station categorized as Tier 2 (but none as Tier 1).
- In about 2.3 percent of reaches, all of the sampling stations were classified as Tier 3.

In the National Sediment Inventory, watersheds (8-digit HUC) containing areas of probable concern (APCs) for sediment contamination were defined as those that include at least 10 Tier 1 sampling stations and in which at least 75 percent of all sampling stations were classified as either Tier 1 or Tier 2. APC designation could result from extensive sampling throughout a watershed, or from intensive sampling at a single contaminated location or a few contaminated locations.

Analysis of survey data showed that:

- Ninety-six eight-digit HUC watersheds were identified as containing APCs (Exhibit 2-28).
- These watersheds represent about 4.2 percent of all eight-digit HUC watersheds in the U.S. (96 of 2,264).
- In many of these watersheds, contaminated areas may be concentrated in specific river reaches in the watershed. For example, within the 96 watersheds containing APCs across the country, 97 individual river reaches or waterbody segments have 10 or more Tier 1 sampling stations.
- Twenty-four percent of reaches in watersheds (eight-digit HUC) containing APCs have at least one Tier 1 sampling station and 18.3 percent have no Tier 1 sampling station but at least one Tier 2 sampling station.

The evaluation results indicate that sediment contamination associated with probable or possible adverse effects for both aquatic life and human health exists in a number of watersheds across the country.

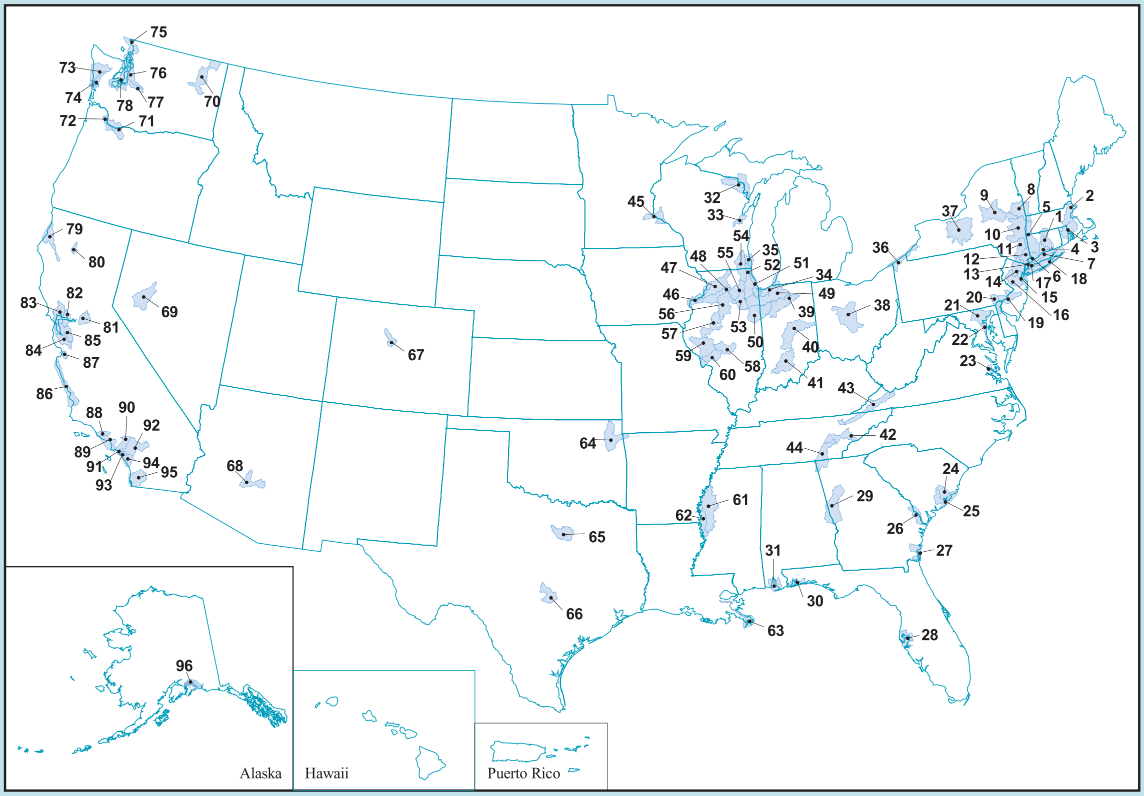
Indicator Gaps and Limitations

Two general types of limitations are associated with the National Sediment Inventory:

- *Limitations of the compiled data.* These limitations include the mixture of data sets derived from different sampling strategies, incomplete sampling coverage of geographic regions and monitored chemicals, the age and quality of the data, and the lack of measurements of important assessment parameters, such as TOC and acid volatile sulfide.
- *Limitations of the evaluation approach.* These include uncertainties in the interpretive tools used to assess the sediment quality, use of assumed exposure potential in screening-level quantitative risk assessment (e.g., fish consumption rates as a surrogate for human health risk), and the subsequent difficulties in interpreting assessment results. Also, because this analysis is based only on readily electronically formatted data, the survey does not include a vast amount of information available from sources such as local and state governments and published academic studies.

Indicator | Sediment contamination of inland waters - Category 2 (continued)

Exhibit 2-28: Watersheds in sediment quality inventory (1980-1999) identified as containing areas of particular concern (APCs)



Source: EPA, Office of Water. *The Incidence and Severity of Sediment Contamination in Surface Waters of the United States, National Sediment Quality Survey: Second Edition, Draft.* December, 2001.

Another key limitation is that most of the NSI data were compiled from monitoring programs that focus their sampling efforts on areas where contamination is known or suspected to occur. While this is important for meeting the stated objective of the NSI survey, which is to identify contaminated sediments, it means that the data cannot be used to accurately characterize the overall condition of the nation's sediment, because national sampling coverage is incomplete and because uncontaminated areas are most likely substantially under-represented. In addition, the data analyzed for this indicator were collected over a relatively long time period; therefore, they do not definitively assess the current condition of sediments, but can serve as a baseline for future assessments.

Data Source

The data are described in Appendix A of the draft report *The Incidence and Severity of Sediment Contamination in Surface Waters of the U.S., National Sediment Quality Survey;* second edition (EPA-822-R-01-01). A draft is available. The final report is expected to be released in 2003. Summary reports on the data are not available. (See Appendix B, page B-15, for more information).

Indicator Sediment contamination of coastal waters - Category 2

Estuaries are important habitats for migratory birds, and many species of fish and shellfish rely on the sheltered waters of estuaries as protected places to spawn. Contamination of sediments in estuaries can pose a threat to individual species and to estuarine ecosystems.

Contaminated sediments may harm benthic organisms that feed on these sediments, and they may accumulate up the food chain as larger organisms feed on smaller organisms, eventually posing a risk to human health. Additionally, contaminants in sediments may be resuspended into the water by dredging and boating activities.

One of the challenges of assessing sediment contamination is distinguishing among naturally occurring contaminants, such as certain organics and metals, from those created by human activities. PAHs and metals occur naturally in estuarine sediments, so a special approach must be used to determine how much of their concentrations in sediment are contributed by human sources (Windom, et al., 1989). On the other hand, pesticides and PCBs are relatively easy to evaluate, as they can only come from human activities.

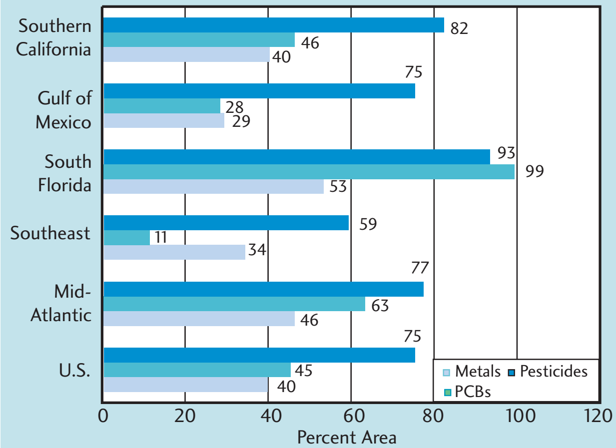
Under the EPA's Environmental Monitoring and Assessment Program (EMAP), contamination was measured for sediments from estuaries in the Virginian, Carolinian, and Louisianian Provinces of the eastern U.S. Chemical concentrations were identified as enriched by human sources if they exceeded values expected to occur naturally. Sediment chemical concentrations also were compared to NOAA-derived effects range low (ERL) values and effects range median (ERM) values. These values identify threshold concentrations that, if exceeded, are expected to produce ecological or biological effects 10 percent and 50 percent of the time, respectively. A site was considered contaminated if five or more chemical concentrations exceeded the ERL, or if one or more exceeded the ERM.

What the Data Show

Sediment contaminant concentrations indicate that 40 percent, 45 percent, and 75 percent of U.S. estuarine sediments that were sampled are enriched with metals from human sources, PCBs, and pesticides, respectively (Exhibit 2-29).

One to two percent of estuarine sediments show concentrations of contaminants (PAHs, PCBs, pesticides, and metals) that are above ERM values (Exhibit 2-30). Between 10 and 29 percent of sediments have contaminant concentrations between the ERM values and lower-level ERL values (Exhibit 2-30). Most of the locations exceeding the ERM guidelines are in the northeast coastal area, while the Gulf of Mexico coast contains many locations where concentrations of five or more contaminants exceed the ERL values. The highest contamination is found in the Northeast. Estuaries most affected are: Hudson River-New York, New Jersey Harbor system; eastern Long Island Sound; Delaware River; Potomac River; and upper Chesapeake Bay.

Exhibit 2-29: Regional sediment enrichment (1990-1997) due to human sources



Source: EPA, Office of Research and Development and Office of Water. *National Coastal Condition Report.* September 2001.

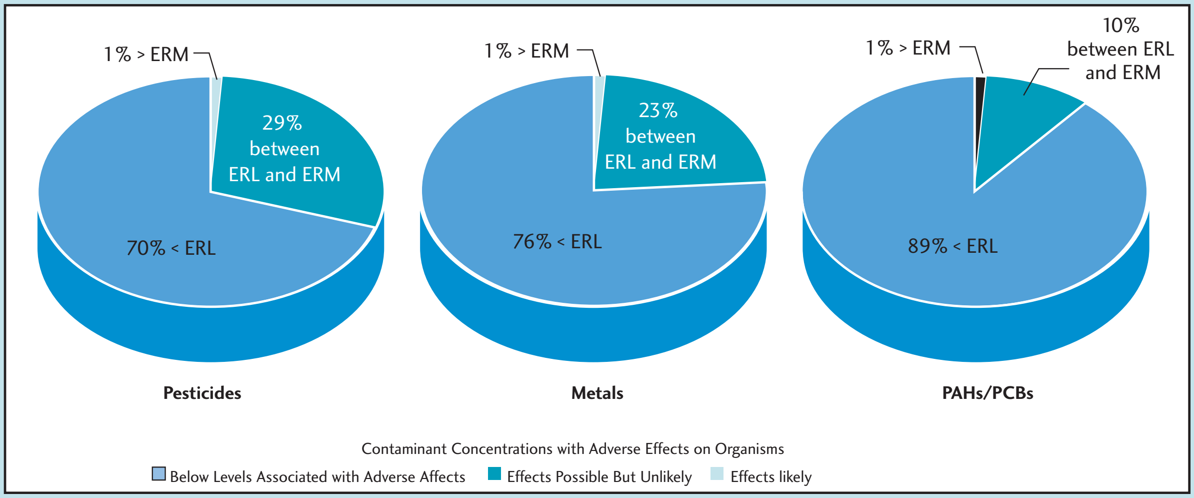
Indicator Gaps and Limitations

Several limitations are associated with this indicator:

- Assessment of contamination is limited to the three provinces noted above. Probabilistic assessments of coastal waters of the Great Lakes, West Coast, and northern New England do not exist, so this indicator does not include data for these regions.
- The sampling design did not proportionately represent shallow habitats (less than 3 meters), which may represent as much as 50 percent of the total estuarine area in the Southeast and Gulf of Mexico.
- While the data currently are adequate to address regional condition, they provide little information on gradients from major sources of contamination (e.g., large urban areas).
- Many factors control availability of contaminants in sediments, including organic content, acid volatile sulfides, pH, particle size and type, and the specific form of chemical (e.g., chromium). Therefore, sediment chemical concentrations, in and of themselves, do not directly estimate the biological availability of those contaminants.

Indicator Sediment contamination of coastal waters - Category 2 (continued)

Exhibit 2-30: Distribution of sediment contaminant concentrations in sampled estuarine sites, 1990 – 1997



Coverage: United States east coast (excluding waters north of Cape Cod) and Gulf of Mexico

Source: EPA, Office of Research and Development and Office of Water. *National Coastal Condition Report.* September 2001.

- The scientific basis for the ERL/ERM criteria may vary among estuaries, habitats, and regions depending upon the kinds and abundances of indigenous biota.
- Sediment contamination is not directly related to the biological availability of contaminants in sediments. Bioavailability of contaminants in sediments can be directly measured by sediment toxicity testing, which forms the basis for the next indicator discussed, "sediment toxicity in estuaries."

Data Source

Sediment contamination data are from the EPA's Environmental Monitoring and Assessment Program Estuaries dataset. (See Appendix B, page B-16, for more information.)

Indicator Sediment toxicity in estuaries - Category 2

Many factors control the biological availability of contaminants in sediments, including acid volatile sulfides, pH, particle size and type, organic content, resuspension potential, and specific species/form of contaminant (e.g., chromium). Sediment toxicity tests are the most direct current measure for determining the bioavailability of contaminants in sediments. These tests provide information that is independent of chemical characterization and ecological surveys (Chapman, et al., 1987). They improve upon the direct measure of contaminants in sediments (the basis for the previous indicator "sediment contamination of coastal waters"), because many contaminants are tightly bound to sediment particles or are chemically complex and are not biologically available. Thus, the presence of contaminants in sediments does not necessarily mean that the sediments are toxic.

To assess bioavailability of sediment contaminants in estuaries, the EPA's EMAP Estuaries Program, in conjunction with the NOAA Status and Trends Program, conducted sediment toxicity tests on estuarine sediments.

What the Data Show

The EPA's EMAP Estuaries Program found that about 10 percent of the sediments in estuaries in the Virginian, Carolinian, Louisianian, West Indian, and Californian Provinces were toxic to

Indicator Sediment toxicity in estuaries - Category 2 (continued)

the marine amphipod, *Ampelisca abdita*, over a 10-day period (EPA, ORD, OW, September 2001). The NOAA Status and Trends Program also used a sea urchin fertility test and a microbial test to evaluate chronic toxicity in selected estuaries, NOAA found that 43 to 62 percent of the sediment samples from these selected estuaries showed chronic toxicity.

Indicator Gaps and Limitations

Sediment toxicity tests are a useful tool to establish the potential availability of contaminants in sediments. That availability can, however, be affected by artifacts of laboratory procedures that may make contaminants more or less available. Also, natural sediment features such as particle size and the presence of ammonia and sulfides may cause toxicity that is not related to the presence of contaminants.

Data Sources

Data for this indicator came from EPA's Environmental Monitoring and Assessment Program, Estuaries Program to Estuaries Dataset, and the National Oceanic and Atmospheric Administration's Status and Trends Program. (See Appendix B, page B-16, for more information.)

2.2.5 What ecological effects are associated with impaired waters?

No single program examines the ecological condition of our nation's surface waters. However, a number of regional programs do track the biotic condition of aquatic organisms and attempt to relate degradations in their condition to observed pressures on aquatic systems. Biotic condition does not fully represent the breadth of ecological parameters that ideally would be needed to answer the question, "What are the ecological effects of impaired waters?" However, biological condition is widely acknowledged as a valuable indicator that contributes to an understanding of overall ecological condition.

There are several measures of biotic condition; three were selected for this report:

- Fish index of biotic integrity (IBI) in streams.
- Macroinvertebrate IBI for streams.
- Benthic community index (coastal waters).

These indicators are discussed in detail in Chapter 5, Ecological Condition. As they are relevant to water quality, they are briefly summarized below to demonstrate their effectiveness for future national assessments.

Fish and Macroinvertebrate Indices of Biotic Integrity

Consistent sampling methods and index development procedures were used to measure the biotic integrity of fish and benthos in streams in the Mid-Atlantic Highlands (EPA, ORD, Region 3, August 2000). The mid-Atlantic streams were assessed using both fish and benthic insect indicators. Of the stream miles assessed in the Mid-Atlantic Highlands, the fish IBI indicated that 17 percent of the streams were in good condition and 31 percent were in poor condition. The macroinvertebrate condition measures indicated that 17 percent of the Mid-Atlantic Highland streams were in good condition, while 26 percent were in poor condition. (See Chapter 5–Ecological Condition, for definitions of these categories.)

The assessment permits estimates of both the number and proportion of stream miles in good, fair, or poor condition, but it does not provide information about where these categories of streams are located. Associations of biological condition with specific stressors have not been completed. While the stressors found in the streams can be identified, it is not possible to determine which stressors are contributing to the observed biological condition.

Benthic Community Index (Coastal Waters)

Samples of bottom sediments were collected and benthic index scores were assessed for the northeast, southeast, and Gulf coastal areas. In these three areas, 56 percent of the coastal waters were assessed in good condition, 22 percent in fair condition, and 22 percent in poor condition. The work of associating biological condition with specific stressors has been completed for these coastal waters, so the stressors that co-occur with poor benthic condition can be evaluated. Of the 22 percent of the coastal areas with poor benthic condition, 62 percent also had sediment contamination, 11 percent had low dissolved oxygen concentration, seven percent had low light penetration, and two percent showed sediment toxicity (EPA, ORD, OW, September 2001).

2.3 Drinking Water

Drinking water comes from surface water and ground water. Large-scale water supply systems tend to rely on surface water resources (including rivers, lakes, and reservoirs), while smaller water systems tend to use ground water. Slightly more than half of our nation's population receives its drinking water from ground water by means of wells drilled into aquifers (USGS, 1998).

To protect human health, EPA, under the Safe Drinking Water Act (SDWA), sets health-based standards (called maximum contaminant levels, or MCLs) for contaminants in drinking water. These standards specify the maximum allowable level of each regulated contaminant in drinking water. The standards also prescribe protocols, frequencies, and locations that water suppliers must use to monitor for about 90 regulated contaminants. The SDWA standards and associated monitoring and treatment by water suppliers provide a critical barrier that serves to protect the quality of much of our nation's drinking water. Some 55,000 community water systems in the U.S. test and treat water to remove contaminants before distributing it to customers.

This section addresses three questions relevant to evaluating progress in drinking water protection:

- What is the quality of drinking water?
- What are sources of drinking water contamination?
- What human health effects are associated with drinking contaminated water?

An indicator has been developed to help answer the first of these questions (Section 2.3.1). The second and third questions are addressed in Sections 2.3.2 and 2.3.3, respectively; however, no indicators were identified to answer these questions.

2.3.1 What is the quality of drinking water?

Indicators

Population served by community water systems that meet all health-based standards

In 2002, state data reported to EPA showed that approximately 251 million people were served by community water systems that had no violations of health-based standards. This number represents 94 percent of the total population served by community water systems, up from 79 percent in 1993. Under-reporting and late reporting of violations data by states to EPA affect the accuracy of this data.

The drinking water standards set by EPA under the Safe Drinking Water Act apply to public water systems (PWSs). PWSs are systems that serve at least 25 people or 15 service connections for at least 60 days a year. They may be publicly or privately owned. PWSs include:

- *Community water systems (CWSs)*—systems that supply water to the same population year- round. There are some 55,000 community water systems in the U.S.
- *Non-transient non-community water systems*—systems that regularly supply water to at least 25 of the same people at least 6 months per year, but not year-round (e.g., schools, factories, office buildings, and hospitals that have their own water systems).
- *Transient non-community water systems*—systems that provide water in a place where people do not remain for long periods of time (e.g., a gas station or campground).

Under the 1996 Amendments to the SDWA, EPA must go through several steps to determine, first, whether setting a standard is appropriate for a particular contaminant, and if so, what the standard should be. To make these determinations, EPA considers many factors for each contaminant, including:

- Its occurrence in the environment.
- Human exposure and the risks of adverse health effects in the general population and sensitive subpopulations.
- Analytical methods of detection.
- Available technology.
- How the regulation would impact water systems and public health.

As of 2003, about 90 contaminants are regulated in drinking water under the SDWA.

Indicator Population served by community water systems that meet all health-based standards - Category 1

Under SDWA regulations, all public water systems must monitor the quality of their drinking water and report the monitoring results to their state. Using these results, states determine whether a maximum contaminant level has been violated and must report all violations of federal drinking water regulations to EPA quarterly. The indicator presents the total population across the nation that is served by community water systems that met all health-based drinking water standards.

What the Data Show

In 2002, community water systems (CWS) served 268 million people—just over 95 percent of the U.S. population as recorded in the 2000 census. Analysis of state-reported violations data shows that, in 2002, 94 percent of this population was served by systems that met all drinking water standards (i.e., did not report violations of health-based standards) for the entire year (Exhibit 2-31).

Indicator Gaps and Limitations

Under-reporting and late reporting of CWS violations data by states to EPA affect the ability to accurately report the quality of our nation's drinking water. EPA last quantified the quality of violations data in 1999. Based on this analysis, the agency estimated that states were not reporting 40 percent of all health-based violations to EPA. EPA is continuing to verify state-reported CWS data and expects to issue an updated estimate of data quality in 2003.

Data Source

The underlying database for this indicator is EPA's Safe Drinking Water Information System/Federal version. (See Appendix B, page B-16 for more information.)

Exhibit 2-31: Population served by community water systems (CWSs) with no reported violations of health-based standards, 1993-2002

Fiscal Year	Population served by CWSs that had no reported violations	Percent of CWS-served population that was served by systems with no reported violations
2002	250,596,287	94
2001	239,927,650	91
2000	239,299,701	91
1999	229,805,285	91
1998	224,808,251	89
1997	215,351,842	87
1996	213,109,672	86
1995	208,700,100	84
1994	202,626,433	83
1993	196,229,162	79

Coverage: all 50 states

Source: EPA, Office of Water. *Safe Drinking Water Information Systems/Federal version (SDWIS/FED)*. 2003.

2.3.2 What are sources of drinking water contamination?

Microbiological, chemical, and radiological contaminants can enter water supplies. These contaminants may be produced by human activity or occur naturally. For instance, chemicals can migrate from disposal sites or underground storage systems and contaminate sources of drinking water. Animal wastes, pesticides, and fertilizers may be carried to lakes and streams by rainfall runoff or snow melt. Nitrates from fertilizers can also be carried by runoff and percolate through soil to contaminate ground water. Arsenic and radon are examples of naturally occurring contaminants that may be released into ground water as it travels through rock and soil.

Human wastes from sewage and septic systems or wastes from animal feedlots and wildlife carrying microbial pathogens may get into waters ultimately used for drinking. Coliform bacteria from human and animal wastes may be found in drinking water if the water is not properly treated or disinfected. These bacteria are used as indicators that other harmful microbial pathogens, such as *Giardia, Cryptosporidium*, and *E. coli* O157:H7, might be in the water.

Disinfection of drinking water is a critical public health measure as it provides a barrier against harmful microbes. Under the SDWA, all surface water supplies, and ground water supplies with close hydrological connections to surface water must disinfect (and most must also filter) their water to remove pathogens. However, disinfectants such as chlorine react with naturally occurring organic matter in source water and in distributions systems to form chemical by-products (known as disinfection by-products) such as trihalomethanes and haloacetic acid compounds.

For systems that disinfect, water leaves the plant with a disinfectant residual. However, in some cases water could become contaminated if there is a breach in the distribution system.

2.3.3 What human health effects are associated with drinking contaminated water?

Effects of exposure to contaminants in drinking water will vary depending on many factors, including the type of contaminant, its concentration in drinking water, and how much contaminated water is consumed over what period of time.

- *Chemical contaminants.* Chemical contaminants found or expected to occur in drinking water can include metals, pesticides, and solvents. Most of these would be expected to cause no health effects at the levels found in treated drinking water, but they may cause a variety of biological responses at high doses. These could include cosmetic effects (such as skin discoloration) or unpleasant odors, as well as more severe health effects such as nervous system or organ damage, developmental or reproductive effects, or cancer. One well-studied consequence of drinking contaminated water is the formation of methemoglobin in infants drinking formula with more than 10 ppm nitrate. This altered hemoglobin does not carry oxygen efficiently; too much of it in the blood of very young children can be fatal (i.e., blue baby syndrome).
- *Pathogens.* The consequences of consuming water with pathogenic microbes can include gastrointestinal illnesses causing stomach pain, diarrhea, headache, vomiting, and fever. Waterborne pathogens can cause diseases that are less common in the U.S., such as typhoid fever and cholera, as well as more common waterborne diseases such as giardiasis or cryptosporidiosis. Pathogenic microbes can enter water from human and animal wastes. One of the largest outbreaks of disease from contaminated water occurred in Milwaukee in 1993, when an estimated 400,000 people became ill from exposure to *Cryptosporidium,* a single-celled parasite that is found in the large intestines of a large number of animals, including cattle and humans. That outbreak killed more than 50 people, the vast majority of whom had seriously weakened immune systems (Hoxie, et al., 1997).

Drinking water disinfection is one of the great public health success stories of the 20th century. It has been a critical factor in reducing the incidence of waterborne diseases such as typhoid, cholera, and hepatitis, as well as gastrointestinal illness in the U.S. Though drinking water disinfection is a critical public health measure, the process does generate disinfection by-products, as mentioned earlier. These compounds have been associated with cancer, developmental, and reproductive risks, the extent of which is still uncertain (see Chapter 4–Human Health).

2.4 Recreation in and on the Water

Our nation's rivers, lakes, and oceans are used for recreation in many different ways, including swimming, fishing, and boating. Environmental programs implemented under the Clean Water Act (CWA) have significantly improved the quality of many of our nation's waters since the early 1970s. These programs help to maintain the quality of waters that have been specifically designated for recreational uses and ensure that they do not become degraded in the future. Despite this progress, recreational waters are threatened or affected by pollution at some times and in various locations. For example:

- During and following heavy rainfall, the sewer systems in some cities may become overloaded, resulting in the temporary discharge of raw sewage, wastewater, and storm water into rivers and coastal areas.
- Lakes and ponds may be affected by non-point source pollution, for example from septic tanks and agricultural sources, resulting in chemical contamination and elevated levels of nutrients.
- Industries are issued permits under the Clean Water Act that allow discharges of certain treated wastewaters to rivers and streams. These discharges compromise our ability to also use those waters for recreational purposes.

Perhaps the greatest human health concern associated with pollution of recreational waters is the potential for exposure to human pathogens. Many Americans risk illness from exposure to contaminated recreational waters. Epidemiology studies in the U.S. and abroad have consistently found an association between disease burden and contaminated waters. State and local officials monitor water quality at public beaches and close the beaches or issue advisories when monitoring indicates that pathogens in water may have exceeded thresholds for public safety. The fact that hundreds of beach advisories and closings are issued every year at recreational rivers, lakes, and coastal waters throughout the U.S. suggests that our recreational waters are significantly impacted by pollution. Three questions are posed with regard to recreational waters:

- What is the condition of waters supporting recreational use?
- What are sources of recreational water pollution?
- What human health effects are associated with recreation in contaminated waters?

An indicator has been developed to help answer the first of these three questions, at least with regard to pathogens in recreational waters. The second and third questions are addressed in Sections 2.4.2 and 2.4.3, respectively. No indicators were identified to answer these two questions. Note that concerns associated with consumption of fish and shellfish, including fish and shellfish caught through recreational activities, are discussed in Section 2.5.

2.4.1 What is the condition of waters supporting recreational use?

Indicators

Number of beach days that beaches are closed or under advisory

As described in Section 2.2.1, a number of programs collect information on the condition of waters at a national scale, including the conditions that support recreational uses of waters. However, for a variety of reasons described in Section 2.2.1, none of these programs (including the widespread CWA-mandated 305[b] state data collection and reporting program) produce data with sufficient confidence and scientific credibility to serve as a national indicator for water quality condition. Nevertheless, data from an entirely different source (state and local monitoring of water quality at beaches) can be used to help answer the question "What is the condition of surface waters that support recreational use?"—at least with respect to pathogen contamination.

When local and state officials monitor water quality at beaches, they generally test for indicator organisms, such as coliforms. Not all of these organisms are harmful themselves, but their presence generally suggests that disease-causing microorganisms are also likely to be present. When indicator organisms exceed certain thresholds, local or state officials will close the beach to the public. The number of days that beaches are closed or under advisory provides the basis for an indicator for recreational water quality with respect to pathogen contamination. This indicator reflects decisions made by state and local governments about whether pathogen levels are above their public health thresholds at beaches under their jurisdiction. Beach closure/advisory data predominantly represent coastal and Great Lakes areas. Data on inland waterways generally are not available or are not collected and reported. Thus, the question "What is the condition of surface waters that support recreational use?" can only be addressed for a portion of coastal and Great Lakes beaches on a national level at this time.

Indicator: Number of beach days that beaches are closed or under advisory - Category 2

Data on beach closures are collected by EPA under the Beaches Environmental Assessment and Coastal Health (BEACH) Program. This program is authorized by Section 104 of the Clean Water Act and described in EPA's Action Plan for Beaches and Recreational Waters (EPA, ORD, OW, March 1999).

The BEACH program collects data for the National Health Protection Survey of Beaches by sending a questionnaire to managers (usually in health or environmental quality departments in states, counties, or cities) who are responsible for monitoring swimming beaches on the coasts or estuaries of the Atlantic Ocean, Pacific Ocean, and Gulf of Mexico, and the shoreline of the Great Lakes. Information on some other inland fresh water beaches has also been collected. Responses to these surveys are voluntary and have increased substantially from 159 local, state, and federal agencies reporting in 1997, to 237 agencies reporting on 2,445 beaches in 2001.

What the Data Show

Using the survey data, EPA compiles the number of days that beaches are closed or under advisory and compares that to the total number of "beach days"—i.e., days that the beaches would normally be open to the public. In 2001, survey respondents reported a total of approximately 320,000 beach days during the swimming season for the 2,445 beaches for which data were collected. These beaches were closed or under advisory on almost six percent (over 19,000) of those beach days.

Indicator Gaps and Limitations

This indicator has a number of limitations:

- Since reporting is voluntary, the data cannot be extrapolated to accurately determine the suitability on a national level of surface waters to support recreation.
- The indicator applies primarily at this time to coastal and Great Lakes beaches, as relatively few fresh water inland beaches are surveyed.
- The causes of closures vary greatly among states; therefore, linking beach closures to human health problems or stressors is difficult.
- Some reports are based upon infrequent monitoring. Infrequent monitoring could miss events that would cause closures.
- In interpreting the data, the assumption is made that the public was at minimal risk of exposure to waterborne illness on days the beach was open. However, this may not always be true.

Data Source

Data for this indicator came from EPA's National Health Protection Survey of Beaches. (See Appendix B, page B-17 for more information.)

2.4.2 What are sources of recreational water pollution?

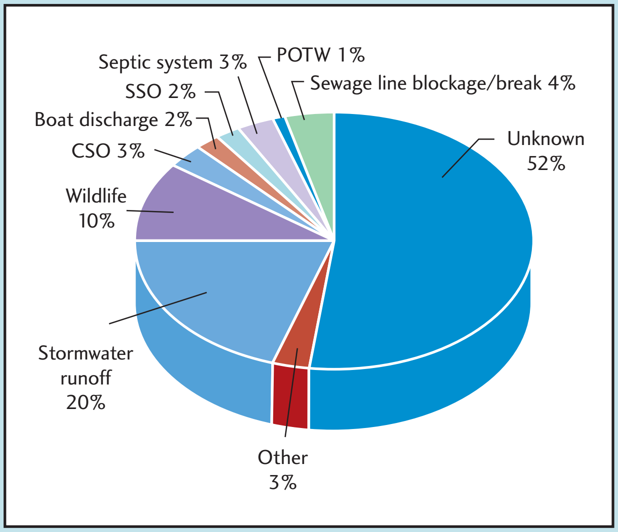
As mentioned earlier, beach advisories and closings in the U. S. are generally due to elevated levels of indicator organisms, such as coliforms, some of which do not themselves cause disease but may indicate the presence of disease-causing microorganisms. In the survey of beaches (see Section 2.4.1), respondents are asked to identify, based on best professional judgment, the sources of pollution (i.e., the indicator organisms and any associated pathogens) that caused a beach advisory or closing. Exhibit 2-32 presents the sources reported for the 2001 swimming season.

For just over half the cases, the sources were unknown. Storm water runoff was the reported cause for one-fifth (20 percent) of the beach closing or advisories. Rainfall, particularly heavy rain, creates runoff from farmland, city streets, construction sites, suburban lawns, roofs and driveways. This runoff contains harmful contaminants, including human and animal wastes, sediments, and excess nutrients. Runoff can enter waterbodies directly or via the storm water drainage system. Other reported causes of beach closings and advisories were: wildlife (10 percent), sewage line blockages and breaks (four percent), improperly functioning onsite wastewater facilities (i.e., septic systems—see Chapter 3–Better Protected Land) (three percent), combined sewer overflows (three percent), sanitary sewer overflows (two percent), boat discharges (two percent), and publicly owned treatment works (one percent). No indicators have been identified to answer the question "What are the sources of recreational water pollution?" at this time.

2.4.3 What human health effects are associated with recreation in contaminated waters?

The primary health concern associated with recreational waters is the risk of infection from waterborne pathogens. People may be at

Exhibit 2-32: Reported sources of pollution that resulted in beach closings or advisories, 2001



CSO - Combined Sewer Overflow
SSO - Sanitary Sewer Overflow
POTW - Publicly Owned Treatment Works

Source: EPA, Office of Water. *EPA's BEACH Watch Program: 2001 Swimming Season.* May 2002.

risk if they ingest or inhale contaminated water, or simply through general dermal contact with the water. Some people may be more vulnerable than others, either because they are more susceptible to infection or because they have greater exposure to the water. For example, children may be more vulnerable to environmental exposure due to their active behavior and developing immune systems. Elderly and immunosuppressed persons may also be more vulnerable.

The health effects of swimming in contaminated waters are usually minor—sore throats, ear infections, and diarrhea. In some instances, however, effects can be more serious and even fatal. Waterborne microbes can cause meningitis, encephalitis, and severe gastroenteritis (EPA, ORD, OW, March 1999). However, data on the effects and number of occurrences are limited. The number of occurrences are likely under-reported because individuals may not link common symptoms (e.g., gastrointestinal ailments, sore throats) to exposure to contaminated recreational waters. At this time, no indicators have been identified to quantify the health effects associated with recreation in contaminated waters. Additional research is needed to better understand the types and extent of health effects associated with swimming in contaminated water.

2.5 Consumption of Fish and Shellfish

Many coastal and fresh water environments are contaminated with a variety of toxic substances. Of particular concern are mercury, DDT, and PCBs because they persist in the environment and bioaccumulate in the food chain. Though PCBs and DDT are no longer manufactured or distributed in the U.S., they persist in historical deposits in watersheds and near-shore sediments. These deposits continue to provide an active source for contaminating fish and shellfish. Mercury can come from several sources, including industrial releases, abandoned mines, the burning of fossil fuels for electric power generation, and natural sources such as weathering of rock and volcanoes.

Persistent chemicals enter the food chain when they are ingested by bottom-dwelling (benthic) organisms. Benthic organisms are eaten by smaller fish, which in turn are eaten by larger fish, which may be consumed by humans or wildlife. Levels of PCBs and DDTs are a concern in bottom-feeding fish and shellfish, as well as in higher-level predators. Mercury is concentrated particularly in larger and longer-lived predators, such as large-mouth bass, tunas, swordfish, and some sharks. Concentrations of all these compounds, especially in larger fish, can reach levels that are harmful to humans. To protect human health, state and local officials monitor levels of these compounds in fish and shellfish, and issue advisories when tissue concentrations exceed threshold levels. Typically, a fish or shellfish advisory will suggest that intake of a particular species be limited, especially for those at higher risk of health effects such as children, pregnant women, and nursing mothers.

Three questions have been posed concerning consumption of fish and shellfish:

- What is the condition of waters that support consumption of fish and shellfish?
- What are contaminants in fish and shellfish, and where do they originate?
- What human health effects are associated with consuming contaminated fish and shellfish?

Sections 2.5.1, 2.5.2, and 2.5.3, respectively, discuss these questions and, where available, the indicators that are used to help answer these questions.

2.5.1 What is the condition of waters that support consumption of fish and shellfish?

Indicators

Percentage of river miles and lake acres with fish consumption advisories
Contaminants in fresh water fish
Number of watersheds exceeding health-based national water quality criteria for mercury and PCBs in fish tissue

Three indicators, presented on the following pages, are available to help answer this question:

- Percentage of river miles and lake acres with fish consumption advisories.
- Contaminants in fresh water fish.
- Number of watersheds exceeding health-based national water quality criteria for mercury and PCBs in fish tissue.

The first indicator describes the extent of fish advisories, such as closed fisheries and/or restricted fish consumption. Fish advisories are issued by state or local authorities when levels of contaminants in monitored fish exceed threshold levels. These advisories, which are widespread across the U.S., limit or restrict consumption of contaminated species. Mercury, dioxin, PCBs, DDT, and chlordane are responsible for many of these advisories (EPA, OW, May 2002a). Increases in the number of advisories over the years may reflect increased monitoring, increased contamination, and in some cases, more stringent health standards.

The second indicator examines the number of contaminants in fish tissue from samples across the nation. This indicator shows that more than 90 percent of sampled fish had at least one contaminant and more than half had at least five.

The third indicator compares average fish tissue concentrations of mercury and PCBs across watersheds to human-health based water quality criteria. This analysis showed that more than 30 percent of the watersheds for which there are data exceed mercury criteria. These watersheds are predominantly located in eastern coastal states, New England, and the lower portion of the Mississippi River watershed.

For all three indicators, data are based on fish tissue data collected by state or local government agencies, which tend to focus primarily on areas where these agencies believe there may be contaminated fish. This bias may result in inaccurate estimates of the extent of contamination.

Coastal Fish

For coastal fish, insufficient data on the edible portion of these fish are available to provide a national indicator. However, examination of fish tissue collected in coastal waters of the eastern U.S. and Gulf of Mexico shows that compounds of concern were present at levels above EPA's threshold for issuing an advisory.

Shellfish

No national indicators are available for shellfish. However, as discussed below, data are available on the extent of shellfish waters that were classified as harvest-limited or harvest-prohibited from 1966 to 1995. These data show a steady decrease over this time period in the extent of waters classified as harvest-limited or harvest-prohibited. Still, as of 1995, harvesting was limited in 31 percent of shellfish waters and prohibited in 13 percent (NOAA, 1997). The predominant causes of closures are both human and non-human coliform bacteria.

Data on shellfish waters come from the National Oceanic and Atmospheric Administration (NOAA), which records areas that are closed to shellfishing or are subjected to restricted or conditional harvesting. NOAA obtains its data from coastal states, which identify, survey, and classify shellfish-growing waters according to National Sanitary Survey Program (NSSP) guidelines (FDA, 1993). Classification status is based on sanitary surveys of water quality and shoreline surveys of pollution sources. Individual shellfish-growing areas are classified either as approved for harvest or as one of four harvest-limited categories: conditionally approved, restricted, conditionally restricted, and prohibited.

All identified shellfish-growing waters must be classified as prohibited unless sanitary surveys indicate that water quality meets specific NSSP standards for the other categories. Harvesting is permissible in approved areas year-round. The conditionally approved and conditionally restricted categories are for voluntary use by states when a predictable pollution event such as seasonal population, heavy rainfall, or fluctuating discharges from local sewage plants affects the suitability of an area for harvest. Most shellfish harvest restrictions are made based on the concentration of fecal coliform bacteria in shellfish. This organism is not directly harmful to humans, but typically is associated with human sewage and with organic wastes from livestock and wildlife.

The *National Shellfish Register* provides a record of the acreage of all classified shellfish-growing waters in the conterminous U.S. The Register was first published in 1966 to meet the need for summary information on the status and extent of the nation's commercial shellfish-growing areas. Since the publication of the first *Register*, the acreage of classified shellfish-growing waters has increased more than two-fold from 10 million acres to more than 21 million acres (Houser and Silva, 1966; FDA, 1971; EPA, OE, 1975; DOC and HHS, 1985; NOAA, 1991; NOAA,1997), primarily due to an expanding consumer demand for shellfish.

Since 1966, the percentage of all classified waters approved for harvest has decreased 10 percent. However, data compiled for the *1995 Register*, the last available compilation, suggest significant improvements. For example, the overall percent of harvest-limited waters decreased from a high of 42 percent in 1985 to 31 percent in 1995. The percent of prohibited waters also decreased from a high of 26 percent in 1974 to 13 percent in 1995—the lowest percentage recorded.

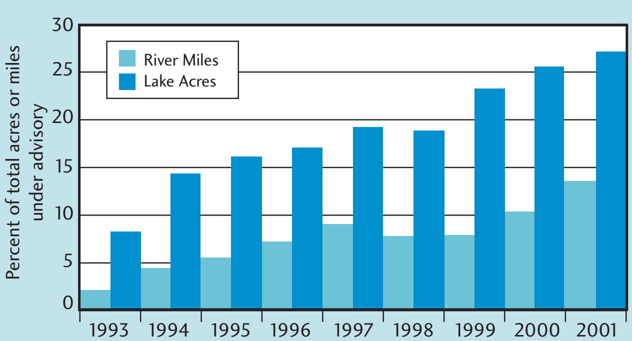
Indicator Percent of river miles and lake acres under fish consumption advisories - Category 2

State and local governments protect people from possible risks of eating contaminated fish by monitoring local waters and issuing fish advisories when contaminant levels are unsafe. A consumption advisory may recommend that people limit or avoid eating certain species of fish caught from certain lakes, rivers, or coastal waters. Advisories are often very specific. They may apply to specific water types (such as lakes), or they might include recommendations for specific groups (such as pregnant women or children). Advisories apply to locally caught fish or wildlife as well as fish purchased in stores and restaurants. EPA has compiled these advisory data into the National Listing of Fish and Wildlife Advisories (NLFWA) database, which lists, among other things, the species and size of fish or wildlife under advisory, the chemical contaminants covered by the advisory, the location and surface area of the waterbody under advisory, and the population subject to the advisory.

What the Data Show

Exhibit 2-33 shows the percent of the nation's river miles and lake acres under advisory for the years 1993 to 2001. Note that the Great Lakes and their connecting waters are considered separately from other waters and are not included in the calculations of total lake acres or river miles. Except for 1998, the percentage increased continuously during this 8-year period. Approximately 79,119 lakes (11,277,276 lake acres) and 485,205 river miles were under advisory in 2001, compared to 14,962 lakes and 74,505 river miles under advisory in 1993. Note that the increase in the total size of waters under advisory is due in part to increased monitoring for chemical contaminants in fish and wildlife tissue

Exhibit 2-33: Trends in percentage of river miles and lake acres under fish consumption advisory, 1993-2001



Coverage: all 50 states

Source: EPA, Office of Water. *Update: National Listing of Fish and Wildlife Advisories.* May 2002.

and the states' increasing use of statewide advisories. Currently, the 2,618 advisories in the national listing represent almost 28 percent of the nation's total lake acreage and 14 percent of the nation's total river miles.

In addition to the NLFWA data, much information is available on the advisory status of our nation's waters. EPA and FDA issued a national mercury advisory in January 2001 recommending that women of childbearing age and young children limit their consumption of fish (<http://www.epa.gov/waterscience/fish>).

Many great waters of the U.S. are currently under fish advisories for a variety of pollutants. The great waters include the Great Lakes, Lake Champlain, the Chesapeake Bay, 20 National Estuary Program (NEP) sites, and 14 National Estuarine Research Reserve System (NERRS) sites.

- All of the Great Lakes and their connecting waters are under advisory.
- Lake Champlain is under advisory for PCBs and mercury.
- Although the Chesapeake Bay is not under any advisories, the Potomac, James, Back, and Anacostia Rivers, which connect to it, are all under PCB advisories.
- Baltimore Harbor, which also connects to the Chesapeake Bay, is under advisory for chlordane and PCB contamination in fish and blue crabs.
- Many of the major estuaries listed in the NEP and/or designated as NERRS sites are under fish and/or shellfish advisories for multiple chemical contaminants. Sixty-five percent of the total number of NEP, NERRS, and combined sites are under fish consumption advisories. Seventeen sites have no current fish consumption advisories.

Several states have issued fish advisories for all of their coastal waters. An estimated 71 percent of the coastline of the conterminous 48 states currently is under advisory. This includes 92 percent of the Atlantic coast and 100 percent of the gulf coast. The Atlantic coastal advisories have been issued for a wide variety of chemical contaminants, including mercury, PCBs, dioxins, and cadmium. All of the gulf coast advisories have been issued for mercury, although other contaminants may also be present. No Pacific coast state has issued a statewide advisory for any of its coastal waters, although several local areas along the Pacific coast are under advisory.

Indicator Gaps and Limitations

Currently, fish consumption advisories are being used as a way of informing the public of risks associated with eating contaminated

Indicator Percent of river miles and lake acres under fish consumption advisories - Category 2 (continued)

fish in certain waterbodies. Advisories are based on fish tissue monitoring data collected by states and are largely focused on areas where states know fishing occurs or suspect contamination. Criteria used to issue advisories vary among states, with some having more stringent criteria and more robust advisory programs than others.

Due to the large range in geographic size of lake acres and river miles affected by chemical contaminants that may be contained under a single advisory, the number of advisories is not as accurate a measure of the contamination as geographic extent. As a result, information is now provided on total lake acres and river miles where advisories are currently in effect. A large-scale fish tissue study is underway and will help identify waters that require further monitoring to determine whether advisories are necessary.

This indicator is based on fish tissue monitoring data collected by the states. It does not provide unbiased geographical coverage, and it is largely focused on areas where states know fishing occurs or suspect contamination problems. At present, 43 states issued risk-based advisories.

Data Source

Fish advisory indicator data are from the National Listing of Fish and Wildlife Advisories program. (See Appendix B, page B-17, for more information.)

Indicator Contaminants in fresh water fish - Category 2

From 1992 to 1998, fish samples were collected from 223 stream sites in the U.S. Geological Survey's (USGS) National Water Quality Assessment (NAWQA) program. Tissue composites from whole fish were analyzed for PCBs, organochlorine pesticides, and trace elements. These contaminants may harm organisms directly or by affecting their reproduction, and they may make fish unsuitable for consumption by humans. These data were compiled for the entire U.S.

What the Data Show

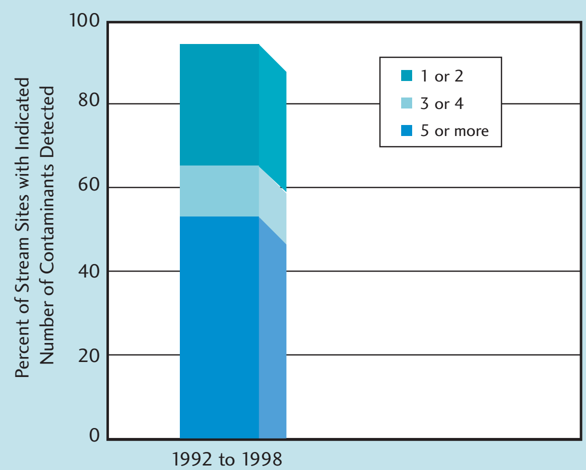
More than 90 percent of sampled fish had at least one contaminant detected and about half of the fish tested had at least five contaminants at detectable levels (Exhibit 2-34) (The Heinz Center, 2002). All fish tested from the Great Lakes had five or more detected contaminants.

Indicator Gaps and Limitations

The sites sampled are representative of a wide range of stream sizes, types, and land uses broadly distributed across the U.S., but they do not represent a probability sample, so confidence bounds on the estimates could not be calculated (Gilliom, et al., 2002; The Heinz Center, 2002).

Fish tissue concentration data are derived from composites of whole fish and not from edible portions alone. Thus it is not possible to compare tissue concentrations to aquatic or human health

Exhibit 2-34: Occurrence of contaminants in stream fish, 1992-1998



Coverage: lower 48 states.

Note: Partial indicator data: freshwater stream fish only,

Source: The Heinz Center. *The State of the Nation's Ecosystems.* 2002. Data from the U.S. Geological Survey.

Indicator Contaminants in fresh water fish - Category 2 (continued)

guidelines. These data do, however, indicate organism exposure to measured chemicals.

Data Source

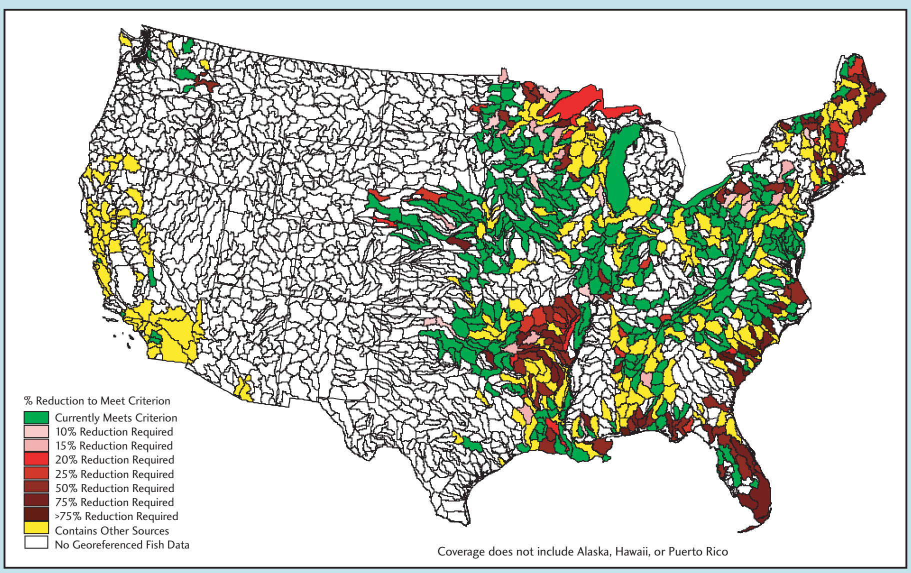
Data for this indicator came from the U.S. Geological Survey's National Water Quality Assessment Program as compiled for The Heinz Center (2002). (See Appendix B, page B-17, for more information.)

Indicator Number of watersheds exceeding health-based national water quality criteria for mercury and PCBs in fish tissue - Category 2

For this indicator, fish tissue concentrations of each chemical in the NLFWA database were averaged across 8-digit hydrologic unit code (HUC) watersheds. The average concentration was then compared to fish- tissue based criteria for mercury and PCBs. The average fish tissue concentration is for all monitored species, fillet samples only (whole fish samples were omitted from the analysis as these are not recommended for use in assessing human health impact). Thus, the average is meant to represent the potential exposure concentration for persons consuming fish from typically frequented local lakes, streams, and rivers.

The mercury criterion used in this comparison was the national fish-tissue-based criterion. The PCBs criterion was based on the fish tissue levels used to derive the current national health-based water concentration criteria. Criteria exceedances can be interpreted as meaning that the watershed, on average, is not meeting maximum tissue contaminant levels designed to be protective of human health.

Exhibit 2-35: Watersheds with fish tissue concentrations exceeding health-based national water quality criteria for mercury, 2001



States currently use water column concentration-based mercury water quality standards and would need to adopt fish tissue-based target levels in order to use this approach for mercury Total Maximum Daily Loads. Additional reductions would be required to meet EPA national and most state fish advisory levels, which are often set below the methyl-mercury criterion.

Note: Watersheds highlighted yellow have "significant" mercury sources other than deposition, defined as where the total estimated load from Publicly Owned Treatment Works (POTWs) and pulp and paper mills is greater than 5% of estimated waterbody delivered mercury at a typical air deposition load (10 g/km2/yr) and/or where mercury cell chlor-alkali facilities, mercury mines, or significant past producer gold mines are present

Source: EPA, Office of Water. *National Listing of Fish and Wildlife Advisories (NLFWA) Mercury Fish Tissue Database.* June 2001.

What the Data Show

The data for mercury are a fairly good representation of conditions in the eastern U.S. and California. Of the 696 8-digit HUC watersheds with available data, 225 exceeded the mercury criterion (Exhibit 2-35). These are predominantly located in eastern coastal states, New England, and the lower portion of the Mississippi River watershed. Data for PCB concentrations are less available; 114 of 153 watersheds where data were available contained tissue above the criterion level (Exhibit 2-36).

Indicator

Number of watersheds exceeding health-based national water quality criteria for mercury and PCBs in fish tissue – Category 2 (continued)

Indicator Gaps and Limitations

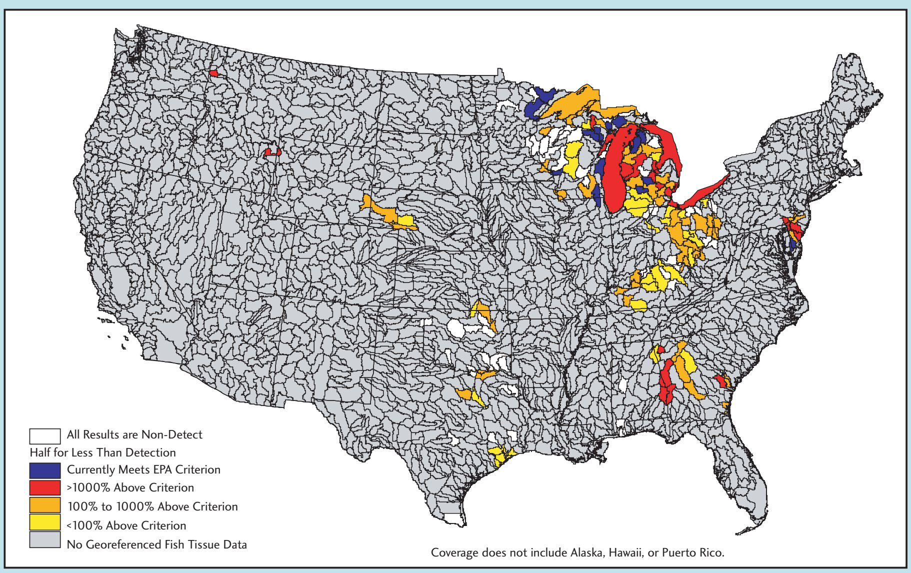
Several limitations should be noted for this indicator:

- The data were compiled based on voluntary contributions from individual states and have not undergone an independent quality assurance/quality control (QA/QC) review. Data quality is a function of the distinct programs for which the data were collected.
- Sampling by state agencies was not generally done on a statistical basis, but rather was targeted toward specific waterbodies and fish species. Some selection of sampling locations was based on fishing pressure and/or suspected elevated contaminant levels. For example, there appears to be a bias in the mercury data towards top predator or sport fish (of the top 10 most frequent species sampled, 83 percent are trophic level 4 species). This bias could potentially skew the average watershed concentration level to higher than actual exposure depending on real consumption patterns.
- Some states may not have reported tissue data when resultant concentrations were found to be below state fish advisory levels.
- Substantially more data are available for the years 1990 to 1995 than for more recent years.
- Spatial gaps in the data are readily apparent from the indicator maps. Since a large fraction (roughly two-thirds) of the database was not georeferenced (i.e., no latitude/longitude coordinates were created), those data could not included in the indicator. Bias imposed by these missing data was not examined. Latitude/longitude coordinates will be assigned in a database update in the near future and can be incorporated in future indicators.
- The human health-based criteria of 0.3 ppm methylmercury that was used for comparison is considerably higher than the more recent federal advisory of 0.18 ppm for consumption of mercury-contaminated fish. State consumption advisories are typically at levels closer to the 0.18 ppm than to the 0.3 ppm level.
- Sampling patterns of state agencies are largely being directed toward areas of higher fishing pressure or based on suspected elevated contaminant levels. Thus this indicator, which is based on generalizing from specific sampling locations to watershed averages, is expected to represent a somewhat conservative estimate of the average concentration in consumed fish in each respective area.

Data Sources

The fish tissue indicator data are from the National Listing of Fish and Wildlife Advisories program. (See Appendix B, page B-18, for more information.)

Exhibit 2-36: Watersheds with fish tissue concentrations exceeding health-based national water quality criteria for polychlorinated biphenyls (PCBs), 2001



Note: Graphic was created for this report in ArcView using NLFWA data.
Source: EPA, Office of Water. *National Listing of Fish and Wildlife Advisories (NLFWA)*. June 2001.

2.5.2 What are contaminants in fish and shellfish, and where do they originate?

Information is available to help answer this question in a general sense. Fish and shellfish can be contaminated by both chemical pollutants and pathogens. Chemical contaminants of greatest concern tend to be those that are toxic and persistent and that bioaccumulate. Contaminants with these properties that are common in fresh and coastal waters include:

- *DDT and PCBs*. The manufacture and use of these compounds have been banned in the U.S. However, deposits from past pollution persist in sediments and land-based sources, and these deposits continue to pollute watersheds. In addition, PCBs can be found in some products manufactured prior to the ban (e.g., electrical transformers).
- *Mercury*. This metal, a natural and highly toxic element, can now be detected (although in small amounts) in all waters. Sources of mercury include wastes from past mining practices and the burning of fossil fuels and wastes, which can create mercury emissions that settle on land and water. In water, bacteria convert mercury to methylmercury, a toxic compound that is absorbed by fish and accumulates in their tissue.

Biological threats to shellfish consumption include bacterial contamination from human and animal wastes and contamination from naturally occurring toxins that shellfish accumulate from consuming certain algae.

Some data are available on the sources of bacterial contamination. When state managers close or otherwise restrict a shellfish-growing area due to high levels of fecal coliform bacteria, they typically cite potential sources of that contamination. This information was collected for the 1990 and 1995 Shellfish Registers (NOAA, 1991; NOAA, 1997). In 1995, sources of shellfish contamination cited by reporting officials were (in decreasing order of frequency):

- Urban runoff (40 percent)
- Unidentified sources upstream of coastal watersheds (39 percent)
- Wildlife (38 percent)
- Individual wastewater treatment systems (e.g., septic tanks) (32 percent)
- Wastewater treatment plants (24 percent)
- Agricultural runoff (17 percent)
- Marinas (17 percent)
- Boating (13 percent)
- Industrial facilities (9 percent)
- Combined sewer overflows (7 percent)
- Direct discharges (4 percent)
- Feedlots (3 percent)

The 1990 Register reflects the same top five sources of pollution, although in slightly different order.

Marine biotoxins associated with "red tides" and other naturally occurring contaminants such as *Vibrio* species (a free-living marine and estuarine bacteria associated with stomach and intestinal disorders of varying intensity) can also cause temporary closures, although they are not usually regarded as a pollution source (Rippey, 1994; FDA, 1993).

At this time, insufficient data are available to develop national-level indicators about the type and origin of fish and shellfish contaminants.

2.5.3 What human health effects are associated with consuming contaminated fish and shellfish?

The health effects of consuming contaminated fish and shellfish depend on many factors, including the type of contaminant, its concentration in the organism, and how much contaminated fish or shellfish is consumed. Health effects include the following:

- Risk assessments show that exposure to sufficient levels of some contaminants in fish tissues may increase the risk of cancer
- Mercury, in sufficient quantities, is toxic—especially to the nervous system.
- Shellfish contaminated with fecal wastes can cause gastrointestinal illness and even death in individuals with compromised immune systems. Mollusks, mussels and whelks are the main shellfish that carry biotoxins causing common symptoms, such as irritation of the eyes, nose, throat, and tingling of the lips and tongue.

Advisories warn the public of these risks and suggest limits or outright bans on consuming some species in certain problem areas. Certain groups may be at higher risk for health effects from contaminated fish and shellfish. These include children, pregnant women, and nursing mothers, who may be more vulnerable to effects, and tribal, ethnic, and other populations that fish for subsistence and therefore consume more fish or shellfish.

At this time, insufficient data are available to develop indicators that can monitor, at the national level, the health effects of consuming contaminated fish and shellfish. Chapter 4, Human Health, provides more information on the human health impacts of contaminated fish.

2.6 Challenges and Data Gaps

Tremendous amounts of data are being collected on water resources. These data provide evidence of water quality condition at the national, regional, and state scales. Some of these data are sufficiently comprehensive in scope to serve as the basis for indicators of water quality at the national level. These indicators provide a starting point for describing our nation's water quality. However, as discussed below, they also have limitations that make it difficult to make confident statements about the condition of water resources at the national scale or to thoroughly describe the stressors that degrade that condition.

2.6.1 Waters and Watersheds

Several indicators are available that provide information about the quality of our nation's waters and watersheds. For wetlands, for example, the relevant indicator shows that the rate of wetland loss has dropped dramatically in recent years. However, as discussed in Section 2.2.2, there currently are no indicators of wetland biological condition and none are being implemented at the national or regional scale. Without these indicators and an assessment process, ensuring that the net gain goal is sustaining not only wetland extent, but also wetland condition, will not be possible.

Drawing accurate conclusions about the condition of surface waters can be equally as challenging as for wetlands, but the indicators in this area do provide evidence of some success in reducing important stressors. In addition, data suggest that atmospheric deposition of sulfates has been reduced (EPA, ORD, January 2003), which will help improve the quality of acidic surface waters. Ongoing efforts by EPA (for example, through the National Pollutant Discharge Elimination System permit program), the U.S. Department of Agriculture, and individual states to reduce the amount of pollutants discharged to our nation's waters from both point and non- point sources will also help to improve water quality.

However, many challenges remain in monitoring water quality and taking steps to improve water quality. This is, in part, because significant environmental problems persist, despite environmental management activities to address these problems. Persistent hypoxia in the Gulf of Mexico and fish contaminated by toxic organics and mercury are examples.

To better address water quality problems in the future, more and better quality data on the condition of waters and watersheds will be needed. This will require a greater collaboration among the federal agencies that participate in monitoring and managing our nation's waters so that results and metadata can be provided in a common format. Data in a common format will be much more useful for developing or improving indicators and can also more easily be made available to the public. In addition, the relevant federal agencies should work with the states to design and implement cost-efficient water quality monitoring programs whose data will be useful not only to the state water quality programs, but also to national water quality characterizations. State resources often are limited for such key activities as characterizing waters, identifying sources of watershed stress, and monitoring the effects of implementing pollution controls. Therefore, it is critical to encourage the development, dissemination, and use of cost-effective monitoring and assessment tools, such as biological methods for water quality assessment and a new framework for design and data collection in water quality monitoring programs.

2.6.2 Drinking Water

The indicator for the quality of treated drinking water in the U.S. shows that quality of drinking water has improved from the early 1990s through 2002. This indicator is based on health standards violations by community water systems that are reported by states to EPA's Safe Drinking Water Information System (SDWIS). The systems that are monitored under SDWIS serve water to about 95 percent of the U.S. population. Compliance trends may change in the future as new regulations create new compliance challenges for public water systems.

The primary limitation of this indicator is under-reporting and late reporting of community water systems violations by states to EPA. This affects the accuracy of annual reports produced using SDWIS and thus the quality of the indicator. EPA last quantified data quality in 1999 and estimated that states were not reporting 40 percent of all health-based violations. EPA and states are taking steps to address identified deficiencies and to improve data quality. A survey of reporting completeness is underway. Another limitation of the indicator is that it does not cover the quality of water from private wells.

It is important to understand the condition of the raw waters (both ground water and surface waters) that serve as drinking water sources. For example:

- States are currently conducting assessments to delineate the extent of source waters and identify potential contaminant sources.
- Data provided by the U.S. Geological Survey under its National Water Quality Assessment program and occurrence data for unregulated contaminants collected by EPA under the Safe Drinking Water Act (SDWA) also provide information about raw water stressors, and are used by EPA to determine whether additional contaminants should be regulated under the SDWA.
- It is important that EPA assure that the frequency of sampling is adequate to characterize episodic events affecting source water quality.

The incidence of waterborne disease is another parameter that could be used to describe and track water quality at the national level. Additional efforts to obtain data could help provide a basis in the future for a national-level indicator in this area. This would, however, require significant new work, as the existing data likely reflect an unknown but probably very large degree of under-reporting. For example, there currently are no consistent national surveillance and reporting requirements for doctors or states with respect to incidence of diarrhea, except as associated with Hepatitis A, cholera, salmonellosis, or shigellosis. Doctors rarely order the tests that would identify these diseases, or tests that would identify other, more common diseases that can be caused by contaminants in drinking water.

2.6.3 Recreation in and on the Water

The quality of recreational waters is compromised when pollution increases the level of pathogens or (to a lesser extent) chemical contaminants in those waters past thresholds judged safe for human exposure. When this happens at a monitored beach, particularly for pathogens, local or state authorities close or issues advisories for beaches. Sufficient information is available to provide the basis for an indicator about the risks to public health from exposure to pathogens in recreational water at coastal and Great Lakes beaches. Although the indicator shows that the number of beaches with advisories or closures has increased in recent years, this trend simply represents the fact that more beaches are providing information. In fact, as the indicator shows, the percent of beaches under advisory or closure has been fairly constant over the last few years. Overall, relatively few days (six percent of the days beaches could be open) have been lost due to pathogen exposure. This indicator is limited by three considerations:

- The number of beach days closed or under advisory does not directly measure pathogens or contaminants in water.
- Reporting of beach days closed or under advisory is voluntary, thus the ability of this indicator to describe conditions nationwide is unknown.
- At this time, this indicator applies primarily to coastal and Great Lakes beaches, as most fresh water inland beaches are not surveyed.
- Improving the value of this indicator as a national measure of recreational water quality would entail an assessment of the presence of pathogens in all waters used for recreational activities. Chemical contaminants would need to be selectively measured in waters with known risk from contamination.

2.6.4 Consumption of Fish and Shellfish

Three indicators are available to help describe the condition of surface waters that support fish and shellfish consumption. For example, information about specific areas where contaminants in fish are above public health thresholds is available. One indicator suggests that the number of lake acres and river miles for which fish consumption advisories have been issued is increasing. This trend may represent an increase in monitoring, more stringent state health standards, or increased contamination. Other indicators show that the vast majority of sampled fish are contaminated to some degree and that contamination for particular pollutants (mercury and PCBs) tends to be concentrated in certain areas of the country. For all three indicators, it is important to note that sampling tends to focus on areas where states know fishing occurs or suspect there may be a contamination problem, so the data may over-report or under-report the degree and extent of contamination. Also, monitoring of fish and shellfish at the state level is very inconsistent, and different criteria are used to issue advisories.

A true national assessment of the safety of fish and shellfish for human consumption can only be accomplished through a comprehensive, representative survey of pathogens and chemical contaminants in edible fish tissue in all waters. A national survey of this type, involving 500 lakes and reservoirs, is underway. Initial data on 268 contaminants in the tissue of fresh water fish have been collected. These data are not presented in this report because they reflect only one year of a four-year study and, as such, are not ready for public release. However, they should be available for future use as a potential indicator.

Chapter 3: Better Protected Land

Indicators that were selected and included in this chapter were assigned to one of two categories:

- **Category 1** –The indicator has been peer reviewed and is supported by national level data coverage for more than one time period. The supporting data are comparable across the nation and are characterized by sound collection methodologies, data management systems, and quality assurance procedures.
- **Category 2** –The indicator has been peer reviewed, but the supporting data are available only for part of the nation (e.g., multi-state regions or ecoregions), or the indicator has not been measured for more than one time period, or not all the parameters of the indicator have been measured (e.g., data has been collected for birds, but not for plants or insects). The supporting data are comparable across the areas covered, and are characterized by sound collection methodologies, data management systems, and quality assurance procedures.

3.0 Introduction

The U.S. landscape can be characterized in many different ways—by its diversity and distribution of natural resources, by its complex pattern of land uses reflecting population distribution and management strategies, and by the various ecological systems that provide habitat for thousands of plant and animal species. This landscape is continuously changing due to population growth, the demand for resources and energy, and changing land management practices.

Our nation's land provides the foundation on which cities are built and from which food and other resources are derived to support the population. At the same time, land used for these purposes can be changed by pollution, waste disposal, and various physical processes (e.g., land clearing) that can change natural processes, such as the hydrologic cycle. Numerous laws and practices have been implemented—especially over the last 30 years—to help protect human health and ecosystems from these types of human actions.

This chapter addresses the types, extent, and uses of land in the geographic area of the U.S., which comprises approximately 2.3 billion acres of land and water (U.S. Census Bureau, 2001). This area includes all 50 states, as well as Puerto Rico, American Samoa, Guam, the Northern Mariana Islands, Palau, and the U.S. Virgin Islands. In total, 2.263 billion acres of the U.S. are land, while 116 million acres are water. This land acreage is the basis for all calculations of percentages in this chapter, unless otherwise noted.

Population growth is probably the single most important factor that has changed and continues to change the land environment of the U.S. The use of land is, to a major extent, a function of human needs and population density. According to the 2000 Census, more than 281 million people live on our nation's land. The U.S. has added at least 20 million people per decade to its population over the last 50 years, and in the last decade (1990-2000), the U.S. population has increased by more than 32 million (13 percent) (Exhibit 3-1). The density of population has also continuously increased, although not evenly across the country (Exhibit 3-2). According to the 2000 Census, the average density of people across our nation is approximately 0.125 people per acre. This represents a significant change from the first census of population, conducted in 1790, showing only 0.007 people per acre (U.S. Census Bureau, 2001).

The exponential growth in the U.S. and world population has created demands for resources and uses of land that have major effects on both human health and ecological condition. The land indicators outlined in this chapter are descriptors of the status, trends, and effects of various conditions and land practices. These indicators are often limited in their capacity to paint an accurate picture of the effects of various human practices, due to incomplete, inconsistent, or dated data.

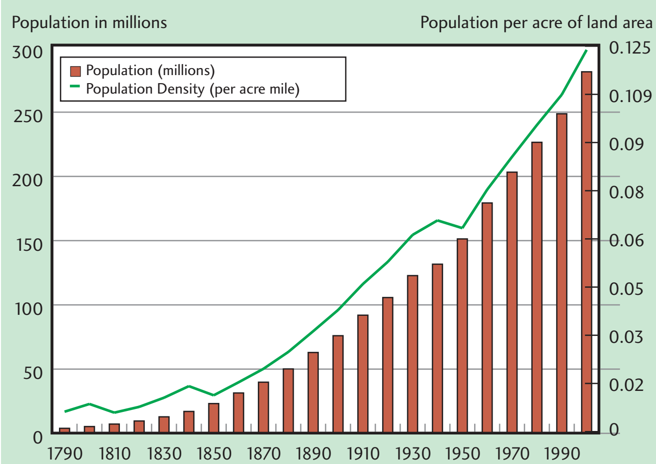
The specific issues explored in this chapter include changing uses of land for development, agriculture, and forest management; the use and presence of chemicals in the form of pesticides, fertilizers, and toxic releases; the generation and management of various types of waste; and the extent of contaminated lands. The chapter poses fundamental questions about these issues and their health and ecological effects, and it uses indicators drawn from well-reviewed data sources to help answer those questions. Exhibit 3-3 lists these questions and indicators, and identifies the chapter section where each indicator is presented.

The chapter is divided into four main sections:

- Section 3.1 examines the extent of various ecological systems and land uses in the U.S.
- Section 3.2 looks at the extent and potential disposition of chemicals used or managed on land.
- Section 3.3 addresses waste generation and management on land and the extent of contaminated lands.
- Section 3.4 reviews the challenges and data gaps that remain in assessing the condition of our nation's land.

Each of the topic sections (e.g., land use, chemicals, waste) also considers what is currently known about associated human health and ecological effects.

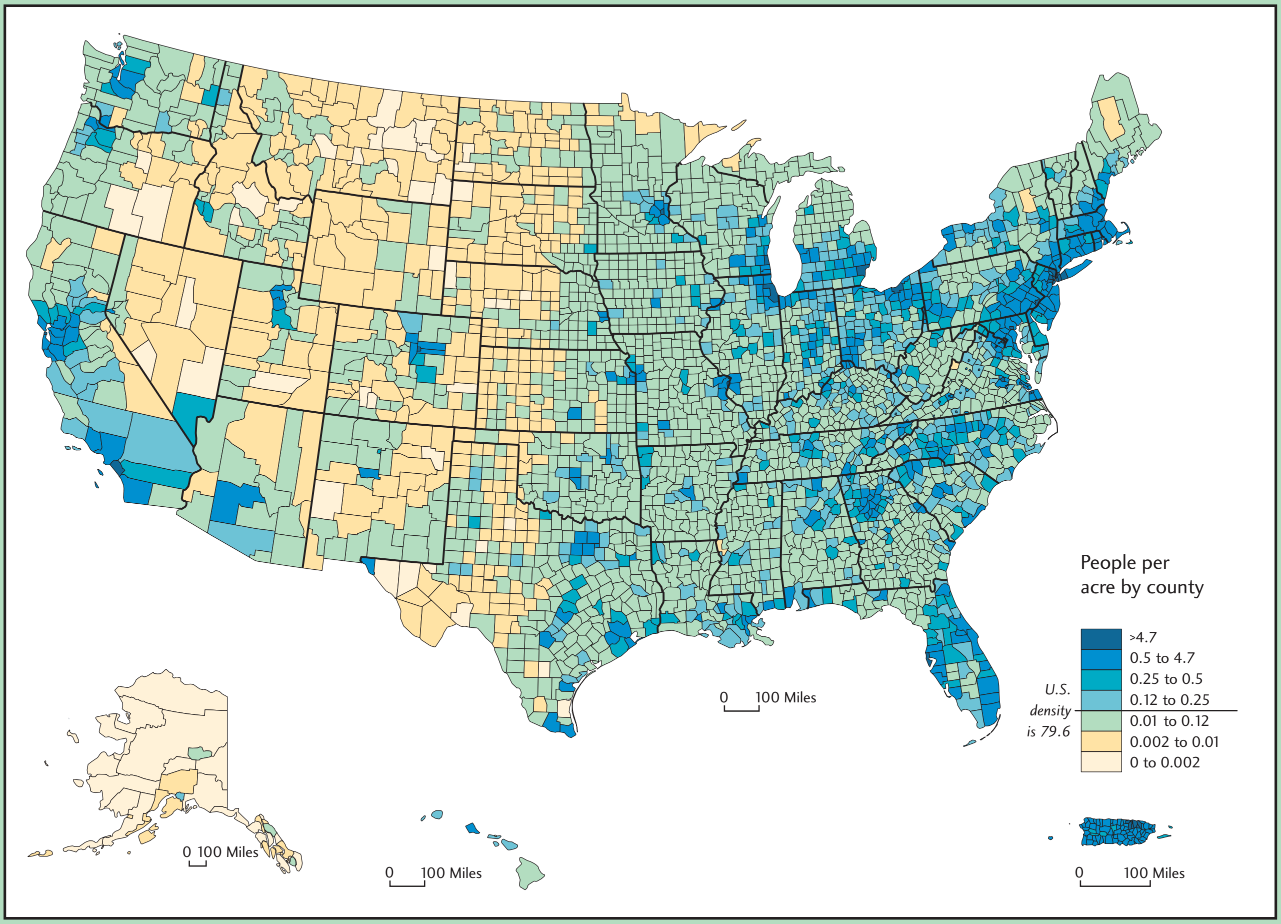
Exhibit 3-1: Population and population density, 1790-2000



Note: Large amounts of land area were added to the United States in the early 1800s (Louisiana Purchase, 1803), mid-1800s (adding the present states of Oregon, Washington, Idaho, California, Nevada, Utah, and parts of Colorado, Kansas, Arizona, and New Mexico), and in 1959 (Alaska and Hawaii statehood). These land increases explain population density decreases during these periods.

Source: U.S. Census Bureau, *Statistical Abstract of the United States 2001: The National Data Book.* Washington DC: U.S. Census Bureau, 2001.

Exhibit 3-2: United States population density by county, 2000



Source: Brewer, Cynthia A. and Trudy A. Suchan. *Mapping Census 2000: The Geography of U.S. Diversity.* June 2001.

Numerous gaps in the data exist that make it difficult or impossible to answer some of the questions posed about the condition of our nation's lands. The gaps and limitations of data are described briefly under each question and in more detail at the end of the chapter.

There are several major sources of data that contribute to this chapter, and a report titled *The State of the Nation's Ecosystems,* developed by The H. John Heinz III Center for Science, Economics and the Environment (The Heinz Center, 2002). These data sets contribute directly and indirectly to many of the indicators throughout the chapter.

Exhibit 3-3: Land – Questions and Indicators

Land Use

Question	Indicator Name	Category	Section
What is the extent of developed lands?	Extent of developed lands	1	3.1.1
	Extent of urban and suburban lands	2	3.1.1
What is the extent of farmlands?	Extent of agricultural land uses	1	3.1.2
	The farmland landscape	2	3.1.2
What is the extent of grasslands and shrublands?	Extent of grasslands and shrublands	2	3.1.3
What is the extent of forest lands?	Extent of forest area, ownership, and management	1	3.1.4
What human health effects are associated with land use?	No Category 1 or 2 indicator identified		3.1.5
What ecological effects are associated with land use?	Sediment runoff potential from croplands and pasturelands	2	3.1.6

Chemicals in the Landscape

Question	Indicator Name	Category	Section
How much and what types of toxic substances are released into the environment?	Quantity and type of toxic chemicals released and managed	2	3.2.1
What is the volume, distribution, and extent of pesticide use?	Agricultural pesticide use	2	3.2.2
What is the volume, distribution, and extent of fertilizer use?	Fertilizer use	2	3.2.3
What is the potential disposition of chemicals from land?	Pesticide residues in food	1	3.2.4
	Potential pesticide runoff from farm fields	1	3.2.4
	Risk of nitrogen export	2	3.2.4
	Risk of phosphorus export	2	3.2.4
What human health effects are associated with pesticides, fertilizers, and toxic substances?	No Category 1 or 2 indicator identified		3.2.5
What ecological effects are associated with pesticides, fertilizers, and toxic substances?	No Category 1 or 2 indicator identified		3.2.6

Waste and Contaminated Lands

Question	Indicator Name	Category	Section
How much and what types of waste are generated and managed ?	Quantity of municipal solid waste (MSW) generated and managed	2	3.3.1
	Quantity of RCRA hazardous waste generated and managed	2	3.3.1
	Quantity of radioactive waste generated and in inventory	2	3.3.1
What is the extent of land used for waste management?	Number and location of municipal solid waste (MSW) landfills	2	3.3.2
	Number and location of RCRA hazardous waste management facilities	2	3.3.2
What is the extent of contaminated lands?	Number and location of Superfund National Priorities List (NPL) sites	2	3.3.3
	Number and location of RCRA Corrective Action sites	2	3.3.3
What human health effects are associated with waste management and contaminated lands?	No Category 1 or 2 indicator identified		3.3.4
What ecological effects are associated with waste management and contaminated lands?	No Category 1 or 2 indicator identified		3.3.5

3.1 Land Use

Land ownership and the management objectives of the owners tend to determine how land is used; thus, U.S. lands are used for many different purposes. Nearly 28 percent of the nation (630 million acres) is owned and managed by the federal government. State and local governments manage another 198 million acres (GSA, 1999). The more than 828 million acres of federal, state, and local government lands in the nation are managed for various public purposes. In contrast, the approximately 1.419 billion acres of private and tribal land are more likely to be managed in the interests of their owners, with various land use constraints imposed by zoning and other regulations (GSA, 1999; USDA, NRCS, 1997; Alaska DNR, 2000).

Management objectives are constantly changing on private and public lands and can have both positive and negative effects on the natural environment and human health. Such effects include loss of native habitat to agricultural practices; loss of prime agricultural lands to urban/suburban development; changes in patterns of runoff as a result of impervious surfaces, stream flow, dams, or irrigation systems; habitat restoration based on land reclamation; and urban/suburban development on previously contaminated land.

There are differing estimates of the extent of various land uses. Those discussed in the context of the following questions are often due to different classifications, definitions, approaches to data collection, and the timing of data collection and analysis. Land cover and land use represent two different concepts and both are discussed in this section. Land cover is essentially what can be seen on the land—the vegetation or other physical characteristics—while land use describes how a piece of land is being used (or not) by humans. In some cases, land uses can be determined by cover types, which are visible (e.g., the presence of housing indicates residential land use). Often, however, more information is needed for those uses that are not visible (e.g., lands leased for mining, “reserved” forest land, shrublands with grazing rights). Techniques for assessing land cover and land use vary, with different data required to accurately assess extent and practices. Remotely sensed data are increasingly being used to track land cover. When combined with knowledge of local land use regulations or other information, such data can be useful for tracking land use.

Six questions are posed in this section to examine the extent of various ecological systems and land uses, including development, agriculture, and forest management. The questions considered are:

- What is the extent of developed lands?
- What is the extent of farmlands?
- What is the extent of grasslands and shrublands?
- What is the extent of forest lands?
- What human health effects are associated with land use?
- What ecological effects are associated with land use?

Tracking national patterns of land use and activities that affect the land can be challenging, primarily because land use is regulated by many levels of government and also because of the significant variations in land cover, geography, and land activities nationwide. Data produced by different agencies at different levels of government must be integrated and analyzed continually to gain a national perspective of patterns and trends.

The primary information sources for this section include the National Resources Inventory (NRI) of the U.S. Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS); the report titled *The State of the Nation's Ecosystems,* which was developed by The H. John Heinz III Center for Science, Economics and the Environment (The Heinz Center, 2002); and data from the Forest Inventory and Analysis (FIA) Program.

This section presents various activities related to land use and land cover. Two examples of activities for which indicators have not been identified, but that can have significant effects in different ways on land are 1) the formal protection or reservation of land for habitat or natural resources and 2) mining and extraction activities. Some data are collected locally and for federal lands (e.g., National Park acreage) or tracked for economic indicators, but the national picture of the extent of land reservation and mining is not generally available. A snapshot of what is known is described in the two sidebars.

PROTECTED LANDS

Across the U.S., lands are protected against or for certain uses in a variety of ways by federal, state, and local land managers and by private landowners. Local zoning ordinances, state and federal land management regulations, and land classifications are used to protect lands for habitat and natural uses. Federal land management agencies protect land in several different use classifications that provide varying degrees of protection. More than 4 percent of the nation is managed as wilderness. Of the 106 million acres of land now designated as federal wilderness, more than half are in Alaska (Wilderness Information Network, 2002). Millions of acres of lands are also protected in the National Park Service System, within the U.S. Fish and Wildlife Service refuge system, as USDA and Bureau of Land Management Wilderness Study Areas, in National Forest Roadless Areas, in the National Trails System, as National Wild and Scenic Rivers, in National Recreation Areas, in Research Natural Areas, and other areas. States also have established park systems, fish and wildlife areas, wilderness systems, and other areas of protected lands. Local government agencies also often manage parks. Conservation easements protect private lands by providing restrictions from development in perpetuity.

MINING AND EXTRACTION ACTIVITIES

The U.S. is the world's largest producer and consumer of energy, and yet there is no inventory of lands used for energy production. There are known to be 1,879 coal mines and associated facilities in the U.S (USGS, 2000a). The West, led by Wyoming, produces about half of the U.S. coal, primarily from surface mines. The Appalachia area, led by West Virginia and Kentucky, accounts for 37 percent of U.S. coal production, mainly from underground mines(DOE, November 2002). Other energy activities include 534,000 producing oil wells (ranging from one to millions of barrels of production per year). Top producing areas of oil and natural gas include the Gulf of Mexico, Texas, Alaska, California, Louisiana, Oklahoma, and Wyoming (DOE, November 2002). Eight uranium mines and 1,965 other mines and processing facilities produce most of the minerals and metals in the U.S (USGS, 2000b). About 5.4 billion metric tons of non-fuel mineral materials were removed in 2000. Overall, 97 percent was mined and quarried at the surface level, and 3 percent was mined underground. The major states in which mining for non-fuel minerals occurs are Nevada, Arizona, New Mexico, Minnesota, California, Florida, Texas, Michigan, Ohio, and Pennsylvania (USGS, 2000b). In addition to active mines, the U.S. Bureau of Land Management estimates approximately 10,200 abandoned hardrock mines are located within the roughly 264 million acres under its jurisdiction. Estimates of abandoned mines on public and private lands range from 80,000 to hundreds of thousands of small to medium-sized sites (DOI, Bureau of Land Management, 2002).

3.1.1 What is the extent of developed lands?

Indicators

Extent of developed lands
Extent of urban and suburban lands

Land development is a process of land conversion that changes lands from natural or agricultural uses to residential, industrial, transportation, or commercial uses to meet human needs. Land development has created urban and suburban ecological systems, which are areas where the majority of the land is devoted to or dominated by buildings, houses, roads, lawns, or other elements of human use and construction (The Heinz Center, 2002). Urban and suburban ecological systems are highly built up and paved, resulting in effects such as more rapid changes in temperature, increased runoff, and increased chemical contaminants than in more natural ecosystems. Plant and animal life is more heavily influenced by species introduced in horticulture and as pets, and native species may be more or less completely removed from large areas and replaced by lawns, gardens, and ornamentals (World Resources Institute, 2000).

The majority of Americans live in areas that are considered "developed land." Between 1950 and 2000, the number of Americans living in U.S. Census Bureau-defined urban areas increased from 64 percent to 79 percent of the total population (U.S. Census Bureau, 2001). Estimates vary widely on the amount of land considered developed in the U.S., depending on definitions of "developed" and different assessment techniques. For example, the Census Bureau definition is a measure of population density; not specifically a measure of actual land use or conversion of land. Census urban areas do not take into account low-density suburbs and other developed lands such as commercial or transportation infrastructure areas that do not include people. The Census definitions may underestimate lands that would be categorized as low-level residential or lands having dispersed development. (See the following sidebar for definitions used in this discussion.)

The two indicators presented in this section provide an estimate of the extent of developed land, with an estimate of urban and suburban lands as a subset of developed lands. These estimates were developed using different definitions and methodologies. The extent of "developed land" indicator uses a national statistical sample that takes into account various development types. The "extent of urban and suburban lands" indicator identifies densely developed areas classified using remotely sensed satellite data.

DEFINITIONS OF DEVELOPED AND URBAN/SUBURBAN LANDS

U.S. Census Bureau Definitions

Urbanized Areas and Urban Clusters. The Census Bureau describes urban areas as Urbanized Areas (UAs) and Urban Clusters (UCs). These are designations for densely settled areas, which consist of core census block groups that have a population density of at least 1,000 people per square mile and other surrounding census blocks that have an overall density of at least 500 people per square mile. UAs contain 50,000 or more people. UCs contain at least 2,500 people, but less than 50,000. Based on 2000 Census data, there are 466 UAs and 3,172 UCs comprising nearly 60 million acres (or 2.6 percent of the U.S. land area). These definitions and delineations of urban areas are used by the Office of Management and Budget to delineate the Census Metropolitan Areas, including Metropolitan Statistical Areas, which are used for various federal and state budget allocation purposes (U.S. Census Bureau, 2001).

USDA, NRCS, National Resources Inventory (NRI) Definitions

Developed land. A combination of land cover/use categories: Large urban and built-up areas, small built-up areas, and rural transportation land (USDA, NRCS, 2000a).

Urban and built-up areas. A land cover/use category consisting of residential, industrial, commercial, and institutional land; construction sites; public administrative sites; railroad yards; cemeteries; airports; golf courses; sanitary landfills; sewage treatment plants; water control structures and spillways; other land used for such purposes; small parks (less than 10 acres) within urban and built-up areas; and highways, railroads, and other transportation facilities if they are surrounded by urban areas. Also included are tracts of less than 10 acres that do not meet the above definition but are completely surrounded by urban and built-up land. Two size categories are recognized in the NRI: areas of 0.25 acre to 10 acres and areas of at least 10 acres.

Large urban and built-up areas. A land cover/use category composed of developed tracts of at least 10 acres—meeting the definition of urban and built-up areas.

Small built-up areas. A land cover/use category consisting of developed land units of 0.25 to 10 acres that meet the definition of urban and built-up areas.

Rural transportation land. A land cover/use category that consists of all highways, roads, railroads, and associated rights-of-way outside of urban and built-up areas, including private roads to farmsteads or ranch headquarters, logging roads, and other private roads, except field lanes.

The Heinz Report Definitions

Urban and suburban lands. An area is considered to be urban/suburban if a majority of the lands within a 1,000 foot by 1,000 foot area (pixel) fall into one of the four "developed" land cover types classified in the NLCD (low-density residential, high-density residential, commercial-industrial-transportation, or urban and recreational grasses). In outlying areas, clusters of pixels had to total at least 270 acres to be considered urban/suburban.

Indicator Extent of developed lands - Category 1

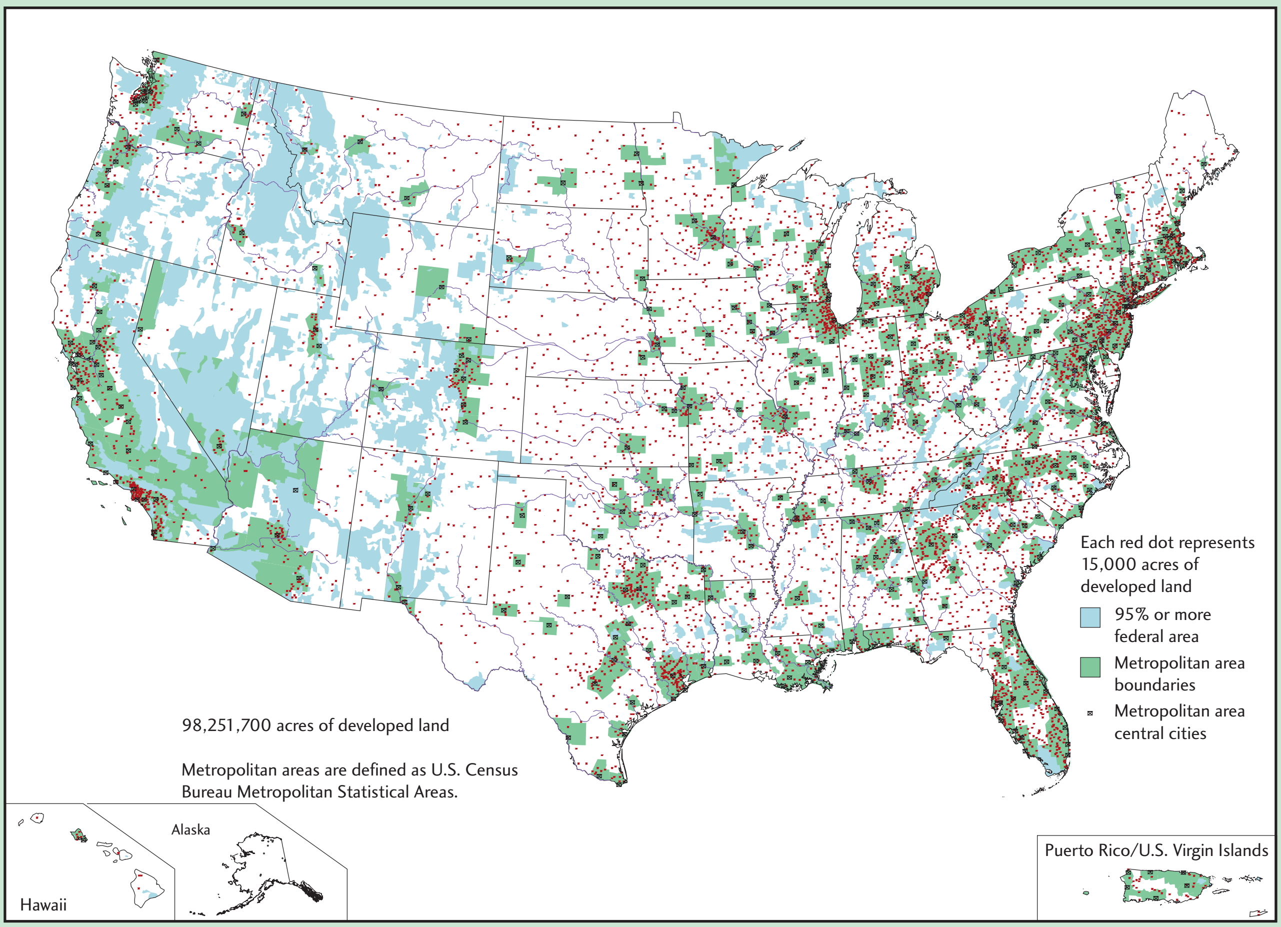
Land development generally results in significant changes in other land uses or cover types. This indicator provides a measure of how much developed land exists, where it is, and how it has changed. The indicator relies on national statistical data samples conducted every five years by the USDA NRCS.

What the Data Show

The NRI reports approximately 98 million acres of developed land in the U.S., not including Alaska (USDA, NRCS, 2001). This figure represents about 4.3 percent of the total land area. Exhibit 3-4 shows the distribution of non-federal developed lands nationwide. Each dot on the map represents 15,000 acres. The map displays the Census Metropolitan Area boundaries, which are larger in western states due to the large size of many counties. States along the Northeast corridor have the highest percentages of developed land, exceeding more than one-third of a state's area in some cases.

Between 1982 and 1997, developed lands increased by 25 million acres, primarily through conversion of croplands and forest lands (USDA, NRCS, 2000a). This represents a 34.1 percent increase. Developed lands as a percentage of the nation rose from 3.2 percent in 1982 to 4.3 percent in 1997 (USDA, NRCS, 2000a). The pace of land development between 1992 and 1997 was more than 1.5 times the rate of the previous 10 years. The distribution of changes in developed land varies nationwide, with extensive changes in the eastern part of the country from south to north.

Exhibit 3-4: Extent of non-federal developed land, 1997



Source: USDA, Natural Resources Conservation Service. National Resources Inventory, 1997, revised December 2000: Acres of Developed Land, 1997. 2000. (January 2003; *http://www.nrcs.usda.gov/technical/land/meta/m4974.html*).

Indicator Extent of developed lands - Category 1 (continued)

Exhibit 3-5 depicts the change in developed land (urban and suburban areas and rural transportation land) by watershed in the 1982 to 1997 time frame.

Indicator Gaps and Limitations

The NRI data are limited in not providing data on Alaska and not assessing development on federal lands, including recreational development and transportation infrastructure.

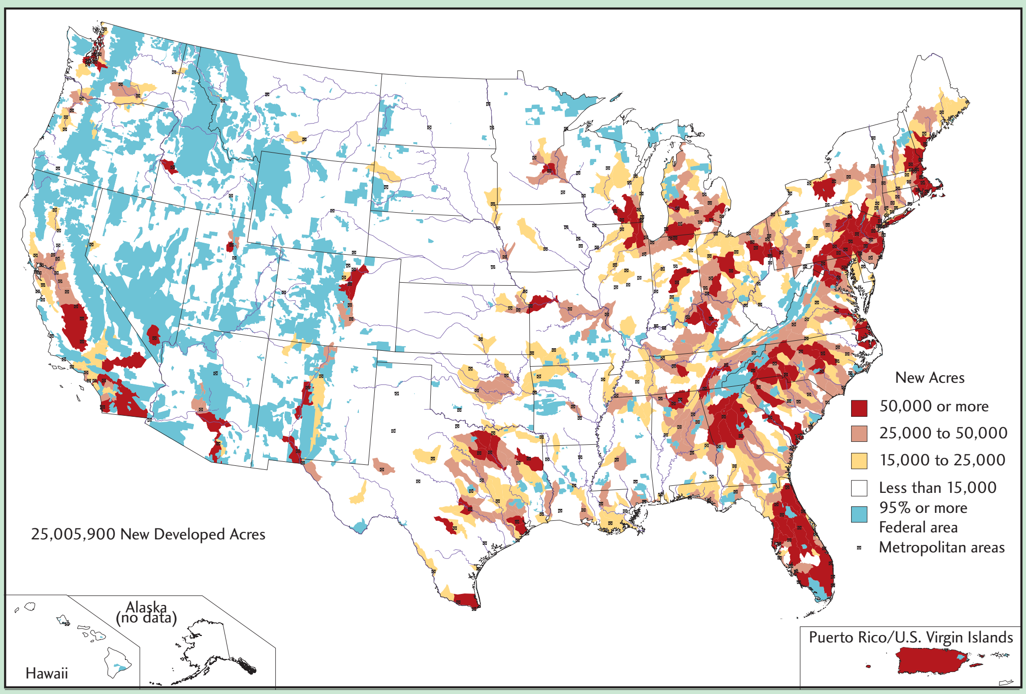
Data Source

Acreage estimates and map data presented for this indicator are from the National Resources Inventory, U.S. Department of Agriculture, Natural Resources Conservation Service, 1997 (Revised December 2000). (See Appendix B, page B-18, for more information.)

National Resources Inventory

The NRI is a longitudinal survey designed to assess conditions and trends of soil, water, and related resources on non-federal lands in the U.S. The NRI statistical sample involves approximately 300,000 sample units and 800,000 sample points on non-federal lands. The sample is a stratified two-stage unequal probability design that can be modified to address specific national survey goals or special studies. Stratification was developed county by county, based on the Public Land Survey System (PLSS) where possible, and on latitude/longitude, Universal Transverse Mercator Grid, or artificial superimposed lines when necessary. The national sampling varies across strata and ranges from 2 to 6 percent. The NRI measures numerous variables, which are then extrapolated as national totals. Variables include the following: soil characteristics, earth cover, land cover and use, erosion, land treatment, vegetative conditions, conservation treatment needs, potential for cropland conversion, extent of urban land, habitat diversity, and Conservation Reserve Program cover. NRI sample data are generally reliable at the 95 percent confidence interval for state and certain broad sub-state area analyses (Goebel, 1998).

Exhibit 3-5: Land development patterns, 1982-1997



Source: USDA, Natural Resources Conservation Service. National Resources Inventory, 1997, revised December 2000: Land Development, 1982-1997. 2000. (January 2003; *http://www.nrcs.usda.gov/technical/land/meta/m5009.html*).

Indicator Extent of urban and suburban lands - Category 2

Urban and suburban lands are considered a subset of developed lands and one of the ecological systems described in Chapter 5, Ecological Condition. These are highly developed areas and surrounding suburbs, including developed outlying areas above a minimum size. Acreage estimates are based on an analysis of the remotely sensed NLCD data conducted by the U.S. Geological Survey (USGS), Areas of at least 270 acres that are substantially covered with roads, buildings, concrete, and other hard surfaces must be identified to be classified and counted as urban/suburban (The Heinz Center, 2002). This definition excludes smaller built-up areas.

What the Data Show

Urban and suburban ecological systems occupied 32 million acres in the conterminous U.S. in 1992, or about 1.7 percent of that land area (The Heinz Center, 2002). This estimate was derived from a re-analysis of the 1992 NLCD. The analysis includes information on the amount and character of undeveloped land within urban/suburban areas. Most of the lands designated urban and suburban are in the South and Midwest, but they account for less than 2 percent of the land in those regions. In the Northeast, urban and suburban lands account for more than 5 percent of the landscape.

Indicator Gaps and Limitations

The NLCD database is derived from a one-time interpretation of satellite imagery of the nation from the early 1990s. Although limited by the ability to detect land use remotely based on spectral characteristics, NLCD data are available for all of the conterminous U.S. Original estimates of the NLCD indicated a total of 36.7 million acres of land in three different "developed" land cover classifications (low density residential, high density residential, and commercial/industrial/transportation) (The Heinz Center, 2002).

Data Source

Acreages presented for this indicator are derived from a re-analysis of the National Land Cover Data, a product of the Multi-Resolution Land Characteristics Consortium, which is a partnership between the U.S. Geological Survey; the U.S. Department of Agriculture, Forest Service; the National Oceanographic and Atmospheric Administration; and the EPA. (See Appendix B, page B-18 for more information).

3.1.2 What is the extent of farmlands?

Indicators

Extent of agricultural land uses
The farmland landscape

Farmlands represent one of the nation's major ecological systems and are discussed in Chapter 5, Ecological Conditions.(The Heinz Center, 2002). As noted in the sidebar, on the following page, croplands, which can include pasturelands and haylands, are at the heart of the farmland ecosystem. The broader "farmland landscape" also includes other lands that are not actively used for crop, pasture, or hay production. The composition of lands that surround croplands, such as forests, wetlands, or built-up areas, are discussed further in the "farmland landscape" indicator.

The U.S. produces a wide range of food crops, grains, and other agricultural products over vast areas of the country that are part of the farmland landscape (see adjacent sidebar). Agricultural lands can be thought of as all those lands that contribute to this production. Other words such as farmland, cropland, pastureland, rangeland, grazing land, or grassland are also used to describe aspects of agricultural lands. Some of these words define cover types, while others define land use. The areas overlap but do not necessarily coincide with each other. This situation creates challenges in establishing accurate estimates of extent. Under the discussion of the agricultural land use indicator, an effort is made to distinguish the various definitions and provide a measure of acreages. (Current definitions as used by the USDA NRCS NRI are shown in the sidebar that follows.)

Aside from the challenges of defining types of agricultural land, assessing the amount of land used for crops is an imperfect science, given the seasonality of agricultural practices and changes in economics and technology. As with developed land, estimates vary depending on the classification criteria and mapping or sampling methodologies. Until the 1950s, the amount of agricultural land needed to meet demands for food continued to grow, reaching a peak of more than a billion acres of cropland and rangeland in the mid 1960s. Since then, crop and farmland acreages have decreased and increased in cycles, as both economics and technology have changed demands and as production capabilities have increased.

Two indicators are considered on the following pages. The first assesses the extent of land used to grow food crops and forage. The second considers the farmland landscape, which includes not only land used for agricultural production but also adjacent areas.

NRI Land Cover Definitions for Agricultural Land

Cropland. A land cover/use category that includes areas used for the production of adapted crops for harvest. Two subcategories of cropland are recognized: cultivated and noncultivated. Cultivated cropland comprises land in row crops or close-grown crops and also other cultivated cropland, such as hayland or pastureland in a rotation with row or close-grown crops. Non-cultivated cropland includes permanent hayland and horticultural cropland.

Conservation Reserve Program (CRP). A federal program established under the Food Security Act of 1985 to help private landowners convert highly erodible cropland to vegetative cover for 10 years.

Pastureland. A land cover/use category of areas managed primarily for the production of introduced forage plants for livestock grazing. Pastureland cover may consist of a single species in a pure stand, a grass mixture, or a grass-legume mixture. Management usually consists of cultural treatments: fertilization, weed control, reseeding or renovation, and control of grazing. For the NRI, it includes land that has a vegetative cover of grasses, legumes, and/or forbs, regardless of whether it is being grazed by livestock.

Rangeland. A land cover/use category on which the climax or potential plant cover is composed principally of native grasses, grasslike plants, forbs or shrubs suitable for grazing and browsing, and introduced forage species that are managed like rangeland. This would include areas where introduced hardy and persistent grasses, such as crested wheatgrass, are planted and such practices as deferred grazing, burning, chaining, and rotational grazing are used, with little or no chemicals or fertilizer being applied. Grasslands, savannas, many wetlands, some deserts, and tundra are considered to be rangeland. Certain communities of low forbs and shrubs, such as mesquite, chaparral, mountain shrub, and pinyon-juniper, are also included as rangeland.
(USDA, NRCS, 2000a)

Indicator | Extent of agricultural land uses - Category 1

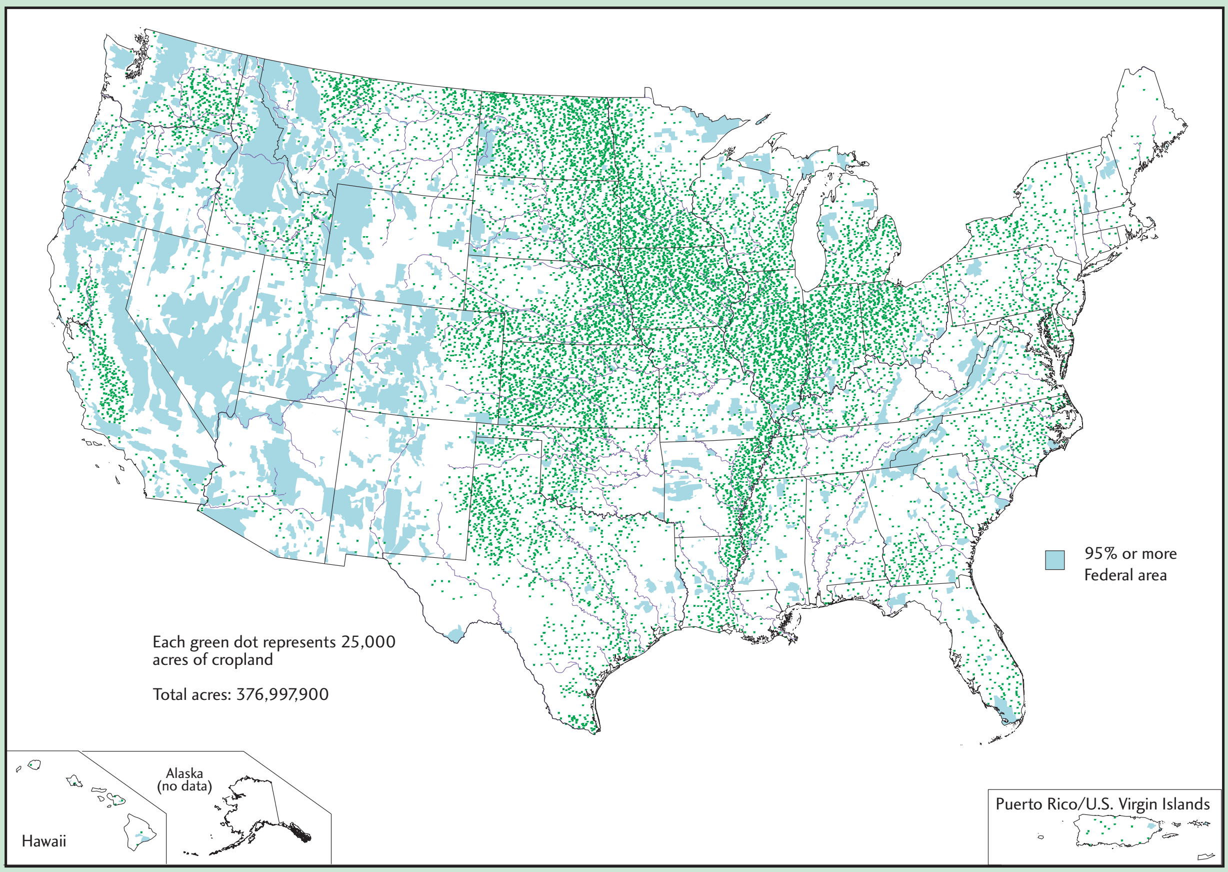
Land can be used for a variety of agricultural purposes. Two general categories are differentiated in this discussion. The first includes lands that are actively managed to cultivate food crops or forage. This category comprises croplands, or lands that grow perennial and annual crops such as fruits, nuts, grains, and vegetables; and pasturelands, or lands that are actively cultivated to produce forage for livestock. The second category includes lands that may be used to produce livestock as an agricultural commodity, but are not planted, fertilized, or otherwise intensively managed. These livestock production lands may be called grazing lands or rangelands and can include forest land, shrubland, and grassland, which are described in the following sections. Livestock production may also include concentrated animal feedlot operations, acreages of which are not included in this discussion.

What the Data Show

In 1997, the NRI identified nearly 377 million acres of cropland and more than 32 million acres of Conservation Reserve Program (CRP) land. CRP lands, as noted in the sidebar, are croplands that are set aside (farmers are provided incentives) for up to 10 years for conservation purposes, but that could be returned to crop production if the program ceased. This total equals nearly 410 million acres of land currently growing or specifically identified with the potential to grow crops in the U.S. (USDA, NRCS, 2000a) (Exhibit 3-6).

The NRI reports about 120 million acres of pastureland. As defined in the sidebar, pastureland includes land that has a vegetative cover of grasses, legumes, and/or forbs, regardless of

Exhibit 3-6: Extent of croplands, 1997



Source: USDA, National Resources Conservation Service. National Resources Inventory, 1997, revised December 2000: Acres of Cropland. 2000. (January 2003; www.nrcs.usda.gov/technical/land/meta/m4964.html).

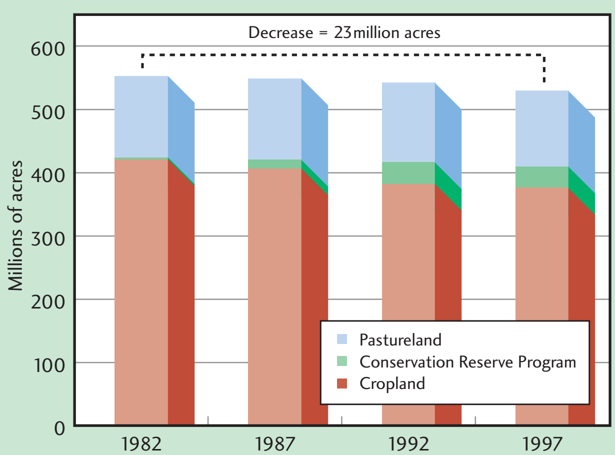
Indicator Extent of agricultural land uses - Category I (continued)

whether it is being grazed by livestock. It is usually managed to produce feed for livestock grazing, using fertilization, weed control, and reseeding. Thus the total estimate from the NRI for cropland, CRP land, and pastureland is 530 million acres.

The Heinz Center (2002), using four different sources of data, estimated that cropland, including pasture and haylands, covered between 430 and 500 million acres in 1997. For the most part, the report did not include CRP lands in its estimates. According to the 1992 NLCD, the U.S. had 510 million acres of agricultural land in the 1990s (EPA, ORD, 1992).

Grazing to support livestock production can potentially occur on pastureland, rangeland, and, in some cases, forest land. These lands can also be defined based on their cover type (e.g., grasslands, shrublands, or forested range). Not counting pastureland, the NRI identified nearly 406 million acres of non-federal rangelands and another 62 million acres of non-federal forest land that can be used for grazing livestock (USDA, NRCS, 2000a). In addition, according to estimates generated by the Bureau of Land Management, more than half of the federal land in the lower 48 states, or 244 million acres, is available for livestock grazing (DOI, 1994). The total of these estimates is 712 million acres of lands that may be used for grazing, but are not cultivated. Adding in the pastureland acreage results in 832 million acres of land that may be used for grazing livestock nationwide (excluding Alaska).

Exhibit 3-7: Change in cropland, Conservation Reserve Program (CRP) land and pastureland, 1982-1997



Source: USDA, Natural Resources Conservation Service. *Summary Report 1997 National Resources Inventory (revised December 2000)*. 2000.

Agricultural lands constantly shift among crop, pasture, range, and forest land to meet production needs, implement rotations of land in and out of cultivation, and maintain and sustain soil resources. Within these shifts, however, trends indicate a gradual decrease in cropland acreage. Between 1982 and 1997, cropland decreased 10.4 percent, from about 421 million acres to nearly 377 million acres (Exhibit 3-7). Of this 44 million acre decrease, however, 30.4 million acres are now enrolled in the CRP, resulting an 13.6 million fewer acres of cropland as a result of conversion to other land uses (USDA, NRCS, 2000a). During this same time frame, pastureland area decreased 9.1 percent, or about 12 million acres (USDA, NRCS, 2000a). The total change in acreage, considering lands in the CRP was 23 million fewer agricultural land acres in 1997 than in 1982.

Decreases in cropland have occurred particularly in the southern and southeastern part of the U.S. The distribution of change in cropland acreage is displayed in Exhibit 3-8. There are no comprehensive estimates of changes in acreages of grazing lands.

Indicator Gaps and Limitations

A specific objective of the NRI is to assess changes in cropland. Again, however, the ability to couple it with current remote sensing imagery would likely contribute to improved resolution and national mapping of cropland types (See the discussion about NRI data in the "Extent of Developed Land" indicator box).

There is no single, definitive, accurate estimate of the extent of cropland. Estimates of the amount of land devoted to farming differ because different programs use different methods to acquire, define, and analyze their data. Cropland is also a flexible resource that is constantly being taken in and out of production. The Heinz report used four different data sources to describe the range of estimates. The four data sets are not fully consistent, and comparisons are difficult to make. For example, the USDA Economic Research Service (ERS) and Census of Agriculture data include croplands in Alaska and Hawaii, while NRI does not. The ERS data used in the Heinz report estimate included CRP lands, while the Census of Agriculture and NRI estimates used by the Heinz report did not (The Heinz Center, 2002).

Data Sources

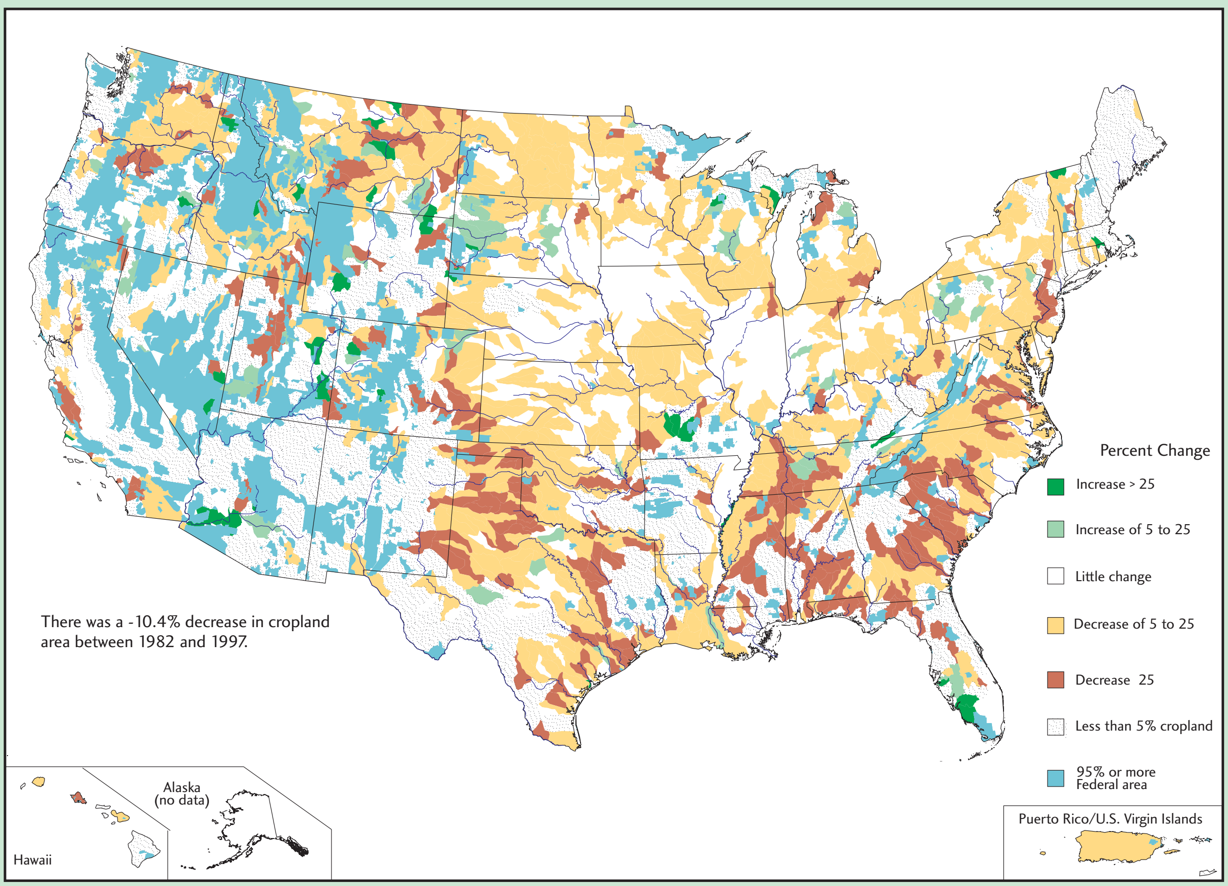
The data sources for this indicator are the National Resources Inventory, U.S. Department of Agriculture, Natural Resources Conservation Service, 1997 (Revised in December 2000); Summary Report: 1997 National Resources Inventory (Revised December 2000), U.S. Department of Agriculture, NRCS; and

Indicator

Extent of agricultural land uses - Category I (continued)

Draft Environmental Impact Statement, U.S. Department of the Interior, Bureau of Land Management, 1994. The Heinz Center estimates of cropland acreages are derived from the National Land Cover Data, a product of the Multi-Resolution Land Characteristics Consortium, which is a partnership between the U.S. Geological Survey; the U.S. Department of Agriculture, Forest Service; the National Oceanographic and Atmospheric Administration; and the EPA. (See Appendix B, page B-19, for more information.)

Exhibit 3-8: Percent change in cropland area, 1982-1997



Source: USDA, Natural Resources Conservation Service. National Resources Inventory, 1997, revised December 2000: Percent Change in Cropland Area, 1982-1997. 2000. (January 2003; www.nrcs.usda.gov/technical/land/meta/m5874.html).

Indicator The farmland landscape - Category 2

Examining the broader context of agricultural lands can provide a better understanding of agricultural ecosystems. As previously noted, the Heinz report defined this term as not only the lands used to grow crops, but also the field borders, windbreaks, small woodlots, grassland and shrubland areas, wetlands, farmsteads, and small villages and other built-up areas within or adjacent to croplands. These covers/uses support not only agricultural production, but provide habitat for a variety of wildlife species as well.

What the Data Show

The farmland landscape indicator describes the degree to which croplands dominate the landscape and the extent to which other lands are intermingled (The Heinz Center, 2002).

Croplands comprise about half of the farmlands in the East and Southeast, while in the Midwest, almost three-quarters of the farmland ecosystem is cropland (The Heinz Center, 2002). Forests make up the remainder of the farmland ecosystem in the East, wetlands the remainder in the Southeast, and both forests and wetlands in the Midwest. In the West, about 60 percent of farmland ecosystem is cropland, with grasslands and shrublands dominating the remainder in the western and northern Plains areas. Forests and grasslands/shrublands are about equal in the farmland landscape for the non-cropland area of the South Central region. In many U.S. areas, other land cover types are almost as prevalent as croplands and can provide habitat for non-agronomic species.

Indicator Gaps and Limitations

This indicator uses satellite data from the early 1990s to describe the farmland landscape. Remote sensing technology can underestimate dispersed land development that is denser than scattered rural settlements, but not as dense as traditional "suburbs."

Data Source

The National Land Cover Database, with 21 land cover classes, was used to estimate the area coverage for the U.S. The NLCD is based on remotely sensed imagery from the Landsat 5 Thematic Mapper. Data are available from <www.usgs.gov/mrlcreg.html>. (See Appendix B, page B-19, for more information.)

3.1.3. What is the extent of grasslands and shrublands?

Indicator
Extent of grasslands and shrublands

Grasslands and shrublands can be viewed as one of the major ecological systems of the U.S. and are discussed in Chapter 5, Ecological Condition, (The Heinz Center, 2002). Grasslands and shrublands can be used for grazing and, in that sense, overlap in extent with agricultural land. As previously defined, pastureland and rangeland are covered by grass and shrub species. This ecosystem is one of the largest types in the U.S. and includes not only the grasslands and shrublands of the American West, but also coastal meadows, grasslands and shrubs in Florida, mountain meadows, hot and cold deserts, tundra, and similar areas in all states.

Indicator Extent of grasslands and shrublands - Category 2

There was an estimated 900 million to 1 billion acres of grasslands and shrublands in the lower 48 states before European settlement (Klopatek, et al., 1979). By 1992, between 40 million and 140 million acres had been converted to other uses. Many pastures are managed in such a way that little of their original grassland character remains, however. Thus, the area of relatively unmanaged grasslands and shrublands has probably declined more than the overall figures would indicate (The Heinz Center, 2002). One factor in the decline of grassland pasture and range acreages since the 1960s is that forage productivity has increased and the number of domestic animals has declined (Vesterby, 2003).

What the Data Show

Based on remote sensing satellite data, it is estimated that grasslands and shrublands (including pasturelands and haylands) occupy about 861 million acres in the lower 48 states and 205 million acres in Alaska, for a total of 1.066 billion acres or about 47 percent of the U.S. (not including Hawaii) (The Heinz Center, 2002) (Exhibit 3-9). This estimate distinguishes 178 million acres of pasturelands and haylands, which are also considered to be part of the farmland landscape, leaving 683 million acres of grasslands and shrublands in the lower 48 states (The Heinz Center, 2002).

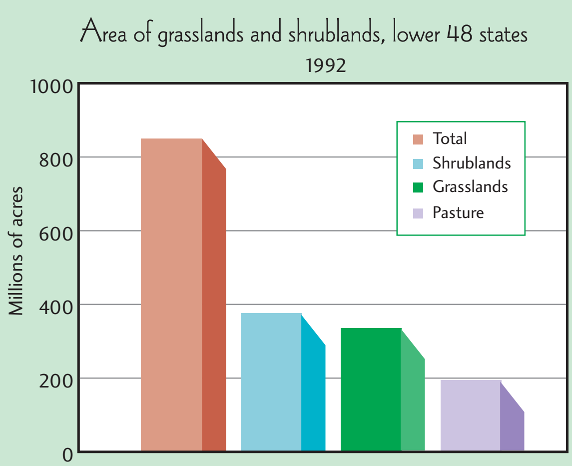
Indicator Gaps and Limitations

NLCD was used to estimate extent of grasslands and shrublands in the lower 48 states. Other data were estimated for Alaska. This is a complicated and changing ecosystem that is subject to conversion to other uses. It would be useful to have better means to characterize and track extent.

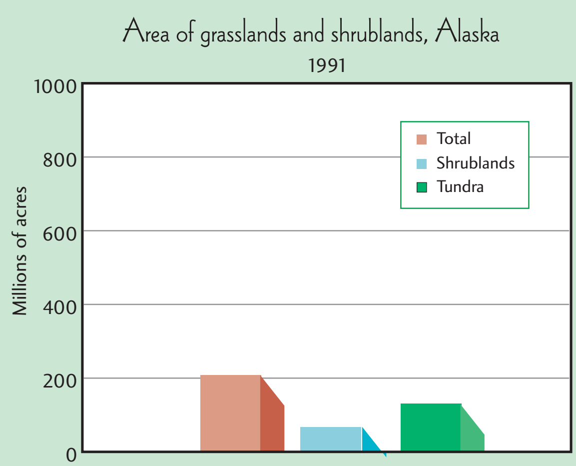
Data Sources

The National Land Cover Database with 21 land cover classes, was used to estimate the area coverage for the U.S. The NLCD is based on remotely sensed imagery from the Landsat 5 Thematic Mapper. Data are available from <www.usgs.gov/mrlcreg.html>. Data for Alaska were estimated from a vegetation map of Alaska by Flemming (1996), based on Advanced Very High Resolution Radiometer remote sensing images with an approximate resolution of 1 kilometer on a side (The Heinz Center, 2002). (See Appendix B, page B-19, for more information.)

Exhibit 3-9: Extent of grasslands and shrublands, 1991 and 1992



Source: EPA, Office of Research and Development. Multi-Resolution Land Characteristics Consortium, National Land Cover Data. 1992. (February 19, 2003; *http://www.epa.gov/mrlc/nlcd.html*).



Source: Flemming, M.D. *A Statewide Vegetation Map of Alaska Using a Phenological Classification of AVHRR Data.* February 1996.

3.1.4 What is the extent of forest lands?

Indicator
Extent of forest area, ownership, and management

Forests provide a range of important benefits to society. In addition to providing wood products, such as paper and lumber, forest lands help to purify air and water, mitigate floods and droughts, regulate climate through storage of carbon dioxide, regenerate soils, provide habitat for fish and wildlife, and support recreational opportunities. Trends in the extent of forests are an important indicator of human management of the landscape, since forest lands cover about one-third of the total U.S. land area. This section provides information on the status and trends relating to the amount and management of forest land. Additional information on the condition of forest land is found in Chapter 5, Ecological Condition.

Indicator Extent of forest area, ownership, and management - Category 1

It is estimated that in 1630, 1.045 billion acres of forest land existed in what would become the U.S. land area. (USDA, FS, 2001). Nearly 25 percent of these lands were cleared by the early 1900s, leaving 759 million acres in 1907. Since that time the total amount of forest land nationwide, while changing regionally has remained relatively stable, with an increase of 2 million acres between 1997 and 2001.

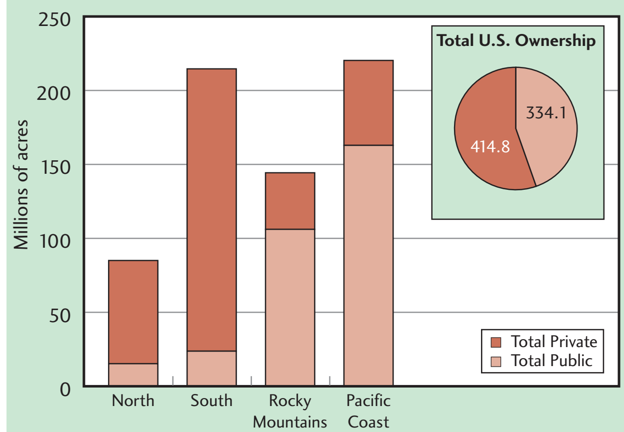
What the Data Show

There were an estimated 749 million acres of forest land in the U.S. in 2001 (USDA, FS, 2002). In the period between 1987 and 2001, forest land acreage increased by about 11 million acres (USDA, FS, 2002).

There have been regional changes in the amount of forest land due to changing patterns of agriculture, development, and reversion to forests. Since the 1950s, forest lands in the northeast and northcentral states have increased by almost 10 million acres, while the South has lost about 11 million acres (USDA, FS, 2001). Private forest lands are being converted to developed land uses faster than any other land type (USDA, NRCS, 2001).

Forest land management varies greatly depending on differences in ownership, management intent, and desired outcomes, ranging from lands managed intact to protect water supplies, to harvesting for timber production. About 55 percent of the nation's forest lands are in private ownership (USDA, FS, 2002). Most forest lands are managed for a mix of uses, such as recreation, timber harvest, grazing, and mining. In the southern and eastern U.S., most forest land is privately held in relatively small holdings, while in the Rocky Mountains and western U.S., most forest lan d is in large blocks of public ownership in national forests (Exhibit 3-10). As previously noted, ownership affects how lands are managed and used.

Exhibit 3-10: Forest land ownership by region, 2001



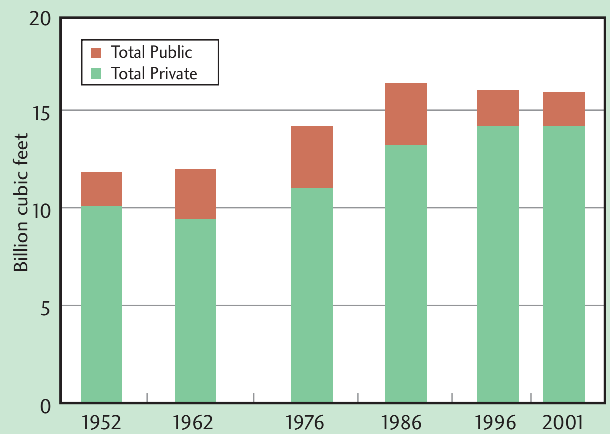
Source: USDA, U. S. Forest Service. Draft Resource Planning Act Assessment Tables. May 3, 2002 (updated August 12, 2002). (September 2003; *http://www.ncrs.fs.fed.us/4801/FIADB/rpa_tabler/Draft_RPA_2002_Forest_Resource_Tables.pdf*).

About 76 million acres, or 10 percent of the nation's forests are "reserved" and managed as national parks or wilderness areas (USDA, FS, 2002). These estimates of reserves include state and federal parks and wilderness areas, but do not include conservation easements, areas protected by non-governmental organizations, or most urban and community parks and reserves. There are significant regional differences in the amount of forest reserves. In the West, reserves are common, comprising nearly 18 percent of the total forest area. Much of the protected forest in the West is in stands over 100 years old. Only 3 percent of eastern forests are in reserves such as parks and wilderness (USDA, FS, 2001).

Indicator Extent of forest area, ownership, and management - Category 1 (continued)

About 66 million acres, or 9 percent of forest lands, are managed by private forest industries to produce timber (USDA, FS, 2002). Much of the remaining forest land receives less intensive management activity, such as periodic harvest of mature timber. Approximately 503 million acres of public and private forest land are currently classified as timberlands by the USDA Forest Service, an increase of 17 million acres since 1987 (USDA, FS, 2002). Approximately 63 percent of all U.S. timber harvesting is conducted in the South, predominately from private lands. Total timber harvest increased substantially between 1976 and 2001 in the East. In the West, after increasing steadily from 1952 to 1986, timber harvesting on public lands has declined sharply. Public lands harvested nationwide dropped nearly 47 percent from 1976 to 2001, to less than 2 billion cubic feet per year. In the same time frame, private lands harvested increased by about 29 percent, from 11 to 14 billion cubic feet annually. (USDA, FS, 2002) (Exhibit 3-11).

Exhibit 3-11: Timber removals in the United States by owner group, 1952-2001



Source: USDA, U. S. Forest Service. Draft Resource Planning Act Assessment Tables. May 3, 2002 (updated August 12, 2002). (September 2003; *http://www.ncrs.fs.fed.us/4801/FIADB/rpa_tabler/Draft_RPA_2002_Forest_Resource_Tables.pdf*).

Between 1980 and 1990, approximately 10 million acres were harvested annually. Of the public and private forest lands harvested for timber approximately 62 percent are selectively cut, while 38 percent are clearcut. Most of the clearcutting occurs in the South (USDA, FS, 2001).

Indicator Gaps and Limitations

Limitations for this indicator include the following:

- The data for this indicator were collected by the USFS FIA program. Forest Industry and Analysis (FIA) currently provides updates of assessment data every five years. Field data are collected on a probability sample of 125,000 forested sites and extended to a remote sensing database on 450,000 sites by the FIA program (Smith, et al., 2001). The resulting data on extent have an uncertainty of 3 to 10 percent per million acres for data reported since 1953. Regional estimates have errors of less than two percent (The Heinz Center, 2002).
- The FIA data on reserved lands do not include information on private lands that are legally reserved from harvest, such as lands held by private groups for conservation purposes. In addition, other forest lands are at times reserved from harvest because of administrative or other restrictions.

Data Source

The data for this indicator are from the *Draft Resource Planning and Assessment Tables*, U.S. Department of Agriculture, Forest Service, 2002. (See Appendix B, page B-20, for more information.)

USDA Forest Service Definitions

Forest land. Land that is at least 10 percent stocked by forest trees of any size, including land that formerly had tree cover and that will be naturally or artificially regenerated. The minimum area for classification of forest land is 1 acre.

Timber land. Forest land that is capable of producing crops of industrial wood (at least 20 cubic feet per acre per year in natural stands) and not withdrawn from timber utilization by statute or administrative regulation.

Reserved forest land. Forest land withdrawn from timber utilization through statute, administrative regulation, or designation. (USDA, FS, April 2001)

3.1.5 What human health effects are associated with land use?

Land development patterns have direct and indirect effects on air and water quality, which can then affect human health. For example, the increased concentration of air pollutants in developed areas can exacerbate human health problems like asthma. Increased storm water runoff from impervious surfaces threatens the waterbodies that urban and suburban residents rely on for drinking and recreation. Development patterns can affect quality of life by limiting recreational opportunities, decreasing open space, and increasing vehicle miles traveled and the amount of time spent on roads. Also, as discussed later, agricultural land uses may expose humans to dust and various chemicals. No specific indicators have been identified at this time.

Land use also can have indirect effects on air quality. Low-density patterns of development can often increase commutes—more people drive more miles. "Heat islands," or domes of warmer air over urban and suburban areas, are caused by the loss of trees and shrubs and the absorption of more heat by pavement, buildings, and other sources. Heat islands can affect local, regional, and global climate, as well as air quality. Agricultural land uses also result in increased wind erosion. Degraded air quality can contribute to human health issues such as asthma. Additional discussion of the effects of land uses on air and water quality, human health, and the environment is included in other chapters.

3.1.6 What ecological effects are associated with land use?

Indicator
Sediment runoff potential from croplands and pasturelands

Land use and land management practices change the landscape in many ways that have both direct and indirect ecological effects. One direct effect is the loss or conversion of acres of certain cover or ecosystem types to other more human-oriented land uses such as developed and agricultural uses. Indirect effects may include changes in runoff patterns or increased soil erosion.

The 25 million acre increase in developed land that occurred between 1982 and 1997 came about through the conversion of about 10 million acres of forest land, 7 million acres of agricultural land, 4 million acres of pastureland, 4 million acres of rangeland, and 1 million acres of various other land cover types including wetlands (USDA, NRCS, 1997). The causes of wetland loss are detailed in Chapter 2, Purer Water. Changing land use patterns have also affected the extent and location of agricultural land. Between 1982 and 1997, approximately 13.6 million acres were converted from cropland to other uses, including 7.1 million acres converted to developed land. At the same time, approximately 4 million acres of rangeland were converted to more intensive crop uses (USDA, NRCS, 2000a). The conversions of land from agricultural, forest land, and rangeland cover types to developed land can affect different species in specific locations that depend on those cover types for habitat and food. Species effects in various ecosystems are discussed in more detail in Chapter 5, Ecological Condition.

Land development also creates impervious surfaces through construction of roads, parking lots, and other structures. Impervious surfaces contribute to non-point source water pollution by limiting the capacity of soils to filter runoff. Impervious surface areas also affect peak flow and water volume, which heighten erosion potential and affect habitat and water quality (e.g., temperature increases). They also affect ground water aquifer recharge. With sufficient storm water infrastructure, higher population density in concentrated areas can reduce water quality impacts from impervious surfaces by accommodating more people and more housing units on less land and developing water runoff systems that address issues of pollutants and sediment. Impervious surfaces developed as the result of suburban or dispersed development patterns are more difficult to mitigate, given that the effects are more dispersed and development of runoff infrastructure is costly.

Storm runoff from urban and suburban areas contains dirt, oils from road surfaces, nutrients from fertilizers, and various toxic compounds. Point source discharges from industrial and municipal wastewater treatment facilities can contribute toxic compounds and heated water. Directing water through channels alters hydrologic flow patterns. Increases in siltation and temperature can make stream habitats unsuitable for native microinvertebrate and fish species. Changes in the nutrient and chemical composition of stream water can encourage growth of toxic algae and harmful organisms. The types of crops planted, tillage practices, and various irrigation practices can limit the amount of water available for other uses, such as municipal, industrial, and natural ecosystems. Livestock grazing in riparian zones also can change landscape conditions by reducing stream bank vegetation and increasing water temperatures, sedimentation, and nutrient levels. Runoff from pesticides, fertilizers, and nutrients from animal manure can also degrade water quality.

An indirect ecological effect of land use is the introduction of invasive species. Certain land use practices, such as overgrazing, land conversion, fertilization, and the use of agricultural chemicals can enhance the growth of invasive plants. Other human activities can result in unstable or disturbed environments and encourage the establishment of invasive plants. These activities include farming; creating highway and utility rights-of-way; clearing land for homes and recreation areas such as golf courses; and constructing ponds, reservoirs, and lakes (Westbrooks, 1998). Failure to manage invasive species can lead to a major threat to native ecosystems. Non-native species can alter fish and wildlife habitat, contribute to decreases in biodiversity, and create health risks to livestock and humans. Introduction of invasive species on agricultural lands also can reduce water quality and water availability for native fish and wildlife species; clog lakes, waterways, and wetlands; weaken the ecosystem; and adversely affect water treatment facilities and public water supplies. Agricultural uses also can encourage the growth of invasive species (USFWS, 2002).

Land practices related to development, timber harvest, and agriculture can affect soil quality both positively and negatively. Some agricultural practices encourage soil conservation, minimizing effects on soil resources. These practices include organic farming; creating buffer strips in riparian zones; tree planting for windbreaks or to decrease water temperature to improve fish habitat; soil erosion control; integrated pest management; and precision pesticide and fertilizer application technology. In contrast, other agricultural activities promote soil compaction or result in loss of topsoil through soil erosion. The indicator identified for this question addresses the potential for sediment to run off from croplands and pasturelands.

Indicator Sediment runoff potential from croplands and pasturelands - Category 2

Soil erosion and transport can occur both by wind and by water and have several major effects on ecosystems. Sediment is the greatest pollutant in aquatic ecosystems—both by mass and volume—and soil erosion and transport are the source (EPA, OW, August 2002). Soil particles also can transport nutrients and pesticides into aquatic systems where they may degrade water quality. Although rates of erosion declined between 1982 and 1997 by about 1.4 tons/acre, more than one-quarter of all croplands still suffer excessive wind and water erosion (USDA, NRCS, 2000f). Excessive is defined as exceeding tolerable rates as defined by USDA NRCS models (USDA, NRCS, 2000g).

Agricultural soil erosion decreases soil quality and can reduce soil fertility, and soil movement can make normal cropping practices difficult (The Heinz Center, 2002). The loss of productive top soil and organic matter affects the productivity of agricultural lands. Further discussion on the extent and effects of soil erosion can be found in Chapter 2, Purer Water, and in Chapter 5, Ecological Condition.

What the Data Show

The potential for soil erosion and sediment runoff varies depending on specific land use, rainfall amounts and intensity, soil characteristics, landscape characteristics, cropping patterns, and farm management practices. This indicator is the result of analyses conducted by combining land cover, weather patterns, and soil information in a process model that incorporates hydrologic cycling, weather, sedimentation, crop growth, pesticide and nutrient loading, and agricultural management to estimate the amount of sediment that could potentially be delivered to rivers and streams in each watershed. The simulation estimated sheet and rill erosion using a process model known as the Soil and Water Assessment Tool (SWAT). SWAT is a model that is supported by the USDA Agricultural Research Service. The sediment runoff data have been categorized and are presented as low, medium, and high potential for runoff.

Exhibit 3-12 displays the distribution of watersheds (based on 8-digit hydrologic unit codes [HUCs]) nationwide and the potential for sediment runoff (or delivery to rivers and streams) from croplands and pasturelands. The highest potential for sediment runoff is concentrated in the central U.S., predominately associated with the upper Mississippi River Valley and the Ohio River Valley. Most of the western U.S. is characterized by low runoff potential (lower percentage of cropland and pastureland).

Indicator Gaps and Limitations

This indicator has several limitations for:

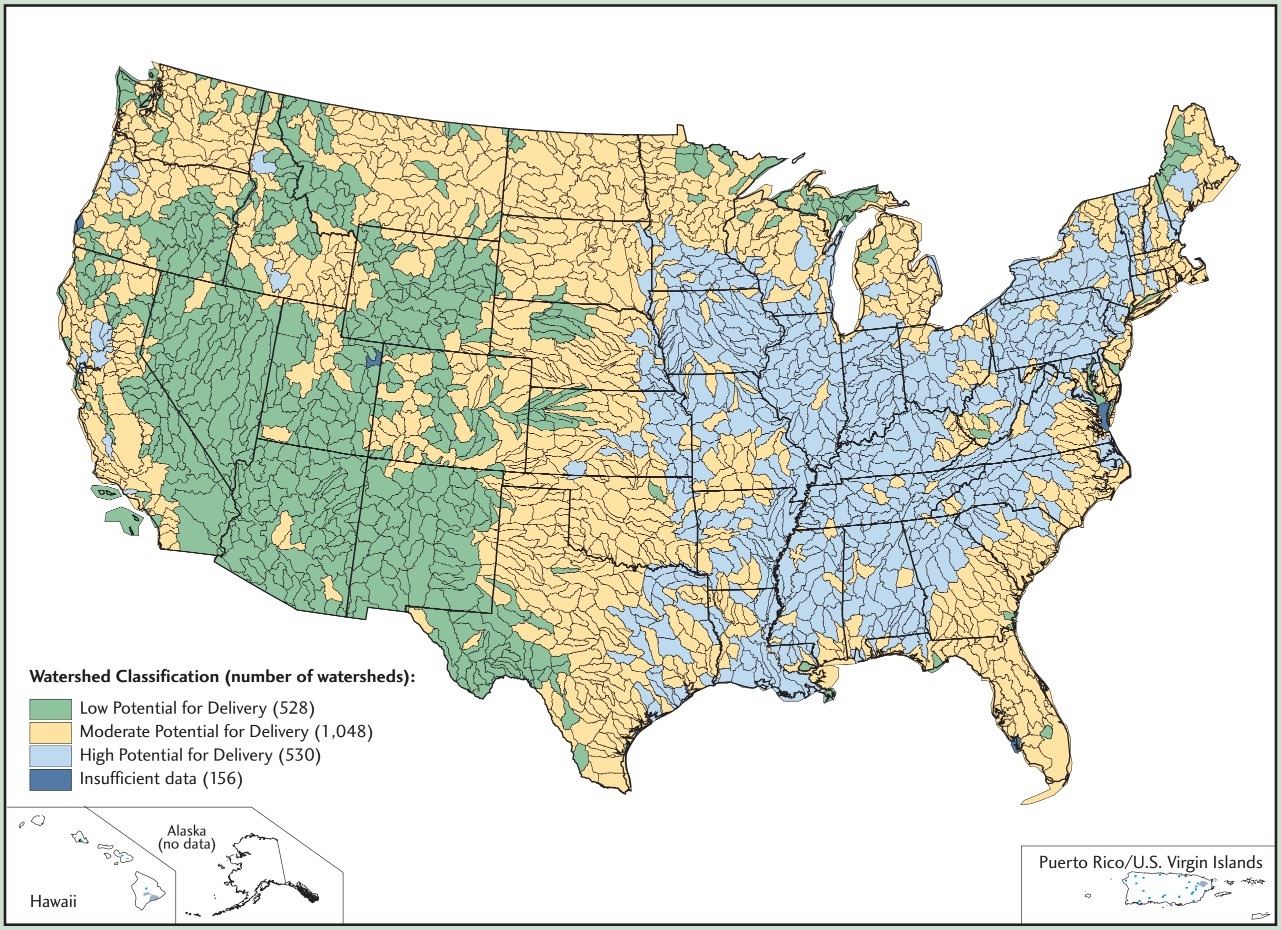
- Sediment loads from non-agricultural land uses are not included in these estimates.
- Estimates represent potential loadings to rivers and streams, and do not represent in-stream loads.
- Gully erosion and channel erosion are not included.

Data Source

The Soil and Water Assessment Tool is a public domain model actively supported by the U.S. Department of Agriculture, Agricultural Research Service at the Grassland, Soil and Water Research Laboratory in Temple, Texas (see http://www.brc.tamus.edu/swat/).
(See also Appendix B, page B-22, for more information.)

Indicator Sediment runoff potential from croplands and pasturelands - Category 2 (continued)

Exhibit 3-12: Sediment runoff potential from croplands and pasturelands, 1990-1995



Source: Walker, C. Sediment Runoff Potential, 1990-1995. August 24, 1999.
(September, 2002; *http://www.epa.gov/iwi/1999sept/iv12c_usmap.html*).

3.2 Chemicals in the Landscape

This section focuses on the extent, potential disposition, and effects of chemicals used or managed on land. The production and use of chemicals in the U.S. has increased over the last 50 years. The use and release of chemicals can have various effects on human health and ecological condition. Commercial and industrial processes such as mining, manufacturing, and the generation of electricity all use and release chemicals. Chemicals that control weeds, insects, rodents, fungi, bacteria, and other organisms are called pesticides and are commonly used on agricultural lands, as well as in urban, industrial, and residential settings. Fertilizers—supplements to improve plant growth—are also used extensively in a variety of settings. Pesticides and fertilizers have contributed to high agricultural productivity levels in the U.S.

EPA began monitoring the production and importation of industrial chemicals in 1977 through the Toxics Substances Control Act Chemical Inventory, which presently identifies more than 76,000 chemicals used in U.S. commerce. Nearly 10,000 of these chemicals are produced or imported in quantities greater than 10,000 pounds per year (excluding inorganics, polymers, microorganisms, naturally occurring substances, and non-isolated intermediaries). About 3,100 of these chemicals are produced or imported in quantities exceeding 1 million pounds per year. Associated annual production/import volumes increased by 570 billion pounds (9.3 percent) to 6.7 trillion pounds between 1990 and 1998 (EPA, OPPTS, 2002).

The questions posed in this section consider the amounts and types of chemicals released to the landscape, addressing toxic substances, pesticides, and fertilizers. The discussion also looks at the potential for chemicals to move from their use on land to places where humans and other organisms can be exposed to them. In this context, questions also address what is currently known about health and ecological effects from exposure to chemicals used on land.

The six questions considered in this section are:

- How much and what types of toxic substances are released into the environment?
- What is the volume, distribution, and extent of pesticide use?
- What is the volume, distribution, and extent of fertilizer use?
- What is the potential disposition of chemicals from land?
- What human health effects are associated with pesticides, fertilizers, and toxic substances?
- What ecological effects are associated with pesticides, fertilizers, and toxic substances?

The primary sources of data for this section are the EPA Toxics Release Inventory (TRI), describing quantities of toxic chemical releases; pesticide use estimates (based on sales) from both EPA and the non-profit National Center for Food and Agricultural Policy (NCFAP); data from the USDA's *Agricultural Resources and Environmental Indicators* report published in 2000 on the volume, distribution, and extent of fertilizer use (see Appendix B); and data from the USDA Pesticide Data Program on pesticide residues found on food samples.

3.2.1 How much and what types of toxic substances are released into the environment?

Indicator

Quantity and type of toxic chemicals released and managed

Many industries release toxic substances into the air, soil, and water through their manufacturing and production activities. Under the Emergency Planning and Community Right-to-Know Act of 1986 and the Pollution Prevention Act of 1990, most facilities are required to calculate and report to EPA and states their release and other waste management quantities of more than 650 toxic chemicals and chemical categories. Intended uses of this information include helping communities prepare for chemical spills and similar emergencies and educating the public on industries' release and other waste management practices for toxic chemicals. EPA makes these toxic release data available to the public annually via the *Toxics Release Inventory* (TRI) *Public Data Release Report*.

The indicator identified for this question addresses quantity and type of toxic chemicals released and managed as waste as well as trends.

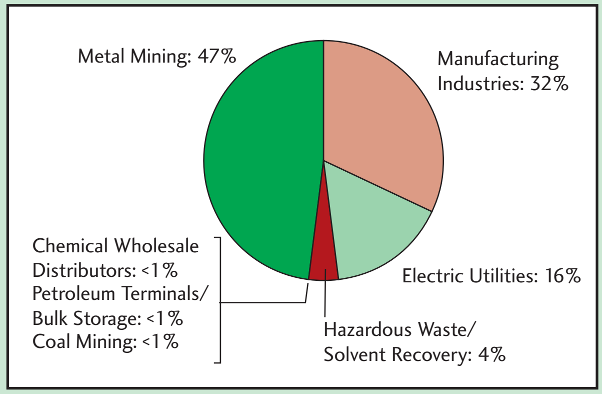
Indicator

Quantity and type of toxic chemicals released and managed - Category 2

The data collected in TRI represent only part of a broader universe of chemicals used and released into the environment. TRI includes a large amount of information on a range of categories of toxic chemicals, including many arsenic, cyanide, dioxin, lead, mercury, and nitrate compounds and provides information on the amount and trends in releases and management of chemicals, including recycling, recovery, and treatment. TRI data cover releases from reporting facilities in all parts of the country and can be searched for releases within individual zip codes. All data presented below can be found in the *EPA 2000 Toxics Release Inventory Public Data Release Report* (EPA, OEI, May 2002).

Exhibit 3-13: Total toxic release inventory (TRI) releases by industry, 2000

(Total = 7 billion pounds)



Source: EPA, Office of Environmental Information. *2000 Toxics Release Inventory (TRI) Public Data Release Report.* May 2002.

What the Data Show

Releases to the environment for all EPA-tracked TRI chemicals from nearly 23,500 facilities totaled 7 billion pounds in 2000. Of these releases, 58 percent were to land, 27 percent were to air, 4 percent each were to water and underground injection at the generating facility, and 7 percent were chemicals disposed of off-site to land or underground injection. Three industries accounted for most of the releases: metal mining (27 facilities) accounted for 47 percent, manufacturing industries (21,352 facilities) for 32 percent, and electric utilities (706 facilities) for 16 percent. The remaining 5 percent was split among hazardous waste/solvent recovery, coal mining, petroleum terminals/bulk storage, and chemical wholesale distributors (Exhibit 3- 13).

Exhibit 3-14: Toxics release inventory (TRI) total releases and change by industry, 1998-2000

Source: EPA, Office of Environmental Information. *2000 Toxics Release Inventory (TRI) Public Data Release Report.* May 2002.

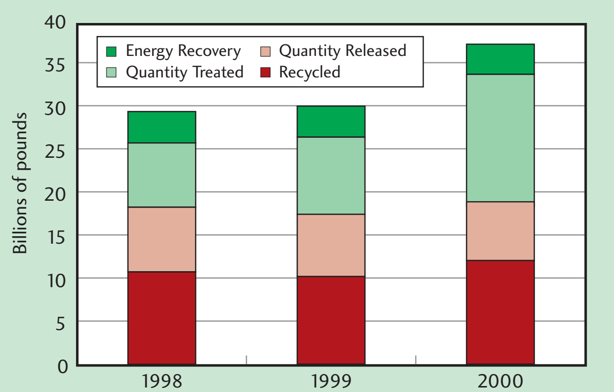
Between 1998 and 2000, the total amount of toxic releases as estimated by the TRI decreased by approximately 409 million pounds, or 5.5 percent. Of that total, releases to land decreased approximately 276 million pounds. Decreases in the releases by certain industries (e.g., manufacturing and metal mining) account for most of the overall decrease between 1998 and 2000. A few industries (e.g., hazardous waste/solvent recovery, coal mining, and chemical wholesale distributors) increased their releases during this time period. Off-site releases from production increased by 75 million pounds in the 1998 to 2000 time frame (Exhibit 3-14).

Indicator Quantity and type of toxic chemicals released and managed - Category 2 (continued)

The seven billion pounds of chemicals actually released into the environment (air, water, and land) are a subset of toxic chemicals managed and tracked in TRI. Another 31 billion pounds of toxic chemicals were managed as waste in 2000. Nearly all (>99 percent) of these toxic chemicals were production related, Of the 31 billion pounds, 50 percent was treated, 39 percent was recycled, and 11 percent was burned for energy recovery.

The total amount of toxic chemicals managed as waste during the three-year period of 1998 to 2000 increased by almost 29 percent, a net increase of 8.4 billion pounds (Exhibit 3-15). Two industries in the southeastern U.S., printing/publishing and chemicals and allied products, accounted for most of this increase. Between 1998 and 2000, the chemicals recycled increased by more than 12 percent (1.3 billion pounds). In contrast, the quantities of chemicals combusted for energy recovery decreased 4.1 percent.

Exhibit 3-15: Trends in toxic chemicals 1998-2000



Note: The data shown as "Quantity Released" vary from the data in Exhibit 3-14 because some facilities include off-site transfers for disposal to other TRI facilities that then report the amount as on-site release.

Source: EPA, Office of Environmental Information. *2000 Toxics Release Inventory (TRI) Public Data Release Report.* May 2002.

The TRI data are also used to support EPA's National Waste Minimization Partnership Program, which focuses on reducing or eliminating the generation of hazardous waste containing any of 30 Waste Minimization Priority Chemicals (WMPC). These chemicals are found in hazardous waste and are documented contaminants of air, land, water, plants and animals. EPA has tracked 17 of these chemicals since 1991 and reports that WMPC generation quantities have been steadily declining since 1993 (Exhibit 3-16). Overall, between 1991 and 1998, the generation of WMPC in industrial hazardous and solid waste decreased by 44 percent.

Indicator Gaps and Limitations

The TRI data do not reflect a comprehensive total of toxic releases nationwide. Although EPA has added to the number of industries (SIC codes) that must report, the TRI program does not cover all releases of chemicals from all industries. Second, industries are not required to report the release of several types of toxic chemicals, because these chemicals are not included in the TRI list. Third, facilities that do not meet the TRI reporting requirements (those with fewer than 10 full-time employees or the

Waste Minimization Priority Chemicals

Organic chemicals and chemical compounds:

*1,2,4-Trichlorobenzene
1,2,4,5-Tetrachlorobenzene
*2,4,5-Trichlorophenol
4-Bromophenyl phenyl ether
Acenaphthene
Acenaphthylene
*Anthracene
Benzo(g,h,i)perylene
*Dibenzofuran
Dioxins/Furans (considered one chemical on this list)
Endosulfan, alpha & Endosulfan, beta (considered one chemical on this list)
Fluorene
*Heptachlor & Heptachlor epoxide (considered one chemical on this list)
*Hexachlorobenzene
*Hexachlorobutadiene
*Hexachlorocyclohexane, gamma-
*Hexachloroethane
*Methoxychlor
*Naphthalene
PAH Group (as defined in TRI)
Pendimethalin
Pentachlorobenzene
*Pentachloronitrobenzene
*Pentachlorophenol
Phenanthrene
Pyrene
*Trifluralin

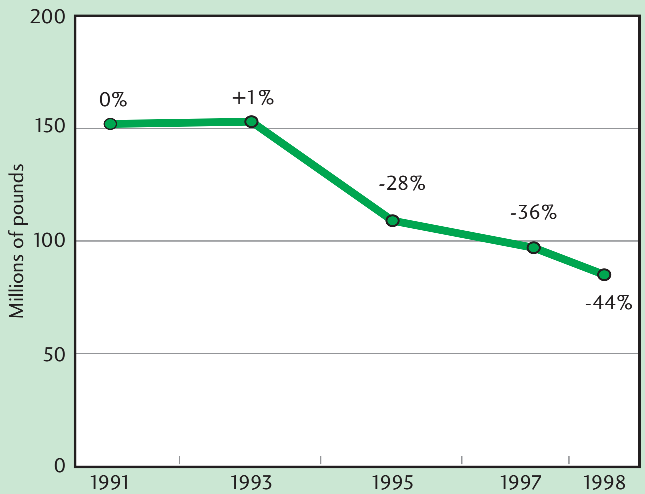
Metal and Metal Compounds:

*Cadmium
*Lead
*Mercury

(*17 chemicals tracked since 1991)

Indicator — Quantity and type of toxic chemicals released and managed - Category 2 (continued)

Exhibit 3-16: Trends in toxics release inventory (TRI) Waste Minimization Priority Chemicals (WMPC), 1991-1998



Source: EPA, Office of Solid Waste and Emergency Response. *Waste Minimization Trends Report (1991-1998)*. September 2002.

employee equivalent, or those not meeting TRI chemical-specific reporting threshold amounts) are not required to report their releases and therefore are not included as part of the total. Finally, facilities report their release and other waste management data to TRI using monitoring data, emission factors, mass balance approaches and engineering calculations. EPA does not mandate monitoring of releases, although many industries do conduct monitoring. Various estimation techniques are used when monitoring data are not available. EPA has published estimation guidance for the regulated community, but not all industrial facilities use consistent estimation methodologies, and variations in reporting may result. With approximately 76,000 different types of chemicals in existence, and new ones constantly being developed, the challenge is to ensure that those that are likely to pose the greatest hazards are tracked and managed.

Data Source

The data source for this indicator is EPA, Toxics Release Inventory, 2000. (See Appendix B, page B-20, for more information.)

3.2.2 What is the volume, distribution, and extent of pesticide use?

Indicator
Agricultural pesticide Use

Pesticides are substances or mixtures of substances intended for preventing, destroying, repelling, or mitigating plant or animal pests. Conventional pesticides include herbicides, plant growth regulators, insecticides, fungicides, nematicides, fumigants, rodenticides, molluscicides, aquatic pesticides, and fish/bird pesticides. Most pesticides create some risk of harm to humans, animals, or the environment because they are designed to kill or otherwise adversely affect living organisms. At the same time, pesticides are useful to society because of their ability to kill potential disease-causing organisms and control insects, weeds, and other pests.

Currently, no reporting system provides information on the volume, distribution, and extent of pesticide use nationwide across all sectors. Estimates, however, of total pesticide use have been developed based on available information such as crop profiles, pesticide sales, and expert surveys. Several of these data sets are collected by the private or non-profit sectors rather than federal agencies.

EPA's recent *Pesticide Industry Sales and Usage Report* estimates show that conventional annual pesticide use declined by about 15 percent between 1980 and 1999. This change has not been steady; in 1999, pesticide use was higher than it was in the early 1990s. Of the three sectors of pesticide use assessed in EPA estimates (agricultural, industry-commercial-government, and home-garden), the industrial-commercial-government use of pesticides has seen the most steady decline over this 20-year period. EPA estimates show that in 1999, agricultural pesticide use accounted for nearly 77 percent (956 million pounds) of all pesticide use; home and garden use was 11 percent (140 million pounds); and industrial, commercial, and government use was nearly 12 percent (148 million pounds) of total conventional pesticide use (1244 million pounds). These estimates do not include wood preservatives, biocides, and chlorine/hypochlorites (EPA, OPPTS, 2002).

An important class of pesticides—insecticides—has undergone significant use reduction in the last 5 years. Insecticides, as a class, tend to be the most acutely toxic pesticides to humans and wildlife. The number of individual chemical treatments per acre, referred to as "acre-treatments," for insecticides labeled "danger for humans" has undergone a 43 percent reduction in use from 1997 to 2001. Over the same period, acre-treatments for insecticides labeled "extremely or highly toxic to birds" have been reduced by 50 percent, and insecticides labeled "extremely or highly toxic to aquatic organisms" have been reduced by 23 percent (EPA, OPP, 2001). The indicator identified for this question specifically addresses agricultural pesticide use.

Indicator | Agricultural pesticide use - Category 2

Building on EPA and USDA estimates, as well as on pesticide use surveys, the National Center for Food and Agricultural Policy (NCFAP), a private, non-profit, research organization, has established a pesticide use database that provides estimates of agricultural pesticide use by chemical, crop, and state.

What the Data Show

According to NCFAP, and as shown in Exhibit 3-17, total agricultural pesticide use increased from 892 to 985 million pounds between 1992 and 1997. (EPA reports a similar increase in use of all pesticides in this same time frame, and a leveling of use between 1997 and 1999.) (EPA, OPPTS, 2002). Approximately half of these agricultural pesticides are herbicides used to control weeds that limit or inhibit the growth of the desired crop. While many pesticides are synthetic chemicals, some biopesticides, such as *Bacillus thuringiensis,* are also broadly used and are key components of organic farming programs.

The 1997 NCFAP summary report shows that more pesticides are used on corn than on any other crop. At the same time, corn is planted on more acres than any other single crop. It is also most effectively treated with a combination of chemicals that are applied in high quantities per acre.

Oil, most often applied as a spray, is used in greater quantities than any other pesticide across all crops. In the context of the NCFAP report, "oil" includes plant oil extracts with insecticidal properties, vegetable oils that work by smothering pests, and petroleum derivatives used as solvents and insecticides. Sulfur—through its broad applicability as an insecticide, fungicide, and rodenticide—and atrazine, largely due to its use with corn, are the next two most commonly used chemicals.

Indicator Gaps and Limitations

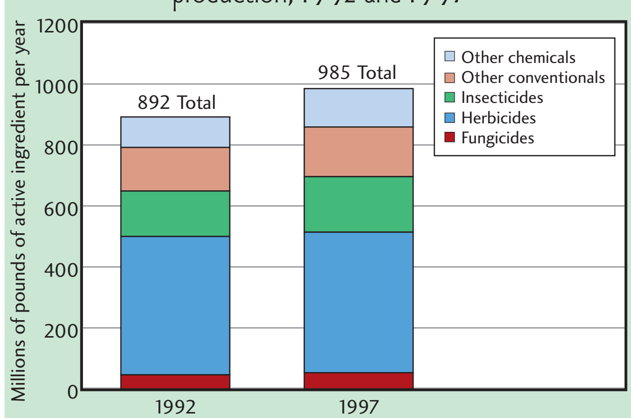
Limitations for this indicator include the following:

- The data quality of the NCFAP national pesticide use database is unknown. The database is not a direct record based on reports of actual usage and application. Some of the database estimates are derived from surveys of farmers, and others are expert opinions from knowledgeable extension service specialists. Also, because of the absence of data for many states and crops, many records have been assigned based on the data from a nearby state. It is unclear how accurate these sources and procedures are. The 1997 summary report for the database carefully makes no claims to statistical accuracy because of the variety of sources and techniques for estimation of chemical usage. Several federal agencies, however, use the information, and NCFAP has received funding from USDA to update the pesticide use database for 2002 (Gianessi and Marcelli, 2000).
- NCFAP data only report on the agricultural use of pesticides, which leaves out other commercial non-agricultural and residential applications. Additional data would be advantageous for tracking these uses of pesticides.

Data Source

The data source for this indicator is the National Center for Food and Agricultural Policy's Pesticide Use Database, 2000. (See Appendix B, page B-21, for more information.)

Exhibit 3-17: Pesticide use in crop production, 1992 and 1997



Source: Gianessi, L.P., and M.B. Marcelli. *Pesticide Use in U.S. Crop Production: 1997, National Summary Report.* November 2000.

3.2.3 What is the volume, distribution, and extent of fertilizer use?

Indicator
Fertilizer use

Fertilizers have contributed to an increase in commercial agricultural productivity in the U.S. throughout the latter half of the 20th century. Using fertilizers and soil amendments, farmers have successfully enhanced the productivity of marginal soils and shortened recovery times for damaged areas. Similar to pesticide use, however, the increasing use of commercial fertilizers in agriculture has consequences for human health and ecological condition. Between World War II and the early 1980s, commercial fertilizer use increased consistently and significantly (Battaglin and Goolsby, 1994). Fertilizer use patterns today are greatly influenced by crop patterns, economic and climatic factors, and crop reduction programs implemented by local and federal government agencies (Council on Environmental Quality, 1993). The indicator identified for this question specifically addresses the volume, distribution, and extent of fertilizer use.

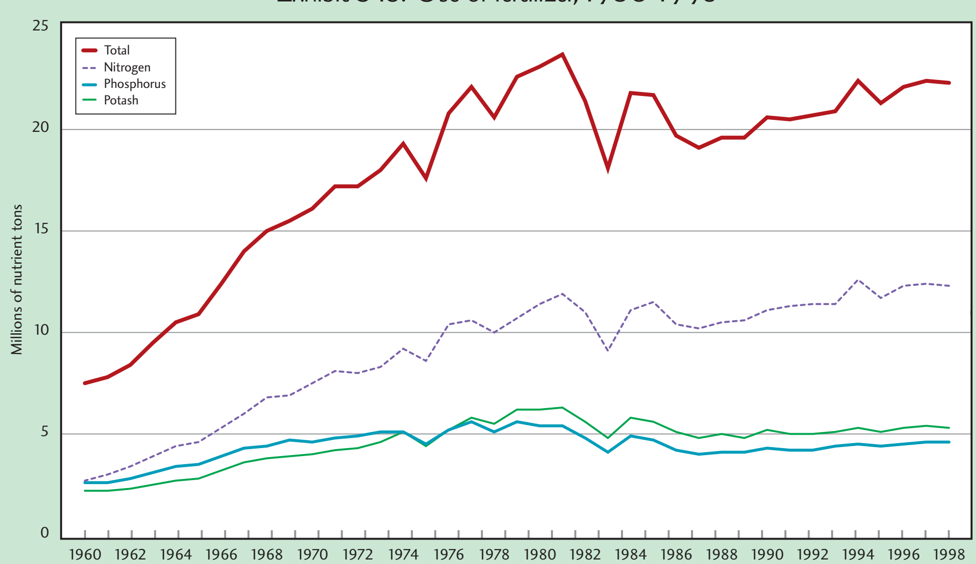
Indicator | Fertilizer use - Category 2

Most data on the volume and distribution of fertilizer use are based on sales data collected by USDA. Usage is concentrated heavily in the midwestern states where agricultural production—particularly that of corn—is greatest.

What the Data Show

According to the *2000 USDA Agricultural Resources and Environmental Indicators Report,* the use of nitrogen, phosphorus, and potash—the most prevalent supplements used in fertilizers for commercial farming—rose from 7.5 million nutrient tons in 1961 to 23.7 million tons in 1981. Although aggregate use dipped in 1983, it increased most recently between 1996 and 1998 to more than 22 million nutrient tons (Daberkow, et al, 2003) (Exhibit 3-18).

Exhibit 3-18: Use of fertilizer, 1960-1998



Source: Daberkow, et al. *Agricultural Resources and Environmental Indicators: Nutrient Use and Management.* February 2003.

Indicator Gaps and Limitations

Several limitations are associated with this indicator:

- The data that do exist are based primarily on sales information and use estimates. Gross sales data are not necessarily a reflection of fertilizer usage, nor do they convey any information about the efficiency of application of various nutrients.
- A variety of factors such as weather and crop type influence the amount of fertilizer used by farmers from year to year. A decrease in usage over time may be due to a reduced reliance on these chemicals or a change in crop rotation, weather, or other factors, and may not be permanent.
- These data do not necessarily reflect residential fertilizer use.

Data Source

The data source for this indicator is the *Agricultural Resources and Environmental Indicators Report,* U.S. Department of Agriculture, Economic Research Service, 2000. (See Appendix B, page B-21, for more information.)

3.2.4 What is the potential disposition of chemicals from land?

Indicators

Pesticide residues in food
Potential pesticide runoff from farm fields
Risk of nitrogen export
Risk of phosphorus export

Disposition describes the potential for chemicals and nutrients to move from their location of use or origin to a place in the environment where humans and other organisms can be exposed to them. People can be affected by these chemicals and nutrients when exposed to them through foods, drinking water supplies, or in the air they breathe. The environment can be affected when these chemicals accumulate on land or enter the water. A significant challenge lies in tracking the movement of pesticides and fertilizers in the environment and then correlating their existence in water or air to health or environmental effects. These chemicals often move through the environment and react in ways that are difficult to track and understand.

Pesticide contamination of ground water is a potential problem when leachable pesticides are applied to soils. Soil leaching potential can be determined by assigning rankings to organic matter, clay content, and acidity, which are the three main factors controlling pesticide leaching through soils (Hellkamp, et al., 1998). Pesticide-leaching potential is a measure of how tightly and quickly a pesticide binds to organic particles and is determined by the leaching potential of the pesticide itself, the pesticide's persistence, and the rate and method of application. Some analysis of the pesticide leaching risk based on these variables has been conducted in the mid-Atlantic region, showing that relatively little acreage has a high potential for leaching. Other variables should also be considered in assessing the risk of pesticide leaching including precipitation, antecedent soil moisture conditions, soil hydraulic conductivities and permeability, and water table depths.

Under ideal circumstances, crops would take up the vast majority of nutrients that are applied as fertilizers to soil, but many factors, including weather, overall plant health, and pests, affect the uptake ability of crops. When crops do not use all applied nutrients, residual concentrations of nutrients and other components of chemical fertilizers remain in the soil and can become concentrated in ground water and surface water. The USGS National Water Quality Assessment provides one measure of these chemical concentrations in waterbodies based on samples from 36 major river basins and aquifers (see Chapter 2, Purer Water). Calculating residual concentrations (known as the "residual balance") for agricultural areas provides an understanding of the potential risks fertilizer use poses to local environmental conditions. If the residual balance is positive, then excessive nutrients may exist and present an ecological risk. If it is negative, then plants are taking up not only the amount of nutrient added by the fertilizer but others already present in the soil and atmosphere. In this case, the soil might be depleted over time (Vesterby, 2003).

Four indicators are considered on the following pages, one that measures the actual presence of chemicals in food, and three that assess the potential for pesticides and nutrients to runoff the land.

Indicator: Pesticide residues in food - Category 1

An indication of the amount of pesticides that are detectable in the U.S. food supply provides information about the disposition of some chemicals. Food is one of the pathways through which people can be exposed to the effects of pesticides. USDA has maintained a Pesticide Data Program (PDP) since 1992 that collects data on pesticide residues on fruits, vegetables, grains, and in dairy products at terminal markets and warehouses. Thousands of samples have been analyzed for more than 100 pesticides and their metabolites on dozens of commodities. Samples are collected by USDA immediately prior to these commodities being shipped to grocery stores and supermarkets. They are then prepared in the laboratory as if for consumption (e.g., washed, peeled, cored, but not cooked) so that samples are more likely to reflect actual exposures. Pesticide residue levels are then measured.

What the Data Show

The Department of Agriculture's Pesticide Data Program (PDP) measures pesticide residue levels in fruits, vegetables, grains, and dairy products from across the country, sampling different commodities each year. In 2000, PDP collected and analyzed a total of 10,907 samples: 8,912 fruits and vegetables, 178 rice, 716 peanut butter, and 1,101 poultry tissue samples which originated from 38 States and 21 foreign countries. Approximately 80 percent of all samples were domestic, 19 percent were imported,

Indicator Pesticide residues in food - Category 1 (continued)

and less than 1 percent were of unknown origin. Overall, approximately 42 percent of all samples contained no detectable residues, 22 percent contained 1 residue, and 35 percent contained more than 1 residue. Detectable residues are not inherently violations of regulatory tolerances. Residues exceeding the pesticide tolerance were detected in 0.2 percent of all composite samples. Residues with no tolerance level were found in 1.2 percent of all samples. These residues were detected at low concentrations and may be due to spray drift, crop rotations, or cross contamination at packing facilities. PDP reports these findings to the Food and Drug Administration.

Indicator Gaps and Limitations

Limitations for this indicator include the following:

- The PDP does not sample all commodities over all years, so some gaps in coverage exist. For example, a specific commodity might be sampled each year for a two or three year period and then not be sampled for two or more years before being re-sampled during a subsequent period. Differences in the percent of detections for any given class of pesticides might not be due to an increase (or decrease) in the predominance of detectable residues, but might simply reflect the changing nature and identity of the commodities selected for inclusion in any given time frame (given that each PDP "market basket" of goods differs to some extent over time).
- The PDP has the ability to detect pesticide residues at concentrations that are orders of magnitude lower than those determined to have human health effects. The simple presence of detectable pesticide residues in foods should not be considered indicative of a potential health concern (USDA, AMS, 2002).

Data Source

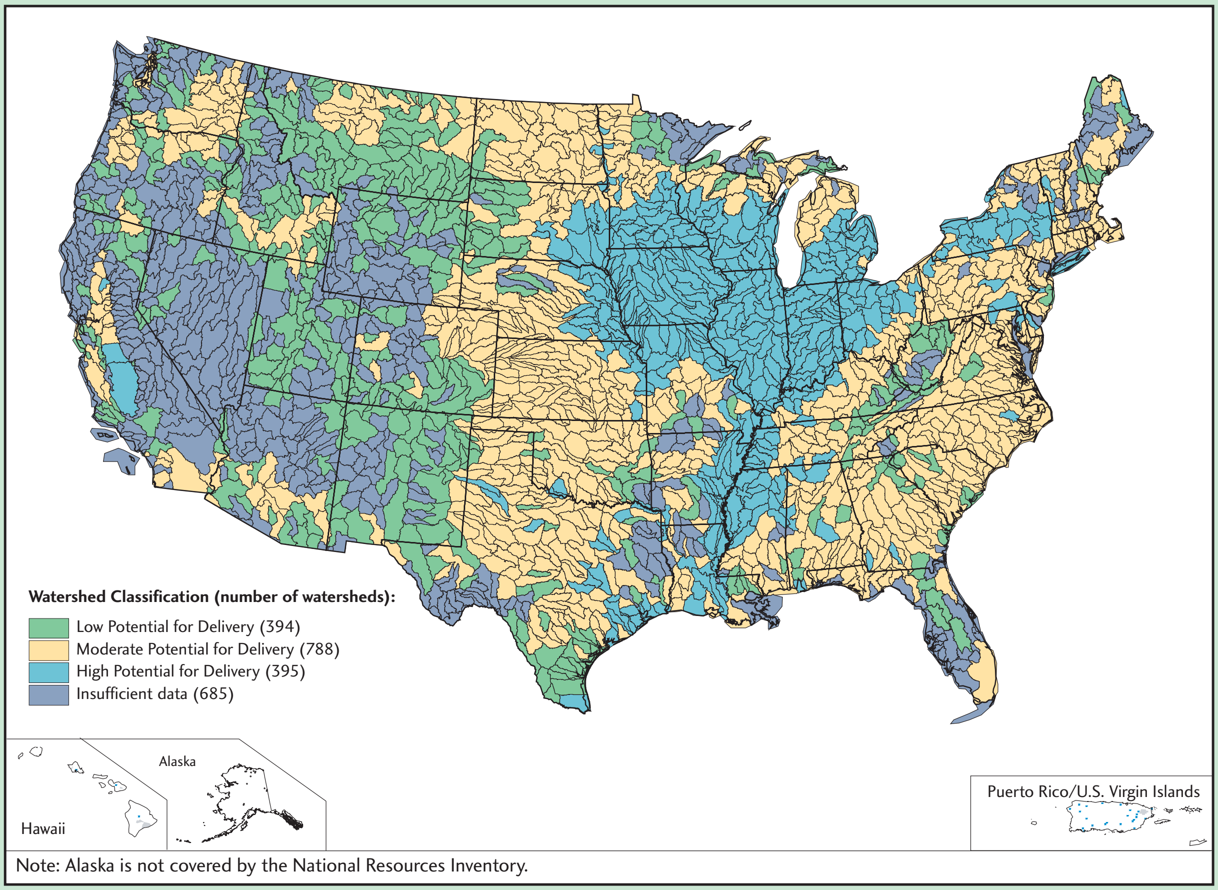
The data source for this indicator is the *Pesticide Data Program: Annual Summary Calendar Year 2000,* U.S. Department of Agriculture, Agricultural Marketing Service. (See Appendix B, page B-21, for more information.)

Indicator Potential pesticide runoff from farm fields - Category 2

This indicator identifies the potential for movement of agricultural pesticides by surface water runoff in watersheds nationwide. The indicator represents potential loss at the edge of a field based on factors that are known to be important determinants of pesticide loss, including: 1) soil characteristics, 2) historical pesticide use, 3) chemical properties of the pesticides used, 4) annual rainfall and its relationship to runoff, and 5) major field crops grown using 1992 as a baseline. Watersheds with high scores (i.e., the "high potential for delivery" class) have a greater risk of pesticide contamination of surface water than do those with low scores (i.e., the "low potential for delivery" class). (See Section 3.1.6 for more on runoff categories.)

Calculations for watershed pesticide runoff potential are based on a National Pesticide Loss Database, that uses the chemical fate and transport model GLEAMS (Groundwater Loading Effects of Agricultural Management). GLEAMS is a model that estimates pesticide leaching and runoff losses using the following as inputs: soil properties, field characteristics (e.g., slope and slope length), management practices, pesticide properties, and climate. GLEAMS estimates were generated for 243 pesticides applied to 120 specific soils; the estimates are for 20 years of daily weather for each of 55 climate stations distributed throughout the U.S. (Knisel, 1993).

Exhibit 3-19: Potential pesticide runoff from farm fields, 1990-1995



Source: USDA, Natural Resources Conservation Service. *National Resources Inventory.* 1992; Gianessi, L.P., and J.E. Anderson. *Pesticide Use in US Crop Production: National Data Report.* February 1995; Goss, Don W. Pesticide Runoff Potential, 1990-1995. August 24, 1999. (September 2002; *http://www.epa.gov/iwi/1999sept/iv12a_usmap.html*).

Indicator Potential pesticide runoff from farm fields - Category 2 (continued)

Chemical use for 13 different crops taken from the National Pesticide Use Database was estimated for 1990-1993 (Gianessi and Anderson, 1995). A total of 145 pesticides were included in the derivation of the pesticide runoff indicator (using the joint set of pesticides from the National Pesticide Use Database and the National Pesticide Loss Database for the 13 crops). Estimates of percent of acres treated and average application rates were imputed to the NRI sample points by crop and state. Each NRI sample point where corn was grown in Iowa, for example, included chemical use for 22 of the pesticides Gianessi and Anderson reported were used on corn in Iowa. The simulation assumed that each pesticide was applied at the average rate for the state. In reality, pesticide use varies widely from field to field. The simulation thus reflects general pesticide use patterns to provide an indication of where the potential for loss from farm fields is the greatest.

The total loss of pesticides from each representative field was estimated by 1) multiplying the estimate of percent loss per acre by the application rate to obtain the mass loss per acre for each pesticide, 2) calculating the number of acres treated for each pesticide by multiplying the estimate of percent acres treated by the number of acres associated with the sample point, 3) multiplying the number of acres treated by the mass loss per acre to obtain the mass loss for the representative field for each pesticide, and 4) summing the mass loss estimates for all the pesticides.

Watershed scores were determined by averaging the scores for the NRI sample points within each watershed. The average watershed score was determined by dividing the aggregate pesticide loss for the watershed by the number of acres of non-federal rural land in the watershed. Dividing by the acres of non-federal rural land provides a watershed level perspective of the significance of pesticide loss.

What the Data Show

Exhibit 3-19 shows the distribution of watersheds and the potential for pesticide runoff nationwide. The highest potential for agricultural pesticide runoff is concentrated in the central U.S., predominately associated with the upper and lower Mississippi River Valley and the Ohio River Valley.

Indicator Gaps and Limitations

The following limitations are associated with this indicator:

- The indicator estimates only the potential for pesticides to run off farm fields. It does not estimate actual pesticide loss. Research has shown that pesticide loss from farmlands can be substantially reduced by management practices that enhance the water-holding capacity and organic content of the soil, reducing water runoff. Where these practices are being used, the potential loss measured by this indicator will be overestimated because the practices are not considered in the analysis.
- The indicator does not include croplands used for growing fruits, nuts, and vegetables. Thus, watersheds with large acreage of these crops will have a greater risk of water quality contamination than shown by this indicator.
- For each field, pesticide usage was assumed as an average for the state, when actual use varies widely.
- This indicator does not address pesticide usage in non-agricultural areas.

Data Sources

The data sources for this indicator are the *Summary Report: 1997 National Resources Inventory (Revised December 2000)*, U.S. Department of Agriculture, Natural Resources Conservation Service, and the National Pesticide Use Database, National Center for Food and Agricultural Policy, 1995. (See Appendix B, page B-21, for more information.)

Indicator Risk of nitrogen export - Category 2

Predictive risk models show higher nutrient concentrations in watersheds dominated by agricultural and urban and suburban land uses. Watersheds with mixed uses tend to have forested lands that reduce concentrations of nutrients. Various field-based studies show a strong relationship between land cover and the amount of nutrients exported from a watershed (e.g., measured in the stream at the watershed outlet) (Beaulac and Reckhow, 1982). Exports are typically measured as mass per unit area per unit time (e.g., lbs/acre/year). Nitrogen exports tend to increase as agriculture and urban and suburban uses replace forest land. Several additional factors affect the actual amount exported, however, such as cropping management practices, the timing of rainfall versus cropping stage, density of impervious surfaces, and soil types.

The risk classes described by this indicator are based solely on proportions of agriculture, forest, and urban and suburban land within a watershed derived from the NLCD. Nutrient export data compiled from watersheds with homogenous land cover were used in a Monte Carlo approach to simulate loads of nitrogen for watersheds with mixed land cover. The model can be used to estimate annual load for any point in the distribution or for risk of exceeding user-defined thresholds. When used to estimate risk, the model conceptually incorporates factors other than land cover as mentioned above.

What the Data Show

Exhibit 3-20 shows the risk of nitrogen export. Risk is expressed as the number of times per 10,000 trials the nitrogen export exceeded a threshold of 6.5 lbs/acre/year. The 6.5 threshold was chosen because it represents the maximum value observed for watersheds that were entirely forest. A risk value of 0.5 indicates a 1 out of 2 chance that a particular watershed would exceed the risk threshold because of its mix of land cover (e.g., forest, agriculture, urban/suburban). The watersheds in Exhibit 3-20 are categorized into five classes based on risk. About 46 percent of the watersheds are in the lowest risk class and 15 percent in the highest. The lowest risk watersheds make up most of the western U.S., northern New England, northern Great Lakes, and southern Appalachians. The highest risk classes are concentrated in the midwestern grain belt. The eastern U.S. shows a mottling of high and low risk classes among adjacent watersheds.

Indicator Gaps and Limitations

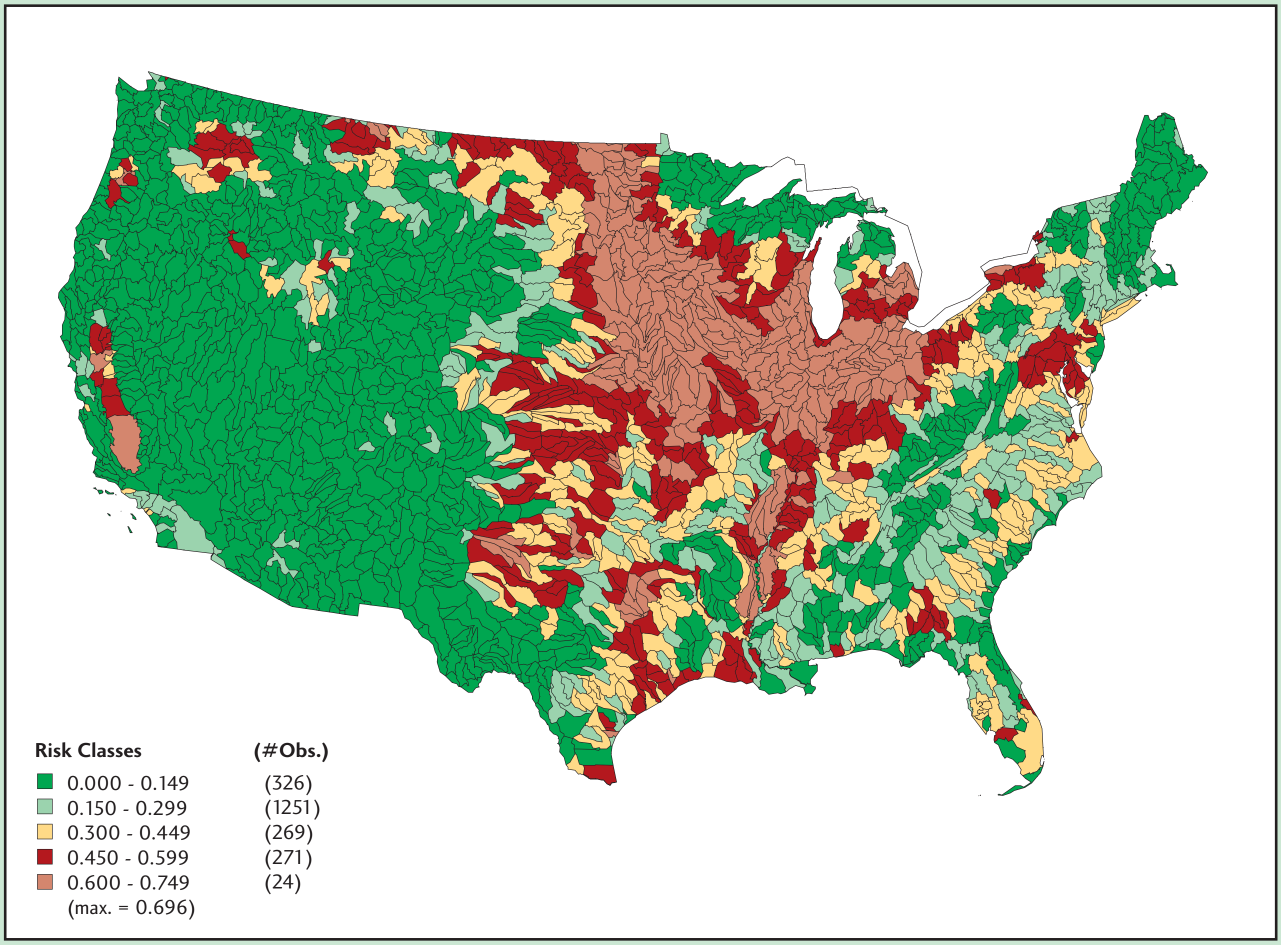
The potential risk of nitrogen runoff calculated from the NLCD data relies on various classifications and models that have inaccuracies that might affect results. To nationally monitor all watershed variables that affect nutrient export is impossible. Therefore, the data for this indicator are based on statistical simulation and the well-documented relationship between land cover and nutrient export to estimate the risk (or likelihood) of export exceeding a certain threshold. The accuracy of the model is affected by the accuracy of the classification of the cover types—forest, agriculture, and urban/suburban—which range from 80 percent to 90 percent in most cases. The accuracy also is affected by lack of model input for other land cover classes that can occur within watersheds, particularly in the western U.S. Model performance has been evaluated in the mid-Atlantic region, and modeled results generally agree with observed values. In the western U.S., shrubland and grassland cover share dominance with forest and agriculture. For national application of the model, shrubland and grassland classes were treated as forest because these land-cover classes, like forest, lack strong anthropogenic inputs of nitrogen. Further research to refine the empirical models for shrubland and grassland cover classes would be useful.

Data Sources

The data source for this indicator is the National Land Cover Data, Multi-Resolution Land Characteristics Consortium, 1992. (See Appendix B, page B-22, for more information.)

Indicator | Risk of nitrogen export - Category 2 (continued)

Exhibit 3-20: Estimates of risk of nitrogen export by watershed, 1992



Source: Wickham, J.D. et al., *Land Cover as a Framework for Assessing Risk of Water Pollution.* 2000.

Indicator | Risk of phosphorus export - Category 2

Like nitrogen export, the same strong relationship exists between land cover and phosphorus export. Risk is expressed as the number of times out of 10,000 trials that the phosphorus export threshold of 0.74 lbs/acre/year was exceeded. The 0.74 threshold was chosen because it represents the maximum value observed for watersheds that were entirely forest. The model uses an identical approach to that just described in the "risk of nitrogen export" indicator.

What the Data Show

Exhibit 3-21 shows potential for phosphorus export at greater than 0.74 pounds per acre per year. About 74 percent of the watersheds are in the two lowest risk classes. These make up most of the western U.S., as well as the eastern seaboard and the Appalachians. Only 1 percent of the watersheds are in the highest risk classes, and these are scattered throughout the midwestern grain belt, but also in many of the nation's major urban/suburban

Indicator Risk of phosphorus export - Category 2 (continued)

areas. Many major urban/suburban areas exist at the intersection of two watersheds, and the "urban" influence, which would make the phosphorus risk higher, is spread over multiple watersheds. This partially explains why some urban/suburban areas show lower risk than others. Identification of higher phosphorus export risk in urban/suburban areas differs somewhat from the spatial pattern for nitrogen export risk, because the empirical data suggest that urban/suburban areas present higher risk of phosphorus export than nitrogen export.

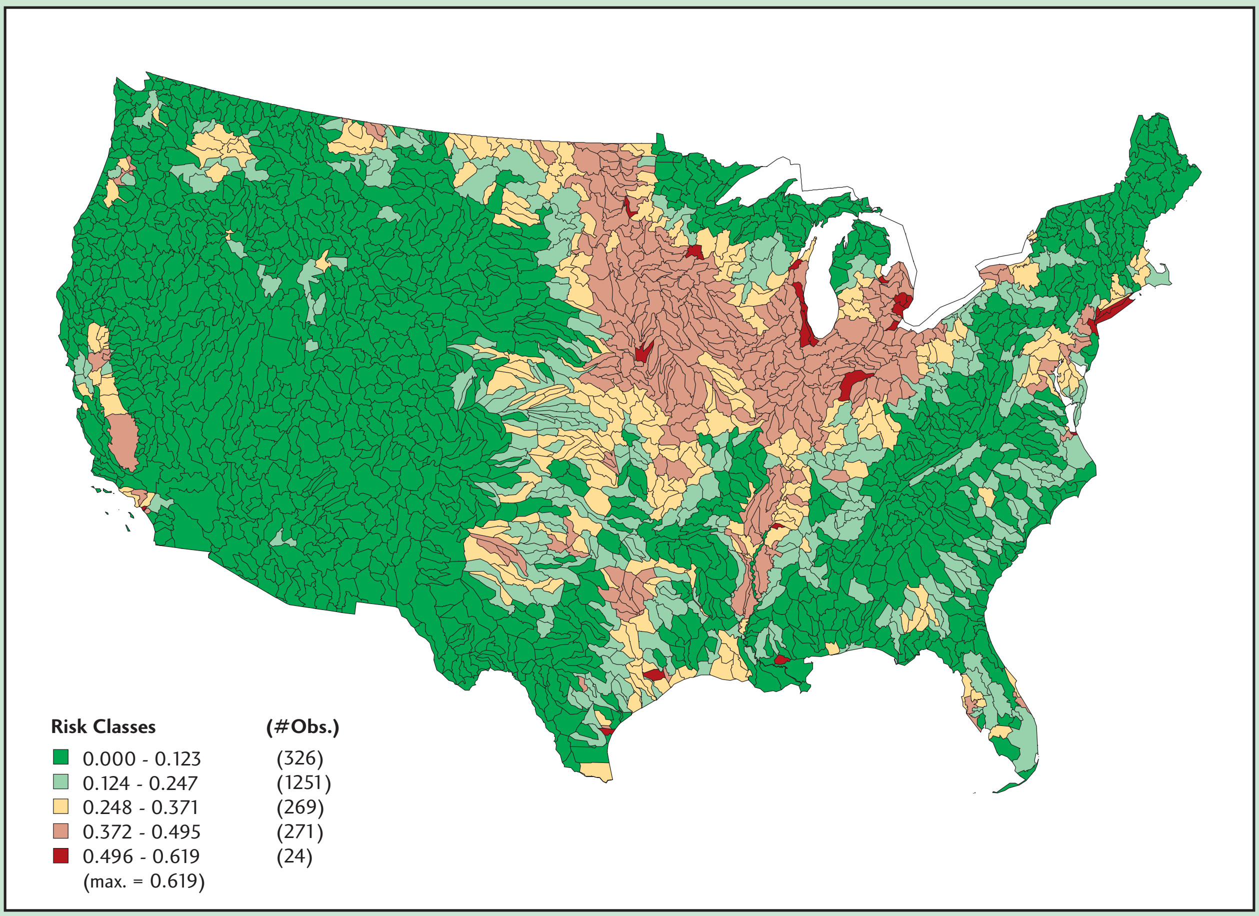
Indicator Gaps and Limitations

The potential risk of phosphorus export is based on the aggregate classes of forest, urban/suburban, and agriculture from the NLCD. Accuracy of these classes ranges from 80 to 90 percent in most cases. Model performance has been evaluated in the mid-Atlantic region, and modeled results generally agree with observed values. In the western U.S., shrubland and grassland cover share dominance with forest and agriculture. For national application of the model, shrubland and grassland classes were treated as forest, because these land-cover classes, like forest, lack strong anthropogenic inputs of phosphorus. Further research to refine the empirical models for shrubland and grassland land-cover classes would be useful.

Data Source

The data source for this indicator is the National Land Cover Data, Multi-Resolution Land Characteristics Consortium, 1992. (See Appendix B, page B-22, for more information.)

Exhibit 3-21: Estimates of risk of phosphorus export by watershed, 1992



Source: Wickham, J.D. et al., *Land Cover as a Framework for Assessing Risk of Water Pollution.* 2000.

3.2.5 What human health effects are associated with pesticides, fertilizers, and toxic substances?

Many pesticides pose some risk to humans and the environment because they are designed to kill or otherwise adversely affect living organisms. The degree to which individuals and populations are exposed to pesticides varies greatly by geographic location and demographics. Children may be more susceptible than adults to the effects of chemicals, including pesticides. Certain populations may be more at risk than others, depending, for example, on sources of drinking water or direct exposure to pesticide application.

Various pesticide surveillance systems exist that collect information on pesticide-related injury and illness, but data are limited. One example, the Toxic Exposure Surveillance System (TESS), contains information from poison control centers around the country that report occurrences of pesticide-related injury and illness.

Other data collected from poison control centers showed that in 2000, more than 100,000 people were sufficiently concerned about exposure to various types of pesticides to call their local Poison Control Center.

The TRI database tracks toxic chemicals because of the risks that these chemicals pose to human health and ecological condition. Studies have made accurate associations between isolated chemicals and their specific health effects. For example, the pesticide atrazine has been shown to have developmental and reproductive effects in animals and fish, depending on the level of exposure (EPA, OPP, 2002). PBT chemicals such as mercury and lead can cause acute or chronic health problems, even when people are exposed to small quantities of the chemicals (See box "Persistant Bioaccumulative Toxic Chemicals") (EPA, October 1999). Though these single chemical assessments are useful, a greater challenge lies in correlating the existence of chemicals that interact in the environment to the health effects observed in a given population.

Fertilizers are often applied in greater quantities than crops can absorb and end up in surface or ground water. Although fertilizers may not be inherently harmful, they can be linked to human health problems when excess nutrients cause algal blooms and eutrophication in waterbodies. Drinking ground water contaminated with runoff from some fertilizers can have severe or even fatal health effects, especially in infants and children (e.g., blue baby syndrome) (Amdur, et al, 1996).

Another emerging issue is the use of recycled industrial waste in fertilizer. Depending on the material and how it is processed, the presence of heavy metals such as lead or cadmium in fertilizers produced with recycled waste can introduce contaminants to the soil and increase the health risks associated with fertilizer use. Many states have begun to test and require labeling for fertilizers containing metals and hazardous waste.

No specific indicators have been identified at this time. There is additional discussion of human health effects of chemical use in Chapter 4, Human Health.

Persistent Bioaccumulative Toxic Chemicals

Human exposure to PBT chemicals increases over time because these chemicals persist and bioaccumulate in the environment. Therefore, even small quantities of these chemicals are of concern. In 1999, EPA lowered the TRI reporting threshold for 13 chemicals called persistent bioaccumulative toxic chemicals (PBTs), including dioxins, mercury, lead, and polychlorinated biphenyls (PCBs). Of the total 38 billion pounds of managed toxic chemicals in 2000, PBTs comprised approximately 72 million pounds. Of the total 7.10 billion pounds of toxic chemicals released to the environment, PBTs accounted for 12.1 million (less than 1 percent). The specific types of PBTs that comprised the 12.1 million pounds were polycyclic aromatic compounds (45 percent), mercury and mercury compounds (36 percent), PCBs (12 percent), pesticides (0.7 percent), and other PBTs (7 percent)(EPA, OEI, 2002).

3.2.6 What ecological effects are associated with pesticides, fertilizers, and toxic substances?

Nitrogen runoff from farmlands and animal feeding operations can contribute to eutrophication of downstream waterbodies and sometimes impair the use of water for drinking water purposes. Nutrient enrichment (nitrogen and phosphorus) is one of the leading causes of water quality impairment in the nation's rivers, lakes, and estuaries. EPA reported to Congress in 1996 that 40 percent of rivers in the U.S. were impaired due to nutrient enrichment; 51 percent of the surveyed lakes and 57 percent of the surveyed estuaries were similarly adversely affected (EPA, OW, December 1997). Nutrients have also been implicated in identification of the large hypoxic zone in the Gulf of Mexico, hypoxia observed in several East Coast states, and harmful algal bloom-induced fish kills and human health problems in the coastal waters of several East Coast and Gulf states .

Just as the sources of nitrogen in watersheds vary, so do the effects of exported nitrogen. While high levels of nitrogen might not affect the watersheds from which the nutrient is exported, exports can influence the condition of coastal estuaries and lakes. The effects vary with such factors as water-column mixing, sunlight, temperature, and the availability of other nutrients.

No specific indicators have been identified at this time. Effects of chemical use on ecological condition are discussed more extensively in Chapter 2, Purer Water; and Chapter 5, Ecological Condition.

3.3 Waste and Contaminated Lands

Waste and contaminated lands are discussed in this section. Waste is broadly defined as unwanted materials left over from manufacturing processes or refuse from places of human or animal habitation. Several waste categories and types are included within this broad definition. In general, waste can be categorized as either hazardous or non-hazardous. Hazardous wastes are the by-products of society that can pose substantial or potential hazards to human health or the environment when improperly managed. These wastes may appear on special EPA lists and they possess at least one of the four following characteristics: ignitability, corrosivity, reactivity, or toxicity. Hazardous waste includes specific types of waste, such as toxic waste and radioactive waste. All other waste is considered to be non-hazardous (EPA, OEI, May 2002).

Several specific kinds of waste consist of mixed hazardous and non-hazardous content. For instance, municipal solid waste (e.g., garbage) is largely non-hazardous but does typically contain some household hazardous waste items such as solvents or batteries. Other materials and waste types that can have mixed hazardous/non-hazardous content include animal waste, by-products of oil and gas production, materials from leaking underground storage tanks, and waste from coal combustion.

Contaminated lands are lands that have been contaminated with hazardous materials and require remediation. Contaminated lands are not the same as lands used for waste management. In many instances, lands used for waste management are not contaminated. Similarly, often no waste is present on contaminated lands. Contaminated lands can pose a direct risk if they expose people, animals, or plants to harmful materials or cause the contamination of air, soil, sediment, surface water, or ground water.

Despite numerous waste-related data collection efforts at the state and national levels, nationally consistent and comprehensive data on the status, pressures, and effects of waste and contaminated lands are limited. Various parties are responsible for tracking types and amounts of waste and contaminated sites. National-level data on waste and contaminated land tend to be collected to satisfy the requirements of specific federal regulations. For example, EPA's Resource Conservation and Recovery Act Information System (RCRAInfo) contains data on RCRA hazardous waste and EPA's Comprehensive Environmental Response, Compensation, and Liability Information System (CERCLIS) contains some data on contaminated sites, including Superfund sites.

Few national data sets exist for the waste types that are not federally regulated, such as non-hazardous industrial waste. Although a significant amount of waste information and some site contamination information is collected and tracked at the local or state government levels, these data are seldom aggregated nationally. Also, most of the available data describe waste in terms of weight, rather than volume. The weight data alone do not address the extent of the waste situation in the U.S. Similarly, national information about contaminated lands tends to focus on number of sites and types of contamination, rather than the extent of land contaminated. Finally, there is a lack of national data that track the effects of waste and contaminated land on human health and ecological condition.

While major improvements have been made in managing the nation's waste and cleaning up contaminated sites, more work remains. National, state, tribal, and local waste programs and policies aim to prevent pollution by reducing the generation of wastes at their source and by emphasizing prevention over management and disposal. Preventing pollution before it is generated and poses harm is often less costly than cleanup and remediation. Source reduction and recycling programs often can increase resource and energy efficiencies, reduce pressures on the environment, and extend the life span of disposal facilities.

The following questions and discussion of indicators provide an overview of what is known about waste generation and management and about contaminated lands in the U.S. Trends and conditions on a national basis are described to the extent that data are available. The five questions considered in this section are:

- How much and what types of waste are generated and managed?
- What is the extent of land used for waste management?
- What is the extent of contaminated land?
- What human health effects are associated with waste management and contaminated lands?
- What ecological effects are associated with waste management and contaminated lands?

EPA is the primary source of data for this section, providing municipal solid waste data on generation, management, recovery, and disposal; data on RCRA hazardous waste and corrective action sites from the RCRAInfo database; and data on the number and location of contaminated sites that are on the Superfund National Priorities List (NPL) from CERCLIS. The U.S. Department of Energy's (DOE) Central Internet Database provides information on the types and quantities of radioactive waste generated and in storage.

3.3.1 How much and what types of waste are generated and managed?

Indicators

Quantity of municipal solid waste (MSW) generated and managed
Quantity of RCRA hazardous waste generated and managed
Quantity of radioactive waste generated and in inventory

There are numerous types of waste, but only three types are tracked with any consistency on a national basis. The three that are described as indicators on the following pages include municipal solid waste (MSW), hazardous waste (as defined by RCRA), and radioactive waste. The other types of waste range from materials generated during mining and agricultural activities to wastes from manufacturing and construction. Current national data are not available on these other types of waste. Exhibit 3-22 summarizes the types of waste.

Exhibit 3-22: Types of Waste

Type	Description
Municipal Solid Waste (Indicator)	Municipal solid waste (MSW) is the waste discarded by households, hotels/motels, and commercial, institutional, and industrial sources. MSW typically consists of everyday items such as product packaging, grass clippings, furniture, clothing, bottles, food scraps, newspapers, appliances, paint, and batteries. It does not include wastewater. In 2000, 232 million tons of MSW were generated. (EPA, OSWER, June 2002)
RCRA Hazardous Waste (Indicator)	The term "RCRA hazardous waste" applies to certain types of hazardous wastes that appear on EPA's regulatory listing (RCRA) or that exhibit the specific characteristics of ignitability, corrosiveness, reactivity, or toxicity. More than 40 million tons of RCRA hazardous waste were generated in 1999. (EPA, OSWER, June 2001)
Radioactive Waste (Indicator)	Radioactive waste is the garbage, refuse, sludge, and other discarded material, including solid, liquid, semi-solid, or contained gaseous material that must be managed for its radioactive content (DOE Order 435.1 Issued July 1999). The technical names for the types of waste that are considered "radioactive waste" for this report are high-level waste, spent nuclear fuel, transuranic waste, low-level waste, mixed low-level waste, and contaminated media. Data on the amounts of these waste types are provided in the radioactive waste discussion. (See Appendix D for definitions of these terms).
Extraction Wastes	Extraction activities such as mining and mineral processing are large contributors to the total amount of waste generated and land contaminated in the U.S. EPA estimates that 5 billion tons of mining wastes were generated in 1988 (EPA, OSWER, October 1988).
Industrial Non-Hazardous Waste	Industrial non-hazardous waste is process waste associated with electric power generation and manufacturing of materials such as pulp and paper, iron and steel, glass, and concrete. This waste usually is not classified as either municipal solid waste or RCRA hazardous waste by federal or state laws. State, tribal, and some local governments have regulatory programs to manage industrial waste. EPA estimated that 7.6 billion tons of industrial non-hazardous wastes were generated in 1988. (EPA, OSWER, October 1988)
Household Hazardous Waste	Most household products that contain corrosive, toxic, ignitable, or reactive ingredients are considered household hazardous waste. Examples include most paints, stains, varnishes, solvents, and household pesticides. Special disposal of these materials is necessary to protect human health and the environment, but some amount of this type of waste is improperly disposed of by pouring the waste down the drain, on the ground, in storm sewers, or by discarding the waste with other household waste as part of municipal solid waste. EPA estimates that Americans generate 1.6 million tons of household hazardous waste per year, with the average home accumulating up to 100 pounds annually. (EPA, OSWER, October 2002)
Agricultural Waste	Agricultural solid waste is waste generated by rearing animals and producing and harvesting crops or trees. Animal waste, a large component of agricultural waste, includes waste from livestock, dairy, milk, and other animal-related agricultural and farming practices. Some of this waste is generated at sites called Confined Animal Feeding Operations (CAFOs). The waste associated with CAFOs results from congregating animals, feed, manure, dead animals, and production operations on a small land area. Animal waste and wastewater can enter water bodies from spills or breaks of waste storage structures (due to accidents or excessive rain) and non-agricultural application of manure to crop land (EPA, OW, November 2001; EPA, OW, June 2002). National estimates are not available.
Construction and Demolition Debris	Construction and demolition debris is waste generated during construction, renovation, and demolition projects. This type of waste generally consists of materials such as wood, concrete, steel, brick, and gypsum. (The MSW data in this report do not include construction and demolition debris, even though sometimes construction and demolition debris are considered MSW.) National estimates are not available.
Medical Waste	Medical waste is any solid waste generated during the diagnosis, treatment, or immunization of human beings or animals, in research, production, or testing. National estimates are not available.
Oil and Gas Waste	Oil and gas production wastes are the drilling fluids, produced waters, and other wastes associated with the exploration, development, and production of crude oil or natural gas that are conditionally exempted from regulation as hazardous wastes. National estimates are not available.
Sludge	Sludge is the solid, semisolid, or liquid waste generated from municipal, commercial, or industrial wastewater. National estimates are not available.

Indicator

Quantity of municipal solid waste (MSW) generated and managed - Category 2

As noted in Exhibit 3-22, municipal solid waste (MSW) is the waste discarded by households and by commercial, institutional, and industrial operations. This type of waste is familiar to most Americans because they are specifically responsible for its generation. MSW typically consists of everyday items such as product packaging, grass clippings, furniture, clothing, bottles, food scraps, newspapers, appliances, paint, and batteries. It does not include wastewater.

What the Data Show

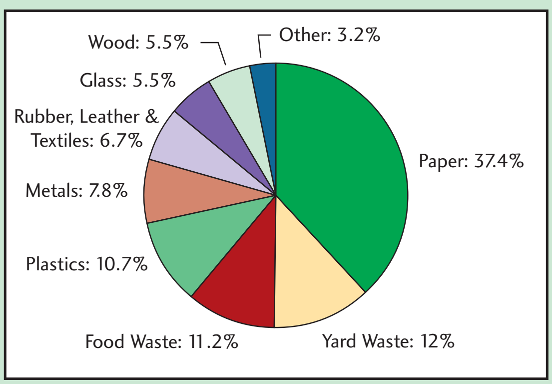
In 2000, Americans generated 232 million tons of MSW (Exhibit 3-23). This total amount, which does not take into account MSW that was ultimately recycled or composted, equated to approximately 4.5 pounds of waste per person per day. Paper and paperboard products accounted for the largest component of MSW generated (37 percent), and yard trimmings constituted the second-largest material component (12 percent). Glass, metals, plastics, wood, and food scraps each constituted 5 to 11 percent of the total. Rubber, leather, and textiles combined made up about seven percent of MSW, while other miscellaneous wastes made up approximately 3 percent (EPA, OSWER, June 2002).

The total amount of MSW generated increased nearly 160 percent between 1960 and 2000 (Exhibit 3-24). For comparison purposes, during that same time frame, the U.S. population increased by 56 percent, gross national product increased nearly 300 percent, and per capita generation of waste rose more than 70 percent (DOC, BEA, 2002; EPA, OSWER, June 2002). The amount of MSW generated per capita generally stabilized between 1990 and 2000, increasing less than one percent.

The data on the total amount of MSW generated do not factor in source reduction and waste prevention or materials recovery (recycling and composting), which are also important contributors to the overall municipal waste picture. Source reduction and waste prevention include the design, manufacture, purchase, or reuse of materials to reduce their amount or toxicity or lengthen their life before they enter the MSW system. Between 1992 and 2000, source reduction in the U.S. prevented more than 55 million tons of MSW from entering the waste stream (EPA, OSWER, June 2002) (Exhibit 3-25).

Exhibit 3-23: Total municipal solid waste generated, 2000

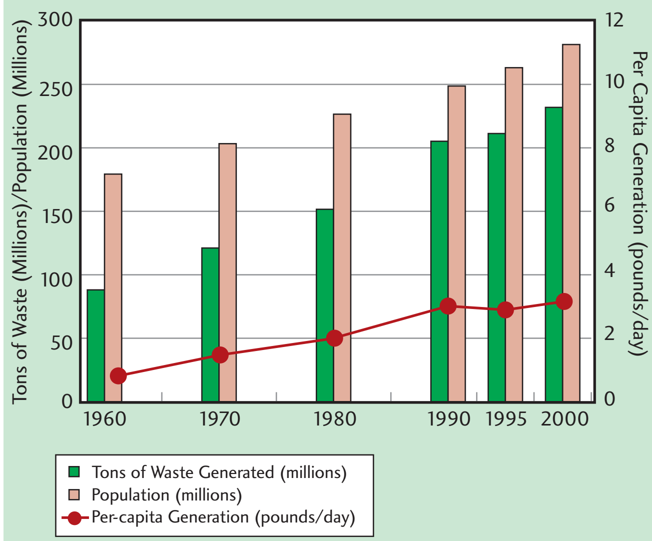
Total (before recycling and composting) = 232 million tons



Source: EPA, Office of Solid Waste and Emergency Response. *Municipal Solid Waste in the United States: 2000 Facts and Figures.* June 2002.

Exhibit 3-24: Municipal solid waste generation rates, 1960-2000

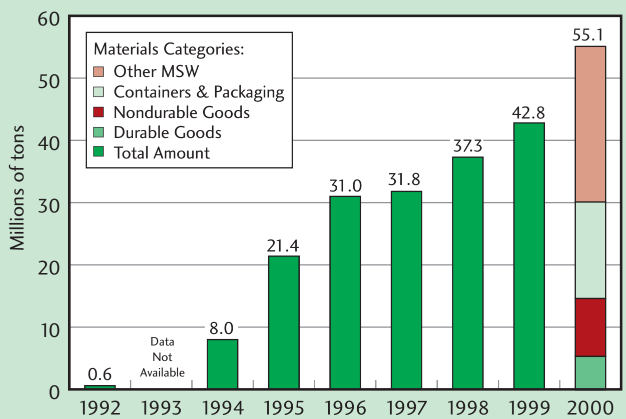
(before recycling and composting)



Source: EPA, Office of Solid Waste and Emergency Response. *Municipal Solid Waste in the United States: 2000 Facts and Figures.* June 2002.

Indicator Quantity of municipal solid waste (MSW) generated and managed - Category 2 (continued)

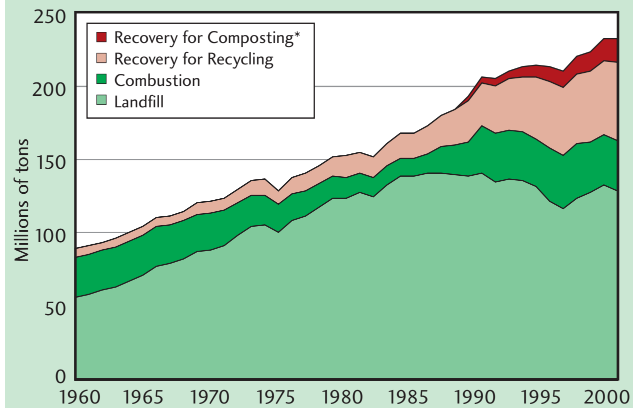
Exhibit 3-25: Source reduction of municipal solid waste, 1992-2000



Source: EPA. Office of Solid Waste and Emergency Response. *Municipal Solid Waste in the United States: 2000 Facts and Figures*. June 2002.

Exhibit 3-26: Municipal solid waste management, 1960-2000

(2000 total = 232 million tons)



* Composting of yard trimmings and food wastes. Does not include mixed MSW composting or backyard composting.

Source: EPA, Office of Solid Waste and Emergency Response. *Municipal Solid Waste in the United States: 2000 Facts and Figures*. June 2002.

Materials recovery (recycling and composting) has also reduced the total amount of MSW being discarded. In 2000, approximately 30 percent (70 million tons) of the MSW generated was recovered and thereby diverted from landfills and incinerators. Between 1960 and 2000, the total amount of MSW recovered has significantly increased from 5.6 million tons to 69.9 million tons, more than a 1,100 percent increase. During this time period, the amount recovered on a per capita basis increased from 0.17 pounds per person per day to 1.35 pounds per person per day—an 8-fold increase (EPA, OSWER, June 2002). The percentage of MSW disposed of in landfills has dropped from 83.2 percent of the amount generated in 1986 to 55.3 percent of the amount generated in 2000 (Exhibit 3-26). Combustion (incineration) is also used to reduce waste volume prior to disposal in a land-based waste management facility. Approximately 33.7 million tons (14.5 percent) of MSW were combusted in 2000. Of this amount, approximately 2.3 million tons were combusted with energy recovery—also known as waste-to-energy combustion (EPA, OSWER, June 2002).

Indicator Gaps and Limitations

Limitations for this indicator include the following:

- The MSW data do not include construction and demolition debris, municipal waste water treatment sludge, automobile bodies, combustion ash, and non-hazardous industrial wastes that may go to a municipal waste landfill. The data (including the generation, recycling, and recovery data) are generated using the materials flow method, which does not include these materials, even though some of these materials (namely construction and demolition debris) are typically counted as MSW.
- Residues associated with other items in MSW (usually containers) are not accounted for in the data.
- The percentage of total waste that MSW represents is unknown.
- The indicator does not necessarily measure the effects of changes in consumer or disposal trends.

Data Source

The data source for this indicator is Municipal Solid Waste Data, EPA, Office of Solid Waste and Emergency Response, 1990-2000. (See Appendix B, page B-22, for more information.)

Indicator Quantity of RCRA hazardous waste generated and managed - Category 2

Businesses that generate a substantial amount of RCRA hazardous waste as part of their regular activities are called "large quantity generators" or LQGs. ("Substantial" is defined as more than 2,200 pounds per month.) National data on "small quantity generators" (SQGs) and "conditionally-exempt small quantity generators" (CESQGs) are not available. Estimates indicate, however, that the amount of RCRA hazardous waste that SQGs and CESQGs generate is relatively small (EPA, OSWER, June 2000).

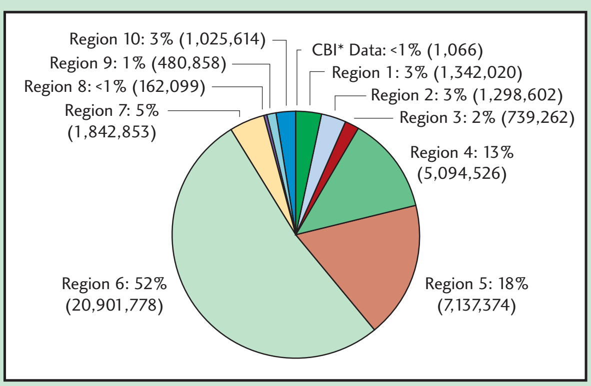
What the Data Show

In 1999, EPA estimated that more than 20,000 LQGs collectively generated 40 million tons of RCRA hazardous waste (EPA, OSWER, June 2001). The number reflects between 95 and 99 percent of the total amount of RCRA hazardous waste generated. The exact total amount of RCRA hazardous waste generated by LQGs, SQGs, and CESQGs combined is not known, but the contributions of SQGs and CESQGs are estimated to be between 0.4 million tons and 2.1 million tons (or 1 to 5 percent) of the total amount of RCRA hazardous waste (EPA, OSWER, June 2000).

LQGs within EPA Region 6 (see Exhibit 1-12 for Regional delineation) generated more than half of all RCRA hazardous waste in 1999 (Exhibit 3-27). Less than 9 percent of the LQGs nationwide are located in Region 6, but 15 of the 22 largest national generators (by quantity generated) are there. Of the large Region 6 generators, 13 manufacture chemicals, petrochemicals, minerals, and metal; and two manage chemical wastes. Generation in Regions 4 and 5 accounted for 18 percent and 13 percent of the national total, respectively, and all other Regions combined accounted for the remaining 17 percent (EPA, OSWER, June 2001).

Exhibit 3-27: Amount of Resource Conservation and Recovery Act (RCRA) hazardous waste generated in EPA regions, 1999

(Tons)



* Confidential Business Information not shown in pie chart

Source: EPA, Office of Solid Waste and Emergency Response. *The National Biennial RCRA Hazardous Waste Report. June* 2001.

Assessing trends in hazardous waste is difficult because the data collected over the last several years have changed. For example, the exclusion of wastewater from the 1999 totals makes a comparison of the 1999 data with previous data (which included wastewater) misleading. What is known, however, is that the amount of a specific set of toxic chemicals (Waste Minimization Priority Chemicals, or WMPC) found in hazardous waste is declining. (See the discussion of WMPC in the "Chemicals in the Landscape" section of this chapter.)

RCRA hazardous waste management is conducted at RCRA treatment, storage, and disposal facilities (TSDs) (see indicator in the following pages on Land Used for Waste Management). In 1999, TSDs managed 26.3 million tons of hazardous waste through treatment, storage, or disposal.

The (non-wastewater) management methods used in 1999 were as follows:

- Land disposal (69 percent): Includes deepwell/underground injection (16.0 million tons), landfill (1.4 million tons), surface impoundment (0.7 million tons), and land treatment/application/farming (30 thousand tons). Prior to land disposal, hazardous waste is treated to reduce toxicity and to prevent exposure of people and the environment to harmful constituents.
- Thermal treatment (11 percent): Includes energy recovery (1.5 million tons) and incineration (1.5 million tons).
- Recovery operations (10 percent): Includes fuel blending (1.1 million tons), metals recovery for reuse (0.72 million tons), solvents recovery (368 thousand tons), and other recovery (152 thousand tons).
- Other (11 percent): Includes other disposal (1.4 million tons), stabilization (1.3 million tons), sludge treatment (48 thousand tons) (EPA, OSWER, June 2001).

Indicator: Quantity of RCRA hazardous waste generated and managed - Category 2 (continued)

Indicator Gaps and Limitations

While RCRAInfo is a reliable source of data about much of the hazardous waste generated throughout the U.S., it does not provide information about all hazardous waste generated nationally. RCRAInfo includes data on amounts and types of hazardous waste generated nationally by large quantity generators only. Data about amounts and types of hazardous waste generated by RCRA SQGs and CESQGs are not collected. Similarly, data on waste that does not fit the RCRA definition of "hazardous" are not available. Some states regulate and collect data on wastes they designate as "hazardous" that are not tracked by EPA, but these data are not aggregated nationally.

Data Source

The data source for this indicator is 1999 RCRAInfo data, from EPA, Office of Solid Waste and Emergency Response. (See Appendix B, page B-22, for more information.)

Indicator: Quantity of radioactive waste generated and in inventory - Category 2

The manufacture and production of nuclear materials and weapons requires activities that can generate large amounts of radioactive waste. Over the past few decades, the production of nuclear weapons has largely been suspended. The largest quantities of radioactive waste generated today (when measured by volume) result from the cleanup of contaminated sites.

What the Data Show

A significant amount of the radioactive waste in existence today will remain radioactive for many years—in some cases thousands of years. When measured by volume, the radioactive waste that is still being generated reflects only a small percentage (<10 percent) of the total amount of waste that is either in storage (inventory) or disposed of already. When measured by radioactivity, the amount of radioactive waste in inventory far exceeds the radioactivity of newly-generated radioactive waste (U.S. DOE, April 2001). Exhibit 3-28 provides summary data on the total amount of radioactive waste generated and in inventory (storage) at the end of fiscal year (FY) 2000.

Over time, the amount of radioactive waste generated has fluctuated primarily due to the progress of site cleanup operations. Trend data on generation rates over the past several years are not available. According to the DOE, however, the amount of waste generated between late 1997 and late 2000 remained fairly constant, while the amount in inventory increased in proportion to the amount generated (DOE, 2002). Although some radioactive waste is still being disposed of (e.g., small amounts of transuranic waste are being disposed of at the Waste Isolation Pilot Plant in New Mexico), most of the highly radioactive waste types remain in storage until they can be placed in safe long-term disposal facilities.

The amount of radioactive waste being generated and stored is expected to drop over the next few decades as cleanup operations are completed and waste currently in storage is disposed of. Depending on the radioactive decay rate, the disposed-of waste will remain radioactive for time periods ranging from days to thousands of years.

Indicator Gaps and Limitations

The radioactive waste data in this report do not account for all radioactive materials in the U.S. The term "radioactive waste" applies to any garbage, refuse, sludge, and other discarded material that must be managed for its radioactive content (DOE Order 435.1, issued July 1999). Other radioactive materials are used for defense, energy production, and other purposes, but these materials are not considered "waste." Further, DOE is not responsible for some additional radioactive waste (quantity unknown). Data on these wastes are not included in this report.

Data Source

The data source for this indicator is radioactive waste data, from U.S. Department of Energy's Central Internet Database, 2000. (See Appendix B, page B-23, for more information.)

Indicator | Quantity of radioactive waste generated and in inventory - Category 2 (continued)

Exhibit 3-28: Total amount of radioactive waste* generated in fiscal year 2000 as reported by Department of Energy

Waste Type	Generated	Inventory (Storage)	Units
Vitrified High-Level Waste	n/a	1,201	Canisters
High-Level Waste	14,166	353,501	Volume (cubic meters)
Low-Level Waste	38,911	101,256	
Mixed Low-Level Waste	10,834	44,588	
Ex-Situ Contaminated Media	559,249	63,570	
Transuranic Waste	1,621	111,226	
Spent Nuclear Fuel	0.85	2,467	Mass (metric tons of heavy metal)

Source: U.S. Department of Energy, Office of Environmental Management, Central Internet Database. 2002. (January 2003; *http://cid.em.doe.gov*).
* For the purposes of this report, all of the materials in this table are considered radioactive waste.

3.3.2 What is the extent of land used for waste management?

Indicators

Number and location of municipal solid waste (MSW) landfills
Number and location of RCRA hazardous waste management facilities

Most types of waste are disposed of in land-based waste management units such as MSW landfills and surface impoundments. Prior to the 1970s, waste disposed of on the land was typically dumped in open pits, and waste was seldom treated to reduce its toxicity prior to disposal (EPA, OSWER, June 2002). Early land disposal units that still pose threats to human health and the environment are considered to be contaminated lands subject to federal or state cleanup efforts and are discussed in the next section. Today, most of the hazardous and MSW land disposal units are subject to federal or state requirements for landfill, surface impoundment, or pile design and management. National data for these disposal units is described in the indicators following.

Many other sites are used for waste management in addition to the MSW landfills and RCRA hazardous waste facilities just mentioned. Although comprehensive data sets are not available to assess the number of additional sites used for waste management, various EPA estimates show that there were approximately 18,000 non-hazardous industrial waste surface impoundments in 2000, more than 2,700 non-hazardous industrial waste landfills in 1985, and more than 5,300 non-hazardous industrial waste piles in 1985 (EPA, OSWER, March 2001). These numbers do not include other waste management sites, such as those used to collect and manage (but not dispose of) waste (e.g., recycling centers, household hazardous waste collection centers), waste transfer stations, sites that store discarded automobile and industrial equipment, and non-regulated landfills.

The two indicators identified for this question address the number and location of MSW landfills and RCRA facilities.

Indicator Number and location of municipal solid waste (MSW) landfills - Category 2

Municipal solid waste landfills are the most commonly known places of waste disposal. Yet this does not mean that there are good data to track them. The data presented in support of this indicator are estimates compiled by a national journal. No federal agency specifically compiles information nationally on these landfills.

What the Data Show

In 2000, approximately 128 million tons (55 percent) of the nation's 232 million tons of MSW were disposed of in the nation's 2,216 municipal waste landfills (EPA, OSWER, June 2002). Between 1989 and 2000, the number of municipal landfills in the U.S. decreased substantially (down from 8,000). Over the same period, the capacity of all landfills remained fairly constant because newer landfills typically have larger capacities. In 2000, these landfills were geographically distributed as follows: 154 (8 percent) in the Northeast, 699 (35 percent) in the Southeast, 459 (23 percent) in the Midwest, and 655 (33 percent) in the West (Goldstein, 2000).

Indicator Gaps and Limitations

MSW data are voluntarily submitted to BioCycle Journal and are not reviewed for quality or consistency. The data exclude landfills in Alaska and Hawaii and do not indicate the capacity or volume of landfills, or in general, a means to estimate extent of lands used for MSW management. For example, the fact that there are fewer landfills does not mean that less land is used for managing wastes because newer landfills are typically larger than their predecessors. The information is also limited by the fact that other lands are also used for waste management, such as for recycling facilities and waste transfer stations, but are not included in the indicator data. The data also do not reflect upon the status or effectiveness of landfill management or the extent to which contamination of nearby lands does or does not occur.

Data Source

The data source for this indicator is *BioCycle Journal* municipal landfill data 1990-2000. (See Appendix B, page B-23, for more information.)

Indicator Number and location of RCRA hazardous waste management facilities - Category 2

The RCRA Treatment, Storage, and Disposal (TSD) facilities used to manage the more than 26 million tons of annually generated hazardous waste are tracked closely by EPA. The data, however, are tracked and reported in terms of number of facilities and volumes of waste managed, not the acres of land used for management.

What the Data Show

Nearly 70 percent of the RCRA hazardous waste (not including wastewater) generated in 1999 was disposed of at one of the nation's 1,575 RCRA TSDs. Of the 1,575 facilities, 1,049 were storage-only facilities. The remaining facilities perform one or more of the following management methods, which include recovery operations (the percentages reflect the percentage of total facilities that conduct each management method): metals recovery (16.8 percent), solvents recovery (21.1 percent), other recovery (8.8 percent), incineration (28.4 percent), energy recovery (18.9 percent), fuel blending (19.8 percent), sludge treatment (3.0 percent), stabilization (16.0 percent), land treatment/application/farming (1.3 percent), landfill (11.4 percent), surface impoundment (0.4 percent), deepwell/underground injection (8.8 percent), or other disposal methods (7.4 percent).

TSD facilities in five states accounted for approximately 65 percent of the national management total. From another perspective, over 80 percent of the TSD facilities are located in EPA Regions 4 (19.6 percent), Region 5 (16.9 percent), and Region 6 (43.7 percent) (EPA, OSWER, June 2001).

Indicator Gaps and Limitations

Some hazardous waste management information that is collected by states is not included in the provided totals because it is not compiled nationally. Further, data on actual extent of land used for waste management are not collected, reported, or aggregated. Basic data on the number of sites or facilities used for waste management do not answer the extent question.

Data Source

The data source for this indicator is 1999 RCRAInfo data from EPA Office of Solid Waste and Emergency Response. (See Appendix B, page B-23, for more information.)

3.3.3 What is the extent of contaminated lands?

Indicators

Number and location of superfund national priorities list (NPL) sites
Number and location of RCRA corrective action sites

Contaminated lands range from sites where underground storage tanks have failed to areas where accidental spills have occurred to legacy sites where poor site management resulted in the contamination of soil, sediment, and ground water. Sites are still being discovered and national data do not currently exist to describe the full extent of contaminated lands. Additionally, sites are continually being cleaned up by a variety of programs, although these sites are not always immediately removed from the tracking lists maintained by the cleanup programs (e.g., Superfund NPL).

Two indicators are described. One addresses Superfund (NPL) sites and the other RCRA Corrective Action sites. They represent the limited data available for a national view of contaminated lands. Both indicators are based on data collected to track cleanup efforts and list numbers of sites, but neither specifically delineate the extent or total area of land contamination. Besides these two indicators that track specific programs, there are several other types of contaminated lands for which national data are limited or are not available. In some cases, states collect and maintain accurate data inventories, but these state-specific data sets are not compiled nationally. Exhibit 3-29 summarizes the types of lands that are or might be considered contaminated.

Exhibit 3-29: Types of contaminated lands

Type	Description
Superfund National Priorities List Sites (Indicator)	Congress established the Superfund Program in 1980 to clean up abandoned hazardous waste sites throughout the U.S. The most seriously contaminated sites are on the NPL. As of October 2002, there were 1,498 sites on the NPL (EPA, SERP, October 2002).
RCRA Corrective Action Sites (Indicator)	EPA and authorized states have identified 1,714 hazardous waste management facilities that are the most seriously contaminated and may pose significant threats to humans or the environment (EPA, OSWER, October, 2002). Some RCRA Corrective Action sites are also identified by the Superfund Program as NPL sites.
Leaking Underground Storage Tanks	EPA regulates many categories of underground storage tanks (USTs), often containing petroleum or hazardous substances. These exist at many sites, such as gas stations, convenience stores, and bus depots. USTs that have failed due to faulty materials, installation, operating procedures, or maintenance systems are categorized as leaking underground storage tanks (LUSTs). LUSTs can contaminate soil, ground water, and sometimes drinking water. Vapors from UST releases can lead to explosions and other hazardous situations if those vapors migrate to a confined area such as a basement. LUSTs are the most common source of ground water contamination (EPA, OW, 2000), and petroleum is the most common ground water contaminant (EPA, OW, 1996). According to EPA's corrective action reports, in 1996 there were 1,064,478 active tanks located at approximately 400,000 facilities. In 2002, there were 697,966 active tanks (a 34 percent decrease) and 1,525,402 closed tanks (a 42 percent increase). As of the fall of 2002, 427, 307 UST releases (LUSTs) were confirmed. (EPA, OSWER, December 2002).
Accidental Spill Sites	Each year, thousands of oil and chemical spills occur on land and in water. Oil and gas materials that have spilled include drilling fluids, produced waters, and other wastes associated with the exploration, development, and production of crude oil or natural gas. Accurate national spill data are not available.

Exhibit 3-29: Types of contaminated lands (continued)

Type	Description
Land Contaminated with Radioactive and Other Hazardous Materials	Approximately 0.54 million acres of land spanning 129 sites in over 30 states are contaminated with radioactive and other hazardous materials as a result of activities associated with nuclear weapons production and research. Although DOE is the landlord at most of these sites, other parties, including other federal agencies, private parties, and one public university, also have legal responsibilities over these lands (DOE, January 2001).
Brownfields	Brownfields are real property, the expansion, redevelopment or reuse of which may be complicated by the presence or potential presence of a hazardous substance, pollutant, or contaminant (Small Business Liability Relief and Brownfields Revitalization Act, 2002). Brownfields are often found in and around economically depressed neighborhoods. As brownfields are cleaned and redeveloped, surrounding communities benefit from a reduction of health and environmental risks, more functional space, and improved economic conditions. A complete inventory of brownfields does not exist. According to the General Accounting Office (1987), there are approximately 450,000 brownfields nationwide (General Accounting Office, 1987). The EPA's national brownfield tracking system includes a large volume of data on brownfields across the nation, but does not track all of them. EPA's Brownfield Assessment Pilot Program includes data collected from over 400 pilot communities (EPA, OSWER, May 2002).
Some Military Bases	Some (exact number or percentage unknown) military bases are contaminated as a result of military activities. A national assessment of land contaminated at military bases has not been conducted; however, under the Base Realignment and Closure (BRAC) laws, closed military bases undergo site investigation processes to determine extent of possible contamination and the need for site cleanup. Currently, 204 military installations that have been closed or realigned are undergoing environmental cleanup. These installations collectively occupy over 400,000 acres, though not all of this land is contaminated. Thirty-six of these installations are on the Superfund NPL list, and, of these, 32 are being cleaned up under the Fast Track program to make them available for other uses as quickly as possible (DOD, 2001).
Poorly Designed or Poorly Managed Waste Management Sites	Prior to the 1970s, untreated waste was typically placed in open pits or directly onto the land. Some of these early waste management sites are still contaminated. In other cases, improper management of facilities (that were typically used for other purposes such as manufacturing) resulted in site contamination. Federal and state cleanup efforts are now addressing those early land disposal units and poorly-managed sites that are still contaminated.
Illegal Dumping Sites	Also known as "open dumping" or "midnight dumping," illegal dumping of such materials as construction waste, abandoned automobiles, appliances, household waste, and medical waste raises concerns for safety, property values, and quality of life. While a majority of illegally dumped waste is not hazardous, some of it is, creating contaminated lands.
Abandoned Mine Lands	Abandoned mine lands are sites that have historically been mined and have not been properly cleaned up. These abandoned or inactive mine sites may include disturbances or features ranging from exploration holes and trenches to full-blown, large-scale mine openings, pits, waste dumps, and processing facilities. The Department of the Interior's (DOI) Bureau of Land Management (BLM) is presently aware of approximately 10,200 abandoned hardrock mines located within the roughly 264 million acres under its jurisdiction. Various government and private organizations have made estimates over the years about the total number of abandoned and inactive mines in the U.S., including estimates for the percent land management agencies, and state and privately-owned lands. Those estimates range from about 80,000 to hundreds of thousands of small to medium-sized sites. The BLM is attempting to identify, prioritize, and take appropriate actions on those historic mine sites that pose safety risks to the public or present serious threats to the environment (DOI, BLM, 2003).

Indicator

Number and location of Superfund National Priorities List (NPL) sites - Category 2

Congress established the Superfund Program in 1980 to clean up abandoned hazardous waste sites throughout the U.S. The Superfund Program tracks and investigates thousands of potentially contaminated sites to determine whether they are indeed contaminated and require cleanup. Some sites are not contaminated, whereas others are seriously contaminated and require either extensive, long-term cleanup action and/or immediate action to protect human health and the environment. The most seriously contaminated sites are proposed for placement on the NPL. "Proposed" NPL sites that meet the qualifications for cleanup under the Superfund Program become "final" NPL sites. Sites are considered for deletion from the NPL when all cleanup goals are met and there is no longer reason for federal action.

What the Data Show

As of October 1, 2002, there were 1,498 sites that were either final (1,233) or deleted (265). Of the 1,498 sites, 846 have completed all necessary cleanup construction. A construction complete site is a former toxic waste site where physical construction of all cleanup actions are complete, all immediate threats have been addressed, and all long-term threats are under control. An additional 62 sites were proposed in 2002 (Exhibit 3-30). The total number of NPL sites (including proposed) grew from 1,236 in 1990 to 1,560 in 2002. During this time period, the number of sites that have been cleaned up and have been transferred from "final" to "deleted" status have increased nearly 10-fold, from 29 in 1990 to 265 in 2002. In 2002, over 56 percent of the final and deleted sites were construction complete, compared to only four percent of the sites in 1990 (EPA, SERP, February 2003).

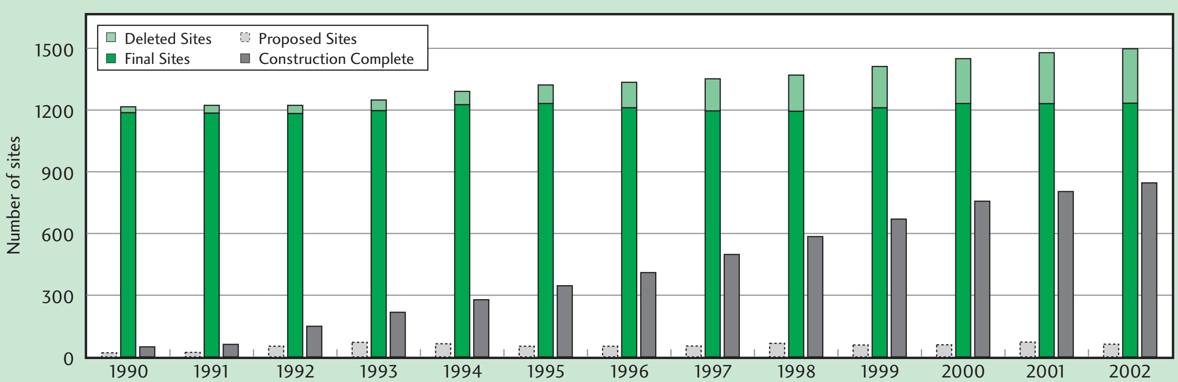
Indicator Gaps and Limitations

The NPL sites are tracked in CERCLIS. This database contains information on hazardous waste sites across the nation and U.S. territories including location, status, contaminants, and actions taken from 1983 to the present. The number of NPL sites provides a general indicator of contaminated lands, but these numbers do not translate directly to the extent of contaminated land. The NPL data cannot easily be used to clarify how many lands are contaminated because the NPL sites are divided into administrative groups (i.e., proposed, final, and deleted) that do not clearly describe whether the sites are currently contaminated. Additionally, there are many contaminated sites in CERCLIS that are not listed on the NPL, some contaminated sites are not in CERCLIS (e.g., are known only by local and state programs), and not all of the sites in CERCLIS are contaminated.

Data Source

The data source for this indicator is Comprehensive Environmental Response Compensation, and Liability Information System (CERCLIS) data, EPA Superfund Emergency Response Program, 1983-2002. (See Appendix B, page B-24, for more information.)

Exhibit 3-30. Superfund National Priorities List (NPL) site totals by status and



Note: "Construction Complete" sites include most "Deleted" sites and some "Final" sites.

Source: EPA, Office of Solid Waste and Emergency Response. National Priorities List Site Totals by Status and Milestone. March 26, 2003. (April 3, 2003; *http://www.epa.gov/superfund/sites/query/queryhtm/npltotal.htm*) and Number of NPL Site Actions and Milestones by Fiscal Year. March 26, 2003. (April 3, 2003; *http://www.epa.gov/superfund/sites/query/queryhtm/nplfy/htm*).

Indicator Number and location of RCRA corrective action sites - Category 2

Congress established the RCRA Corrective Action Program in 1984 because many hazardous waste management facilities were contaminated from current or past solid and hazardous waste management activities and required cleanup to protect humans and the environment. As with the Superfund Program, some sites subject to RCRA corrective action may be investigated and found to require little or no cleanup, while others may be found to have extensive soil, ground water, and/or sediment contamination.

What the Data Show

EPA estimates that approximately 3,700 hazardous waste management facilities may be subject to cleanup under the RCRA corrective action program (EPA, OSWER, October 2002). To date, EPA and authorized states have identified approximately 1,700 hazardous waste management facilities that are the most seriously contaminated and may pose significant threats to human health or the environment (EPA, OSWER, October 2002). These sites typically have both soil and ground water contamination and many also have contaminated sediments. Some RCRA corrective action sites are also identified by the Superfund Program as NPL sites.

Indicator Gaps and Limitations

RCRAInfo contains information about hazardous waste generators and management facilities in the U.S. and its territories. RCRAInfo includes data on site location, status, contaminants and contaminant sources, and actions taken. RCRAInfo provides reliable data about the number and location of RCRA corrective action sites and about cleanup priorities; however, information on cleanup status at sites is less reliable, particularly for lower priority sites. Cleanup status data for the 1,700 high priority sites is current—particularly with respect to ongoing exposures of humans to contamination and migration of contaminated ground water, the two site conditions that the RCRA corrective action program has chosen to track most closely. Also, there are overlaps between the list of high priority RCRA corrective action sites and NPL sites. Due to these overlaps, number-of-site comparisons between programs and simple counts of contaminated sites can be misleading.

Data Source

The data source for this indicator is EPA Office of Solid Waste and Emergency Response, RCRA Info Data, 1997-1999. (See Appendix B, page B-24, for more information.)

3.3.4 What human health effects are associated with waste management and contaminated lands?

While some types of waste (e.g., most food scraps) are not typically toxic to humans, other types (e.g., mercury) pose dangers to human health and must be managed accordingly. The number of substances that exist that can or do affect human health is unknown; however, the TRI program requires reporting of more than 650 chemicals and chemical categories that are known to be toxic to humans.

The EPA Superfund Emergency Response Program and the Agency for Toxic Substances and Disease Registry (ATSDR) have created useful lists of common contaminant sources and their potential health effects. Every 2 years, the ATSDR and EPA prepare a list, in order of priority, of hazardous substances that are most commonly found at the NPL sites and pose the most significant threat to human health due to their known or suspected toxicity and potential for human exposure (EPA, SERP, September 2002; ATSDR, 2001). Arsenic, lead, and mercury are the highest ranking substances on the list. All three of these substances are toxic to the kidneys, and lead and arsenic can cause decreased mental ability, weakness, abdominal cramps, and anemia (EPA, SERP, September 2002). Additional discussion of these substances is available in Chapter 4, Human Health.

EPA also maintains a separate list of common contaminants and their potential health effects. The list includes commercial solvents, household items, dry cleaning agents, and chemicals. With chronic exposure, commercial solvents such as benzene, can suppress bone marrow function and cause blood changes. Dry cleaning agents and degreasers contain trichloroethane and trichloroethylene, which can cause fatigue, depression of the central nervous system, kidney changes (e.g., swelling, anemia), and liver changes (e.g., enlargement). Chemicals used in commercial and industrial manufacturing processes such as arsenic, beryllium, cadmium, chromium, lead, and mercury, are toxic to kidneys. Long-term exposure to lead can cause permanent kidney and brain damage. Cadmium can cause kidney and lung disease. Arsenic, beryllium, cadmium, and chromium have been implicated as human carcinogens (EPA, SERP, September 2002).

Contaminants can come into contact with humans through three exposure pathways: inhalation, ingestion, and direct contact. Exposure routes can vary for each substance. Chemicals can contaminate ground water due to leaking tanks, runoff, and leaching through soil or sediment. In addition, the cleanup of sites contaminated with radioactive materials has involved the remediation of approximately 1.7 trillion gallons of ground water—an amount equal to four times the U.S. daily water consumption (DOE, 2000).

Information on waste generation amounts alone does not lead to a complete understanding of the effects of waste on people and the environment. The specific risks and burdens differ substantially from waste type to waste type. For example, one pound of grass clippings is not "equal" in terms of potential risk in exposure to one pound of dioxin. Exposure to waste is likely to vary as a function of management practices: treatment, storage, transfer, and disposal actions. Waste that is efficiently and safely treated and disposed of is likely to have relatively little effect on human health. No specific indicators have been identified at this time. Additional discussion of the human health effects associated with waste management and contaminated lands is found in Chapter 4, Human Health.

3.3.5 What ecological effects are associated with waste management and contaminated lands?

Hazardous substances can have negative effects on the environment by degrading or destroying wildlife and vegetation in contaminated areas, causing major reproductive complications in wildlife, or otherwise limiting the ability of an ecosystem to survive. Certain hazardous substances also have the potential to explode or cause a fire, threatening both wildlife and human populations (EPA, SERP, September 2002).

Waste from extraction activities can contaminate water, soil, and air; affect human health; and damage vegetation, wildlife, and other biota. Toxic residues left from mining operations can be transported into nearby areas, affecting resident wildlife populations. This type of damage is often the result of unlined land-based units that have minimal release controls. These units include surface impoundments containing mill tailings and/or process wastewater, heap-leaching solution ponds, dusts, piles of slags, refractory bricks, sludge, waste rock/overburden, and spent ore. Spills and leaks from lined management units, valves, and pipes also are known to occur.

Contaminated lands can pose a threat depending on several factors such as site characteristics and potential exposure of sensitive populations. The negative effects of land contamination on ecosystems and wildlife occur after contaminants have been released on land (soil/sediment) or into the air or water. Often, land contamination leads to water or air contamination by means of gravity, wind, or rainfall. No specific indicator was identified at this time.

3.4 Challenges and Data Gaps

Many of the specific data gaps related to development of the described indicators and their ability to answer the questions posed have already been identified. The discussion below augments the previously identified gaps.

3.4.1 Land Use

The ability to accurately characterize and track land use over time is limited. Various federal efforts, such as the USDA NRCS, NRI, the USDA Forest Service FIA, the U.S. Fish and Wildlife Service (USFWS) Status and Trends Program, and the NLCD, contribute in part to tracking some land uses and a variety of cover types. None of these are comprehensive for all lands or land uses, and some have limitations in their frequency of data collection or analysis. Some cover types and land uses are not sampled in any detail, including private and federal desert lands, federal shrublands and grasslands, and rangeland. In addition, Alaska is seldom included in national inventories, although Alaska represents approximately 16 percent of the land area of the U.S. and includes extensive shrublands, grasslands, and tundra.

Each of the national systems has developed different methods, definitions, and classification criteria. While some effort has been made to share definitions across some of these systems (e.g., the NRI and FIA systems use essentially the same definition of forest land, and NRI and FWS define wetlands similarly), not all are consistent, especially in descriptions of developed or urban land, cropland, and rangeland. Examples of differences in classifications and acreage from several current national efforts are shown in Exhibit 3-31 for developed and agricultural land uses. The NLCD uses different classification and land use definitions because it is based on remote sensing data (an aerial perspective) rather than on ground sampling. FWS information is also based on aerial photo interpretation. Given the increasing availability of high resolution aerial imagery, remotely sensed techniques for land cover delineations are likely to increase and classifications based on this inventory approach should be coordinated and defined.

Another challenge is developing data on uses and cover types that at present are not adequately sampled. Further challenges include effectively integrating and harmonizing the various results of multi-agency, as well as state and local, efforts and coordinating the limited resources dedicated to national tracking of land cover/land use changes among agencies, so that inventories can be performed as frequently and as comprehensively as possible. The overarching goal is to assess national patterns in such a way that changes in land cover and land use that might have implications for human health or ecological condition can be detected and addressed.

Exhibit 3-31: Land cover/land use estimates

Data Source	Developed Land	Agricultural Land
National Resources Inventory (NRI)[A]	98 million acres developed land	377 million acres cropland 32 million acres Conservation Reserve Program land 120 million acres pastureland
The Heinz Center[B]	32 million acres urban and suburban land	430-500 million acres cropland, hayland, and pastureland
U.S. Census Bureau[C]	47 million acres urbanized areas 13 million acres urban clusters	No data
National Land Cover Data (NLCD)[D]	36.7 million acres low and high density residential and commercial/industrial/ transportation	331 million acres cropland 179 million acres pastureland and hayland

Note: The NRI, Heinz Center, and NLCD sources do not include Alaska as part of the estimates.

[A] USDA, Natural Resources Conservation Service. *Summary Report: 1997 National Resources Inventory (Revised December 2000)*. 2000.
[B] The Heinz Center. *The State of the Nation's Ecosystems*. 2002.
[C] U.S. Census Bureau. Corrected Lists of Urbanized Areas and Urban Clusters. November 25, 2002. (March 2003; *http://www.census.gov/geo/www/ua/ua_state_corr.txt and http://www.census.gov/geo/www/ua/uc_state_corr.txt*).
[D] USGS, National Land Cover Dataset. NLCD Land Cover Statistics. 2001. (March 2003; *http://landcover.usgs.gov/nlcd.html*).

The data available that actually summarize a national picture of land use are extremely limited. Relatively little comprehensive information exists about federal land management practices and extent. For example, while the USDA Forest Service tracks acres managed for timber production, data are not easily accessible on acres used for grazing; oil, gas, and mineral development; or recreation. Data needed to summarize all lands under some form of "protection," such as parks, wilderness areas, reserves, or conservation easements at all levels of government, do not exist.

In many cases, where land is used to produce food or fiber, indicators that report the amounts and values of these commodities might be used to identify the condition/stress/pressure on the land. Examples of commodities include agricultural products, forest products, and cattle produced from grazing land. The amount of fresh water used by humans might also be a good indicator of the pressure being applied to land and water resources. Commodity production is commonly correlated closely to population growth. Reporting of commodity production trends in agriculture and forestry might also provide another view of the effects of these activities on the land and help evaluate policy options for ensuring long term, sustainable commodity production while reducing environmental effects.

Land provides many other benefits in addition to commodity production. Research is being conducted on the subject of quantifying these "ecosystem services." Indicators are needed that will enable measuring and tracking some of these services.

3.4.2 Chemicals

Most of the national efforts to track chemical usage focus on how much is produced, used, or released, with less emphasis on tracking the extent or area of use. The TRI database requires reporting of releases of certain volumes of specific chemicals, but aside from knowing the location of initial releases, it does not track the extent of the area that might in some way be affected by the chemicals. In addition, pesticide and fertilizer use are primarily tracked by understanding where these chemicals are sold, rather than where they are actually used.

Further, not all toxic chemicals are on the list of TRI chemicals and, therefore, some toxics are not reported. The TRI program faces the challenge of maintaining a current list that reflects the constant development, use, and release of new chemicals that might have effects on human and ecological health.

Indicators for pesticide residue in food, potential pesticide runoff from farmlands, risk of nitrogen runoff, and risk of phosphorus runoff all address some part of the question of potential chemical disposition. Only the indicator for pesticide residues in food, however, goes beyond stating the potential for chemicals to leave their point of use and actually shows the potential for consumers to be exposed to these chemicals. Indicators to better understand the actual disposition of chemicals, rather than potential disposition, would be useful to correlate with actual human health and ecological condition indicators.

State Pesticide Use Reporting Systems

While there is no national pesticide use reporting system, several state systems exist. For example, California, with the most advanced system in the country, has had full pesticide use reporting since 1990. Reports about the specifics of application are filed by large- and small-scale farmers, commercial agricultural pesticide applicators, structural pest control companies, and commercial landscaping firms. (California Department of Pesticide Regulation, 2000.)

Better indicators of the linkages between chemical applications on the landscape and chemicals that find their way into the bodies of humans and other species are needed. This includes better information on the chemistry, quantities, and longevity of various substances; on the cumulative effects of various chemicals on the environment and humans; and on the pathways and effects of exposure. In cases where nutrients do reach receiving waterbodies and raise the concentrations above background levels, considerable uncertainty still exists concerning ultimate ecological effects. Current research does not clearly quantify the relationship between raised nutrient levels and resulting ecological changes.

Better information is needed to provide an accurate picture of the human health effects of pesticide use. This information is difficult to collect, however. Even in California, where significant resources are dedicated to pesticide regulation, the best available indicator is a measure of reported illnesses and injuries from pesticide exposure in the workplace. While this is valuable information, it does not address potential long-term health effects of non-workplace exposure that might result through drinking water and food exposure.

3.4.3 Waste and Lands Used for Waste Management

Several challenges and data gaps limit the understanding of waste and its effects on human health and ecological condition. First, as noted, waste data tend to be developed in response to the requirements of specific mandates or regulations. Because these regulations do not apply to all types of waste and are carried out at different levels of government, and in the private sector, complete data do not exist to answer the question: "How much waste is generated?" Additionally, most waste generation is reported only by weight, providing little understanding of the volume of waste produced.

Information about the amount of waste generated does not provide a complete picture on either the extent of waste-related problems or the effects of waste on human health, ecosystems, or the ambient environment. Different waste types pose substantially different types of risks. Some wastes are known to be hazardous to humans and the environment, but specifics about exposures and the effects of many other waste types are not well understood and data are limited. Finally, the risks posed by waste are largely a function of the type and effectiveness of waste management. The available data on waste and waste management have been limited by the stringent regulatory requirements and definitions that have driven most of the national information collection efforts.

Data to describe how lands are affected by waste management are also limited. Even basic statistics on the acreage of lands used for managing waste and the condition of those lands are not available at the national level. To gain a more complete understanding of the extent and effects of land used for waste management would require information on waste management methods, standards, and compliance, as well as information on lands where illegal dumping occurs. Establishing linkages to human populations or ecosystems within close proximity to lands managed for waste is an additional challenge.

3.4.4 Contaminated Land

Today, the best available information used to describe extent of contaminated land includes measures of the number and location of sites. two indicators of contaminated land that lack national-quality data are the extent of contaminated land and the effects of contamination.

Determining the extent of contaminated land would require national-level information on the number, location, and area of contaminated lands, and data on the specific site contaminants and the associated risks, hazards, and potential exposures. Additional factors such as the potential contamination of ground water sources and the transportation or disposal methods needed to clean up the contamination would have to be considered. Such data are currently captured for only a subset of the nation's contaminated lands. In addition, information on known contaminated lands (e.g., some sites in EPA's Comprehensive Environmental Response, Compensation, and Liability Information System) that are not on the Superfund's NPL, data in state and local databases, and information on the other types of contaminated lands (e.g., leaking underground storage tanks) are not captured in the existing data.

Chapter 4: Human Health

Indicators that were selected and included in this chapter were assigned to one of two categories:

- **Category 1** –The indicator has been peer reviewed and is supported by national level data coverage for more than one time period. The supporting data are comparable across the nation and are characterized by sound collection methodologies, data management systems, and quality assurance procedures.
- **Category 2** –The indicator has been peer reviewed, but the supporting data are available only for part of the nation (e.g., multi-state regions or ecoregions), or the indicator has not been measured for more than one time period, or not all the parameters of the indicator have been measured (e.g., data has been collected for birds, but not for plants or insects). The supporting data are comparable across the areas covered, and are characterized by sound collection methodologies, data management systems, and quality assurance procedures.

4.0 Introduction

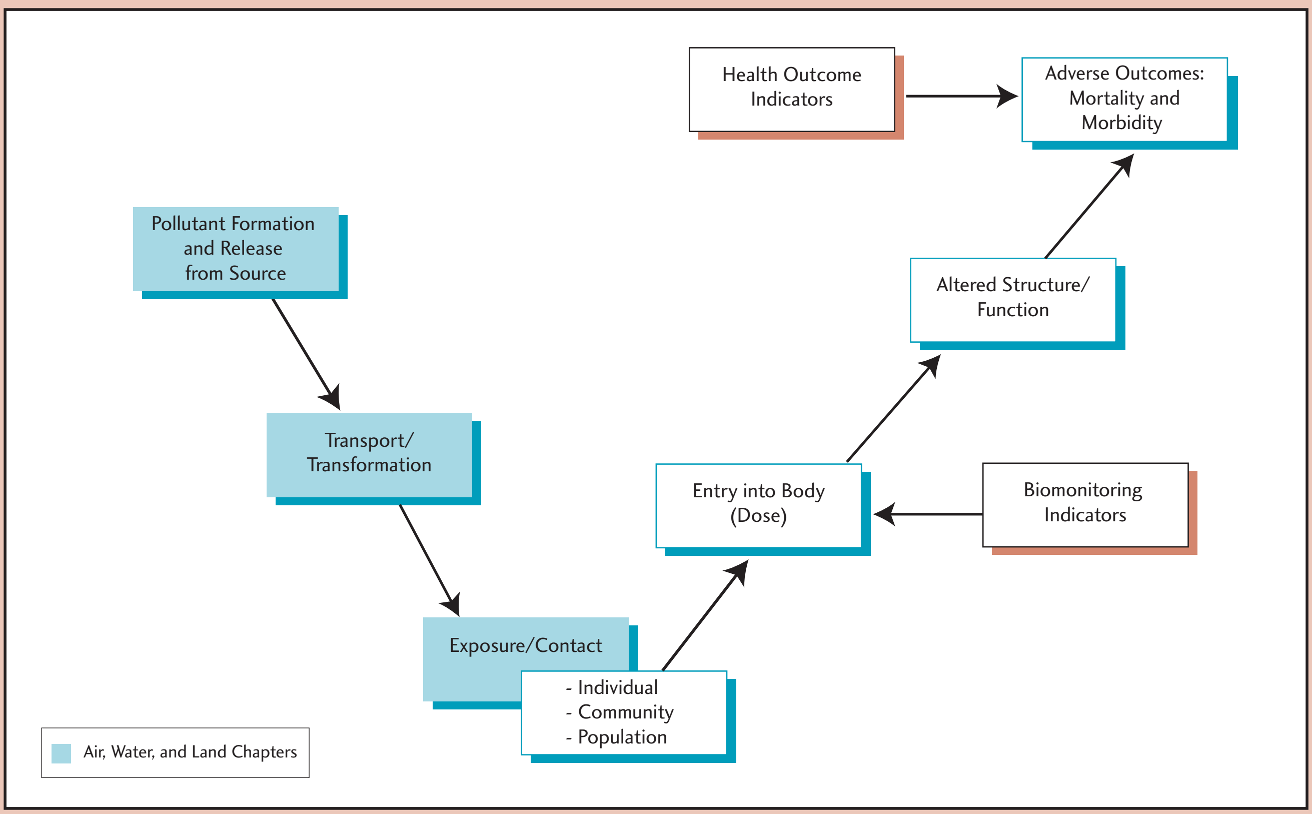
The U.S. Environmental Protection Agency (EPA) is moving in the direction of measuring and assessing human health and ecological outcomes. Traditionally, EPA has used indicators such as decreases in emissions/discharges or decreases in ambient pollutant levels to measure environmental improvement. Health outcome measures complement these traditional approaches by reflecting the actual public health or ecological impacts that result from environmental pollution. By providing a quantitative assessment of these impacts, outcome indicators can strengthen environmental decision-making and enhance EPA's ability to evaluate, prospectively or retrospectively, the success of those decisions.

The key to using outcome-based indicators is a clear understanding of the sequence of events that link changes in environmental conditions to health or ecological outcomes. Exhibit 4-1 depicts this sequence for human health. Each block in the diagram can have indicators associated with it. Indicators for the presence of pollutants or other stressors affecting air, water, and land are covered in Chapters 1 (Cleaner Air), 2 (Purer Water), and 3 (Better Protected Land), respectively, of this report. Indicators for the presence of pollutants in the body and their effects on health (altered structure or function, morbidity, or mortality) are covered in this chapter.

The paradigm depicted in Exhibit 4-1 underlies the science upon which EPA bases its risk assessment process (NRC, 1983). Risk assessments, to a large degree, seek to estimate all linkages depicted in the exhibit. However, understanding the link between human exposure and health outcomes has always been challenging. Decades of research have provided the scientific foundation for understanding how exposure to individual pollutants at elevated levels may affect human health. There is less certainty, however, about the effects of ambient exposures, which typically involve exposure to multiple pollutants at lower levels. Improved understanding of the linkages between these exposures and public health would strengthen EPA's ability to make and evaluate decisions.

The indicators that describe the public health consequences of environmental exposures are called environmental public health indicators (EPHIs). Numerous national and international organizations have recognized the compelling need for EPHIs. The greatest impetus came from a series of reports, by the Pew Environmental

Exhibit 4-1: Environmental public health paradigm



Source: Modified from National Research Council. *Risk Assessment in the Federal Government: Managing the Process*. 1983

Health Commission, which called on "Congress and the White House to protect Americans from chronic diseases—by tracking where and when these health problems occur and possible links to environmental factors." The commission proposed that a Nationwide Health Tracking Network be established to track selected diseases and priority environmental exposures (Pew, 2001). When combined with other information, such as environmental monitoring data and data from toxicological, epidemiological, or clinical studies, EPHIs can be an important key to improving understanding of the relationship between pollution and health outcomes.

Use of Environmental Public Health Indicators

Environmental public health indicators can be used to:

- **Describe** the health status of a population and discover important time trends in disease and exposure frequency. Most, if not all, of the indicators presented in this chapter perform this function.
- **Explain** the occurrence or prevalence of diseases and exposure by helping to identify causal factors for specific diseases or trends. For example, the decline in the lung cancer rate in men has been related to the decline in smoking. For some areas presented in this chapter, the evidence for a relationship is quite strong (e.g., air pollution and pulmonary-cardiovascular related-illnesses). Other areas will require further research to better understand these linkages.
- **Predict** the number of disease occurrences and the distribution of exposure in specific populations. Such predictions could be used, for example, as input for setting priorities and making decisions to protect public health—e.g., establishing cleanup levels for environmental waste sites or regulatory levels for ambient pollutant levels. (Understanding the relationship between exposure and consequent health effects is critical to using indicators for predictive purposes.)
- **Evaluate** policy decisions or interventions. (Again, understanding the relationship between exposure and effect is critical for this use.)

Two types of environmental public health indicators are described in this chapter:

- **Health outcome indicators.** These indicators measure the occurrence in a population of diseases or conditions that are known or believed to be caused to some degree or exacerbated by exposure to environmental pollutants or stressors.
- **Exposure indicators.** While there are four types of exposure indicators (see sidebar), this chapter focuses on biomonitoring indicators, which involve using tests of human fluid and tissue samples to identify the presence of a substance or combination of substances in the human body.

For some of the EPHIs described in this chapter, a strong linkage has been established between environmental exposure and outcome. However, for many of the EPHIs presented, such as the outcome indicator of overall mortality, no linkage between environmental exposure and outcome has been determined. For these, further research would be needed to establish and strengthen any linkages. Similarly, for some EPHIs, the linkage with the source of the pollution is clear (e.g., lead in gasoline), while for others the source or sources are much less certain.

Types of Exposure Indicators

Four approaches can be used to measure or estimate exposure (i.e., direct human contact with a pollutant). No approach is best suited to all pollutants. Different approaches are appropriate to different types of pollutants, and each approach has strengths and weaknesses.

- **Ambient pollutant measurements.** Historically, environmental measurements of ambient pollutant concentrations have generally been used to estimate human exposures. One limitation of ambient measurements is that the presence of a pollutant in the environment does not necessarily mean that anyone has been exposed. Chapters 1 (Cleaner Air), 2 (Purer Water), and 3 (Better Protected Land) provide examples of ambient measurement indicators.
- **Stochastic models of exposure.** This approach combines knowledge of environmental pollutant concentrations with information on people's activities and locations (e.g., time spent working, exercising outdoors, sleeping, shopping) to account for their contact with pollutants. This approach requires knowledge of pollutant levels where people live, work, and play, as well as knowledge of the choices that they make in regard to day-to-day activities.
- **Personal monitoring data.** With personal monitoring, the monitoring device is worn by individuals as they proceed through their normal activities. This approach is most common in workplaces. Personal monitoring data provide valuable insights into the sources of the pollutants to which people are actually exposed. However, a challenge with personal monitoring (as with biomonitoring) is ensuring that sufficient sampling is done to be representative of the population being studied.
- **Biomonitoring data.** Several environmental pollutants, notably heavy metals and some pesticides, can be found in the body. These pollutants or their breakdown products (i.e., metabolites formed when a pollutant is broken down in the body) leave residues that can be measured in human tissue or fluids such as blood or urine. These residues reflect the amount of the pollutant that actually gets into the body, but by themselves they provide no information on how the individual came into contact with the pollutant.

One of the greatest challenges to elucidating the connection between environmental exposure and disease is the fact that exposure to an environmental pollutant or stressor is rarely the sole cause of an adverse health outcome. More generally, individuals are exposed to more than one pollutant at a time, and exposure is just one of several factors that contribute to the disease occurring or to the severity of a preexisting disease. Other factors include, for example, diet, exercise, alcohol consumption, heredity, medications, and whether other diseases are also present. Also, different people have different vulnerabilities, so some may experience effects to certain ambient exposure levels while others may not. All these factors make it difficult to establish a causal relationship between exposure to environmental pollutants and disease outcome except in rare cases, such as some historical occupational exposures, where exposure was unusually high.

This chapter presents a broad spectrum of indicators that can now be used, or could potentially be employed in the future, to assess and track the public health impacts of environmental exposures. These indicators provide an overview of the health and exposure of people in the U.S. and identify the trends of those indicators in the U.S. Specific indicators for exposure and outcomes in children are presented, as children may be especially susceptible to environmental pollutants.

This chapter is organized into six sections:

- **Section 4.1** describes three case studies that illustrate the role of indicators in establishing linkages between effects and outcomes and in evaluating environmental management actions.
- **Section 4.2** compares health measures within the U.S. to these same measures throughout the rest of the world.
- **Section 4.3** discusses outcome indicators and trends for selected diseases that either have a major impact on the health of people in the U.S. or may be caused to some extent by environmental pollution. Exhibit 4-2 lists the key public health questions that are asked in this section and the indicators that are available to help answer these questions.
- **Section 4.4** presents biomonitoring indicators and trends for specific environmental pollutants. The section begins by providing background on biomonitoring indicators and their limitations and data sources. The section then presents biomonitoring indicators for numerous specific pollutants and discusses other important pollutants for which biomonitoring data are not yet available. Exposure information for many of these pollutants is discussed in Chapters 1 (Cleaner Air), 2 (Purer Water), and 3 (Better Protected Land) of this report. The key exposure questions asked in this section and the indicators available to help answer these questions are presented in Exhibit 4-2.
- **Section 4.5** discusses an emerging field that attempts to quantify the overall burden of environmental disease on society.
- **Section 4.6** discusses the key challenges and data gaps for understanding the link between environmental exposure and health outcomes, and some recent government activities to continue and advance the work in this area.

Many federal and state government agencies collect data that underlie environmental public health indicators. Continued effective coordination and collaboration among such agencies will be vital to further the development and use of environmental public health indicators. Key data sources used for this chapter include the:

- **World Health Organization (WHO), World Health Statistics Annual,** a joint effort by the national health and statistical administrations of many countries, the United Nations, and WHO.
- **United Nations, Demographic Yearbook,** a comprehensive collection of international demographic statistics compiled from questionnaires sent annually and monthly to national statistical services and other government offices.
- **National Center for Health Statistics, National Vital Statistics System,** which provides data on births, deaths, marriages, and divorces in the U.S. since 1933.
- **National Center for Health Statistics, National Health Interview Survey (NHIS),** a continuous nationwide survey in which data on personal and demographic characteristics, illnesses, injuries, impairments, chronic conditions, utilization of health resources, and other health topics are collected through personal household interviews.
- **Centers for Disease Control and Prevention, Epidemiology Program Office, National Notifiable Diseases Surveillance System,** which provides weekly provisional information on the occurrence of diseases defined as notifiable (i.e., a disease that health providers must report to state or local public health officials due to its contagiousness, severity, or frequency).
- **National Institutes of Health, National Cancer Institute, Surveillance, Epidemiology, and End Results Program,** which provides data on all residents diagnosed with cancer in 11 geographic areas of the U.S.
- **The EPA's National Human Exposure Assessment Survey (NHEXAS),** a multiday, multimedia study that examined chemical concentrations in indoor air, outdoor air, dust, soil, food, beverages, drinking water, and tap water.
- **National Center for Health Statistics, National Health and Nutrition Examination Survey (NHANES)**, a series of surveys designed to collect data on the health and nutritional status of the U.S. population. Chemicals and their metabolites were measured in blood and urine samples from selected participants.

The chapter is not intended to be exhaustive. Rather, it provides a snapshot, at the national level, of the current U.S. environmental public health indicators and status based on key data sources with sufficiently robust design, quality assurance, and maturity. The chapter does not provide health status information that may be more applicable to certain geographic areas or to subgroups with potentially greater susceptibility to environmental pollution due to such factors as age, genetics, lifestyle, or medical status.

Exhibit 4-2: Human Health - Questions and Indicators

Health Status of the U.S. : Indicators and Trends of Health and Disease

Question	Indicator Name	Category	Section
What are the trends for life expectancy?	Life expectancy	1	4.3.1
What are the trends for cancer, cardiovascular disease, chronic obstructive pulmonary disease and asthma?	Cancer mortality	1	4.3.2
	Cancer incidence	2	4.3.2
	Cardiovascular disease mortality	1	4.3.2
	Cardiovascular disease prevalence	1	4.3.2
	Chronic obstructive pulmonary disease mortality	1	4.3.2
	Asthma mortality	1	4.3.2
	Asthma prevalence	1	4.3.2
What are the trends for gastrointestinal illness?	Cholera prevalence	2	4.3.3
	Cryptosporidiosis prevalence	2	4.3.3
	E. coli O157:H7 prevalence	2	4.3.3
	Hepatitis A prevalence	2	4.3.3
	Salmonellosis prevalence	2	4.3.3
	Shigellosis prevalence	2	4.3.3
	Typhoid fever prevalence	2	4.3.3
What are the trends for children's environmental health issues?	Infant mortality	1	4.3.4
	Low birthweight incidence	1	4.3.4
	Childhood cancer mortality	1	4.3.4
	Childhood cancer incidence	2	4.3.4
	Childhood asthma mortality	1	4.3.4
	Childhood asthma prevalence	1	4.3.4
	Deaths due to birth defects	1	4.3.4
	Birth defect incidence	1	4.3.4

Measuring Exposure to Environmental Pollution: Indicators and Trends

Question	Indicator Name	Category	Section
What is the level of exposure to heavy metals?	Blood lead level	1	4.4.3
	Urine arsenic level	2	4.4.3
	Blood mercury level	1	4.4.3
	Blood cadmium level	1	4.4.3
What is the level of exposure to cotinine?	Blood cotinine level	1	4.4.4
What is the level of exposure to volatile organic compounds?	Blood volatile organic compound levels	1	4.4.5
What is the level of exposure to pesticides?	Urine organophosphate levels to indicate pesticides	1	4.4.6
What is the level of exposure to persistent organic pollutants?	No Category 1 or 2 indicators identified		4.4.7
What are the trends in exposure to environmental pollutants for children?	Blood lead level in children	1	4.4.8
	Blood mercury level in children	1	4.4.8
	Blood cotinine level in children	1	4.4.8
What is the level of exposure to radiation?	No Category 1 or 2 indicators identified		4.4.9
What is the level of exposure to air pollutants?	No Category 1 or 2 indicators identified Also see Cleaner Air chapter		4.4.9
What is the level of exposure to biological pollutants?	No Category 1 or 2 indicators identified		4.4.9
What is the level of exposure to disinfection by-products?	No Category 1 or 2 indicators identified		4.4.9

4.1 Environmental Pollution and Disease: Links Between Exposure and Health Outcomes

Many studies have demonstrated an association between environmental exposure and certain diseases or other health problems. Examples include radon and lung cancer; arsenic and cancer in several organs; lead and nervous system disorders; disease-causing bacteria such as *E. coli* O157:H7 (e.g., in contaminated meat and water) and gastrointestinal illness and death; and particulate matter and aggravation of cardiovascular and respiratory diseases.

As mentioned in Section 4.0, indicators of outcome and exposure can be important tools both for elucidating these links and monitoring the success of environmental management efforts. Indicators are one of several components needed to establish linkage. Other important components include ambient pollutant measures and toxicological, epidemiological, and clinical studies. Three case studies are described in this section to demonstrate how indicators can be used to establish associations between exposure and effect and to evaluate environmental management actions.

Case Study on Waterborne Disease

This case study focuses on the impact of drinking water treatment on the decrease in mortality related to waterborne diseases. It demonstrates the valuable contribution to public health protection that can occur when the link between exposure and health outcomes is successfully made. As the case study describes, officials knew there was a high incidence of gastrointestinal disease, but they were not able to protect human health until they understood what caused these diseases. Based on this connection, officials were able to take effective action to protect public health. They also were able to use an outcome measure (deaths due to typhoid) to evaluate the success of these protective actions.

At the beginning of the 20th century, waterborne diseases such as typhoid fever and cholera were major health threats across the U.S. More than 150 in every 100,000 people died from typhoid fever each year. Deaths due to diarrhea-like illnesses, including typhoid, cholera, and dysentery, represented the third largest cause of death in the nation.

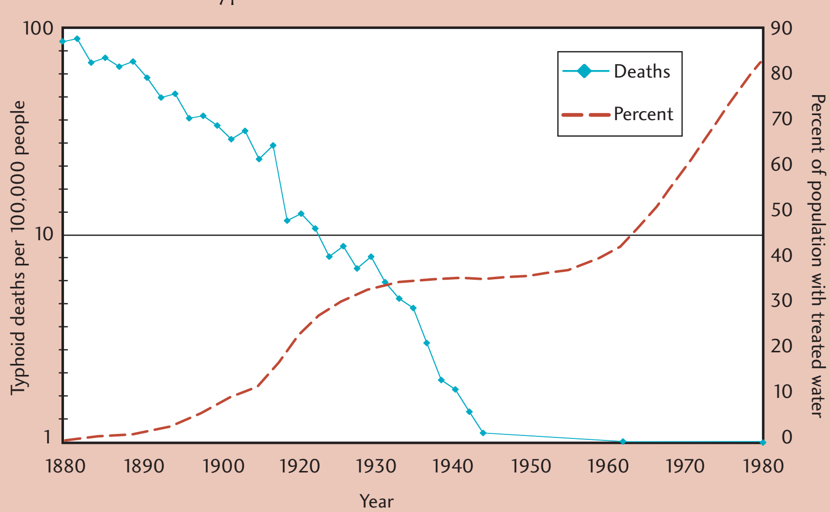
Then scientists identified the bacteria responsible for most diarrhea deaths (typhoid, cholera, and dysentery) and elucidated how these bacteria were transmitted to and among humans. Infected and diseased individuals shed large quantities of microbes in their feces, which flowed into and contaminated major water supplies. The contaminated water was then distributed untreated to communities, which used the water for drinking and other purposes. This created a continuous transmission cycle.

When treatment (filtration and chlorination) of drinking water was initiated to remove pathogens, the number of deaths due to diarrhea diseases dropped dramatically. Deaths due to typhoid fever were tracked throughout the early 20th century, as drinking water treatment was implemented across the country. Exhibit 4-3 shows the percent of the U.S. population that had treated water and the disease rate for typhoid fever from 1880 to 1980.

In this example, the outcome measure was death rates due to typhoid, which was used in conjunction with an environmental process (the number of people getting treated drinking water) to evaluate and promulgate the use of drinking water treatment across the U.S.

Drinking water treatment was one of the great public health success stories of the 20th century (NAE, 2000). It dramatically and significantly reduced death rates from waterborne disease, increasing

Exhibit 4-3: Percent of population with treated water versus typhoid deaths in the United States, 1880-1980



Source: Craun, C.G. *Waterborne Diseases in the United States*. 1986; Whipple, G.C. *Typhoid Fever - Its Causation. Transmission and Prevention.* 1908; Fox, K. National Risk Management Research Laboratory, personal communication, 2003.

life expectancy and reducing infant mortality. Today, public health is protected against new and emerging waterborne microbial contaminants by continual improvements to the drinking water treatment process and continual monitoring of waterborne diseases. Deaths due to cholera, typhoid, and dysentery are so rare in this country that they do not provide valuable information for evaluating the public health impacts of drinking water treatment. Instead, the number of cases of these diseases are tracked to some extent, although reporting is not federally required. Indicators for waterborne disease and other important diseases with actual or potential environmental origins are discussed in Section 4.3.

Case Study on Air Pollution

This case study illustrates how the association between deaths and peak air pollution concentrations was initially discovered by comparing mortality rates and air monitoring data. It also describes how basic research on the health effects of air pollution has helped to establish strong linkages between levels of certain air pollutants and human health effects. These associations have provided sufficient basis for establishing regulations to control the level of pollutants in air. The success of these environmental management efforts can be evaluated by monitoring levels of regulated pollutants in air. However, except for lead (the subject of the third case study below), there are as yet no biomonitoring or outcome indicators that can more directly measure reduced human exposure or outcome on a national level. Nevertheless, a number of potential outcome indicators are discussed that could be available in the future if systems can be set up to track relevant biomonitoring or outcome data with sufficient reliability and coverage at a national level.

Air pollution has been associated with several human health outcomes, including reported symptoms (nose and throat irritation), acute onset or exacerbation of existing disease (e.g., asthma, hospitalizations due to cardiovascular disease), and deaths. The impact of air pollution on health was underscored in London in December of 1952, when a slow-moving area of high pressure came to a halt over the city. Fog developed, and particulate and sulfur pollution began accumulating in the stagnating air mass. Smoke and sulfur dioxide concentrations built up over 3 days. Mortality records showed that deaths increased in a pattern very similar to that of the pollution measurements. (This is illustrated in Exhibit 4-4.) It was estimated that 4,000 extra deaths occurred over a 3- to 4-day period. This was the first quantitative air pollution exposure data with a link to an adverse health outcome (i.e., mortality).

While the London episode highlighted the hazard of extreme air pollution episodes, it was unclear whether health effects were associated with lower concentrations. By the 1970s, the association between respiratory disease and particulate and/or sulfur oxide air pollution had been well established (Dockery and Pope, 1997).

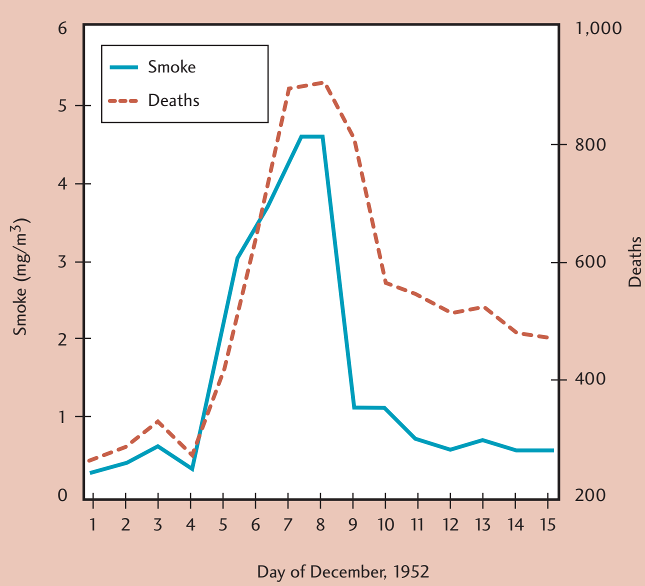
Clinical studies (controlled studies in healthy adult subjects) also provide information about the association between air pollutants and health effects. For example, these studies have demonstrated that ozone causes a number of functional, symptomatic, and inflammatory responses, which tend to increase with an increase in ozone exposure dose (EPA, 1996). Effects of ozone include:

- Decreased pulmonary function, characterized by changes in lung volumes and flow; changes in airway resistance and responsiveness; and respiratory symptoms, such as cough and pain on deep inspiration (EPA, 1996).
- An inflammatory response in the lungs (EPA, 1996).

Based on these types of associations from toxicological, epidemiological, and clinical studies, EPA has established National Ambient Air Quality Standards for six pollutants of concern: ozone, particulate matter, carbon monoxide, lead, nitrogen dioxide, and sulfur dioxide. These standards set limits to protect human health, including the health of "sensitive populations" such as asthmatics, children, and the elderly (EPA, 1999).

Improvements in measuring air pollution and health endpoints, together with advances in analytical techniques, have made it possible to begin to quantitatively evaluate the success of air pollution control measures—such as the National Ambient Air Quality Standards and associated regulations—to protect and improve public health. Though insufficient data were available at the time of this report to develop EPHIs for any criteria pollutants except lead, possible future EPHIs for air pollution include death due to respiratory and cardiovascular disease as well as increased hospital admissions for respiratory and cardiovascular disease.

Exhibit 4-4: London fog episode deaths, 1952



Source: Based on Dockery, D.W. and C.A. Pope. *Outdoor Air I: Particulates.* 1997.

Future EPHIs include:

- **Mortality.** In many countries including the U.S., particulate air pollution has been associated with increased daily mortality from heart and lung diseases (e.g., congestive heart disease, chronic obstructive lung disease). In addition, chronic exposure to air pollution has been linked with increased risk of premature mortality (EPA, April 2002).
- **Hospital admissions.** Hospitalization records are not widely available, and studies have been limited by their availability in communities around the U.S. Nevertheless, many studies have shown that increased admissions for cardiovascular and respiratory diseases are associated with increased pollutant concentrations.

Most recently, subtle changes in the cardiovascular system that can increase a person's risk of heart attack and bring about other cardiovascular effects have been identified as possible EPHIs.

Establishing EPHIs for air pollution and health effects, whether cardiovascular or pulmonary, is still challenged by limits in knowledge of how much air pollution contributes to the risk of both cardiovascular and respiratory disease. Research is still needed to better understand which components of air pollution (i.e., gases, metals, or organics) cause health effects; the extent to which they contribute to risk; and the extent to which other factors (e.g., genetics, lifestyle, age) contribute to risk. Given these limitations, no indicators are presented for any of the six criteria pollutants except lead. A case study on lead is presented below, with further discussion on lead as an indicator provided in Section 4.4.

Case Study on Lead

The third case study concerns lead, a toxic pollutant to which there is human exposure from many different sources. In the previous case studies, outcome indicators were an important key to establishing a linkage between a health effect and its cause. Understanding the cause enabled officials to take action to protect public health. In the case of lead, though it was a known toxin, exposure came from so many sources that it was difficult to know what actions at the national level would effectively reduce lead exposure. Once regulations to do so were put in place, biomonitoring data provided a way to evaluate the success of this environmental management effort in reducing exposure to lead in the U.S.

Lead is a neurotoxic metal that affects areas of the brain that regulate behavior and nerve cell development (NAP, 1993). Its adverse effects range from subtle responses to overt toxicity, depending on how much lead is taken into the body and the age and health status of the person (CDC, 1991).

Currently in the U.S., human exposure to lead may occur in several ways, as listed in Exhibit 4-5. For example:

- Homes built before 1978, commercial buildings, and steel structures may contain deteriorating lead-based paint, which creates lead-contaminated dust (EPA, 1996). An estimated 24 million housing units in the U.S. are at risk for containing some lead paint hazards (U.S. Department of Housing and Urban Development, 2000). Of these, 16 million homes with lead-based paint have children in residence who are younger than 6 years old.
- Other sources of lead exposure include lead-contaminated soil, dust, and drinking water; industrial emissions; and miscellaneous sources (CDC, 1991).

For many years, the largest source of lead in the U.S. environment came from leaded gasoline. Elemental lead was emitted in the exhaust and settled on the ground and in people's homes.

Most lead enters the body via ingestion and inhalation, after which it is absorbed by the bloodstream. Also, lead can cross the placenta, exposing the fetus to lead (EPA, 1996). In adults, most lead poisoning is associated with occupational exposures.

Infants, children, and fetuses are more vulnerable to the effects of lead because their blood-brain barrier is not fully developed (Nadakavukaren, 2000). In addition, ingested lead is more readily absorbed into a child's bloodstream. Children absorb 40 percent of ingested lead into their bloodstreams, while adults absorb only 10 percent. In children, three major organ systems are affected by lead: the nervous system (the brain), the kidney, and the blood-forming organs (NRC, 1993).

Exhibit 4-5: Sources of lead exposure in the United States

Lead-based paint	Homes (built before 1978) Commercial buildings Steel structures (bridges, water towers)
Lead-contaminated soil and dust	Industrial emissions Past leaded gasoline use Deteriorating lead-based paint
Lead-contaminated drinking water	Leaded plumbing solder (now banned)
Miscellaneous	Home hobbies - art, jewelry, fishing weights Use of pewter dishware Cosmetics, traditional medicines Parental occupations

Source: CDC. *Preventing Lead Poisoning in Young Children.* 1991.

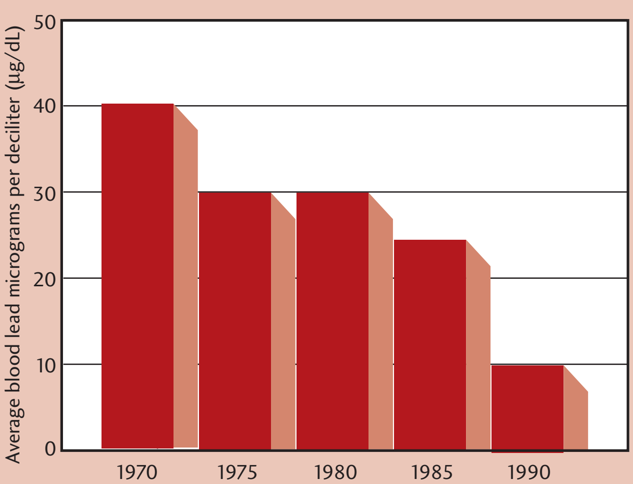
As awareness of the health effects of lead has increased, the CDC has lowered the level considered to be a human health hazard (Exhibit 4-6) (CDC, 1991). In 1970, a blood lead level of 40 micrograms per deciliter (µg/dL) or higher was considered a hazard. Today, 10 µg/dL or higher is considered a hazard (EPA, December 2000). Recent research suggests that blood lead levels less than 10 µg/dL may still produce subtle, subclinical health effects in children (Schmidt, 1999). In 1984, an estimated 6 million children and 400,000 fetuses were exposed to lead at levels that placed them at risk for adverse effects (NAP, 1993). Approximately 4.4 percent of all U.S. children in the 1990s had elevated blood lead levels (NCEH, 1998). As of 1998, an estimated 1 million U.S. children had blood lead levels above 10 µg/dL (NCEH, 1998).

Lead is one of the few pollutants for which biomonitoring and linkage data are sufficient to clearly evaluate environmental management efforts to reduce lead in the environment. The National Center for Health Statistics' National Health and Nutrition Examination Survey (NHANES), a national survey of the health status of the U.S. population, has determined blood lead levels for the U.S. population since the early 1970s. In the 1970s, lead poisoning occurred increasingly in children who did not live in dwellings with lead-based paint, suggesting that another source or sources of lead exposure were of even greater concern than lead paint. Research found that combustion of leaded gasoline was the primary source of lead in the environment. EPA promulgated two regulations:

- One required the availability of unleaded fuel for automobiles designed to meet federal emission standards (e.g., catalytic converters) (EPA, 1973).
- The second required a reduction of the lead content in leaded gasoline (EPA, 1986).

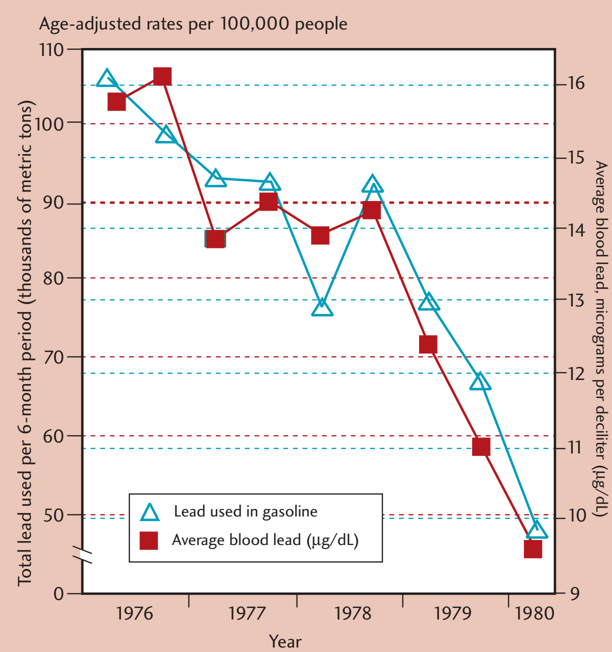
Over the next decade, peak outdoor-air lead concentrations decreased as a result of these controls. Exhibit 4-7 compares the amount of lead used in gasoline production and the average blood lead levels provided by the NHANES from 1976 to 1980. The NHANES survey found a similar decline in children's blood lead levels (Exhibit 4-8). In 1991, a report from the National Academy of Sciences predicted that declining ambient lead levels would reduce the average blood lead level to less than 15 µg/dL. By the late 1990s, the average blood lead level in the U.S. for children was 3 µg/dL (Schmidt, 1999). These data show a demonstrable effect between regulatory actions to control lead and human exposure.

Exhibit 4-6: Blood lead levels considered elevated by the Centers for Disease Control and Prevention and the Public Health Service, 1970-1990



Source: CDC. *Preventing Lead Poisoning in Young Children.* 1991.

Exhibit 4-7: Lead used in gasoline production and average National Health and Nutrition Examination Survey (NHANES) blood lead, United States, 1976-1980

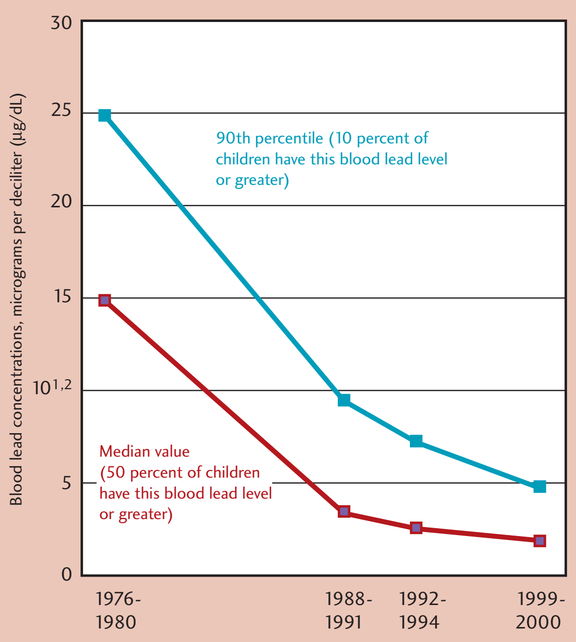


Source: National Research Council. *Measuring Lead Exposures in Infants, Children and Other Sensitive Subpopulations.* 1993.

Elucidating Other Linkages

For all three case studies, the linkage between exposure and disease is fairly strong. Subsequent sections of this chapter describe a number of areas of concern regarding the potential human health impacts of environmental exposure. The linkage in these areas ranges from strong to weak. For example, in some cases outcome indicators are available, but scientists are not yet sure how much of that outcome is contributed by environmental factors. In other cases, biomonitoring indicators are available, but scientists are not sure whether the presence of a contaminant in the body at the levels shown by the indicators causes adverse health effects. These areas are discussed in this chapter, despite relatively weak linkages, because the use of outcome and biomonitoring indicators is a developing area. Understanding of linkages will be strengthened over time as more research is conducted to develop environmental public health indicators and other data that reveal how pollutants contribute to disease.

Exhibit 4-8: Concentration of lead in blood of children age 5 under, 1976-1980, 1988-1991, 1992-1994, 1999-2000



[1] 10 µg/dL of blood lead has been identified by CDC as elevated, which indicates the need for intervention. (CDC. *Preventing Lead Poisoning in Young Children.* 1991.)

[2] Recent research suggests that blood levels less than 10 µg/dL may still produce subtle, subclinical health effects in children. (Schmidt, C.W. *Poisoning Young Minds.* 1999.)

Source: U.S. Environmental Protection Agency. *America's Children and the Environment-Measures of Contaminants, Body Burdens, and Illnesses, Second Edition.* February 2003. Data from CDC, National Center for Health Statistics, National Health and Nutrition Examination Survey, 1976-2000.

4.2 Health Status of the U.S. Compared to the Rest of the World

Several measures are used worldwide to describe health status. These indicators include life expectancy (i.e., the number of years people can expect to live at birth), the number of infant deaths, and the major causes of deaths.

Collecting and reporting the data necessary to compare these measures between nations is a challenge. Yet, as travel and communications increasingly link the health of nations in the world, the importance of having comparable information has increased. Fortunately, considerable progress has been made to improve the comparability of the necessary data among nations.

In addition to enabling comparisons of health status, the data also can be used to inform U.S. environmental health policy and programs, to focus research efforts, and to provide insights into linkages between environmental factors and health.

Life Expectancy

Life expectancy is the average number of years at birth that a group of infants would live if throughout life they experienced the age-specific death rates present at birth. In 2000, life expectancy at birth for all people in the U.S. was a record 76.9 years (Pastor, et al., 2002). In 1997, the U.S. ranked 19th in terms of life expectancy for both females and males when compared with other countries (Exhibit 4-9). Life expectancy at birth varies widely, both between males and females and between nations. For both sexes, Japan reports the highest life expectancy of all nations, with males expected to live 77.2 years and females expected to live 83.8 years.

Infant Mortality

Infant mortality is a particularly useful measure of health status because it indicates both the current health status of the population and predicts the health of the next generation (NCHS, 2001). Between 1970 and 2000, the infant mortality rate in the U.S. declined from 20.0 to 6.9 per 1,000 live births, the lowest ever recorded in the U.S. (Pastor, et al., 2002; Mannino and Smith, 2001). When compared to other countries, the U.S. ranked 11th in 1960 with regard to infant mortality. In 1998, the U.S. ranked 28th (Exhibit 4-10).

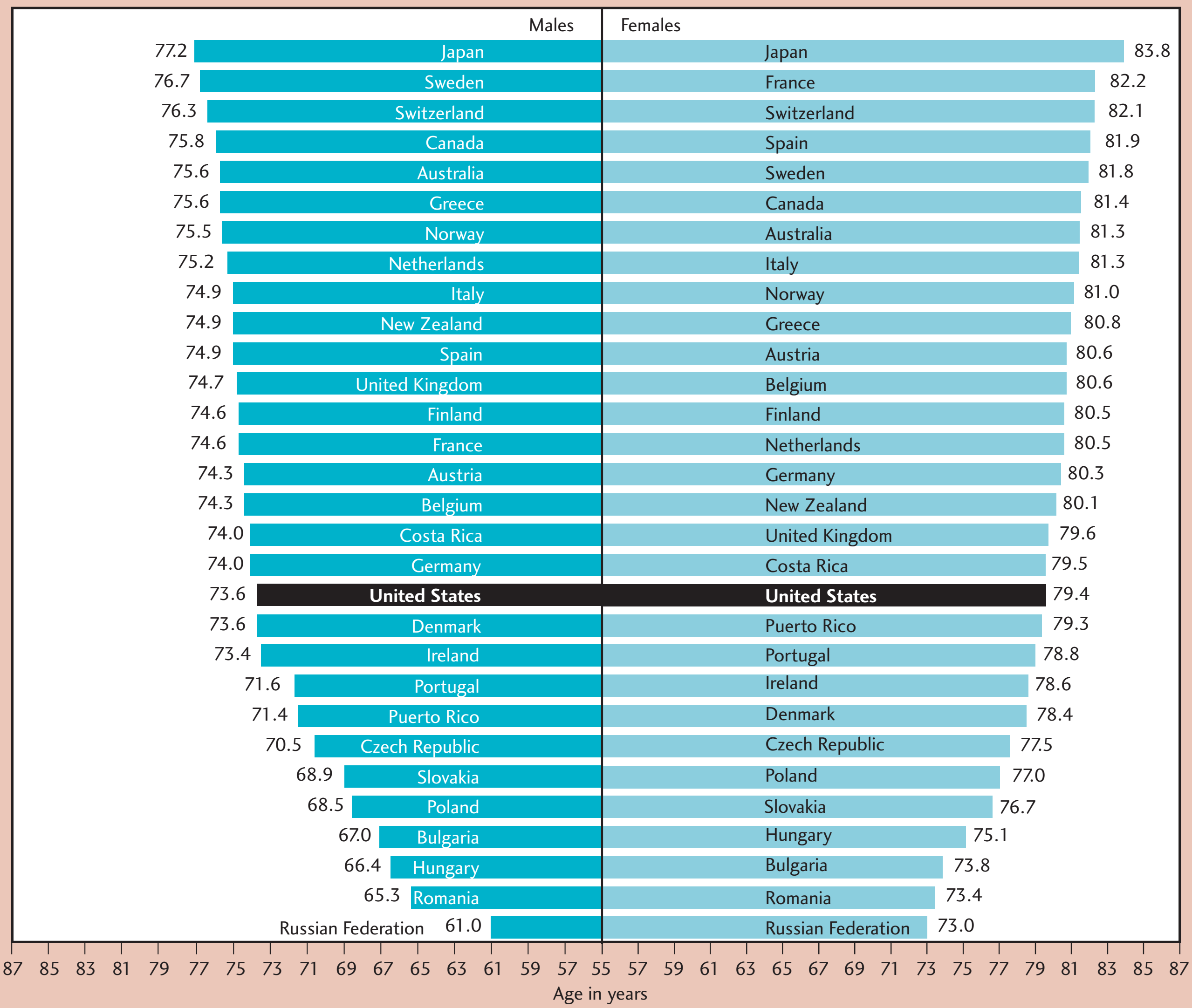
Leading Causes of Death

It is customary to measure the health of a nation by listing the leading causes of death. Comparisons of the 10 leading causes of death in the U.S. and for the world demonstrate that infectious diseases are a major contributor to deaths outside of the U.S. Four of the 10 leading causes of death in the world are infectious diseases (Exhibit 4-11). These diseases account for 20.3 percent of the deaths worldwide. Heart disease is the leading cause of death in the U.S. as well as in the world. While heart disease accounts for nearly one-third of the deaths in the U.S., it accounts for only 12.4 percent of the deaths in the world.

Cancer Morbidity and Mortality

The age-adjusted cancer mortality rates for all body sites except skin are higher for males than females in all of the countries presented in Exhibit 4-12. There is wide variation among men and women in age-adjusted cancer death rates. Hungary has the highest age-adjusted total cancer (except skin) death rates for both males and females (272.3 and 149.4 per 100,000 people, respectively). The U.S. ranks 16th for males, with an age-adjusted cancer death rate of 161.8 per 100,000, and 10th for females, with an age-adjusted cancer death rate of 116.4 per 100,000. Sweden has the lowest age-adjusted

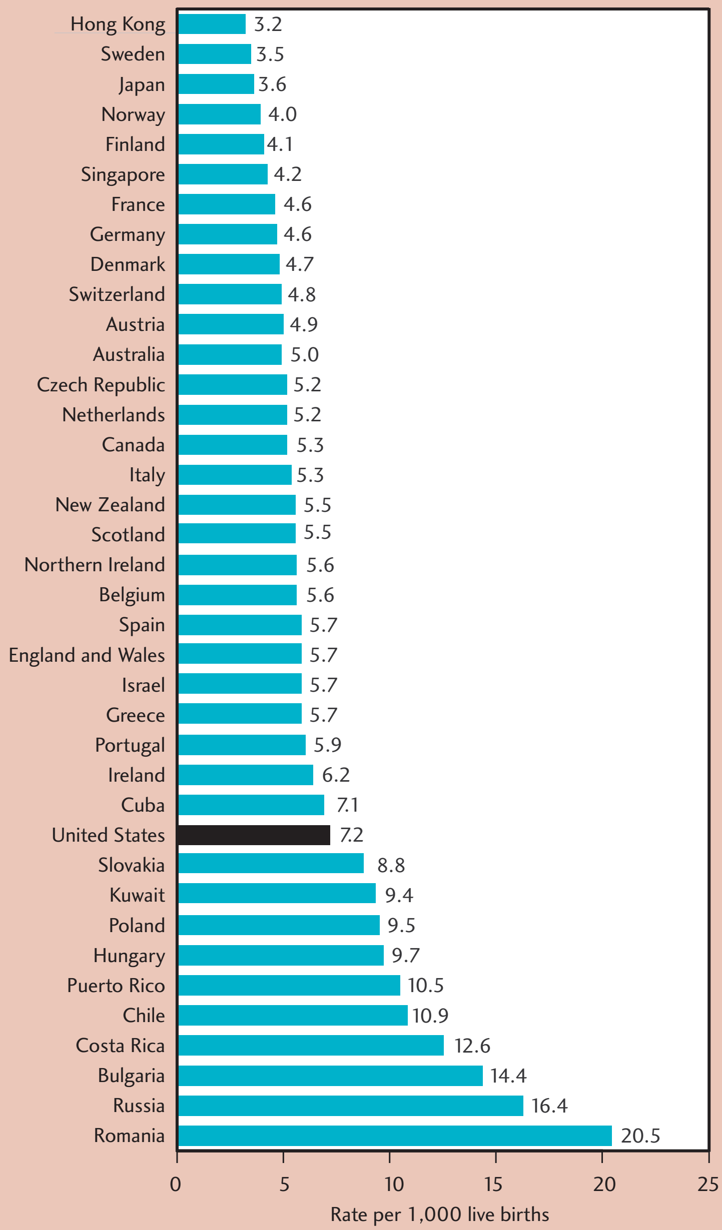
Exhibit 4-9: Life expectancy at birth, according to sex, United States and selected countries, 1997



Note: Rankings are from highest to lowest life expectancy based on the latest data available for countries or geographic areas with at least 1 million people.

Source: Pastor, R.N., et al. *Health. United States, 2002*. 2002.

Exhibit 4-10: Infant mortality rates per 1,000 live births, United States and selected countries, 1998*



* Data for Kuwait, Slovakia, and Spain are for 1996.

Source: Pastor, R.N., et al. *Health. United States,2002*. 2002.

cancer death rate for males, and Greece has the lowest rate for females (137.9 and 81.8 per 100,000, respectively) (United Nations, 2001).

The age-adjusted incidence of cancer for all sites except skin varies widely among different countries (Exhibit 4-13). Hungary reported the highest age-adjusted incidence of cancers for males (405.4 per 100,000 people). New Zealand had the highest age-adjusted cancer incidence rate for females (303.2 per 100,000 people). The U.S. has the third highest age-adjusted cancer incidence rates for both males and females (361.4 and 283.2, respectively). Age-adjusted cancer incidence rates are higher for males than females in each of the countries presented in Exhibit 4-13 except Denmark (GLOBOCAN 2000, 2001).

The varying incidence and mortality rates for cancer between different countries could be due to many factors. Factors related to the economic, social, cultural, psychological, behavioral, and biological mechanisms that influence the onset of cancer may contribute to these differences in rates (NCI, 2002). A portion of these differences might also be attributable to the varying prevalence of certain behavioral risk factors for cancer—such as cigarette smoking, diet, and alcohol consumption—within different countries. The availability and use of certain drugs, such as anticancer and immunosuppressive drugs, may also cause differences in the rates of cancer among different countries. The extent to which early diagnoses and treatment methods are available and utilized could also account for some portion of the variation in cancer rates among different countries, as could variations in methods of classifying and reporting cancer.

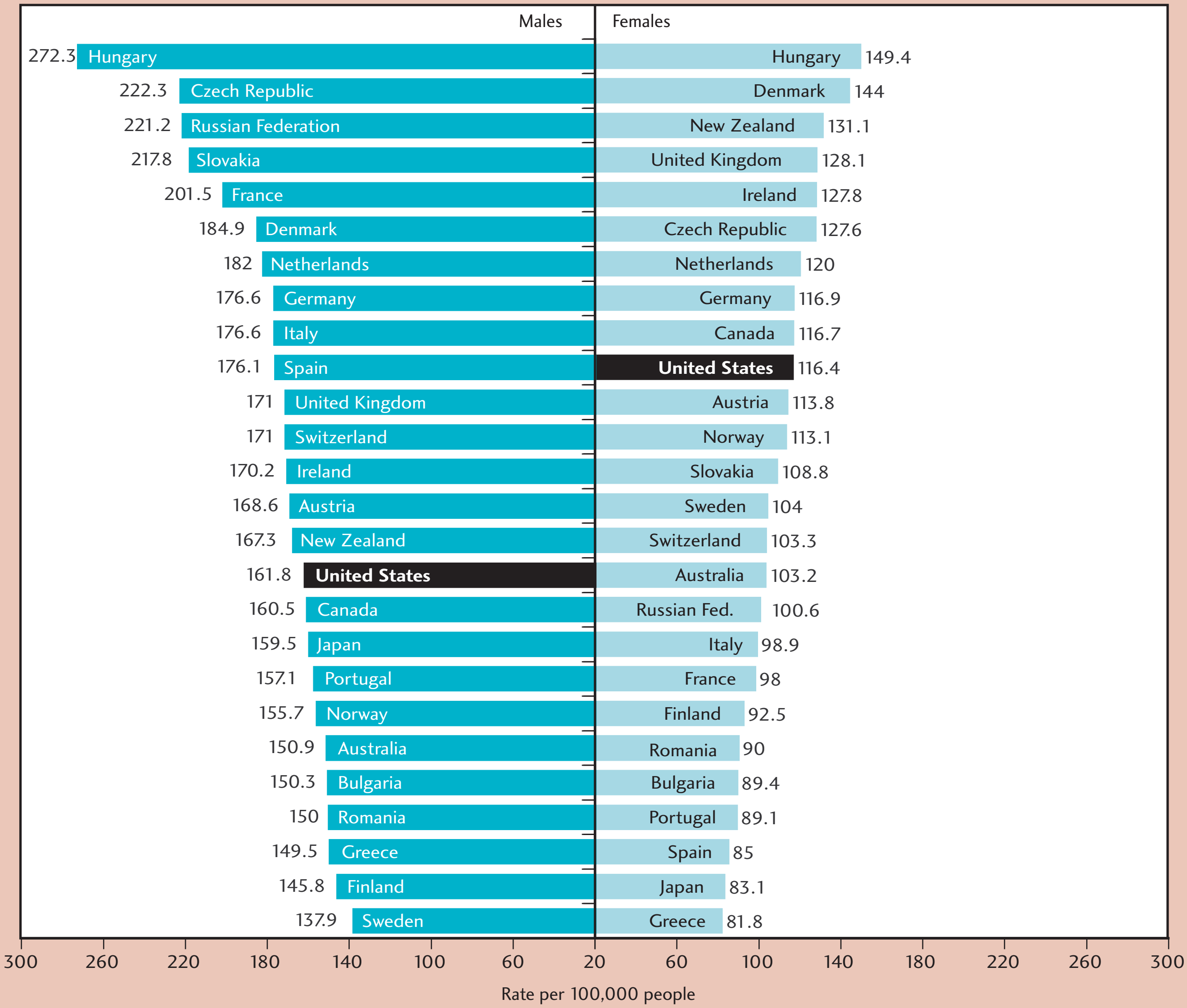
For more on morbidity, mortality, and age-adjusted rates, see Section 4.3.

Exhibit 4-11: Number of deaths and percent of total deaths for 10 leading causes of death, world (including U.S.), 1990, and United States, 1999

Cause of Death	Number of Deaths	Percent of Total Deaths
World (Including U.S.) (1990)		
All causes	50,467,000	100.0
Heart disease	6,260,000	12.4
Stroke	4,381,000	8.7
Lower respiratory infections	4,299,000	8.5
Diarrheal diseases	2,946,000	5.8
Conditions arising during the perinatal period	2,443,000	4.8
Chronic obstructive pulmonary disease	2,211,000	4.4
Tuberculosis	1,960,000	3.9
Measles	1,058,000	2.1
Road traffic accidents	999,000	2.0
Trachea, bronchus and lung cancers	945,000	1.9
All other causes	27,502,000	54.5
United States (1999)		
All causes	2,391,399	100.0
Heart disease	725,192	30.3
Cancer	549,838	23.0
Stroke	167,366	7.0
Chronic lower respiratory diseases	124,181	5.2
Accidents (unintentional injuries)	97,860	4.1
Diabetes mellitus	68,399	2.9
Influenza and pneumonia	63,730	2.7
Alzheimer's disease	44,536	1.9
Nephritis, nephritic syndrome, and nephrosis	35,525	1.5
Septicemia	30,680	1.3
All other causes	484,092	20.2

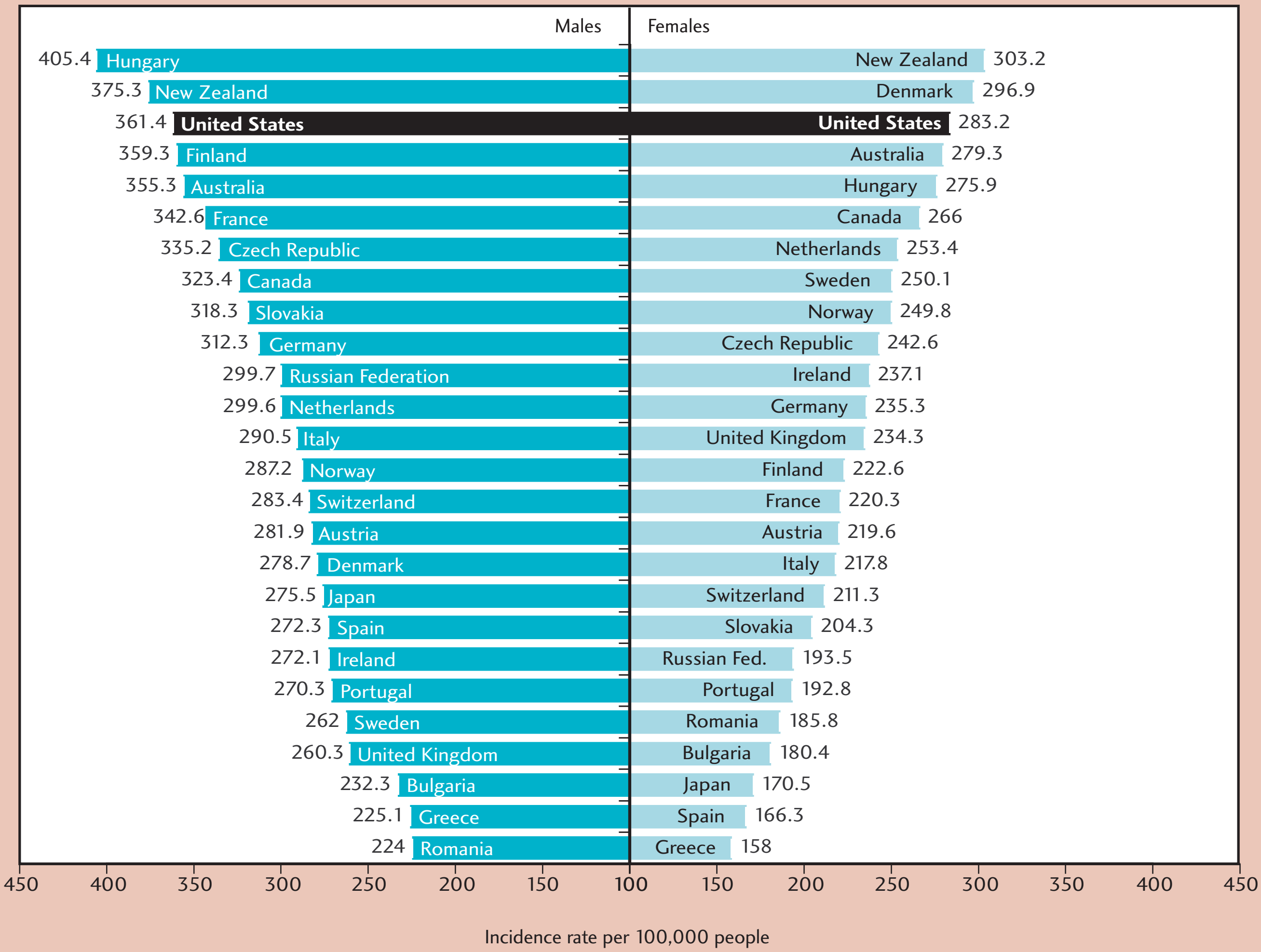
Sources: World Resources Institute, et al. *World Resources 1998-99*. 1998; Anderson, R.N. *Deaths: Leading Causes for 1999*. 2001.

Exhibit 4-12: Age-adjusted cancer mortality rates for all sites except skin, by sex for selected countries, 2000



Source: United Nations. *Demographic Yearbook, 1999*. 2001.

Exhibit 4-13: Age-adjusted cancer incidence rates for all sites except skin, by sex for selected countries, 2000



Source: GLOBOCAN. *Cancer Incidence, Mortality, and Prevalence Worldwide, Version 1.0.* 2001; International Agency for Research on Cancer. *IARC Cancer Base No. 5.* 2001.

4.3 Health Status of the U.S.: Indicators and Trends of Health and Disease

This section identifies key indicators of health outcomes (mortality and disease) in the U.S. and describes trends for these outcomes. These outcomes are featured in this report because they are important measures of the health of people in the U.S., and/or because environmental exposure does or may play a role in contributing to the outcome.

The case study on air pollution, presented earlier in Section 4.1, provides an example of how health outcome data can be used to elucidate the linkage between pollution exposure and health outcomes. In this case study, a comparison between mortality rates and air monitoring data revealed an association between deaths and peak air pollutant concentrations.

Mortality

Overall mortality is a key measure of health in a population. There were more than 2,391,399 deaths in the U.S. in 1999 (Anderson, 2001), a number much larger than the 1,989,841 recorded in 1980. The increase in the number of deaths reflects the increase in the size and the aging of the U.S. population. The age-adjusted death rate for all causes has declined steadily since 1950, from 1,446 per 100,000 people to 876 in 1998. The age-adjusted death rates are higher for men than for women, a relationship that has not changed over the years. Heart disease, cancer, and stroke are the three leading causes of death, accounting for about 60 percent of all deaths.

This section presents trends in life expectancy and in mortality due to cancer, cardiovascular disease, chronic obstructive pulmonary disease, and asthma. It also presents trends in mortality for children, including infant mortality and mortality due to cancer, asthma, and birth defects.

Unless otherwise noted, the death statistics are based on the underlying cause of death and are compiled from death certificates. The underlying cause of death is the disease or injury that is judged to have initiated the events that led to death. The mortality rate is the proportion of the population that dies of a disease. The rate is usually calculated for a calendar year, is often expressed per 100,000 population, and is called the crude death rate.

Morbidity

Morbidity is another measure of health for a population. Morbidity data are often described by using the incidence and prevalence of a disease or condition:

- **Incidence** refers to the number of new cases of a disease or condition in a given time period in a specified population.
- **Prevalence** refers to the total number of persons with a given disease or condition in a specified population in a particular time period.

This section provides information on trends for several diseases, including cancer, cardiovascular disease, asthma, and gastrointestinal illness. It also examines trends in children's environmentally related diseases, including cancer and asthma as well as low birthweight and the incidence of birth defects.

Comparison Across Time, Populations, and Geographic Areas

Incidence, prevalence, and mortality statistics may be used to compare the rates of disease at two or more points in time or across different populations or between different geographic areas. These comparisons are particularly useful to determine whether the populations differ by some factor (often called a risk factor) that is known or suspected of affecting the risk of developing the disease or condition. For example, different populations that are compared can be countries, workers in factories, or states.

In general, disease incidence, prevalence, and mortality increase with age. For this reason, when comparing different populations, the data must often be adjusted to account for the age differences between the populations. The adjusted data, called "age-adjusted rates," are used when appropriate in this chapter.

Perceived Well-Being

Another measure of health, perceived well-being, is discussed briefly here, but is not covered by an indicator. The reporting of health as excellent, very good, good, fair, or poor captures both the physical health of the individual and the emotional aspects of well-being (Kramarow, et al., 1999). In 1999, approximately 90 percent of the population of the U.S. reported that they were in good, very good, or excellent health (Eberhardt, et al., 2001), a slight increase from 89.6 percent in 1991. As might be expected, the percentage of people reporting good-to-excellent health decreases with age. While 95 percent of those 18 to 44 years of age reported good-to-excellent health, only 77 percent of persons 65 years of age and older reported that they were in good-to-excellent health. Also, non-Hispanic African Americans and Hispanics of all ages reported worse health than non-Hispanic Whites (Eberhardt, et al., 2001).

This section addresses five questions:

- What are the trends for life expectancy? (Section 4.3.1)
- What are the trends for cancer, cardiovascular disease, chronic obstructive pulmonary disease, and asthma? (Section 4.3.2)
- What are the trends for gastrointestinal illness? (Section 4.3.3)
- What are the trends for children's environmental health issues? (4.3.4)
- What are the trends for emerging health effects? (Section 4.3.5)

4.3.1 What are the trends for life expectancy?

Life expectancy is the average number of years at birth that a group of infants would live if throughout life they experienced the age-specific death rates present at birth.

Indicator Life expectancy - Category 1

The primary source for data on life expectancy in the U.S. is the National Center for Health Statistics (NCHS). Through its National Vital Statistics System, the NCHS has collected and published data on births, deaths, marriages, and divorces in the U.S. since 1933. U.S. data are for the 50 states and the District of Columbia, unless otherwise specified. Virtually all births and deaths are registered. U.S. Standard Certificates of Live Birth and Death are revised periodically, usually every 10 to 15 years. New versions of the U.S. Standard Certificates of Live Birth and Death are planned for 2003. Most state certificates conform closely in content and arrangement to the standard certificate recommended by NCHS, and all certificates contain a minimum data set specified by NCHS. At the time of birth, the mother provides demographic information on the birth certificate, such as race and ethnicity. Medical and health information is based on hospital records. Demographic information on the death certificate is provided by the funeral director based on information supplied by an informant. A physician, medical examiner, or coroner provides medical certification of cause of death.

What the Data Show

Throughout the 20th century there has been a general improvement in life expectancy at birth in the U.S. (Hoyert, et al., 2001). In 2000, life expectancy at birth reached a record high of 76.9 years, based on preliminary data. In 1999, life expectancy was 76.7 years (Pastor, et al., 2002). This follows 5 consecutive years of improvement and a general upward trend in life expectancy throughout the 20th century.

The gap in life expectancy between males and females widened from 2.0 years to 7.8 years between 1900 and the late 1970s. Now this gap is narrowing, and in 2000 the difference in life expectancy between the sexes was 5.4 years. This improvement was primarily due to a greater reduction in mortality for males from heart disease, cancer, suicide, and homicide. Between 1970 and 1999, life expectancy at birth in the U.S. increased from 67.1 to 73.9 years for males and from 74.7 to 79.4 years for females (Pastor, et al., 2002; Mannino and Smith, 2001).

In 1999, life expectancy at birth for the African American population reached a record high of 71.4 years. In 2000, the difference in life expectancy between the African American and White populations was 5.6 years, based on preliminary data. Based on 1999 data, White females continue to have the highest life expectancy (79.9 years), followed by African American females (74.7 years), White males (74.6 years), and African American males (67.8 years). The narrowing of the gap in life expectancy between Whites and African Americans was largely due to a greater reduction in mortality for African Americans due to homicide, cancer, stroke, and HIV-related disease.

Data Source

National Vital Statistics System, National Center for Health Statistics. (See Appendix B, page B-25, for information.)

4.3.2 What are the trends for cancer, cardiovascular disease, chronic obstructive pulmonary disease, and asthma?

Several chronic diseases that are important indicators of health are presented in this section. Cardiovascular disease, cancer, and stroke are the three leading causes of death in the U.S., accounting for 60.3 percent of all deaths (Anderson, 2001). Chronic obstructive pulmonary disease, a category of diseases that restrict airflow through parts of the respiratory system, was the fourth leading cause of death in the U.S. in 1999 (Hoyert, et al., 2001). Asthma, a chronic condition characterized by inflammation of the airways and lungs, affected more than 10 million people in the U.S. in 1999 (Mannino, et al., 2002).

Indicators

Cancer mortality - Category 1
Cancer incidence - Category 2

The term "cancer" is used to characterize diseases in which abnormal cells divide without control. A cancerous cell loses its ability to regulate its own growth, control cell division, and communicate with other cells. Cancer cells can invade nearby tissues and can spread through the bloodstream and lymphatic system to other parts of the body (NCI, 2003).

What the Data Show

In the U.S., 549,838 people died of cancer in 1999. The death rate was 201.6 per 100,000 people. Cancer accounted for 23 percent of all deaths (Anderson, 2001). Between 1990 and 1998, the age-adjusted death rates for all types of cancer for all persons declined from 173.3 to 161.5 per 100,000 people. The death rate for cancer is highest for non-Hispanic Whites (232.8 per 100,000 people). The death rate for cancer for non-Hispanic African Americans is 185.6 per 100,000 and for Hispanics is 64.6 per 100,000 (Hoyert, et al., 2001). Death rates for different types of cancer show differences across age, gender, and ethnic lines.

Over the past century, the age-adjusted incidence rate for all cancers for all persons decreased from 400.3 per 100,000 people to 395.3. Age-adjusted incidence rates have not declined uniformly over all types of cancer. For example, the incidence of lung cancer for men was 69.8 per 100,000 in 1998, a decline from 81.8 in 1990 and from 76.2 in 1975. For women, the 1998 age-adjusted lung cancer incidence rate of 43.4 per 100,000 people was an increase from 41.6 in 1990 and was nearly 2 times the 1975 rate of 21.5 (Ries, et al., 2001).

Exhibit 4-14 shows the estimated percent change in death and incidence rates according to the type of cancer for men and women of all races, between 1973 and 1998. Notable is the 150.6 percent increase in lung cancer deaths for females between 1973 and 1998. Despite the progress in reducing the number of new cases of some types of cancer, the incidence rates for all types of cancers combined increased 22.4 percent (Ries, et al., 2001).

Data Sources

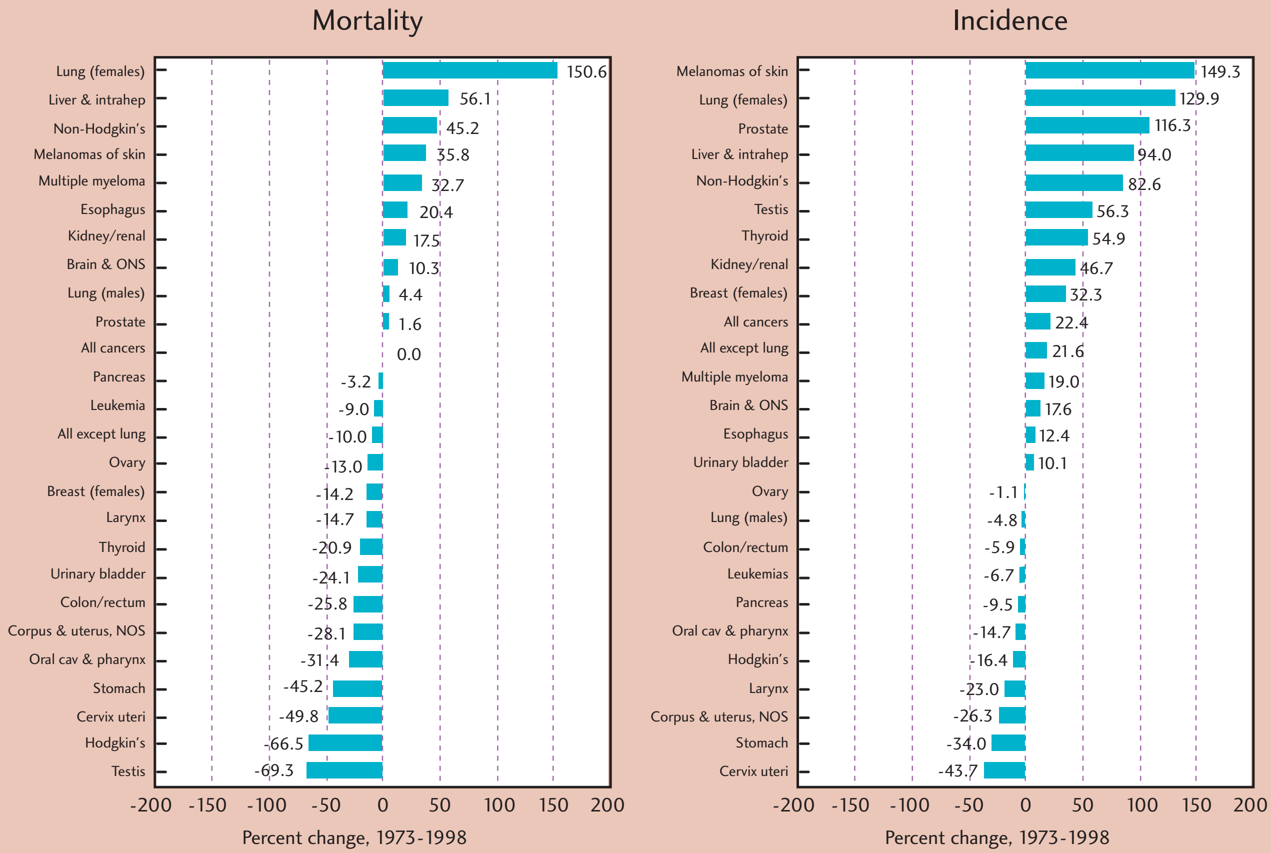
Mortality: National Vital Statistics System, National Center for Health Statistics. (See Appendix B, page B-25 for more information.)

Incidence: National Notifiable Diseases Surveillance System, Centers for Disease Control and Prevention. (See Appendix B, page B-25 for more information.)

Indicators

Cancer mortality - Category 1 (continued)
Cancer incidence - Category 2 (continued)

Exhibit 4-14: Trends in United States cancer mortality rates and Surveillance, Epidemiology and End Results (SEER) incidence (annual percentage change 1973-1998)



NOS = Not otherwise specified
ONS = Other nervous system

Source: Ries, L.A.G., et al. *Surveillance, Epidemiology and End Results (SEER) Cancer Statistics Review, 1973-1998*. 2001.

Indicators

Cardiovascular disease mortality - Category 1
Cardiovascular disease prevalence - Category 1

The broad category of cardiovascular disease (CVD) includes any disease involving the heart and blood vessels. Coronary heart disease (CHD) and cerebrovascular disease, commonly known as stroke, are the major cardiovascular diseases.

What the Data Show

Because there are several conditions included in the cardiovascular disease category, it is not surprising that the National Heart, Lung, and Blood Institute (NHLBI) estimates that approximately 59.7 million people in the U.S. have some form of CVD (NHLBI, 2000). An estimated 12.2 million people have coronary heart disease and 4.4 million have had a stroke.

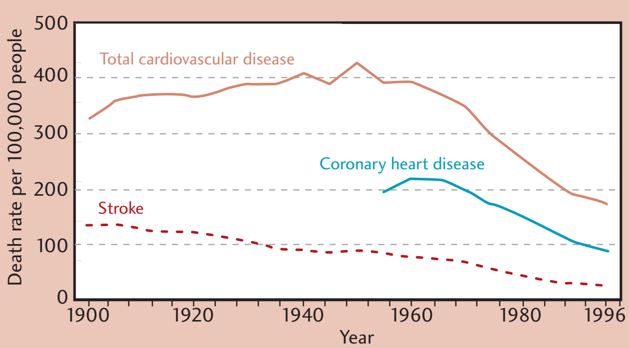
CVD is the leading cause of death for both men and women in the U.S. (AHA, 2001). The age-adjusted death rate for CVD reached a peak in 1950. Between 1950 and 1999, the age-adjusted death rate for CVD declined 60 percent (Exhibit 4-15) (CDC, 1999a). The percentage of all deaths due to CVD increases with age, from 19 percent at 35 to 44 years of age, to 53 percent for people 85 years and older.

The prevalence of cardiovascular disease varies depending upon the age and sex of the individual (Exhibit 4-16). CVD is more prevalent in men than in women until 65 years of age, when the prevalence among women equals that in men. After age 74 years, the prevalence is greater in women than in men. The age-adjusted prevalence of CVD in adults for non-Hispanic Whites is 30.0 percent for men and 23.8 percent for women; for non-Hispanic African Americans it is 40.5 percent for men and 39.6 percent for women.

The death rate for CHD was 195.6 per 100,000 people in 1999 (AHA, 2001). The death rates were lower for White men (249.4 per 100,000 people) than for African American men (272.6) and higher for African American women (192.5) than for White women (152.5) (AHA, 2001).

After age 45, the prevalence of CHD is lower for women than for men at all ages and increases with age for both men and women, peaking after 75 years of age (Exhibit 4-17). The age-adjusted prevalence for CHD for non-Hispanic Whites is 6.9 percent for men and 5.4 percent for women. For non-Hispanic African Americans, the prevalence is 7.1 percent for men and 9.0 percent for women (AHA, 2001).

Exhibit 4-15: Death rates for total cardiovascular disease, coronary heart disease, and stroke, by year, United States, 1900-1996

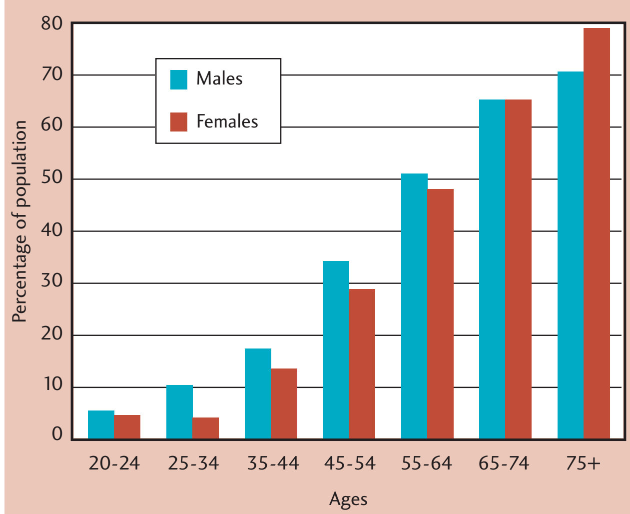


Notes: Rates are per 100,00 people, age adjusted to the 1940 U.S. population.

Diseases are classified according to International Classification of Diseases (ICD) codes in use when the deaths were reported.

Source: CDC. *Decline in Deaths from Heart Disease and Stroke, United States, 1900-1999*. 1999.

Exhibit 4-16: Prevalence of cardiovascular diseases among adults by age and sex, United States, 1988-1994



Source: American Heart Association. 2001 Heart and Stroke Statistical Update. 2001. Data from NHANES III, 1988-1994, the CDC, National Center for Health Statistics, and the American Heart Association.

Indicators

Cardiovascular disease mortality - Category 1 (continued)
Cardiovascular disease prevalence - Category 1 (continued)

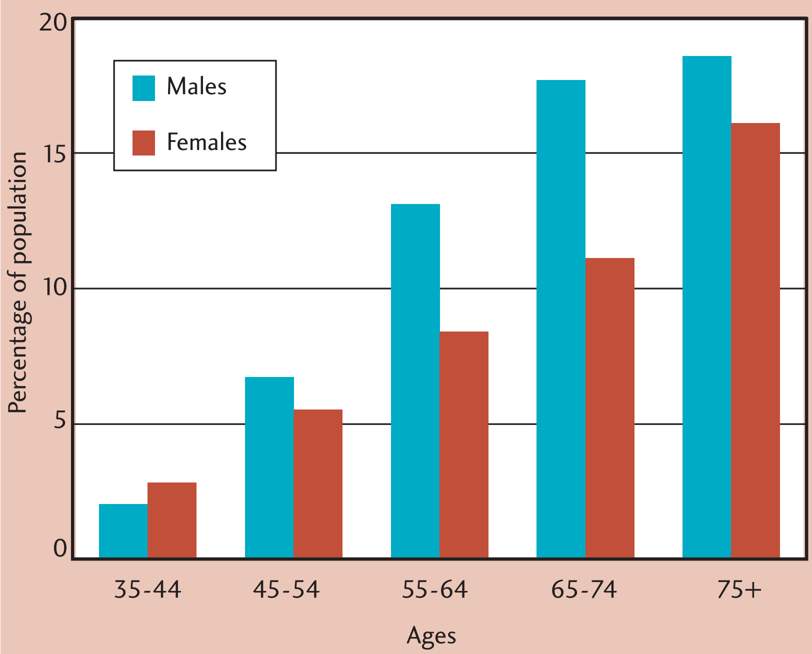
Stroke ranks as the third leading cause of death in the U.S. Stroke accounted for 7.0 percent of total deaths. The death rate for stroke was 61.4 deaths per 100,000 people. The age-adjusted prevalence of stroke is higher for men than for women at all ages. In 1999, there were 167,366 deaths (102,881 were females) attributed to stroke (Anderson, 2001). Death rates for stroke were highest among non-Hispanic Whites (70.8 per 100,000 people), followed by non-Hispanic African Americans (56.6) and Hispanics (18.8).

Data Sources

Mortality: National Vital Statistics System, National Center for Health Statistics. (See Appendix B, page B-26 for more information.)

Prevalence: NHANES III (1988-1994), National Center for Health Statistics. (See Appendix B, page B-26, for more information.)

Exhibit 4-17: Prevalence of coronary heart disease by age and sex, United States, 1988-1994



Source: American Heart Association. 2001 *Heart and Stroke Statistical Update.* 2001. Data from NHANES III, 1988-1994, the CDC, National Center for Health Statistics, and the American Heart Association.

Indicator | Chronic obstructive pulmonary disease mortality - Category 1

Chronic obstructive pulmonary disease (COPD), sometimes referred to as chronic lung disease, is a disease that damages lung tissue or restricts airflow through the bronchioles and bronchi (ALA, 2001). Chronic bronchitis and emphysema are the most frequently occurring COPDs.

What the Data Show

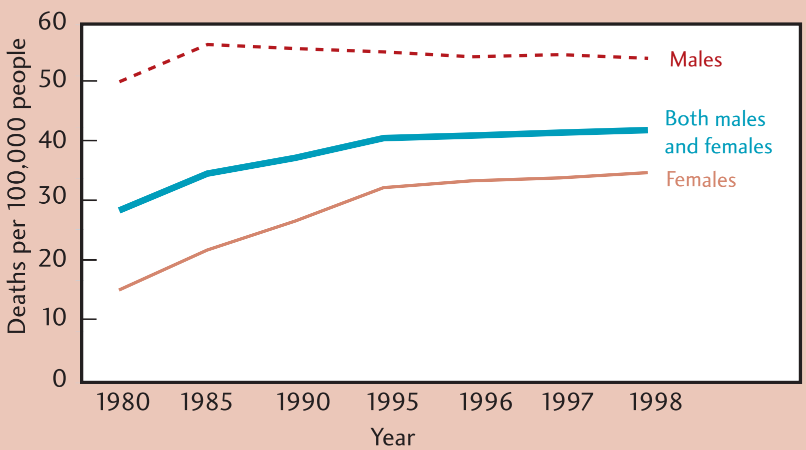
In 1999, COPD was the fourth leading cause of death, accounting for more than 124,181 deaths (5.2 percent of total deaths) (Hoyert, et al., 2001). The age-adjusted death, rate for COPD was 45.8 per 100,000 population. From 1980 to 1998, the age-adjusted death rates for COPD increased from 28.3 to 42.0 per 100,000 population for men and women of all racial and ethnic groups in the U.S. (Eberhardt, et al., 2001). For females, the age-adjusted death rates for COPD increased steadily from 1980 to 1998, from 14.9 per 100,000 population to 34.8 in 1998 (Exhibit 4-18). For males, the age-adjusted death rates rose between 1980 and 1985 from 49.9 to 56.2 per 100,000. From 1990 to 1998, the rate remained generally stable, declining slightly in 1998 to 54.0 per 100,000.

In 1998, the age-adjusted death rate for COPD was highest for White males at 55.4 per 100,000 population, followed by African American males (45.2) and Hispanic males (26.2 per 100,000 population). Among females, White females had the highest rates (36.5) followed by African American females (22.3) and Hispanic females (13.7 per 100,000 population) (Hoyert, et al., 2001).

Data Source

National Vital Statistics System, National Center for Health Statistics. (See Appendix B, page B-26, for more information.)

Exhibit 4-18: Age-adjusted death rates for chronic obstructive pulmonary disease according to sex, selected years, in the United States 1980-1998



Source: Eberhardt, M.S., et al. *Health, United States, 2001 with Urban and Rural Health Chartbook.* 2001.

Indicators

Asthma mortality - Category I
Asthma prevalence - Category I

Asthma is a chronic respiratory disease characterized by inflammation of the airways and lungs. During an asthma attack the airways that carry air to the lungs are constricted, and as a result less air is able to flow in and out of the lungs (NCHS, 2001). Asthma attacks can cause a multitude of symptoms ranging in severity from mild to life-threatening. These symptoms include wheezing, breathlessness, chest tightness, and coughing (NCHS, 2001).

What the Data Show

In 1999, 4,657 people died from asthma. The age-adjusted death rate was 17.2 per 1,000,000 population. Exhibit 4-19 shows the trends in age-adjusted death rates with asthma as the underlying cause of death.

In 1999, approximately 10.5 million people in the U.S. reported that they had an asthma attack or episode in the preceding 12 months (Mannino, et al., 2002). This included approximately 7.3 million people over 14 years of age. The 1999 age-adjusted prevalence of asthma for people of all ages was 38.4 per 100,000 population in 1999 (Exhibit 4-20). That same year, the prevalence of asthma in adults was highest (42.2 per 100,000) for people 15 to 34 years of age, and lowest (22.1 per 100,000) for those 65 years of age and older. African Americans were more likely to report an asthma episode or attack than other race/ethnic groups, and females were more likely than males to have had an asthma episode or attack. Since 1997, the age-adjusted prevalence of asthma has decreased slightly from 40.7 per 100,000 population to 38.4 per 100,000. Changes in the way asthma data are collected were made in 1997, limiting the ability to compare current data with earlier reports.

There are regional differences in the prevalence of asthma with the highest prevalence in the Northeast (61.8 per 1,000 people) (Adams, et al., 1999). The prevalence in the Midwest was 56.6 per 1,000 people. The prevalence in the South (51.8 per 1,000) was similar to the prevalence in the West (52.9 per 1,000). People who lived in a central city reported a higher number of cases (61.7 per 1,000 people) than those who did not live in the central city (54.9 per 1,000). Those who did not live in a Metropolitan Statistical Area (an urbanized area with at least 50,000 inhabitants) had the lowest prevalence, 46.9 per 1,000 people.

Data Sources

Mortality: National Vital Statistics System, National Center for Health Statistics. (See Appendix B, page B-27 for more information.)

Prevalence: National Health Interview Survey, Centers for Disease Control and Prevention. (See Appendix B, page B-27, for more information.)

Exhibit 4-19: Annual rate* of deaths with asthma as the underlying cause of death diagnosis, by race, sex, and age group, United States, 1980-1999

	1980	1985	1990	1995	1996	1997	1998	1999
Race								
White	12.9	15.6	17.5	18.8	18.1	17.4	17.0	14.2
Black	27.6	34.8	40.9	46.2	48.0	42.5	44.7	38.7
Other	13.5	16.9	23.6	23.3	27.6	26.6	22.7	20.4
Sex								
Male	14.7	15.9	17.8	17.9	17.7	16.6	16.5	13.1
Female	14.4	19.2	22.1	25.1	25.0	23.7	23.3	20.4
Age Group (years)								
0-4	1.8	1.5	2.0	1.8	2.3	1.9	2.1	1.7
5-14	1.9	2.9	3.2	4.0	4.6	3.4	3.8	3.6
14-34	3.0	4.2	5.0	6.7	6.5	6.1	6.4	5.9
35-64	14.0	17.7	18.8	20.6	20.3	19.0	17.8	15.8
65+	61.8	72.5	87.0	90.8	90.3	86.7	86.9	69.9
Total**	**14.4**	**17.7**	**20.2**	**21.9**	**21.8**	**20.6**	**20.3**	**17.2**

* Per 1,000,000 population. ** Age adjusted to the 2000 U.S. population.

Source: Mannino, D.M., et al. *Surveillance for Athma - United States, 1980-1999.* 2002.

Indicators

Asthma mortality - Category I (continued)
Asthma prevalence - Category I (continued)

Exhibit 4-20: Estimated annual prevalence of self-reported asthma (1980-1996) or an episode of asthma attack (1997-1999) during the preceding 12 months, by race, sex, and age group, United States, 1980-1999

	1980	1985	1990	1995	1996	1997	1998	1999
	Self-Reported Asthma Prevalence During the Preceding 12 Months					Episode of Asthma or Asthma Attack During the Preceding 12 Months		
Race								
White	31.4	37.0	41.5	54.5	53.6	40.5	37.5	37.6
Black	33.1	38.6	45.8	64.8	65.6	45.4	46.7	42.7
Other	19.9	12.8	40.2	44.4	43.2	34.7	33.7	38.9
Sex								
Male	30.5	33.8	39.1	48.6	43.0	33.0	31.7	31.6
Female	31.9	38.9	44.2	61.1	65.6	47.9	44.4	44.5
Age Group (years)								
0-4	23.0	36.7	44.0	60.5	40.1	41.2	46.4	42.1
5-14	45.1	50.9	63.7	82.0	69.8	60.0	57.8	56.4
15-34	30.0	36.1	37.3	57.8	67.2	44.2	37.5	42.2
35-64	29.9	30.8	38.4	50.1	46.2	37.0	35.7	33.4
65+	31.9	38.6	36.3	39.4	45.5	27.3	28.7	22.1
Total	**31.4**	**38.6**	**41.9**	**55.2**	**54.6**	**40.7**	**39.2**	**38.4**

Data are per 100,000 population, per year.

Source: Mannino, D.M., et al. *Surveillance for Asthma - United States, 1980-1999*. 2002.

4.3.3 What are the trends for gastrointestinal illness?

The human gastrointestinal tract includes the stomach, the large intestine, and the small intestine. Gastrointestinal infections and illnesses are caused by several types of microorganisms—that is, bacteria, protozoa, fungi, and viruses. Food and water contaminated with pathogenic microorganisms are the major environmental source of gastrointestinal illness. A system for reporting food- and waterborne disease outbreaks has been in place for many years in the U.S. This system enables public health officials to investigate and determine the role of food and water in contributing to intestinal illness, and identify actions that may be needed to protect public health. For example, the system tracks the number of waterborne disease outbreaks reported voluntarily by state, territorial, and local public health officials (See box, "Waterborne Disease Outbreaks Associated with Drinking Water 1971-2000"). These data should be interpreted with caution, however, because many factors can influence whether a waterborne disease outbreak is recognized, investigated, and reported. Changes in the number of outbreaks reported could reflect actual changes or simply changes in surveillance and reporting. (For additional information on waterborne disease, see Chapter 2, Purer Water.)

The number of deaths from microorganism-induced gastrointestinal illnesses recently increased in the U.S., after decades of relatively stable death rates (Peterson and Calderon, 2003). The increases were particularly dramatic in young children (less than 6 years of age) and older Americans (more than 65 years of age). Many milder cases of gastrointestinal illnesses go unreported or are not diagnosed, making it difficult to estimate the number of people affected every year. Often, symptoms are not serious enough to warrant a visit to a doctor or hospital, which further contributes to the underestimation of gastrointestinal illness.

Seven notifiable gastrointestinal diseases caused by microorganisms have been chosen as indicators for this report: cholera, cryptosporidiosis, *Escherichia coli* O157:H7, Hepatitis A, salmonellosis, shigellosis, and typhoid fever. The reporting period includes five years 1997-2001. These include two diseases—cholera and typhoid fever—that are rarely identified in this country. These diseases are nevertheless included because they can be severe illnesses and a sudden increase in their reporting would signal a public health emergency for which prompt action would be needed. In addition to the seven diseases discussed here, a number of other gastrointestinal diseases are caused by microorganisms. These include giardiasis, caused by the pathogen *Giardia.* Giardiasis has become notifiable only as recently as 2002 (CDC, 2003), so no indicator is available at this time.

The primary means of transmission for the seven diseases reported here is oral-fecal. The disease microbes shed in the feces of infected individuals and then can be transmitted to humans through food, water, person-to-person contact, or contact with ill animals. The seven diseases are cholera, cryptosporidiosis, *E. coli* O157:H7, Hepatitis A, salmonellosis, shigellosis, and typhoid fever. Exhibit 4-22 shows the incidence of each for 1997 through 2001.

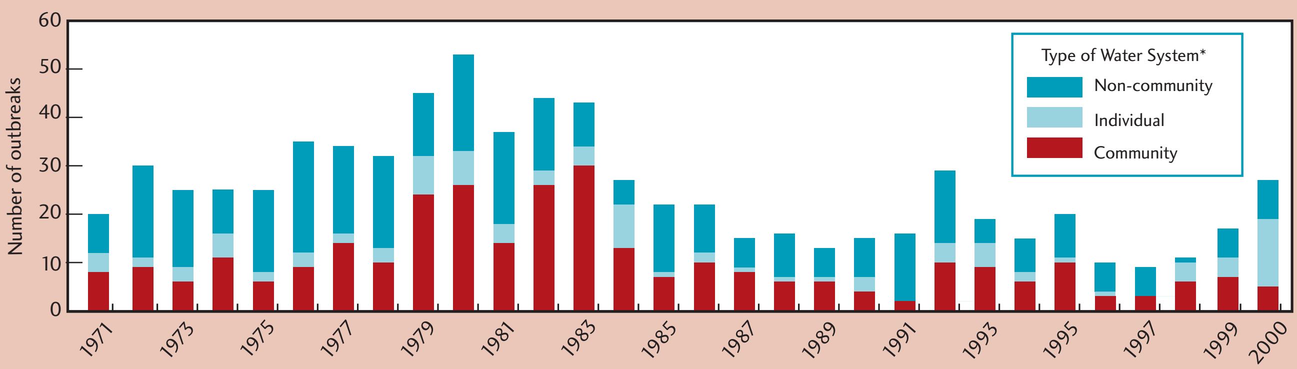
Waterborne Disease Outbreaks Associated with Drinking Water 1971-2000

Since 1971, the Centers for Disease Control and Prevention (CDC), EPA, and the Council of State and Territorial Epidemiologists have maintained a collaborative surveillance system for the occurrences and causes of waterborne-disease outbreaks (WBDO). These data are only a small part of the larger body of information related to drinking water quality in the United States. State, territorial, and local public health agencies are primarily responsible for detecting and investigating WBDOs and voluntarily reporting them to CDC. These data are used to identify types of water systems, their deficiencies, the etiologic agents (e.g., microorganisms and chemicals) associated with outbreaks, and to evaluate current technologies for providing safe drinking water and safe recreational waters. This system reports outbreaks and estimated numbers of people who become ill. It does not provide information on non-outbreak related or endemic levels of waterborne illness. Moreover, the focus is on acute illness. The system does not address chronic illnesses such as cancer, reproductive, or developmental effects. CDC and EPA are collaborating on a series of epidemiology studies to assess the magnitude of non-outbreak waterborne illness associated with consumption of municipal drinking water.

Between 1971 and 2000, there were 751 reported waterborne disease outbreaks associated with drinking water from individual, non-community systems, and community water systems (Exhibit 4-21). During 1999-2000, a total of 44 outbreaks (18 from private wells, 14 from non-community systems, and 12 from community systems) associated with drinking water were reported by 25 states (Craun and Calderon, 2003).

However, these data should be interpreted with caution. Many factors can influence whether a WBDO is recognized and investigated by local, territorial, and state public health agencies. For example, the size of the outbreak, severity of the disease caused by the outbreak, public awareness of the outbreak, whether people seek medical care or report to a local health authority, reporting requirements, routine laboratory testing for organisms, and resources for investigation can all influence the identification and investigation of a WBDO. This system underreports the true number of outbreaks because of the multiple steps required before an outbreak is identified and investigated. Thus, an increase in the number of outbreaks reported could either reflect an actual increase or improved surveillance and reporting at the local and state level.

Exhibit 4-21: Number of reported waterborne disease outbreaks associated with drinking water by year and type of water system, United States, 1971-2000 (n=751)



***Non-community water systems** are systems that either (1) regularly supply water to at least 25 of the same people at least 6 months per year, but not year round (e.g., schools, factories, office buildings, and hospitals that have their own water systems), or (2) provide water in a place where people do not remain for long periods of time (e.g., a gas station or campground).

Individual water systems are not regulated by the Safe Drinking Water Act and serve fewer than 25 persons or 15 service connections, including many private wells.

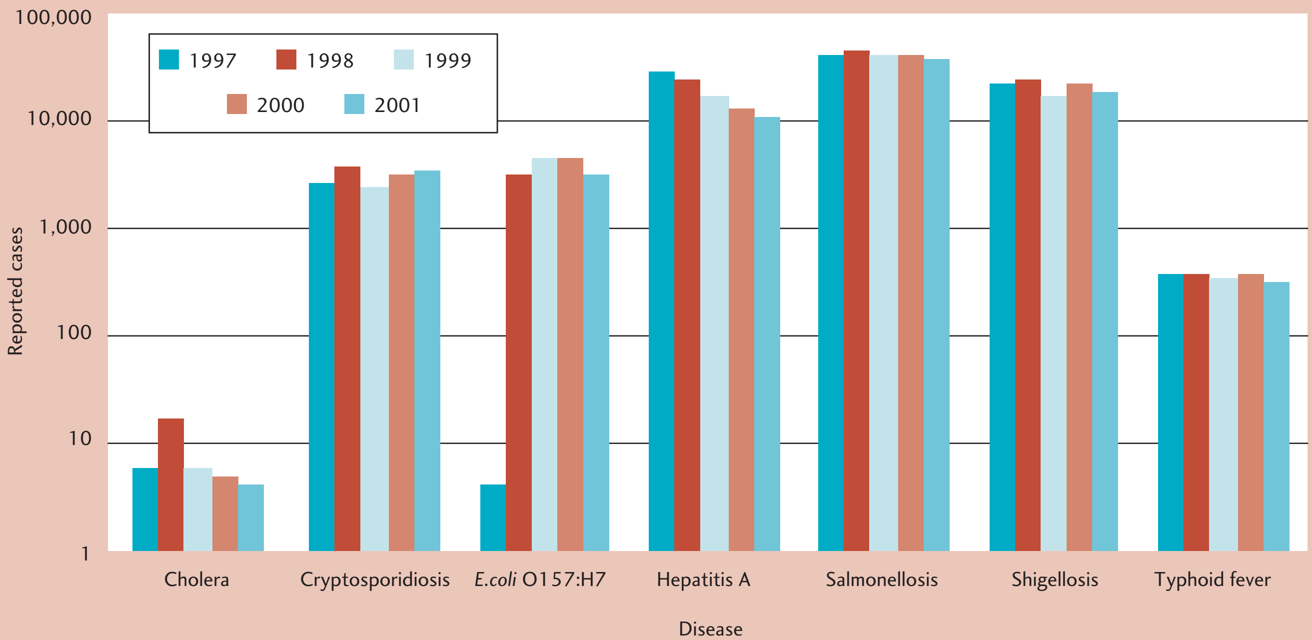
Community water systems provide water to at least 25 of the same people or service connections year round.

Source: Based on data presented in Craun, G.F. and R.L. Calderon. *Waterborne Outbreaks in the United States, 1971-2000.* 2003.

The data source for these seven indicators is the Centers for Disease Control and Prevention, Epidemiology Program Office, National Notifiable Diseases Surveillance System. This system provides weekly provisional information from the Council of State and Territorial Epidemiologists (CSTE) on the occurrence of diseases defined as notifiable. A notifiable disease is one that, when diagnosed, health providers report to state or local public health officials. Notifiable diseases are of public interest because of their contagiousness, severity, or frequency (Pastor, et al., 2002). State epidemiologists report cases of notifiable diseases to CDC, and CDC tabulates and publishes these data in *Morbidity and Mortality Weekly Report (MMWR)* and *Summary of Notifiable Diseases, United States*. Policies for reporting notifiable disease cases can vary by disease or reporting jurisdiction. CSTE and CDC annually review and recommend additions or deletions to the list of nationally notifiable diseases based on the need to respond to emerging priorities. *Reporting nationally notifiable diseases to CDC, however, is voluntary.* Reporting is currently mandated by law or regulation only at the local and state level. Therefore, the list of diseases that are considered notifiable varies slightly by state.

Notifiable disease data are useful for analyzing disease trends and determining relative disease burdens. These data, however, must be interpreted in light of reporting practices. The degree of completeness of data reporting is influenced by many factors such as the diagnostic facilities available; the control measures in effect; public awareness of a specific disease; and the interests, resources, and priorities of state and local officials responsible for disease control and public health surveillance. Finally, factors such as changes in case definitions for public health surveillance, introduction of new diagnostic tests, or discovery of new disease entities can cause changes in disease reporting that are independent of the true incidence of disease.

Exhibit 4-22: Prevalence of reported gastrointestinal diseases, United States, 1997-2001



Sources: CDC. *Notice to Readers: Final 2001 Reports of Notifiable Diseases.* 2002; CDC. *Notice to Readers: Final 2000 Reports of Notifiable Diseases.* 2001; CDC. *Notice to Readers: Final 1999 Reports of Notifiable Diseases.* 2000: CDC. *Notice to Readers: Final 1998 Reports of Notifiable Diseases.* 1999; CDC. *Notice to Readers: Final 1997 Reports of Notifiable Diseases.* 1998.

Indicator Infectious disease prevalence - Cholera - Category 2

Cholera is a diarrhea illness caused by infection of the intestine with the bacterium *Vibrio cholerae*. Infections can often be mild or without symptoms, but can sometimes be severe, and even fatal. Approximately 1 in 20 infected persons has severe disease characterized by severe, watery diarrhea that can lead to dehydration and shock. Without treatment, death can occur within hours (ICTDRN, 2002).

What the Data Show

Very few cases of cholera are reported on an annual basis in the U.S. It is believed most cases are associated with consumption of contaminated seafood or with international travel to areas where cholera is endemic (e.g., South America) (CDC, 2001a).

Data Source

National Notifiable Diseases Surveillance System, Centers for Disease Control and Prevention. (See Appendix B, page B-27, for more information.)

Indicator Infectious disease prevalence - Cryptosporidiosis - Category 2

Cryptosporidiosis is an illness resulting from infection of the gastrointestinal tract with *Cryptosporidium parvum* and other species of *Cryptosporidium*. This pathogen is excreted by humans, as well as wild and domestic animals, including farm animals; it contaminates water sources via animal feces or domestic sewage. Runoff from agricultural operations into drinking water sources has been one cause of cryptosporidiosis outbreaks (Franzen and Muller, 1999).

Severe diarrhea is the most common symptom. Additional symptoms include gastric pain, fever, nausea, and fatigue (Guerrant, 1997). There is no antibiotic that is effective for treatment of cryptosporidiosis. As a result, a healthy immune system is important in limiting an individual's response to *Cryptosporidium parvum* infection. Cryptosporidiosis can be deadly when contracted by immunocompromised individuals. In extreme cases of cryptosporidiosis, infection can spread beyond the gastrointestinal tract to the gall bladder and biliary tract.

What the Data Show

The occurrence of symptoms or conditions associated with cryptosporidiosis are likely underreported. "We do not know exactly how many cases of cryptosporidiosis actually occur. Many people do not seek medical attention or are not tested for this parasite and so *Cryptosporidium* often goes undetected as the cause of intestinal illness" (CDC, 1998b).

Data Source

National Notifiable Diseases Surveillance System, Centers for Disease Control and Prevention. (See Appendix B, page B-28, for more information.)

Indicator — Infectious disease prevalence - *E. coli* O157:H7 - Category 2

E. coli O157:H7 is one of over 170 strains and many hundred sub-strains of the bacterium *Escherichia coli*. Most strains are harmless and live in the intestines of healthy humans and animals; this strain can cause severe illness. *E. coli* O157:H7 is not a disease itself, but rather a cause of illness. The identifier in the name of the bacterium refers to the specific antigenic markers found on its cell wall and distinguishes it from other types of *E. coli*. Infection often leads to bloody diarrhea and occasionally to kidney failure, particularly in young children (CDC, 2001b). A 1982 outbreak of severe bloody diarrhea was traced to contaminated hamburgers.

What the Data Show

CDC estimates that 73,000 cases of *E. coli* O157:H7 occur annually in the U.S., and that 61 fatal cases occur annually. The illness is often misdiagnosed; therefore, expensive and invasive diagnostic procedures may be performed. Patients who develop severe disease may require prolonged hospitalization, dialysis, and long-term follow-up (CDC, 2001b).

Data Source

National Notifiable Diseases Surveillance System, Centers for Disease Control and Prevention. (See Appendix B, page B-28, for more information.)

Indicator — Infectious disease prevalence - Hepatitis A - Category 2

Hepatitis A virus (HAV) is one of five viruses in the hepatitis group of viruses (A to E) that cause liver disease. Symptoms include jaundice, fatigue, abdominal pain, loss of appetite, nausea, diarrhea, and fever. Adults tend to be more symptomatic than children. HAV is found in the feces of infected people and is usually spread through contaminated food, water, or intimate contact (CDC, 2002d).

What the Data Show

The annual number of reported cases for HAV in the U.S. exceeds 10,000. The estimated number of new infections approaches 100,000 per year. It continues to occur in epidemics both nationwide and in communities. The number of cases is now reaching historic lows and continues to slowly decline, though about one-third of Americans show evidence of past infection (CDC, 2002e).

Data Source

National Notifiable Diseases Surveillance System, Centers for Disease Control and Prevention. (See Appendix B, page B-28, for more information.)

Indicator: Infectious disease prevalence - Salmonellosis - Category 2

Salmonellosis is a disease caused by one of the more than 2,000 strains of the bacterial genus *Salmonella*. Most persons infected with *Salmonella* develop diarrhea, fever, and abdominal cramps 12 to 72 hours after infection. The illness usually lasts 4 to 7 days, and most persons recover without treatment, though antibiotics can be used. In some persons, however, the diarrhea may be so severe that the patient needs to be hospitalized. In these patients, the *Salmonella* infection may spread from the intestines to the bloodstream and then to other body sites. It can cause death unless the person is treated promptly with antibiotics. The elderly, infants, and those with impaired immune systems are more likely to become severely ill from salmonellosis (CDC, 2001f).

What the Data Show

Every year, approximately 40,000 cases of salmonellosis are reported in the U.S. Because many milder cases are not diagnosed or reported, CDC estimates the actual number of infections to be 1.4 million. Salmonellosis is more common in the summer than winter. It is estimated that somewhat more than 500 persons die each year with acute salmonellosis (CDC, 2001f).

Data Source

National Notifiable Diseases Surveillance System, Centers for Disease Control and Prevention. (See Appendix B, page B-29, for more information.)

Indicator: Infectious disease prevalence - Shigellosis - Category 2

Shigellosis is a bacterial disease affecting the intestinal tract. Anyone can get shigellosis, though it is most common in children between the ages of 1 and 14. Most who are infected with *Shigella* develop diarrhea, fever, and stomach cramps starting a day or two after they are exposed to the bacterium. The diarrhea is often bloody. Shigellosis usually resolves in 5 to 7 days. In some persons, especially young children and the elderly, the diarrhea can be so severe that hospitalization is necessary. Some persons who are infected may have no symptoms at all, but may pass the *Shigella* bacteria to others (CDC, 2001g).

What the Data Show

Every year, about 14,000 cases of shigellosis are reported in the U.S. Because many milder cases are not diagnosed or reported, the CDC estimates the actual number of infections to be 448,000. Shigellosis is particularly common and causes recurrent problems in settings where hygiene is poor (CDC, 2001g).

Data Source

National Notifiable Diseases Surveillance System, Centers for Disease Control and Prevention. (See Appendix B, page B-29, for more information.)

Indicator Infectious disease prevalence - Typhoid fever - Category 2

Typhoid fever is a life-threatening illness caused by the bacterium *Salmonella typhi*. Typhoid fever is characterized by fever, headache, nausea, and loss of appetite. *Salmonella typhi* lives only in humans. Persons with typhoid fever carry the bacteria in their bloodstream and intestinal tract. In addition, a small number of persons (2 to 5 percent), called carriers, recover from typhoid fever but continue to carry and shed the bacteria. Both ill persons and carriers shed *S. typhi* in their feces and urine (WHO, 1997).

What the Data Show

In the U.S., about 400 *S. typhi* cases occur each year, many of which are acquired while traveling internationally. Typhoid fever is transmitted by eating food or drinking beverages that have been handled by a person who is shedding *S. typhi*, or by consuming water contaminated with *S. typhi* bacteria (CDC, 2001h).

Data Source

National Notifiable Diseases Surveillance System, Centers for Disease Control and Prevention. (See Appendix B, page B-30, for more information.)

4.3.4 What are the trends for children's environmental health issues?

Special consideration must be given to children's health issues because children may be more susceptible to disease and generally may be more vulnerable to their surroundings for many physiological reasons. This section discusses five indicators for children's environmental health issues: infant mortality, low birthweight, childhood cancer, childhood asthma, and birth defects.

Indicator

Infant mortality - Category 1

Infant mortality in the U.S. is defined as the death of a child before age 1.

What the Data Show

In 1999, a total of 27,937 deaths occurred in infants under 1 year of age (Hoyert, et al., 2001). The infant mortality rate was 7.1 per 1,000 live births, the lowest ever recorded in the U.S. The infant mortality rate for African American infants was 14.6 per 1,000 live births, more than twice the rate for White infants (5.8 per 1,000 live births). The infant mortality rate for Hispanic infants was 5.8 per 1,000 live births. The 10 leading causes of infant deaths account for 67.6 percent of all infant deaths in the U.S. (Exhibit 4-23). Delaware, Maine, Massachusetts, and Utah have the lowest infant mortality rates. Mississippi, Alabama, and Louisiana have the highest (Hoyert, et al., 2001).

Data Source

National Vital Statistics System, Centers for Disease Control and Prevention. (See Appendix B, page B-30, for more information.)

Exhibit 4-23: Number of infant deaths, percent of total deaths, and infant mortality rates for the 10 leading causes of infant death, United States, 1999

Rank	Cause of Death	Deaths	Rate	Percent of Total Deaths
	All causes	27,937	705.6	100.0
1	Congenital malformations, deformations, and chromosomal abnormalities	5,437	138.2	19.6
2	Disorders related to short gestation and low birthweight	4,392	110.9	15.7
3	Sudden Infant Death Syndrome	2,648	66.9	9.5
4	Newborn affected by maternal complications of pregnancy	1,399	35.3	5.0
5	Respiratory distress of newborn	1,110	28.0	4.0
6	Newborn affected by complications of placenta, cord, and membranes	1,025	25.9	3.7
7	Accidents	845	21.3	3.0
8	Bacterial sepsis of newborn	691	17.5	2.5
9	Diseases of the circulatory system	667	16.8	2.4
10	Atelectasis	647	16.3	2.3
	All other causes	9,040	228.3	32.4

Rate is per 100,000 live births in 1999.

Source: Hoyert, D.L., et al. *Deaths: Final Data for 1999*. 2001.

Indicator **Low birthweight - Category 1**

An infant with low birthweight is defined as a full-term infant, born between week 37 and 44 of pregnancy, and weighing 2,500 grams or less at birth. Weight is a critical health measure because low birthweight children are more prone to death and disability than their counterparts.

What the Data Show

The percentage of infants who were born with a low birthweight (weighing less than 2,500 grams) was 7.6 percent in 2000 (Martin, et al., 2002). In 2000, the low birthweight rate for non-Hispanic African Americans (13.1 percent) was twice the rate of that for non-Hispanic Whites (6.6 percent), a relationship that existed for at least the 9 prior years as well (Exhibit 4-24). In 2000, the low birthweight rate for Hispanics was similar to that of non-Hispanic Whites (6.4 and 6.6, respectively). Also shown in Exhibit 4-24 is that non-Hispanic African Americans had the highest proportion of very low birthweight infants (weighing less than 1,500 grams) in 2000, compared with Hispanic and non-Hispanic White populations in the U.S.

Data Source

National Vital Statistics System, Centers for Disease Control and Prevention. (See Appendix B, page B-30, for more information.)

Exhibit 4-24: Percent of live births of very low birthweight and low birthweight, by race and Hispanic origin of mother, United States, 1991-2000

	Very Low Birthweight[1]			Low Birthweight[2]		
	White Non-Hispanic	Black Non-Hispanic	Hispanic[3]	White Non-Hispanic	Black Non-Hispanic	Hispanic[3]
2000	1.14	3.10	1.14	6.6	13.1	6.4
1999	1.15	3.18	1.14	6.6	13.2	6.4
1998	1.15	3.11	1.15	6.6	13.2	6.4
1997	1.12	3.05	1.13	6.5	13.1	6.4
1996	1.08	3.02	1.12	6.4	13.1	6.3
1995	1.04	2.98	1.11	6.2	13.2	6.3
1994	1.01	2.99	1.08	6.1	13.3	6.2
1993	1.00	2.99	1.06	5.9	13.4	6.2
1992	0.94	2.97	1.04	5.7	13.4	6.1
1991	0.94	2.97	1.02	5.7	13.6	6.1

[1]Less than 1,500 grams (3 lb. 4 oz.)

[2]Less than 2,500 grams (5 lb. 8 oz.)

[3]Includes all persons of Hispanic origin of any race.

Source: Martin, J.A., et al. *Births: Final Data for 2000.* 2002.

Indicators

Childhood cancer mortality - Category 1
Childhood cancer incidence - Category 2

Cancer is a disease characterized by uncontrolled growth of cells. A cancerous cell loses its ability to regulate its own growth, control cell division, and communicate with other cells. These cellular changes are complex and occur over a period of time. They may be accelerated in children. Cancer cells can invade nearby tissues and can spread through the bloodstream and lymphatic system to other parts of the body (NCI, 2003). The classification of cancers in children differs from the classification used for adult cancers.

What the Data Show

In 1999, there were nearly 2,200 deaths due to cancer in children and adolescents under 20 years of age (Anderson, 2001). The age-adjusted cancer mortality rates by race and age group are presented in Exhibit 4-25. In 1999, cancer was the third leading cause of death in children 1 to 4 years of age, accounting for 8 percent of the total deaths in this age group (Anderson, 2001). The death rate for cancer in this age group was 2.8 per 100,000 population. For children 5 to 9 years of age, cancer was the second leading cause of death accounting for 14.7 percent of total deaths. The death rate was 2.6 per 100,000 for children 5 to 9 years of age. In older children (15 to 19 years of age), 5.4 percent of total deaths in this age group were due to cancer. Cancer ranked fourth among leading causes of death, with a mortality rate of 3.8 per 100,000 population.

Exhibit 4-26 presents the age-adjusted incidence rates for cancers in children of all races between the ages of 0 and 19 years, 1975 to 1998. There has been an increase in the incidence for all types of childhood cancer since 1975. There also has been a substantial decline in the cancer death rate for children, largely due to improved treatment (EPA, December 2000).

Data Sources

Mortality: National Vital Statistics System, National Center for Health Statistics. (See Appendix B, page B-31, for more information.)

Incidence: Surveillance, Epidemiology, and End Results Program, National Cancer Institute. (See Appendix B, page B-31, for more information.)

Exhibit 4-25: Age-adjusted Surveillance, Epidemiology and End Results (SEER) childhood cancer (all sites) incidence and United States mortality rates by race and age group, 1994-1998

	Ages 0-14						Ages 0-19					
	Incidence			Mortality			Incidence			Mortality		
Race	Total	Male	Female	Total	Male	Female	Total	Male	Female	Total	Male	Female
All Races	14.4	15.4	13.4	2.7	3.0	2.4	15.9	16.7	15.0	3.0	3.3	2.6
White	14.8	15.6	13.9	2.7	3.0	2.4	16.4	17.2	15.6	3.0	3.4	2.6
Black	12.0	13.0	10.9	2.8	2.9	2.6	12.5	13.3	11.7	3.1	3.2	2.9

Rates are deaths per 100,000 per year and are age adjusted to the 1970 U.S. standard population.

Source: Ries L.A.G., et al. *SEER Cancer Statistics Review, 1973-1988.* 2001

Indicators

Childhood cancer mortality - Category 1 (continued)
Childhood cancer incidence - Category 2 (continued)

Exhibit 4-26: Age-adjusted Surveillance, Epidemiology and End Results (SEER) cancer incidence rates by international classification of childhood cancer (ICCC) selected group and subgroup and year of diagnosis, children 0 to 19 years, 1975-98

	1975-1980	1981-1986	1987-1992	1993-1998
All groups combined	140.0	149.0	157.5	159.1
Leukemia	33.2	36.3	37.6	37.4
Lymphomas and reticuloendothelial neoplasms	24.1	24.9	24.8	23.9
Central nervous system	23.4	24.3	29.6	27.8
Sympathetic nervous system tumors	7.7	8.1	7.6	8.5
Retinoblastoma	2.6	2.7	2.9	3.1
Renal tumors	6.0	6.6	6.3	7.1
Hepatic tumors	1.2	1.5	1.7	1.8
Malignant bone tumors	7.8	9.2	8.9	9.4
Soft tissue sarcomas	10.4	10.9	11.2	11.4
Germ cell, trophoblastic and other gonadal neoplasms	8.6	9.8	11.3	11.7
Carcinomas and other malignant epithelial neoplasms	13.9	13.5	14.6	15.0

Notes: Rates are cases per 1,000,000 per year and are age adjusted to the 1970 U.S. standard population.

Source: Ries, L.A.G., et al. *SEER Cancer Statistics Review, 1973-1998*. 2001.

Indicators

Childhood asthma mortality - Category 1
Childhood asthma prevalence - Category 1

Asthma is a chronic respiratory disease characterized by inflammation of the airways and lungs. During an asthma attack, the airways that carry air to the lungs are constricted. As a result, less air is able to flow in and out of the lungs (NCHS, 2001). Currently, there are no preventive measures or cure for asthma; however, children and adolescents who have asthma can still lead quality, productive lives if they control their asthma. Asthma can be controlled by taking medication and by avoiding contact with environmental “triggers” for asthma. Environmental triggers include cockroaches, dust mites, furry pets, mold, tobacco smoke, and certain chemicals (CDC, 2002g; CDC, 2003b).

What the Data Show

In 2001, approximately 6 million (9 percent) of U.S. children had asthma, compared to approximately 3.6 percent of children in 1980 (EPA, 2003a).

In 1999, there were 32 deaths due to asthma for children under 5 years of age and 144 deaths for children 5 to 14 years of age (Mannino, et al., 2002). This number is slightly lower than the 189 asthma deaths among children under 15 years of age in 1998.

Boys were more likely to have been diagnosed with asthma than girls; the condition was diagnosed in 13 percent of boys compared with 10 percent for girls. Of the 4 million children who reported that they had an asthma attack in the last 12 months, boys were most likely to have had an attack when they were 5 to 11 years of age. Girls were most likely to have had an attack in the previous year at 12 to 17 years of age. Fourteen percent of non-Hispanic African American children had been diagnosed with asthma. The proportion of non-Hispanic White and Hispanic children who had ever been diagnosed with asthma was nearly the same, 11 percent and 10 percent, respectively. Asthma rates in children have increased since 1980, especially for children age 4 and younger and for African-American children (Exhibit 4-27).

Data Sources

Mortality: National Vital Statistics System, National Center for Health Statistics. (See Appendix B, page B-31, for more information.)

Prevalence: National Health Interview Survey, Centers for Disease Control and Prevention (See Appendix B, page B-32, for more information.)

Exhibit 4-27: Asthma prevalence, 1980-1996, asthma lifetime diagnosis, current asthma, and asthma attack prevalence, 1997-2001, in children

Note: The survey questions for asthma changed in 1997; data before 1997 cannot be directly compared to data in 1997 and later.

Source: Based on and updated from Akinbami, L.J. and K.C. Schoendorf. *Trends in Childhood Asthma: Prevalence, Health Care Utilization and Mortality.* 2002. Data from CDC, National Center for Health Statistics, National Health Interview Surveys, 1980-2001.

Indicators

Deaths due to birth defects - Category I
Birth defect incidence - Category I

Congenital anomalies, or birth defects, are structural defects that are present in the fetus at birth. Because the causes of about 70 percent of all birth defects are unknown, the public continues to be anxious about whether environmental pollutants cause birth defects, developmental disabilities, or other adverse reproductive outcomes. The public also has many questions about whether various occupational hazards, dietary factors, medications, and personal behaviors cause or contribute to birth defects (CDC, 2002c).

What the Data Show

Birth defects (congenital anomalies) are a leading cause of infant deaths, accounting for 5,473 (19.6 percent) of the 27,937 infant deaths in 1999 (Hoyert, et al., 2001). The most frequently occurring types of birth defects were those affecting the heart and the lungs. Because some birth defects are not recognized immediately, they are underreported on the death certificate, so the numbers underestimate the problem (Friis, et al., 1999). Exhibit 4-28 presents the number and rate of live births with congenital anomalies.

Exhibit 4-28: Number and rate of live births with selected congenital anomalies, United States, 2000

Congenital Anomaly (All races)	Number of Congenital Anomalies Reported	Rate
Anencephalus	425	10.7
Spina bifida/Meningocele	822	20.7
Hydrocephalus	940	23.7
Microcephalus	284	7.2
Other central nervous system anomalies	822	20.7
Heart malformations	4,958	124.9
Other circulatory/respiratory anomalies	5,484	138.1
Rectal atresia/stenosis	333	8.4
Tracheo-esophageal fistula/Esophageal atresia	481	12.1
Omphalocele/Gastroschisis	1,180	29.7
Other gastrointestinal anomalies	1,185	29.9
Malformed genitalia	3,344	84.2
Renal agenesis	547	13.8
Other urogenital anomalies	3,943	99.3
Cleft lip/palate	3,259	82.1
Polydactyly/Syndactyly/Adactyly	3,460	87.2
Clubfoot	2,271	57.2
Diaphragmatic hernia	427	10.8
Other musculoskeletal/integumental anomalies	8,614	217.0
Down's syndrome	1,863	46.9
Other chromosomal anomalies	1,575	39.7

Rates are number of live births with specified congenital anomaly per 100,000 live births in specified group.

Note: Of the 4,031,591 live births, there was no response recorded for the congenital anomaly item for 61,744 births.

Source: Martin, J.A., et al. *Births: Final Data for 2000.* 2002.

Data Source

National Vital Statistics System, National Center for Health Statistics. (See Appendix B, page B-32, for more information.)

4.3.5 What are the trends for emerging health effects?

In addition to the diseases reported in the preceding pages, several other diseases are the cause of emerging concern because of their potential impacts on the health of the U.S. population. Information for eight such diseases—diabetes, Alzheimer's disease, Parkinson's disease, renal disease, autism, and three arthropod-borne diseases (Lyme disease, Rocky Mountain spotted fever, and West Nile virus)— is presented in this section. The increasing prevalence of these "emerging" illnesses positions them as potential future candidates for consideration as EPHIs. This will be dependent on their increasing prevalence in the population or a better determination of the role of exposure to environmental pollutants in the onset or exacerbation of these diseases. No specific indicators have been presented for these diseases at this time, but data collected by the CDC, individual states, and other sources illustrate the recent trends in these diseases.

Diabetes

Diabetes is a set of metabolic disorders. Diabetes mellitus (type 2) is the most common form of diabetes and is a disease whereby the body's insulin activity is altered. Insulin is a hormone that signals many biological processes such as the conversion of glucose to glycogen. Glycogen is the form in which food energy is stored in the body. The general symptoms of diabetes are elevated blood glucose levels, excessive thirst, frequent urination, and unexplained weight loss. Heredity, obesity, and age are factors that also contribute to diabetes. Estimates of the prevalence of diabetes vary widely. However, CDC estimates that there are about 11.1 million diagnosed cases of diabetes (CDC, 2002b). In addition to these cases, CDC estimates that there may be about 5.9 million more cases that are undiagnosed (CDC, 2002b). The total of 17 million diagnosed and undiagnosed cases combined amounts to a prevalence of 6.2 percent of the U.S. population. CDC estimates that 1 million new cases of diabetes are diagnosed per year among people aged 20 years and older (CDC, 2002b).

In 1999, diabetes ranked as the sixth leading cause of death in the U.S. There were 68,399 deaths due to diabetes (Hoyert, et al., 2001). The age-adjusted death rates for diabetes increased between 1980 and 1996 from 15.3 to 20.6 per 100,000 people. By 1999, the rate had risen to 25.2 per 100,000 people.

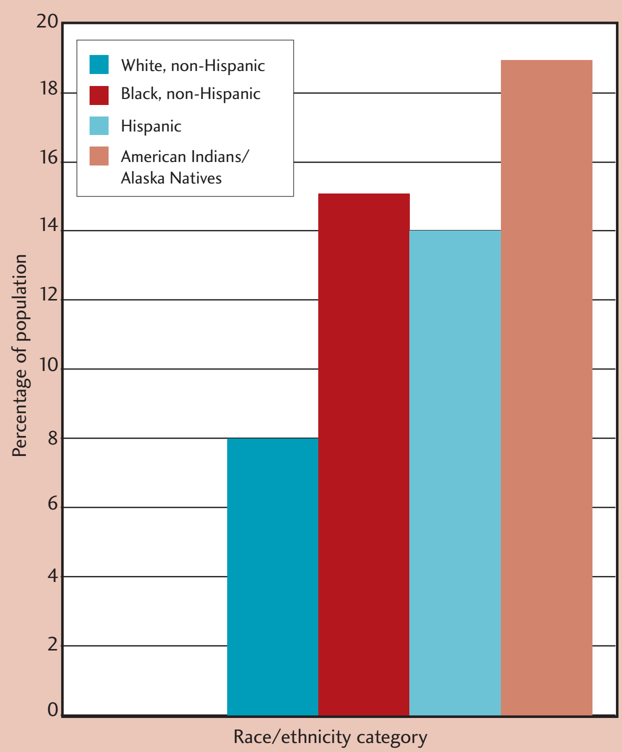
On average, Hispanic Americans are 1.9 times more likely to have diabetes than non-Hispanic Whites of similar age. The risk of diabetes for Mexican Americans and non-Hispanic Blacks is almost twice that for non-Hispanic Whites. Similarly, residents of Puerto Rico are 2.0 times more likely to have diagnosed diabetes than U.S. non-Hispanic Whites. On average, American Indians and Alaska Natives are 2.6 times more likely to have diabetes than non-Hispanic Whites of similar age. Approximately 15 percent of American Indians and Alaska Natives receiving care from the Indian Health Service have diabetes. At the regional level, diabetes is least common among Alaska Natives (5.3 percent) and most common among American Indians in the southeastern U.S. (25.7 percent) and in certain tribes from the Southwest (CDC, 2002b). Exhibit 4-29 shows age-adjusted prevalence data for diabetes in the U.S. by race/ethnicity.

Alzheimer's Disease

Alzheimer's disease is a neurodegenerative disorder. The symptoms of Alzheimer's disease may include dementia, loss of memory, and decreasing physical abilities such as dressing or eating. In the U.S., an estimated 4 million people, mostly elderly, have Alzheimer's disease (Hoyert and Rosenberg, 1999). In 1999, an estimated 354,000 non-institutionalized adults 18 to 64 years of age reported Alzheimer's disease as their main disability (CDC, 2001e).

The death rate due to Alzheimer's disease rose steadily from 1979 to 1996. In 1999, Alzheimer's disease was the eighth leading cause of

Exhibit 4-29: Age-adjusted prevalence of physician-diagnosed diabetes in persons 20 years of age and older, by race/ethnicity, United States, 2000



Source: CDC. *National Diabetes Fact Sheet.* 2002. Data from CDC, National Center of Health Statistics, National Health Interview Survey, 1997-1999 and National Health and Nutrition Examination Survey, 1988-1994.

death in the U.S. (Hoyert, et al., 2001). There were 44,536 deaths attributed to Alzheimer's disease (16.3 deaths per 100,000 population). The death rate for Alzheimer's disease rises sharply with age. In 1999, among people 75 to 84 years of age, there were 15,836 deaths and in this age group Alzheimer's disease ranked as the seventh leading cause of death (Anderson, 2001). The death rate for Alzheimer's disease for this age group was 130.4 per 100,000 population. Among persons 85 years of age and older, there were 24,980 deaths due to Alzheimer's disease for a death rate of 598.3 per 100,000 population.

Death rates for Alzheimer's disease are higher for women than for men and higher for Whites than African Americans (Hoyert, et al., 2001). The 1999 death rates for Alzheimer's disease are highest for White females (25.6 per 100,000), followed by White males (11.4), African American females (9.0), and African American males (4.2). The Alzheimer's disease death rate for Hispanics is 3.1 per 100,000. Hispanic females have a higher death rate (4.3 per 100,000 population) than Hispanic males (2.0 per 100,000). The death rates from Alzheimer's disease are higher in the Northeast and in the Northwest regions of the U.S. (Hoyert and Rosenberg, 1999).

Parkinson's Disease

Parkinson's disease is a neurodegenerative disorder characterized by symptoms such as tremors, muscle rigidity, and changes in walking patterns. The National Institute of Neurological Diseases and Stroke (NINDS) estimates that there are about 500,000 people in the U.S. with Parkinson's disease (NINDS, 2002). The disease mostly affects elderly people and is second only to Alzheimer's disease in the number of older people that are affected (Checkoway and Nelson, 1999). It affects about 0.4 percent of those 40 years of age and older, 1 percent of those older than 65 years, and about 3 percent of those 80 years of age and older. Males are 1.3 times more likely than females to have Parkinson's disease.

A steady increase in the death rate due to Parkinson's disease among people 75 years of age and older has been observed in the U.S. In 1999, there were 14,593 deaths due to Parkinson's disease (Hoyert, et al., 2001). Virtually all of the deaths (14,298) occurred in people 65 years of age and older. The death rate was 5.4 per 100,000 population, with males having a higher death rate than females (6.2 versus 4.5 per 100,000).

The 1999 death rate due to Parkinson's disease was higher for Whites (6.2 per 100,000 people) than for African Americans (1.5 per 100,000) (Hoyert, et al., 2001). The death rate for White males was 7.1 per 100,000 and for White females 5.3 per 100,000. The death rate for African American males was 1.6 and for African American females 1.3 per 100,000. The death rate for Hispanics was 1.2 per 100,000, with Hispanic males having a slightly higher death rate (1.4 per 100,000) than Hispanic females (1.1 per 100,000).

Renal Disease

The kidneys are vital organs and can be seriously affected by a number of primary diseases such as diabetes or hypertension. As these diseases progress, the kidneys may fail to function. Total and permanent kidney failure is called end stage renal (kidney) disease (ESRD). It is estimated that about 424,179 people in the U.S. have ESRD (NIDDK, 2001). Most ESRD occurred in people who have diabetes (150,404 people), hypertension (100,169 people), or glomerulonephritis, a kidney disease (62,119 people).

The U.S. government maintains the U.S. Renal Data System, which provides information on the incidence, prevalence, and mortality for ESRD (CDC, 2000a). Data from this system indicate that there were 89,252 people with ESRD who began treatment in 1999. These cases of ESRD resulted from diabetes for 38,160 people and from hypertension for 23,133 people. Kidney diseases and other primary diseases were responsible for the remainder.

Between 1979 and 1998, the age-adjusted death rates for all types of kidney disease increased, peaking between 1984 and 1988. The age-adjusted death rates for all types of kidney disease are higher among African Americans than among Whites, with African American males having the highest rates during the 1979 to 1998 period.

In 1979, the death rate for total kidney disease was 8.6 per 100,000 people. By 1999, kidney disease had risen to rank as the ninth leading cause of death in the U.S. (Hoyert, et al., 2001). That year there were 35,525 deaths due to all types of kidney disease; 34,719 of them were due to kidney failure. The death rate for kidney disease was 13.0 per 100,000 people; the death rate for kidney failure was 12.7 per 100,000 people (Exhibit 4-30). Death rates for kidney failure were highest for African American females at 19.0 per 100,000, followed by African American males at 17.8 per 100,000.

African Americans and American Indians have higher rates of ESRD than Whites or Asians (AHA, 2001). African Americans represent 32 percent of the patients receiving treatment for ESRD. Recently there has been an increase in ESRD due to diabetes among American Indians and Alaskan Natives (CDC, 2000c). Between 1990 and 1996, the age-adjusted rate of new ESRD treatment among American Indians with diabetes increased 24 percent, from 472 to 584 per 100,000 persons with diabetes.

Autism

Autism is one of several related severe cognitive and neurobehavioral disorders that are classified under the term autistic spectrum disorders. Information about the prevalence of autism in the U.S. is limited, reflecting the use of different diagnostic criteria and a lack of research. First described in the 1940s, autism was thought to affect 2 to 4 children per 10,000 population. Today the prevalence is currently believed to be as high as 1 in 500 children` for all autistic

Exhibit 4-30: Death rates for kidney disease, United States, 1999

	All Races			White			All Other			Black		
Cause of Death	Both Sexes	Male	Female	Both Sexes	Male	Female	Both Sexes	Male	Female	Both Sexes	Male	Female
Nephritis, nephrotic syndrome, nephrosis	13.0	12.8	13.3	12.5	12.4	12.6	15.6	14.8	16.3	19.3	18.2	20.2
Kidney failure	12.7	12.5	13.0	12.2	12.1	12.3	15.2	14.4	16.0	18.9	17.8	19.0
Other	0.3	0.3	0.3	0.3	0.3	0.3	0.4	0.4	0.3*	0.4	0.4*	0.4*

Rates are per 100,000 population.

*Figure does not meet the standards of reliability or precision.

Source: Hoyert, et al. *Deaths: Final Data for 1999*. 2001.

spectrum disorders (Iversen, 2000). Currently, autism affects about 400,000 people in the U.S., and occurs about four times more often in boys than in girls.

Researchers have reported that the number of persons with autism is increasing. For example, a recent California Department of Developmental Services (CDDS) report showed an over 200 percent increase in the number of persons entering the regional center service system with autism between 1987 and 1998 (CDDS, 1999). Other states have reported increasing numbers as well (Yazbak, 1999). However, these reports do not necessarily reflect a change in the rate of autism because they do not consider the increase in the total population (Fombonne, 2001).

The number of cases of autism in children in the U.S. has increased over time. The number of children 0 to 21 years old with autism who are also enrolled in federally supported programs for the disabled has grown from 5,000 in 1991 to 79,000 in 2000 (NCES, 2001). This represents an increase from 0.1 to 1.1 percent of all children with disabilities served, or an increase from 0.01 to 0.14 percent of all children in public schools.

Arthropod-Borne Diseases

Certain ticks and mosquitoes (arthropods) can carry bacteria and viruses that cause disease in humans. They acquire the bacteria and viruses when they bite an infected mammal or bird. Arthropod-borne diseases include Lyme disease, Rocky Mountain spotted fever (RMSF), and West Nile virus (WNV).

Lyme Disease

Lyme disease is the most commonly reported arthropod-borne disease in the U.S. (Orloski, et al., 2002). The illness was first described in Europe during the 1800s; however, it was not identified in the U.S. until the early 1970s when a cluster of children with "juvenile rheumatoid arthritis" in Lyme, Connecticut, was reported by their parents (Shapiro and Gerber, 2000). Investigation of the cluster led to the description of Lyme arthritis in 1976 and then to the identification of the causal pathogen. Between 1992 and 1998, there were 88,967 cases of Lyme disease reported to the CDC. The number of cases increased from 9,896 in 1992 to 16,802 in 1998 (Exhibit 4-31).

The incidence of Lyme disease was highest in eight northeastern and mid-Atlantic states and two north central states. These states accounted for 92 percent of the total cases.

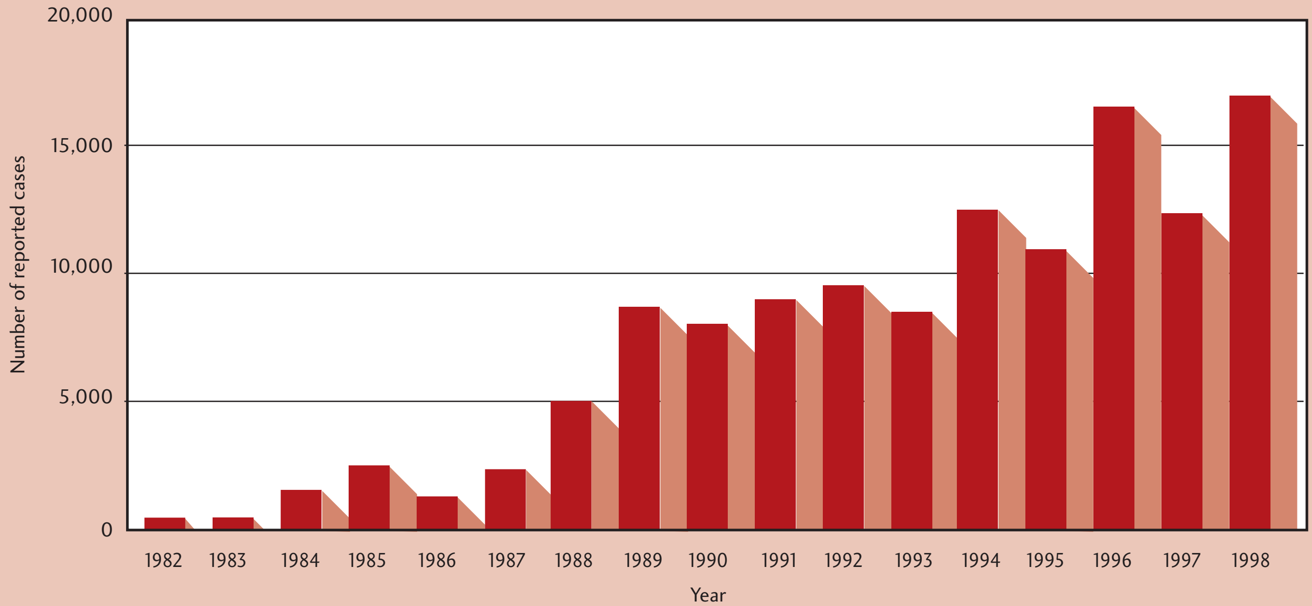
Rocky Mountain Spotted Fever

Although Lyme disease is the most commonly reported tick-borne disease in the U.S., RMSF is the most commonly *fatal* tick-borne disease in the U.S. (Holman, et al., 2001). Physicians first recognized RMSF in the northwestern U.S. during the late 1800s; Howard Ricketts identified the causal pathogen in the early 1900s (Gayle and Ringdahl, 2001; Paddock, et al., 1999). RMSF was the first disease in the U.S. shown to be transmitted by tick bite (Walker, 1998). Although RMSF was first identified in the Rocky Mountain states, fewer than 3 percent of cases were reported from that area between 1993 and 1996. The highest incidence of cases in that time period was found in North Carolina and Oklahoma. These two states accounted for 35 percent of the total cases from 1993 to 1996 (CDC, 2002c). RMSF has been reported throughout the continental U.S. (except in Maine, New Hampshire, and Vermont).

Between 1990 and 1998, there were approximately 4,800 cases of RMSF reported to the CDC (CDC, 2000b). The annual number of cases has varied between 250 and 1,200 cases since 1942, with a peak between 1975 and 1981.

The ratio of the number of deaths due to RMSF compared to the number of cases of the disease is the highest in children under 10

Exhibit 4-31: Number of reported cases of Lyme disease, United States, 1982-1998



Source: Orloski K.A., et al. *Surveillance for Lyme Disease*. 2002.

years of age (2 to 3 percent) and those over 70 years of age (9 percent) (CDC, 2000b).

West Nile Virus

In 1937, WNV, a strain of encephalitis, was first identified as a human pathogen in the West Nile region of Uganda. The pathogen was found in blood taken from a woman during a yellow fever investigation (Rappole, et al., 2000). Since 1937, WNV has been determined to be widespread in many areas of the world, particularly Africa, the Middle East, Europe, Russia, India, and Indonesia (Horga and Fine, 2001).

Cases of WNV were first documented in the U.S. in 1999 (CDC, 2000d). A total of 80 cases in humans were reported in 1999 (62 cases) and 2000 (18 cases). Because severe neurological illness (encephalitis meningitis) occurs in fewer than 1 percent of persons infected, it is thought that a greater number of cases with less severe symptoms may go unreported. Based on this assumption, it is estimated that approximately 2,000 persons may have been infected with WNV during 2000 (CDC, 2000d). The prevalence of the disease in humans is increasing. During 2002 there were 3,989 diagnosed cases in humans (CDC, 2002f). The number of deaths caused by West Nile encephalitis has increased from 7 in 1999 to 259 in 2002 (CDC, 2002f).

4.4 Measuring Exposure to Environmental Pollution: Indicators and Trends

Historically, human exposure to pollutants has been estimated based on:

- Measurements of ambient pollutant concentrations in air, water, or land, combined with:
- Estimates or measurements (through personal monitoring) of the frequency and duration of human contact with the contaminated media.

This approach has provided a valuable foundation for many of the regulatory and non-regulatory actions that have been taken to limit exposure to ambient pollutants. However, ambient measurements do not provide information on the degree to which ambient pollutants actually enter into the body. Another type of indicator—biomonitoring data—can help provide this information. Biomonitoring measures the amount of a pollutant in human tissue or fluids. It provides an important complement to more traditional exposure assessment indicators. National-scale biomonitoring data can be used to:

- Measure and track average body burden resulting from exposure across the entire population to a variety of pollutants.
- Enhance environmental disease prevention efforts by providing an important bridge to understanding the relationships between ambient pollutant concentrations, exposures to these pollutants, and health problems. (The lead case study, discussed earlier in Section 4.1, provides an excellent example of this application.)
- Establish reference ranges to identify people with unusually high exposures or the percentage of the population with pollutant exposures above established levels of concern (CDC, 2003a).

This section focuses primarily on biomonitoring indicators and is divided into ten parts:

- Section 4.4.1 provides background information on biomonitoring indicators—what they are and their limitations.
- Section 4.4.2 describes the major data sources for these indicators.
- Sections 4.4.3 to 4.4.8 describe specific pollutants and the data available to monitor these pollutants, including heavy metals (Section 4.4.3), cotinine (Section 4.4.4), volatile organic compounds (Section 4.4.5), pesticides (Section 4.4.6), and persistent organic pollutants (Section 4.4.7). Section 4.4.8 presents indicators that are available to specifically monitor children's exposure to some of these pollutants. In all, 10 biomonitoring indicators are currently available for tracking trends in human exposure to specific environmental pollutants. Summaries of the data linking exposure to human health effects can be found in ATSDR's toxicological profiles and EPA's criteria documents for these chemicals.
- Section 4.4.9 briefly discusses a number of pollutants—radiation, air pollutants (except for lead), biological pollutants, and disinfection by-products —for which no biomonitoring indicators currently are available or feasible. For these pollutants, traditional exposure assessment will continue to serve as the method for estimating human exposure until biomonitoring indicators become available or feasible.
- Finally, Section 4.4.10 touches on endocrine disruptors—considered an emerging issue.

4.4.1 Biomonitoring Indicators

"Dose" (the amount of a pollutant that enters the body) is often expressed as average daily dose or total potential dose. Once a pollutant crosses the boundary into the body, biological processes act on that contaminant to utilize, remove, or store the contaminant and/or its metabolites. Body burden is the concentration of a contaminant dose that is retained in the human body. Body burden can be estimated from measurements of the contaminant in the blood, urine, or adipose tissue. These measurements provide the basis for biomonitoring indicators.

The buildup of a contaminant in the body (i.e., the level of body burden) depends on a variety of factors, including the nature of the contaminant; the efficacy of the biological removal processes; and the magnitude, timing, frequency, and duration of exposure. Some contaminants, such as lead, are not easily removed and are retained in the body for long periods of time. Other contaminants, such as many volatile organic compounds (VOCs), are rapidly eliminated in exhaled breath or other removal processes.

The level of body burden is usually estimated from the concentration of a contaminant (or its metabolite) measured in the blood, urine, hair, or adipose tissue, and can be used to infer that an exposure occurred. In some cases, the level of body burden associated with a particular contaminant may prove to be an indicator of the person's extent of exposure to that pollutant.

There are a number of potential problems, however, with using body burden as an indicator of exposure. In some cases, several different pollutants may give rise to the same biomarker. Further, most measures of body burden reflect only a "snapshot" in time and many different exposure scenarios can lead to the same concentration measurement. Lastly, the measure gives no information about how the person was exposed.

Nonetheless, national scale measures of body burden are useful indicators of exposure in the population. While such measures do not necessarily provide information about the nature of the exposures, they do represent the average levels of exposure in the population as a whole. Such national scale measures of body burden are often more convenient to obtain than to estimate the exposures by accounting for all of the exposure concentrations and durations for the whole population. As mentioned earlier, body burden (biomonitoring) data are not available for all pollutants of interest to EPA. In such cases, ambient data or exposure measurements and models are used to assess human exposure.

4.4.2 Data Sources for Biomonitoring Indicators

Two primary sources provided data for the biomonitoring indicators presented in this section:

- **The National Health and Nutrition Examination Survey (NHANES)**, conducted by the National Center for Health Statistics (NCHS). Specifically, data were used from the second, third, and fourth surveys (NHANES II; NHANES III; and NHANES IV [1999-2000]).
- **EPA's National Human Exposure Assessment Survey (NHEXAS)**. Specifically, data were used from surveys of three regions: Maryland, EPA Region 5, and Arizona (NHEXAS–MD; NHEXAS–Region 5; and NHEXAS–AZ).

Two others sources of biomonitoring data—autopsy data and tissue registry data—were considered but not used for these indicators. As described below, neither of these sources contains rich biomonitoring data, which significantly limits their usefulness as data sources for human contaminant levels.

National Center for Health Statistics, National Health and Nutrition Examination Survey (NHANES)

NHANES consists of a series of surveys conducted by CDC's NCHS. The survey is designed to collect data on the health of the U.S. population, including information on topics such as nutrition, cardiovascular disease, and exposure to chemicals (CDC, 2001c). The NHANES surveys have been performed over a number of years. The first survey, NHANES I, took place from 1971 through 1975; NHANES II occurred from 1976 through 1980; NHANES III was performed from 1988 through 1994; and the most recent NHANES for which data are available took place in 1999-2000. In this section, the year(s) in which the data were collected are identified in each citation of NHANES.

As part of the survey, blood and urine samples were collected to measure the amounts of certain chemicals thought to be potentially harmful to people. Because of the extensive work involved with laboratory analysis, some chemicals were measured for all people in the survey, while other chemicals were only measured in representative subsamples of people in an age group.

The CDC National Report on Human Exposure to Environmental Chemicals (often referred to as the "CDC Report Card") (CDC, 2001c) summarizes chemical exposure data from NHANES. Information from the CDC report is presented hereafter under the heading "NHANES 1999-2000." To date, this report has been released twice. Data from the first report are updated in the larger, second report. The second report represents the U.S. population over a 2-year period, 1999-2000. Two years of data provide more stable estimates for the total population and are necessary for adequate sample sizes for some subgroup analysis. Future reports will be released every 2 years and will cover data for a 2-year period (e.g., 2001-2002, 2003-2004, 2005-2006).

National Human Exposure Assessment Survey (NHEXAS)

The goal of NHEXAS was to better understand the complete picture of human exposure to toxic chemicals by looking at humans' many exposures to all types of toxic chemicals. NHEXAS was a multiday, multimedia study that examined chemical concentrations in indoor air, outdoor air, dust, soil, food, beverages, drinking water, and tap water. For some contaminants, body burden measurements were obtained from samples of blood, hair, or urine.

Phase 1 of NHEXAS consisted of demonstration and scoping studies in Maryland; Phoenix, Arizona; and EPA Region 5 using probability-based sampling designs. Although the study was conducted in three different regions of the U.S., it was not designed to be nationally representative. The Region 5 study was conducted in Ohio, Michigan, Illinois, Indiana, Wisconsin, and Minnesota and measured metals and VOCs. The Arizona study measured metals, pesticides, and VOCs. The target population for the NHEXAS-MD study consisted of the non-institutionalized permanent residents of households in the city of Baltimore or four counties in Maryland. Samples from select environmental and biological media, as well as questionnaire data, were collected in NHEXAS-MD. The three NHEXAS studies are identified in this section as NHEXAS-AZ, NHEXAS-Region 5, or NHEXAS-MD, to indicate where they were performed.

Autopsy Data

Autopsies can provide important information about deaths resulting from known or suspected environmental or occupational hazards. For example, one of the earliest indications of the rise in lung cancer deaths came from reports that lung cancers were being identified with increasing frequency in autopsies (Hanzlick, 1998).

The value of an autopsy database for body burden and epidemiologic studies has been recognized; however, few such studies have been conducted. This is partly because autopsies are performed on a non-random sample of deaths and because environmental contaminant levels are typically not measured during an autopsy (Moore, et al., 1996). Also, autopsies are performed on only a small percentage of the U.S. population. In 1980, autopsies were performed in approximately 17 percent of deaths in the U.S. By 1985, the percentage had declined to 14 percent. While nearly all deaths due to homicide and other medico-legal causes were autopsied, autopsies were performed in only 12 percent of all deaths due to natural causes (CDC, 1998a).

Difficulties in accessing autopsy data can limit their usefulness as well. Prior to 1995, the National Center for Health Statistics (NCHS) collected data from death certificates indicating whether an autopsy was performed. Since that time, however, such information is no longer available from the NCHS national mortality statistics databases (Hanzlick, 1998).

Tissue Registry Data

Human tissues are stored for study in many forms including solid organs, organ sections, histology slides, cells, and DNA. Tissue registries are maintained for medical education and biological research, but few studies have been conducted to identify trends in environmental contaminants in tissues using tissue registries. Tissue registry samples and information are not population-based, and at present there is no central database containing information about tissue samples (Eiseman and Haga, 1999).

EPA has conducted one of the most extensive tissue studies. From 1976 to 1987, the EPA conducted the National Human Adipose Tissue Survey (NHATS). NHATS was a national survey that collected adipose tissue samples to monitor exposure to toxic compounds among the general population. Pathologists and medical examiners from 47 metropolitan areas collected samples from autopsies and elected surgeries (Crinnion, 2000; Orban, et al., 1994). Even though the study was a significant biomonitoring effort, data from NHATS are not presented in this report because newer data sources are available.

4.4.3 What is the level of exposure to heavy metals?

Heavy metals are important environmental pollutants because they are related to several adverse health effects when ingested or inhaled. Five metals have been selected for in-depth presentation in this section: chromium, lead, arsenic, mercury, and cadmium. These metals are known to be related to severe adverse health effects and are relatively common in household, work, and school environments. Exhibit 4-32 presents EPA regulatory standards and guidelines for these five metals. Indicators are available for lead, arsenic, mercury, and cadmium and are discussed on the following pages. At present, no indicator is available for chromium, but it is discussed below because human health may be adversely affected by chromium in the environment. (For additional information on heavy metals in the environment, see Chapter 1, Cleaner Air.)

Chromium

Chromium is a naturally occurring element found in rocks, animals, plants, soil, and in volcanic dust and gases. Chromium is present in the environment in several different forms, but primarily in two valence states: trivalent chromium (III) and hexavalent chromium (VI). Chromium (III) is an essential nutrient and is much less toxic than chromium (VI), which is generally produced by industrial processes. Chromium (III) and chromium (VI) are used for chrome plating, dyes and pigments, leather tanning, and wood preserving (ATSDR, 2001).

In air, chromium compounds are present mostly as fine dust particles that eventually settle over land and water. Chromium can strongly attach to soil and only a small amount can dissolve in water and move deeper in the soil to underground water. Fish do not accumulate much chromium in their bodies from water (ATSDR, 2001).

People can be exposed to chromium by eating food containing chromium (III); breathing contaminated workplace air or experiencing skin contact during use in the workplace; drinking contaminated well water; or living near uncontrolled hazardous waste sites containing chromium or near industries that use chromium (ATSDR, 2001). Although studies have been conducted that measure the amount of chromium in drinking water, ground water, soil, and air, there are no studies that measure the body burden of chromium in human tissue.

Chromium III is an essential nutrient that helps the body use sugar, protein, and fat. An intake of 50-200 µg of chromium (III) per day is recommended for adults. On average, adults in the U.S. take in an estimated 60-80 µg of chromium per day in food. Therefore, many people's diets may not provide enough chromium (III). Without chromium III in the diet, the body loses its ability to use sugars, proteins, and fat properly, which may result in weight loss or decreased growth, improper function of the nervous system, and a diabetic-like condition. Therefore, chromium (III) compounds have been used as dietary supplements and are beneficial if taken in recommended (but not excessive) dosages (ATSDR, 2000). Chronic high exposures to chromium (III), however, may affect the skin, liver, or kidneys (ACGIH, 1991; Rom, 1992).

In general, chromium (VI) is more toxic than chromium III. Breathing in high levels (greater than 2 $\mu g/m^3$) of chromium (VI), such as in a compound known as chromic acid or chromium (VI) trioxide, can irritate the nose, causing symptoms such as runny nose, sneezing, itching, nosebleeds, ulcers, and holes in the nasal septum. These effects have primarily occurred in factory workers who make or use chromium (VI) for several months to many years. Long-term exposure to chromium (VI) has been associated with lung cancer in workers exposed to levels in air that were 100 to 1,000 times higher than those found in the natural environment. Lung cancer may occur long after exposure to chromium VI has ended (ATSDR, 2000).

No biomonitoring data are readily available for chromium. Interest is developing in examining chromium as an emerging environmental pollutant.

Exhibit 4-32: United States federal standards and criteria for five heavy metals

Heavy Metal	Drinking Water Maximum Contaminant Level (MCL)[1]	Ground Water Cleanup Level[2]	Air Standards
Lead	0.015 mg/L	0.015 mg/L	1.5 µg/L[3]
Arsenic	0.01 mg/L	0.01 mg/L	Not Applicable[4]
Mercury	0.002 mg/L	0.002 mg/L	Not Applicable[5]
Chromium	0.1 mg/L	0.1 mg/L	Not Applicable[4]
Cadmium	0.005 mg/L	0.005 mg/L	Not Applicable[4]

1. MCLs are regulatory standards developed pursuant to the Federal Safe Drinking Water Act (SDWA).
2. A groundwater cleanup level is most often the MCL (per the Comprehensive Environmental Response, Compensation, and Liability Act [CERCLA] [also known as Superfund] and Resource Conservation and Recovery Act [RCRA] guidance) for the particular contaminant. Groundwater cleanup levels are established by EPA and states on a case-by-case basis for Superfund site clean-ups and corrective actions at RCRA solid and hazardous waste management.
3. This standard is a quarterly average. Lead is a criteria air pollutant (under the Clean Air Act) and therefore has a health-based standard.
4. This heavy metal is not a criteria air pollutant and thus there is not a health-based standard. Air pollution standards for this heavy metal are technology-based standards, not health-based standards. For example, the emission standard for arsenic is that which is achievable with the best available technology (BAT) for treating arsenic air emissions. In addition, the BAT for arsenic emissions varies across industry sectors and thus emission standards for arsenic also vary across industry sectors.

Source: EPA. *Current Drinking Water Standards.* 2002; EPA. EPA. *Handbook of Groundwater Policies for RCRA Corrective Action.* 2000; EPA. *National Air Quality and Emissions Trends Report 1999*. 2001.

Indicator Blood lead level - Category 1

Lead is a naturally occurring metal found in small amounts in rock and soil. Lead has been used industrially in the production of gasoline, ceramic products, paints, and solder. Lead-based paint and lead-contaminated dust from paint are the primary sources of lead exposure in the home. The body burden of lead can be measured as the amount of lead in blood or the amount of lead in urine. The health effects of lead are discussed in Section 4.1 of this chapter.

What the Data Show

NHANES 1999-2000. The mean blood lead levels for adults are illustrated in Exhibit 4-33. The mean blood lead level for all males in the survey was 2.0 micrograms per deciliter (µg/dL) and 1.4 µg/dL for all females. The mean blood lead level for non-Hispanic African Americans was 1.9 µg/dL. The mean blood lead level for Mexican Americans was 1.8 µg/dL (CDC, 2001c).

NHANES III (1988-1994). Blood lead levels of people were surveyed in two separate phases of NHANES III. The data collected during Phase 2 (1991 through 1994) indicated that the U.S. population's exposure to lead was decreasing.

NHEXAS-Region 5. Blood lead levels for 165 participants were obtained during NHEXAS-Region 5. Lead levels in blood were detectable for about 94 percent of the population; most of the individuals had lead levels well below 10 µg/dL. The mean blood lead level of the participants was 2.18 µg/dL (Clayton, et al., 1999).

Data Source

NHANES 1999-2000, National Center for Health Statistics. (See Appendix B, page B-33, for more information.)

Exhibit 4-33: Geometric mean and selected percentiles of total blood lead concentrations (in µg/dL) for the United States population, aged 1 year and older, by selected demographic groups, National Health and Nutrition Examination Survey (NHANES), 1999-2000

			Selected Percentiles				
	Sample Size	Geometric Mean	10th	25th	50th	75th	90th
Total, Age 1 and older	7,970	1.7	0.8	1.0	1.6	2.4	3.8
Sex							
Male	3,913	2.0	0.8	1.3	1.8	2.9	4.4
Female	4,057	1.4	0.6	0.8	1.3	1.9	3.0
Race/Ethnicity							
Black, non-Hispanic	1,842	1.9	0.7	1.1	1.7	2.8	4.2
Mexican American	2,743	1.8	0.8	1.2	1.8	2.7	4.2
White, non-Hispanic*	2,715	1.6	0.6	1.0	1.6	2.4	3.6
Age Group							
1-5 years	723	2.2	1.0**	1.4	2.2	3.3	4.8**
6-11 years	905	1.5	0.7	0.9	1.3	2.0	3.3
12-19 years	2,135	1.1	0.4	0.8	1.0	1.4	2.3
20 years and older	4,207	1.8	0.7	1.0	1.7	2.5	3.9

* Includes other racial/ethnic groups.

Source: CDC. *Second National Report on Human Exposure to Environmental Chemicals.* 2003.

Indicator

Urine arsenic level - Category 2

Arsenic occurs in rock, soil, water, air, plants, and animals. Exposure occurs when arsenic is further released into the environment through erosion, volcanic action, forest fires, or human actions. Human activities involve its use in wood preservatives, dyes, paints, paper production, and cement manufacturing. Arsenic mining is also a source of human exposure (EPA, 2001a).

Inorganic arsenic has been recognized as a human poison since ancient times, and large oral doses (above 60,000 ppb in food or water) can produce death. Lower levels of inorganic arsenic (ranging from about 300 to 30,000 ppb in food, water, or pharmaceuticals) may cause symptoms such as stomach ache, nausea, vomiting, and diarrhea. Inorganic arsenic is a multi-site human carcinogen. Populations with exposures above several hundred ppb are reported to have increased risks of skin, bladder, and lung cancer. The U.S. Department of Health and Human Services (USDHHS) has determined that inorganic arsenic is a known carcinogen. The International Agency for Research on Cancer (IARC) had determined that inorganic arsenic is carcinogenic to humans. Both the EPA and the National Toxicology Program (NTP) have classified inorganic arsenic as a known human carcinogen (ATSDR, 2001).

A large number of adverse noncarcinogenic effects have been reported in humans. The most prominent are changes in the skin, (e.g., hyperpigmentation and keratoses). Other effects that have been reported include alterations in gastrointestinal, cardiovascular, hematological, pulmonary, neurological, immunological, and reproductive developmental function (NRC, 1999).

Children who are exposed to arsenic may have many of the same effects as adults, including irritation of the stomach and intestines, blood vessel damage, skin changes, and reduced nerve function. Thus, all health effects observed in adults are of potential concern in children (ATSDR, 2001).

What the Data Show

NHEXAS-Region 5. Arsenic levels in urine were measured for approximately 202 participants during NHEXAS-Region 5. The mean urine arsenic level was 29.32 micrograms per liter (μg/L), while the median urine arsenic level was 3.65 μg/L. The mean level is much higher than the median level, indicating that the distribution is highly skewed to the higher values (Clayton, et al., 1999).

NHANES. Future NHANES studies will include arsenic. Therefore, NHANES will serve as the biomonitoring data source for arsenic. When NHANES becomes the indicator data source for arsenic, the indicator will become a Category 1 indicator.

Data Source

NHEXAS, Environmental Protection Agency. (See Appendix B, page B-33, for more information.)

Indicator Blood mercury level - Category 1

Mercury is a naturally occurring metal that is widespread and persistent in the environment. It is found in elemental form and in various organic compounds and complexes. Methylmercury (one organic form of mercury) can accumulate up the food chain in aquatic systems and lead to high concentrations of methylmercury in predatory fish. Consumption of contaminated fish is the major source of human exposure to methylmercury in the U.S. (NRC, 2000).

Methylmercury is rapidly absorbed from the gastrointestinal tract and readily enters the brain, where it accumulates and is slowly converted to inorganic mercury. A spectrum of adverse health effects has been observed following methylmercury exposure, with the severity depending largely on the magnitude of the dose. The most severe effects reported in humans were seen following high-dose poisoning episodes in Japan and Iraq. The fetus is considered much more sensitive than the adult. Prenatal exposures interfere with the growth and migration of neurons and have the potential to cause irreversible damage to the developing central nervous system. Infants exposed in utero during the Japan and Iraqi episodes were born with severe disabilities, such as mental retardation, seizure disorders, cerebral palsy, blindness, and deafness. Chronic low-dose prenatal methylmercury exposure from maternal consumption of fish has been associated with more subtle end points of neurotoxicity (e.g., IQ deficits, abnormal muscle tone, decrements in motor function, attention and visuospatial performance) (NRC, 2000).

The human health effects of mercury are diverse and depend upon the forms of mercury encountered and the severity and length of exposure. Large acute exposures to elemental mercury vapor can result in lung damage. Lower dose or chronic inhalation may affect the nervous system, resulting in symptoms such as weakness, fatigue, weight loss, gastrointestinal problems, and behavioral and personality changes. Organic mercury is more toxic than inorganic and elemental mercury (CDC, 2001c). Health effects of organic mercury include vision changes, sensory changes in the limbs, cognitive disturbances, dermatitis, and muscle deterioration. The developing nervous system of the fetus and infants is susceptible to the effects of methylmercury (CDC, 2003).

Exhibit 4-34: Geometric mean and selected percentiles of blood mercury concentrations (in µg/L) for males and females aged 1-5 years and females aged 16 to 49 years in the U.S. population, National Health and Nutrition Examination Survey (NHANES), 1999-2000

			Selected Percentiles				
	Sample Size	Geometric Mean	10th	25th	50th	75th	90th
Age Group and Sex							
Males/Females 1-5 years	705	0.3	<LOD	<LOD	0.3	0.5	1.4
Males	387	0.3	<LOD	<LOD	0.2	0.5	1.1
Females	318	0.3	<LOD	<LOD	0.2	0.8	1.6
Females 16-49 years	1709	1.0	0.2	0.4	0.9	2.0	4.9
Race/Ethnicity (females 16-49 only)							
Mexican Americans	579	0.8	0.2	0.4	0.9	1.4	2.6
Non-Hispanic blacks	370	1.4	0.3	0.6	1.3	2.6	4.8
Non-Hispanic whites	588	0.9	<LOD	0.4	0.9	1.9	5.0

<LOD means less than the limit of detection, which is 0.14 µg/L.

Source: CDC. *Second National Report on Human Exposure to Environmental Chemicals*. 2002.

What the Data Show

NHANES 1999-2000. The blood mercury level reported in NHANES is total blood mercury, including both organic and inorganic mercury. Mercury levels were measured in blood and urine during NHANES 1999-2000 for 705 children aged 1-5 years, and 1,709 adult females aged 16-49. The mean blood mercury level for males and females aged 1-5 years was 0.34 micrograms per liter (µg/L), and the mean blood mercury level for adult females was 1.02 µg/L.

NHEXAS-Region 5. Mercury concentrations in human hair were measured for 182 participants during NHEXAS-Region 5. The mean mercury level in hair, annualized for seasonality, was 287 ppb. More people in older age categories have high levels of mercury in their hair. This increase in mercury level was found not to be an effect of income level (Pellizari, et al., 1999).

Data Source

NHANES 1999-2000, National Center for Health Statistics. (See Appendix B, page B-33, for more information.)

Indicator Blood cadmium level - Category 1

Elemental cadmium is a metal that is usually found in nature combined with other elements such as oxygen, chlorine, or sulfur. Cadmium enters the environment from the weathering of rocks and minerals that contain cadmium. Exposure to cadmium can occur in occupations such as mining or electroplating, where cadmium is used or produced. Cadmium exposure can also occur from exposure to cigarette smoke (CDC, 2001c).

Cadmium and its compounds are toxic. Once absorbed into the human body, cadmium can remain for decades. Exposure to cadmium for many years may result in cadmium accumulation in the kidneys and serious kidney damage. Chronic ingestion of cadmium has resulted in osteomalacia, a bone disorder similar to rickets. Acute airborne exposure, as occurs from welding on cadmium-alloy metals, can result in swelling (edema) and scarring (fibrosis) of the lungs (CDC, 2003).

What the Data Show

NHANES 1999-2000. This survey measured blood cadmium levels in people 1 year and older, and urine cadmium levels in a sample of people 6 years and older. Recent advances in analytical chemistry have made it possible to measure cadmium in very small amounts in blood and urine. Finding a measurable amount of cadmium in the blood or urine does not mean that the level of cadmium causes an adverse health effect (CDC, 2001c). The blood cadmium biomonitoring measurements are similar among males and females as well as among the racial or ethnic groups sampled. Exhibit 4-35 shows that blood levels were higher among people 20 years of age or older than for people younger than 20 years of age (CDC, 2001c). The mean urine cadmium level was 0.3 µg/L (CDC, 2001c).

Data Source

NHANES 1999-2000, National Center for Health Statistics. (See Appendix B, page B-34, for more information.)

Exhibit 4-35: Geometric mean and selected percentiles of blood cadmium concentrations (in µg/L) for the United States population, aged 1 year and older, by selected demographic groups, National Health and Nutrition Examination Survey (NHANES), 1999-2000

			Selected Percentiles				
	Sample Size	Geometric Mean	10th	25th	50th	75th	90th
Total, Age 1 and Older	7,970	0.4	<LOD	<LOD	0.3	0.6	1.0
Sex							
Male	3,913	0.4	<LOD	<LOD	0.4	0.6	1.0
Female	4,057	0.4	<LOD	<LOD	0.3	0.6	1.0
Race/Ethnicity							
Black, non-Hispanic	1,842	0.4	<LOD	<LOD	0.3	0.6	1.0
Mexican American	2,743	0.4	<LOD	<LOD	0.4	0.4	0.7
White, non-Hispanic*	2,715	0.4	<LOD	<LOD	0.4	0.5	1.0
Age Group							
1-5 years	723	**	<LOD	<LOD	<LOD	0.3	0.4
6-11 years	905	**	<LOD	<LOD	<LOD	0.3	0.4
12-19 years	2,135	0.3	<LOD	<LOD	0.3	0.3	0.8
20+ years	4,207	0.5	<LOD	<LOD	0.4	0.6	1.0

* Includes other racial/ethnic groups. <LOD= Less than the limit of detection of the analytical method.

Source: CDC. *Second National Report on Human Exposure to Environmental Chemicals.* 2003.

4.4.4 What is the level of exposure to cotinine?

Environmental tobacco smoke (ETS) is a dynamic, complex mixture of more than 4,000 chemicals found in both vapor and particle phases. Many of these chemicals are known toxic or carcinogenic agents (ALA, et al., 1994). The EPA has classified ETS as a known human carcinogen and estimates that it is responsible for approximately 3,000 lung cancer deaths per year among non-smokers in the U.S. (EPA, NCEA, December 1992).

Cotinine is a major metabolic product of nicotine and is currently regarded as the best biomarker for exposure of active smokers and non-smokers to ETS. Measuring cotinine is preferred over measuring nicotine because, although both are specific for exposure to tobacco, cotinine remains in the body much longer than nicotine.

Indicator Blood cotinine level - Category I

Cotinine can be measured in blood, urine, saliva, and hair. Non-smokers exposed to ETS have cotinine levels of less than 1 nanogram per milliliter (ng/mL), with heavy exposure to ETS producing levels in the 1 to 15 ng/mL range. Active smokers almost always have levels higher than 15 ng/mL (CDC, 2001c).

What the Data Show

NHANES 1999-2000. Exhibit 4-36 presents data for the U.S. non-smoking population aged 3 years and older. Males have higher levels than females, and people aged 20 years and older have lower levels than those younger than 20 years of age. Levels for non-Hispanic African Americans are higher than for other ethnic groups (CDC, 2001c).

NHANES III (1988-1991). As part of NHANES III, CDC determined that the median level of cotinine among non-smokers in the U.S. was 0.20 ng/mL (Pirkle, et al., 1996, in CDC, 2001c). Results from NHANES 1999-2000 show that the median cotinine level has decreased to less than 0.050 ng/mL—more than a 75 percent decrease from NHANES III to NHANES 1999-2000 (CDC, 2001c). NHANES III (1988-1991) provided the first evidence from a national study that serum cotinine levels are higher among Black smokers than among White or Mexican American smokers at all levels of cigarette smoking (Caraballo, et al., 1998).

Data Source

NHANES 1999-2000, National Center for Health Statistics. (See Appendix B, page B-34, for more information.)

Exhibit 4-36: Selected percentiles of serum cotinine concentrations (in ng/mL) for the United States non-smoking population, aged 3 years and older, National Health and Nutrition Examination Survey (NHANES), 1999-2000

	Sample Size	Selected Percentiles				
		10th	25th	50th	75th	90th
Total, Age 3 years and Older	5,999	<LOD	<LOD	0.06	0.24	1.02
Sex						
Male	2,789	<LOD	<LOD	0.08	0.30	1.20
Female	3,210	<LOD	<LOD	<LOD	0.18	0.85
Race/Ethnicity						
Black, non-Hispanic*	1,333	<LOD	<LOD	0.13	0.50	1.43
Mexican American	2,242	<LOD	<LOD	<LOD	0.14	0.51
White, non-Hispanic**	1,949	<LOD	<LOD	0.05	0.21	0.95
Age Group						
3-11 years	1,174	<LOD	<LOD	0.11	0.50	1.88
12-19 years	1,773	<LOD	<LOD	0.11	0.54	1.65
20+ years	3,052	<LOD	<LOD	<LOD	0.17	0.63

* Research in progress to determine whether levels for black, non-Hispanic people may be affected by biological factors.
** Includes other racial/ethnic groups.
<LOD= Less than the limit of detection of 0.05 ng/mL in serum.

Source: CDC. *Second National Report on Human Exposure to Environmental Chemicals.* 2003.

4.4.5 What is the level of exposure to volatile organic compounds?

In addition to the health effects attributed to VOCs themselves, VOCs are also chemical compounds that contribute significantly to the formation of ground-level ozone (smog) when released to the air. Exposure to ground-level ozone can damage lung tissue and cause serious respiratory illness. (For additional information on VOCs in the environment, see Chapter 1, Cleaner Air.)

Indicator Blood VOC levels - Category 1

Biomonitoring data for volatile compounds are difficult to obtain because these compounds do not persist for very long in the body. For this reason, biomonitoring data are indicative of recent exposure only. Only relatively older sources of data, NHEXAS and NHANES III, are available for the body burden of VOCs.

What the Data Show

NHEXAS-Region 5. Blood levels of four VOCs were obtained for participants in NHEXAS-Region 5. The four compounds were benzene, chloroform, tetrachloroethylene (PERC), and trichloroethylene (TCE). The mean level of benzene measured in blood was 0.07 µg/L. The mean level of chloroform was 0.07 µ/L. The mean level of PERC was 0.21 µg/L. The mean level of TCE was below the limit of detection (Clayton, et al., 1999).

NHANES III (1988-1994). Blood samples were analyzed for the presence of VOCs during NHANES III. NHANES III was conducted on a nationwide probability sample of approximately 33,994 persons aged 2 months or older. Of these, an exposure questionnaire was administered and blood samples analyzed for VOCs in a convenience sample of 1,018 adult participants aged 20 to 59 years. Toluene, styrene, and benzene were present in the blood of more than 75 percent of the participants. Analysis of this and other data collected during NHANES III shows a strong association between lifetime cigarette smoking and toluene, benzene, and styrene levels (Churchill and Kaye, 2001).

Data Source

NHANES III (1988-1994), National Center for Health Statistics. (See Appendix B, page B-34, for more information.)

4.4.6 What is the level of exposure to pesticides?

Organophosphate pesticides account for about half of the insecticides used in the U.S. Organophosphate pesticides are active against a broad spectrum of insects and are used on food crops as well as in residential and commercial buildings and on ornamental plants and lawns. Exposure to these pesticides occurs primarily from ingestion of food products or from residential use (CDC, 2001c).

The mechanism of toxicity of the organophosphate pesticides is to inhibit the enzyme that breaks down acetylcholine, which transfers nerve impulses between nerve cells or from a nerve cell to other types of cells, such as muscle cells. This leads to a buildup of acetylcholine, which overstimulates muscles, causing symptoms such as weakness and paralysis (CDC, 2001c). (For additional information on pesticides in the environment, see Chapter 1, Cleaner Air; Chapter 2, Purer Water; and Chapter 3, Better Protected Land.)

Indicator

Urine organophosphate levels to indicate pesticides - Category I

Pesticides biomonitoring data are obtained by measuring the chemicals that pesticides are broken down into in the body. Measurement of these pesticide metabolites reflects exposure to pesticides that has occurred predominantly in the last few days (CDC, 2001c). The reason is that these metabolites persist within the body for only a short time.

Presently, national biomonitoring data are available primarily for organophosphate pesticides. Future studies may provide additional indicators for non-organophosphate pesticides, such as carbamates and persistent pesticides.

What the Data Show

NHANES 1999-2000. Urine levels of organophosphate pesticide metabolites were measured in a subsample of NHANES participants 6 through 59 years of age who were selected to be representative of the U.S. population. Finding a measurable amount of one or more metabolites in urine does not mean that the level of the organophosphate causes an adverse health effect. Whether organophosphate pesticides at the levels of metabolites reported during NHANES 1999-2000 are a cause for health concern is not known (CDC, 2001c). Exhibit 4-37 shows the amount of each metabolite in urine reported in NHANES 1999-2000.

NHEXAS-MD. Urine levels of metabolites of some common pesticides were measured during NHEXAS-MD. 1-naphthol (1NAP) is a urinary metabolite of both carbaryl and naphthalene. The mean urine level of 1NAP measured for 338 participants was 33.7 µg/L. 3,5,6-trichloro-2-pyridinol (TCPY) is the major metabolite in urine of the pesticides chlorpyrifos, chlorpyrifos-methyl, and triclopyr. The mean urine level of TCPY measured for 346 participants was 6.8 µg/L. Malathion dicarboxylic acid (MDA) is a principal metabolite of malathion, an organophosphate pesticide used against insects. The mean urine level for MDA measured during NHEXAS-MD was below the level of detection. Atrazine mercapturate (AM) is a urinary metabolite of atrazine, a widely used herbicide in the U.S. The mean urine level for AM measured during NHEXAS-MD was below the level of detection (MacIntosh, et al., 1999).

Exhibit 4-37: Geometric mean and selected percentiles of selected pesticide metabolite urine concentrations and creatinine-adjusted levels for the United States population aged 6-59 years, National Health and Nutrition Examination Survey (NHANES), 1999-2000

	Sample Size	Geometric Mean	Selected Percentiles (95% confidence interval) 10th	25th	50th	75th	90th
Dimethylphosphate							
µg/L of urine	1,949	NC	< LOD	< LOD	0.74	2.80	7.90
µg/g of creatinine*	1,949	NC	< LOD	< LOD	0.81	2.93	8.46
Dimethylthiophosphate							
µg/L of urine	1,948	1.82	< LOD	< LOD	2.70	10.0	38.0
µg/g of creatinine*	1,948	1.64	< LOD	< LOD	2.12	9.57	32.0
Dimethyldithiophosphate							
µg/L of urine	1,949	NC	< LOD	< LOD	< LOD	2.30	12.0
µg/g of creatinine*	1,949	NC	< LOD	< LOD	< LOD	1.86	10.1
Diethylphosphate							
µg/L of urine	1,949	1.03	< LOD	< LOD	1.20	3.10	7.50
µg/g of creatinine*	1,949	0.92	< LOD	< LOD	0.93	2.73	7.94
Diethylthiophosphate							
µg/L of urine	1,949	NC	< LOD	< LOD	0.49	0.76	1.3
µg/g of creatinine*	1,949	NC	< LOD	< LOD	0.25	0.71	1.7
Diethyldithiophosphate							
µg/L of urine	1,949	NC	< LOD	< LOD	0.08	0.20	0.47
µg/g of creatinine*	1,949	NC	< LOD	< LOD	0.07	0.20	0.55

µg per gram of creatinine in urine.
<LOD= Less than the limit of detection for the analytical method.

NC=Not calculated - Proportion of results below limit of detection was too high to provide a valid result.

Data Source

NHANES 1999-2000, National Center for Health Statistics. (See Appendix B, page B-35, for more information.)

4.4.7 What is the level of exposure to persistent organic pollutants?

Persistent organic pollutants (POPs) are manmade organic chemicals that remain in the environment for long periods of time. Some POPs are toxic; others are not. Toxic POPs are of a special concern because they often remain toxic for decades or longer. The more persistent a toxic chemical is, the greater the probability for human exposure over time.

POPs have been linked to adverse health effects such as cancer, nervous system damage, reproductive disorders, and disruption of the immune system in both human and animals. POPs released in one part of the world can travel to regions far from their place of origin, because they circulate globally long after their release into the atmosphere, oceans, and other pathways (EPA, 2001b).

Under the United Nations Environment Program, the international community has identified 12 chemicals as primary POPs. These chemicals include certain insecticides such as dichlorodiphenyl-trichloroethane (DDT) and chlordane, which were once commonly used to control pests, and polychlorinated biphenyls (PCBs), which were used in hundreds of commercial applications for electrical, heat transfer, and hydraulic equipment, and in plasticizers in paints, plastics, and rubber products.

The 12 chemicals targeted by EPA as POPs are the pesticides aldrin, chlordane, DDT, mirex, toxaphene, dieldrin, endrin, and heptachlor; hexachlorobenzene, an industrial chemical; PCBs; polychlorinated dibenzo-p-dioxins (dioxins); and polychlorinated dibenzo-p-furans (furans) (EPA, 2001b).

The following discussion of human exposure to POPs is derived from the *Second National Report on Human Exposure to Environmental Chemicals,* published in January 2003 by the CDC National Center for Environmental Health (CDC, 2003). Four of the 12 POPs are not addressed by the CDC report and are therefore not addressed specifically in this chapter. These four chemicals are aldrin, toxaphene, dieldrin, and endrin. The remaining POPs were not evaluated for indicators at this time but EPA anticipates that these chemicals will become indicators in the future.

Chlordane and Heptachlor

In 1988, EPA banned the use and production of chlordane in the U.S. Chlordane is an organochlorine pesticide that was applied in and around buildings to eliminate termites and was also used as an agricultural and lawn pesticide. The technical grade of chlordane consists of a group of related chemicals, including heptachlor, *cis*-chlordane, *trans*-chlordane, and *trans*-nonachlor. Note that heptachlor was also used individually as a pesticide separate from chlordane. However, pesticide applications were mostly made with technical grade chlordane and therefore chlordane is the main form of heptachlor exposure.

Within the body, chlordane is metabolized to oxychlordane and heptachlor is metabolized to heptachlor epoxide. Human exposure to chlordane and heptachlor is determined by measuring the blood serum concentrations of oxychlordane, *trans*-nonachlor, and heptachlor epoxide. However, generally recognized guidelines for serum levels of these metabolites have not been established.

The NHANES 1999-2000 mean levels of oxychlordane and heptachlor epoxide in the overall population were below the lipid-adjusted level of detection, which averaged 7.4 ng/g of lipid. The NHANES II (1976-1980) 95th percentile level was about twice the NHANES 1999-2000 level for oxychlordane and *trans*-nonachlor.

DDT

DDT was initially used by the military during the 1940s to control mosquitoes that carried vector-borne diseases such as malaria. EPA banned the use of DDT in the U.S. in 1973. DDT, however, is still produced and used in other countries.

For the general population, food is the most common pathway of exposure. Diets that involve large amounts of Great Lakes fish will increase an individual's exposure to DDT. Food intake of DDT has decreased since the 1950s; however, food imported to the U.S. may have DDT contamination, especially food imported from tropical regions where DDT is used in the greatest quantities.

Dichlorodiphenyldichloroethylene (DDE) (more persistent than DDT) is a major DDT metabolite that can be produced in people or in the environment. DDT in the human body reflects either a relatively recent exposure or a cumulative past exposure over time. A high DDT-to-DDE ratio may indicate a recent exposure, and a low DDT-to-DDE ratio may indicate an exposure in the more distant past.

The NHANES 1999-2000 95th percentile levels (lipid-adjusted serum) for DDT and DDE in the overall population range from 5-fold to 15-fold lower than levels detected in a non-random subsample of NHANES II (1976-1980). These decreases in the U.S. levels are consistent with the decreased use and manufacture of these chemicals. Also, within NHANES 1999-2000, the group aged 12 to 19 years had DDE levels 2-fold lower than the group 20 years and older.

Hexachlorobenzene (HCB)

Hexachlorobenzene is a persistent, bioaccumulative, and toxic pollutant (EPA, 2003b). It was commonly used as a pesticide until 1965, as a fungicide to protect wheat seeds, and for a variety of industrial purposes, including rubber, aluminum, and dye production and wood preservation (EPA, 2003c). In 1984, EPA canceled its registered use. There currently are no commercial uses of HCB in the U.S. (EPA, 2003c); however, HCB is still formed as a by-product during the manufacture of other chemicals (mainly solvents) and pesticides.

Human exposure to HCB can occur through work in or proximity to chemical manufacturing sites where it is formed as a by-product or to waste facilities where it is disposed. People also can be exposed by consuming foods tainted with hexachlorobenzene (EPA, 2003c). EPA has set the maximum contaminant level (MCL) for hexachlorobenzene in drinking water at 1 part per billion. If HCB levels exceed this level, the water supplier must notify the public (EPA, 2002g).

HCB has been found to potentially cause skin lesions and nerve and liver damage when people are exposed at levels above the MCL for relatively short periods (EPA, 2002g). Lifetime exposure at levels above the MCL can damage the liver and kidneys and cause reproductive effects, benign tumors of endocrine glands, and cancer (EPA, 2002g).

Epidemiologic studies of persons orally exposed to HCB have not shown an increased cancer incidence. However, EPA has classified HCB as a probable human carcinogen (Group B2) based on animal studies that have reported cancer of the liver, thyroid, and kidney from oral HCB exposure. Very few inhalation data are available (EPA, 2003c).

Generally recognized guidelines for HCB serum levels are not available. HCB was detected in 0.6 percent of people during the 1999-2000 NHANES study. Finding detectable amounts does not mean that those levels produce adverse health effects. HCB has a residence time of approximately 15 years in body fat.

PCBs

PCBs are chlorinated aromatic hydrocarbon chemicals that were once used as electrical insulating and heat exchange fluids. Within the U.S., peak production occurred in the early 1970s and production within the U.S. was banned in 1979. Concern over these chemicals remains high because they are still released into the environment.

Sources of exposure for the general population include release of PCBs from waste sites and from fires involving transformers and capacitors; ingestion of foods containing PCBs due to contamination of animal feeds; migration from packaging materials; and accumulation in the fatty tissues of livestock. PCBs are found at higher concentrations in fatty foods. In occupational settings, workers can be exposed to PCBs from remediation activities at hazardous waste sites and from the repair of transformers, capacitors, and hydraulic systems (CDC, 2003a).

The Food and Drug Administration and the Occupational Safety and Health Administration have developed criteria for allowable levels of PCBs in foods and the workplace. EPA has established criteria for water and for the storage and removal of PCB-contaminated wastes.

Overall, there are three categories of at least 25 different PCB compounds (termed congeners) as determined by molecular structure. Congeners are closely related chemical compounds. The three categories are coplanar PCBs, mono-ortho substituted PCBs, and other PCBs. The significance of these categories is that coplanar and mono-ortho substituted PCBs have health effects similar to dioxins. Overall, the human health effects of PCBs include liver disorders, elevated lipids, and gastrointestinal cancers (CDC, 2003a).

The detection of serum PCBs can reflect either recent or past exposures to PCBs. Those PCBs with higher degrees of chlorination persist in the human body from several months to years after exposure. In the NHANES 1999-2000 subsample, the frequency of detection of the eight mono-ortho substituted PCBs ranged from 2 percent to 47 percent. Finding detectable amounts does not mean that those levels result in adverse health effects. (For additional information on PCBs in the environment, see Chapter 2, Purer Water; Chapter 3, Better Protected Land; and Chapter 5, Ecological Condition.)

Polychlorinated Dibenzo-p-Dioxins (Dioxins) and Polychlorinated Dibenzo-p-Furans (Furans)

Dioxins and furans are similar classes of chlorinated aromatic chemicals usually generated as pollutants or by-products. They have no commercial or natural use. Processes that result in their generation include the incineration of waste, the production of pulp and paper, and the synthesis of various manmade chemicals. Releases from industrial sources have decreased by approximately 80 percent since the 1980s. The largest releases of dioxins and furans today are the open burning of household and municipal trash, landfill fires, and agricultural and forest fires. In the environment, dioxins and furans occur as a mixture of about 20 congeners (i.e., closely related chemical compounds).

Human exposure occurs primarily through foods that are contaminated with dioxins and furans. Food contamination occurs due to the accumulation of these chemicals in the food chain and in high-fat foods, such as dairy products, eggs, animal fats, and some types of fish. People have also been exposed through industrial accidents, the burning of PCBs, and through the spraying of contaminated herbicides such as Agent Orange. Workplace exposures are rare and generally recognized standards for external exposure have not been established.

Human health effects associated with dioxins and furans are wide-ranging. Given that the exposure of the general population occurs as exposure to a mixture of congeners, the effects of individual congeners are difficult to determine. Overall, associated dioxin and furan health effects include liver disorders, fetal injury, porphyria, elevated lipid levels, chloracne, hormonal changes, neurologic damage, and immunogic changes. The dioxin cogener termed TCDD is the most toxic form of dioxin and it is classified as a known human carcinogen.

It is estimated that human serum lipid-based levels of overall dioxins and furans have decreased by 80 percent since the 1980s and the low NHANES 1999-2000 values support that estimation. The levels detected via NHANES 1999-2000 are far below those associated with occupational and unintentional exposures that resulted in human health effects.

Further, the NHANES 1999-2000 subsample reveals that the more highly chlorinated dioxin and furan cogeners are the main contributors to the human body burden. The higher concentrations in human tissues of these cogeners are due to their greater presence in the food chain, resistance to metabolic breakdown, and greater solubility in body fat. Half-lives for all the dioxin and furan cogeners range from 3 to 19 years and TCDD is estimated to be 7 years.

4.4.8 What are the trends in exposure to environmental pollutants for children?

Children may be affected by environmental pollutants quite differently than adults, both because children may be more highly exposed to pollutants and because they may be more vulnerable to the toxic effects of pollutants. Children generally eat more food, drink more water, and breathe more air relative to their size than do adults, and consequently may be exposed to relatively higher amounts of pollutants. Also, unlike adults, children's normal activities, such as putting their hands in their months or playing on the ground, create greater opportunities for exposures to pollutants. In addition, environmental pollutants may affect children disproportionately because their organ systems are still developing and therefore may be more susceptible (EPA, December 2000). This section presents three environmental pollutants that represent exposures of concern to children: lead, mercury, and cotinine.

Indicator   Blood lead level in children - Category 1

Infants, children, and fetuses are more vulnerable to the effects of lead because the blood-brain barrier is not fully developed (Nadakavukaren, 2000). Thus, a smaller amount of lead will have a greater effect in children than in adults. In addition, ingested lead is more readily absorbed into a child's bloodstream. Children absorb 40 percent of ingested lead into the bloodstream, while adults absorb only 10 percent. Because of lead's adverse effects on cognitive development, CDC has defined an elevated blood lead level as equal to or greater than 10 µg/dL for children under 6 years of age (CDC, 2001c).

What the Data Show

In NHANES III (1988-1994), the mean blood lead levels for children ages 1 to 5 declined from 3.6 µg/dL in Phase 1 (1988 to 1991) to 2.7 µg/dL in Phase 2 (1991 to 1994). Over the same time interval, the percentage of children aged 1 to 5 years with elevated blood lead levels decreased from 8.6 percent to 4.4 percent (Pirkle, 1998). In NHANES 1999-2000, the geometric median blood lead level for children 1 to 5 years old is 2.2 µg/dL. The median blood lead level for children 6 to 11 years old is 1.5 µg/dL (see exhibit 4-8 in this chapter).

Data Source

NHANES 1999-2000, National Center for Health Statistics. (See Appendix B, page B-35, for more information.)

Indicator Blood mercury level in children - Category I

Children may be more highly exposed to mercury and may be more vulnerable to its toxic effects. The health effects of mercury are diverse and can include developmental and neurological effects in children.

What the Data Show

Extremely limited information has been available about children's exposure to mercury and how it relates to levels in adults. Exhibit 4-38 shows that the geometric mean of blood mercury levels among U.S. children measured in NHANES 1999-2000 was 0.34 μg/L. The geometric mean of blood mercury levels of women of childbearing age was 1.02 μg/L. Levels among women of childbearing age are particularly important because they reflect levels of mercury to which the fetus is exposed (NRC, 2000). During a toxicological review of mercury levels, the National Research Council estimated a benchmark dose, which was an estimate of a methylmercury exposure to the fetus, associated with an increase in abnormal scores on cognitive function tests among children. The lower 95 percent confidence bound on the benchmark dose was 58 μg/L (NRC, 2000). To account for uncertainties in exposure measures and variability in individual response to toxic effects of mercury, the NRC recommended an uncertainty factor of 10 to calculate a reference dose. EPA published its final reference dose of 5.8 μg/L, agreeing with NRC. Ninety percent of children 1 to 5 years old and women of childbearing age are below this level (CDC, 2001c).

Exhibit 4-38: Geometric mean and selected percentiles of total blood mercury concentrations (in μg/L) for United States children aged 1-5 years, and women aged 16-49 years, National Health and Nutrition Examination Survey (NHANES), 1999-2000

			Selected Percentiles				
	Sample Size	Geometric Mean	10th	25th	50th	75th	90th
Children, aged 1-5 years, males and females	705	0.34	<LOD	<LOD	0.30	0.50	1.40
Females, 16-49 years	1,709	1.02	0.20	0.40	0.90	2.00	4.90

<LOD = below the limit of detection of the analytical method of 0.14 μg/dL blood.
Source: CDC. *Second National Report on Human Exposure to Environmental Chemicals.* 2003.

Data Source

NHANES III (1999), National Center for Health Statistics. (See Appendix B, page B-35, for more information.)

Indicator Blood cotinine level in children - Category I

Children are at particular risk from ETS, which may exacerbate asthma among susceptible children and also greatly increase the risk for lower respiratory-tract illness, such as bronchitis and pneumonia, among young children (CDC, 2001c). NHANES 1999-2000 data show that people younger than 20 years have higher cotinine levels than people 20 years and older (CDC, 2003). (See Exhibit 4-35 located in Section 4.4.4.) Blood cotinine level is an indicator of exposure to ETS. During NHANES 1999-2000, the average blood cotinine level for children aged 3 to 11 years was 0.11 ng/mL. This level was the same for children in the 12 to 19 years subgroup (CDC, 2003).

For the general population, as part of NHANES III (1988-1991), CDC determined that the median serum level (50th percentile) of cotinine among non-smokers in the U.S. was 0.20 ng/mL. As determined during NHANES 1999-2000, the median cotinine level decreased to 0.059 ng/mL, a 70 percent decrease. This reduction suggest a marketed decrease in exposure of the general U.S. population to ETS since the 1988-1991 period. Further, compared with the results for the 1988-1991 period, NHANES 1999-2000 reveals that cotinine levels declined in each of the population groups defined by age, sex, and race/ethnicity (CDC, 2003).

Data Source

NHANES 1999-2000, National Center for Health Statistics. (See Appendix B, page B-36, for more information.)

4.4.9 Pollutants for Which Biomonitoring Data Are Not Available

As mentioned above, biomonitoring is an emerging field. More biomonitoring indicators are available now than a few years ago. Still, there are many environmental pollutants for which biomonitoring techniques are not available or feasible. These include radiation, air pollutants (except for lead), biological pollutants, and disinfection by-products. Biomonitoring efforts have begun recently for disinfection by-products; however, at this time data are not sufficient to develop indicators for these pollutants. All these pollutants are of concern because exposure is widespread. For these pollutants, exposure assessments currently rely primarily on ambient data.

What is the level of exposure to radiation?

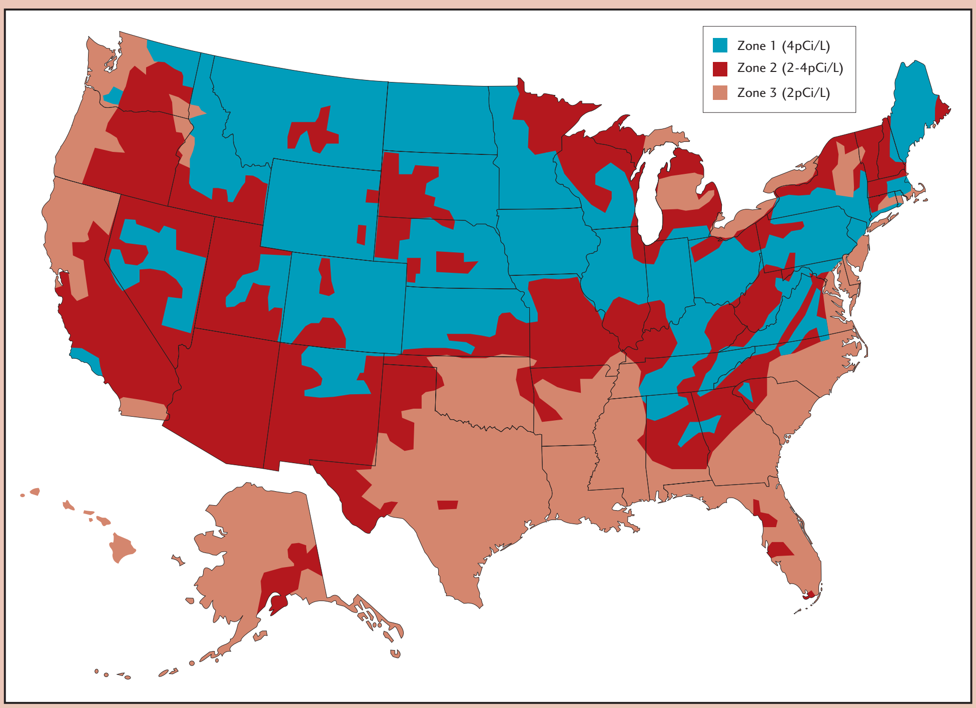
Radiation is energy given off by atoms in the form of particles or electromagnetic rays. There are actually many different types of electromagnetic radiation that have a range of energy levels. They form the electromagnetic spectrum and include radio and micro waves, heat, light, and x-rays (EPA, 2002w).

Radiation that has enough energy to move atoms in a molecule around or cause them to vibrate, but not enough to change them chemically, is referred to as "non-ionizing radiation." Examples of this kind of radiation are sound waves, visible light, and microwaves (EPA, 2002y). Non-ionizing radiation can be used for some common tasks, such as using microwave radiation for telecommunications and heating food, infrared radiation for producing warmth, and radio waves for broadcasting (EPA, 2002y). Non-ionizing radiation has relatively long wavelengths and low frequencies, in the range of 1 million to 10 billion Hertz (EPA, 2002y).

Radiation that has enough energy to actually break chemical bonds or strip electrons away from atoms is called "ionizing radiation (EPA, 2002x)." Radioactive materials that decay spontaneously produce ionizing radiation. Any living tissue in the human body can be damaged by ionizing radiation. The body attempts to repair the damage, but sometimes the damage is too severe or widespread, or mistakes are made in the natural repair process. The most common forms of ionizing radiation are alpha and beta particles, or gamma and X-rays (EPA, 2002x). Ionizing radiation has very short wavelengths, and very high frequencies, in the range of 100 billion billion Hertz (EPA, 2002y). This is the type of radiation that people usually think of as 'radiation.' Ionizing radiation can be used to generate electric power, to kill cancer cells, and in many manufacturing processes (EPA, 2002y).

Radiation can affect the body in a number of ways, and the adverse health consequences of exposure may not be seen for many years. These adverse health effects can range from mild effects, such as skin reddening, to serious effects such as cancer and death, depending on the amount of radiation absorbed by the body (the dose), the type of radiation, the route of exposure, and the length of time a person is exposed. Exposure to very large doses of radiation may cause death within a few days or months. Exposure to lower doses of radiation may lead to an increased risk of developing cancer or other adverse health effects (CDC, 2003).

Exhibit 4-39: EPA map of radon zones in the United States



Source: Modified from EPA, Office of Air and Radiation. EPA Map of Radon Zones. April 2003. (May 2, 2003; *http://www.epa.gov/iaq/radon/zonemap.html*).

There are three basic pathways for radiation exposure. These are inhalation, ingestion, and direct exposure. Each of the different routes, or pathways, by which people can be exposed to radiation result in exposure to different parts of the body (EPA, 2002z). Exposure by the inhalation pathway occurs when people breathe radioactive materials into the lungs. The chief concerns are radioactively contaminated dust, smoke, or gaseous radionuclides such as radon (EPA, 2002z). Radon is a colorless, tasteless, and odorless gas that comes from the decay of uranium found in nearly all soils. Levels of radon vary throughout the country. Radon usually moves upward from the ground and migrates into homes and other buildings through cracks and other holes in their foundations. The buildings trap radon inside, where it accumulates and may become a health hazard if the building is not properly ventilated (EPA, June 2000; EPA, 2002b).

No biomonitoring data are feasible for national estimates of exposure to radon. Data for average national indoor and outdoor radon levels are available, but unlike biomonitoring data, these data do not represent the amount of radon found in human tissue. Rather, they are the levels of radon measured in the air. Radon levels vary throughout the U.S. Exhibit 4-39 shows the distribution of radon levels throughout the country (EPA, 2003d). Based on a national residential radon survey completed in 1991, the average indoor radon level is 1.3 picocuries per liter in the U.S. The average outdoor level is about 0.4 picocuries per liter (EPA, 2002b).

Radiation exposure by the ingestion pathway occurs when someone swallows radioactive materials. For example, exposure by ingestion can occur when drinking water becomes radioactively contaminated, or when food is grown in contaminated soil. Alpha and beta emitting radionuclides are of most concern for ingested radioactive materials. They release large amounts of energy directly to tissue, causing DNA and other cell damage (EPA, 2002z).

The third pathway of concern is direct or external exposure from radioactive material. The concern about exposure to different kinds of radiation varies by the particular type of particle or wave that is being emitted. Alpha particles cannot penetrate the outer layer of skin, but open wounds may pose a risk. Beta particles can burn the skin in some cases, or damage eyes. Greatest concern is about gamma radiation. Different radionuclides emit gamma rays of different strength, but gamma rays can travel long distances and penetrate entirely through the body. Gamma rays can be slowed by dense material (shielding), such as lead, and can be stopped if the material is thick enough. Examples of shielding are containers; protective clothing, such as a lead apron; and soil covering buried radioactive materials (EPA, 2002z).

Radiation can occur from man-made sources such as x-ray machines; or from natural sources such as the sun and outer space, and from some radioactive materials such as uranium in soil (CDC, 2003). About 80 percent of human exposure to radiation is from naturally occurring forms of radiation. The remaining 20 percent of exposure is to manmade radiation sources, primarily medical x-rays (CDC, 2003).

Radiation doses that people receive are measured in units called "rem (CDC, 2003)." Most people receive about 300 mrem every year from natural background sources of radiation, primarily radon. Health physicists generally agree on limiting a person's exposure beyond background radiation to about 100 millirem (mrem) per year from all sources. Exceptions are occupational, medical or accidental exposures. (Medical X-rays generally deliver less than 10 mrem). EPA and other regulatory agencies generally limit exposures from specific sources to the public to levels well under 100 mrem. This is far below the exposure levels that cause acute health effects (EPA, 2002x).

For additional information on radiation in the environment, see Chapter 1, Cleaner Air.

What is the level of exposure to air pollutants?

Criteria air pollutants are common air pollutants comprised of ozone, nitrogen dioxide, carbon monoxide, sulfur dioxide, lead, and particulate matter. The health effects associated with criteria air pollutants are discussed in Chapter 1, Cleaner Air, Section 1.1.3. Ozone is the result of a chemical reaction in the atmosphere between VOCs and nitrogen oxides. Nitrogen dioxide comes from the burning of gasoline, natural gas, coal, and oil. Cars are an important source of nitrogen dioxide.

Carbon monoxide comes from the burning of gasoline, natural gas, coal, and oil. Carbon monoxide reduces the ability of blood to bring oxygen to body cells and tissues. Carbon monoxide may be particularly hazardous to people who have heart or circulatory problems.

Particulate matter (PM) can be emitted directly into the atmosphere, such as dust from roads or elemental carbon (soot) from wood combustion. PM can also be formed in the atmosphere from primary gaseous emissions such as sulfur dioxide and nitrogen oxides, which come from power plants, industrial facilities, automobiles, and other types of combustion sources.

The primary source of sulfur dioxide is the burning of coal and oil, especially high-sulfur coal from the eastern U.S., and industrial processes (paper, metals). The primary source of lead in ambient air was leaded gasoline, which has been phased out in the U.S. Other sources of lead include paint, smelters, and the manufacture of lead storage batteries. Major health effects associated with lead are discussed in Section 4.1.

Except for lead, biomonitoring methods are not available or feasible for the remaining criteria air pollutants. Data for average national ambient air pollutant levels are available (see Chapter 1, Cleaner Air). Research on actual intake measures of air pollutants and their relationship to ambient levels as measured by monitoring networks is under way. Many other studies have found links between air pollutants and disease, as noted in the discussion of diseases and their relationships to environmental pollutants (see Section 4.1).

What is the level of exposure to biological pollutants?

Biological pollutants are or were living organisms. In addition to arthropod-borne, foodborne, or waterborne disease discussed previously, other biological agents can promote poor indoor air quality and may be a major cause of days lost from work or school and of doctor and hospital visits. Some can even damage surfaces inside and outside the residence. Some common indoor biological pollutants include: animal dander (minute scales from hair, feathers, or skin); dust mite and cockroach parts, fungi (molds); infectious agents (bacteria or viruses); and pollen.

Everyone is exposed to biological pollutants. The effects on one's health, however, depend upon the type and amount of biological pollution and the individual person. Some people do not experience health reactions from certain biological pollutants, while others may experience one or more of the following reactions: allergic, infectious, or toxic.

Except for the spread of infections indoors, allergic reactions may be the most common health problem with indoor air quality in homes. They are often connected with animal dander (mostly from cats and dogs), with house dust mites (microscopic animals living in household dust), and with pollen. Allergic reactions can range from mildly uncomfortable to life-threatening, as in a severe asthma attack. Health experts are especially concerned about people with asthma, who have very sensitive airways that can react to various irritants, making breathing difficult. Infectious diseases caused by bacteria and viruses, such as flu, measles, chicken pox, and tuberculosis, may be spread indoors. Most infectious diseases pass from person to person through physical contact. Crowded conditions with poor air circulation can promote this spread. Some bacteria and viruses thrive in buildings and circulate through indoor ventilation systems. (For additional information on indoor air pollution, see Chapter 1, Cleaner Air.)

As with air pollutants and radiation, biomonitoring methods are not available or feasible for many of the biological pollutants discussed in this section.

What is the level of exposure to disinfection by-products?

Disinfection by-products (DBPs) are chemicals that form in drinking water when disinfectants are added during the drinking water treatment process. Disinfectants are added to drinking water to kill bacteria and other microbes that cause disease. DBPs are formed when the disinfectants react with organic matter (primarily from leaf and vegetation decay) that is found naturally in drinking water sources such as rivers and lakes (EPA, 2002c). The most common drinking water disinfectant is chlorine. Other lesser-used disinfectants include chloramines, chlorine dioxide, ozone, and ultraviolet light. More than 200 million people within the U.S. drink disinfected water (EPA, June 2001a).

Hundreds of different DBPs—most of which result from chlorine—have been identified in drinking water, and occurrence data have been reasonably established for over 30 DBPs (EPA, ORD, November 1997). The two types of DBPs that are typically measured by drinking water utilities are trihalomethanes (THMs) and haloacetic acids (HAs).

DBP levels vary throughout the country because the levels are dependent on several factors, including amount of organic matter in the drinking water source, amount of rainfall in the area, season of the year, water temperature, type of disinfectant used, water treatment plant configuration, and size of the water system distribution system (EPA, 1999).

Current information on DBP exposures draws on monitoring results from drinking water systems. Data for average national levels of THMs in treated drinking water are available. Water monitoring for DBPs is of limited value in classifying or identifying individual exposures to DBPs. Individual exposures are influenced by route of exposure (ingestion, inhalation, dermal absorption), individual habits relating to water use or consumption, time and spatial distribution of DBPs in the water system, and seasonal variables that affect the precursors to DBPs (e.g., rainfall, temperature). The complex nature of exposure to DBPs will require a better understanding of the chain of events as illustrated in Exhibit 4-1.

4.4.10 Endocrine Disruptors—An Emerging Issue

An endocrine disruptor is defined as an exogenous agent that alters the function of the endocrine system and consequently causes adverse health effects in an intact organism, or its progeny or (sub)populations (IPCS, 2002). A number of pharmaceuticals, pesticides, commercial chemicals and environmental contaminants are known to disrupt the endocrine system across a wide range of species—invertebrates, fish, birds, reptiles, and mammals.

There is little information on the magnitude and pattern of human exposures to endocrine disruptors. The limited exposure data that exist are primarily for various environmental media, such as chemical concentrations in air, food, and water. Often these data are limited by geographical regions and cannot be extrapolated to national trends. More relevant measures of human exposure, such as chemical concentrations in human blood, breast milk, and human tissue, are rare. Often these data are available only for high exposure areas and populations. As chemicals suspected of contributing to endocrine disruption in humans are identified, it will be necessary to obtain high-quality exposure data to perform human risk assessments. Each major state of the science report on endocrine disruptors has acknowledged the critical need for research to increase our understanding of human exposures and related health outcomes.

The human health issue regarding exposure to endocrine disruptors primarily relates to: (1) adverse effects observed in fish and wildlife, (2) the increased incidence of specific endocrine-related adverse human health outcomes/diseases, and (3) observations of endocrine disruption in well-conducted experiments involving laboratory animals. These chemicals can affect the endocrine system in several ways including interfering with hormone synthesis and release from the endocrine gland, competing with the hormone for the binding sites on transport proteins in the blood, binding to the receptor to either block hormone action or mimic it, and producing changes in hormone metabolism and elimination (IPCS, 2002).

There are a few clear examples of adverse human health effects following high exposures to environmental chemicals (e.g., accidental releases or poisoning incidents). Analysis of the human data by itself has not provided firm evidence of direct causal associations between low level exposure to endocrine-disrupting chemicals and adverse human health outcomes.

Of particular interest is exposure during very early development, both *in utero* and postnatally. Sexual differentiation, growth, and development are under hormonal control. Many of these early processes are unique to this time period and disruptions of carefully timed processes may lead to irreversible adverse human health outcomes. Interest has focused on: (1) adverse effects on reproductive and sexual development and function, (2) altered immune system, nervous system, and thyroid development and function, and (3) cancers of various endocrine-sensitive tissues including the testes, breast, and prostate. Additional research is needed to determine whether linkages exist between these adverse human health outcomes/diseases and exposure to suspected endocrine disruptors. However, this research is challenging as the manifestation of the condition is frequently not observed until years after exposure has occurred and the measured concentration of the chemicals in the affected adult may be very different from in utero, neonatal, or pre-pubertal exposures/concentrations that may have given rise to the adverse outcome.

4.5 Assessing the Environmental Burden of Disease

Many factors may cause or influence disease in humans. These factors include heredity, social factors, dietary factors, and environmental factors (e.g., chemical pollutants, infectious microorganisms, and radiation). The extent to which environmental factors influence overall disease is not entirely understood. Disease burden, global burden of disease, and environmental burden of disease are concepts used to express the burden of disease on society:

- **Disease burden** is the effect on society of both disease-related mortality and disease-related morbidity (Kay, 2000; WHO, 2002). It is assessed by several health measures, including mortality rates, morbidity rates, and the number of days in the hospital. Historically, disease burden has been investigated by analyzing disease outcomes, such as cancer, rather than analyzing risk factors that may cause cancer or disease in general. For example, it is easier to compare cancer incidence between two countries than to compare risk factors of cancer; ionizing radiation may be the major risk factor for cancer in country A, while dioxin may be the major risk factor in country B.
- **Global burden of disease (GBD)** assesses the disease burden on a worldwide basis and then apportions that burden to various causes, such as genetic, behavioral, and environmental.
- **Environmental burden of disease (EBD)** measures that portion of the GBD which is due solely to environmental risk factors.

EBD provides a method for summarizing the environmental health of populations. The summary health data collected from EBD measurements help identify environmental risk factors with significant public health implications. EBD data can also be used to help prioritize funding allocations for health and environmental research, assist in environmental policy development, justify environmental advocacy, assess the cost-effectiveness of interventions, and monitor the progress of a population's health (Prüss, et al., 2001). More important, EBD provides a way to normalize risk factors, allowing comparable health evaluations between populations. Two approaches are commonly used to determine the degree of disease burden that stems from environmental risk factors:

- The **outcome-based approach** determines the degree to which specific environmental risk factors cause a disease relative to other environmental risk factors.

- The **exposure-based approach** assesses the adverse health outcomes resulting from dose-response relationships between risk factors and associated disease outcomes (Prüss, et al., 2001).

This section summarizes estimates, in different studies, of the environmental burden of disease.

World Health Organization Evaluation

In 1998, WHO estimated that 23 percent of GBD is due to environmental hazards, including occupational exposures (WRI, et al., 1998). In 1999, WHO researchers and researchers from the University of California reported that an estimated 25 to 30 percent of the GBD was attributable to the environment (Smith, et al., 1999).

In 2000, WHO introduced a new methodology for evaluating changes to EBD, termed comparative risk assessment (CRA). CRA measures the GBD due to risk factors. WHO is currently developing CRA guidelines to help countries and smaller population groups, such as villages and towns, measure their respective EBD (Kay, 2000). CRA does not have one standard unit, however, and it incorporates other methodologies used to assess EBD. Because of this variability in assessment methodologies, comparing EBD for different countries can be difficult. Further, because EBD has not been quantified extensively in the U.S., this country's level of EBD cannot be easily compared with that of the rest of the world.

Doll and Peto Estimates

Richard Doll and Richard Peto quantified the environmental contribution to disease in their 1981 landmark study *The Causes of Cancer: Quantitative Estimates of Avoidable Risks of Cancer in the United States Today.* In that study, they concluded that pollutants in air, water, and food contributed from 2 to 5 percent to cancer mortality (Doll and Peto, 1981). They quantified the portion of cancer deaths that were attributable to various environmental causes, excluding tobacco smoke (Exhibit 4-40). Thirty percent of cancer was ascribed to tobacco use.

Other Estimates

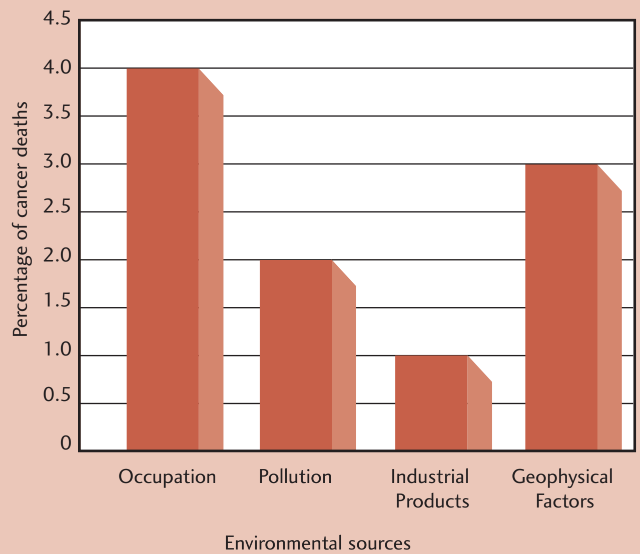
Other studies of EBD have investigated specific environmental risk factors and disease outcomes. For example, Wynder and Gori concluded in 1972 that environmental factors caused 12 percent of all cancer cases for men and 14 percent for women in the U.S. (Doll and Peto, 1981).

Why EBD Estimates Differ

EBD estimates are affected by the definition of "environment" that is used in making the determination (Smith, et al., 1999), as well as the measurement unit used, such as reporting mortality as a percentage of the population. For example, some researchers include factors such as stress or injury as environmental causes of disease, while others include stress and injury as social causes of disease.

The quantity of disease burden (such as disease outcome or risk factors) measured in EBD studies also produces variation in EBD estimates. These differences can be attributed to the different ways that risk factors are categorized, or to differences in the amount of disease burden attributed to a particular source.

Exhibit 4-40: Estimated proportions of cancer deaths in the United States attributed to selected environmental factors



Note: Tobacco is not included in this table. There was not a distinction between environmental tobacco smoke and mainstream smoke.

Source: Doll, Richard and Richard Peto. *The Causes of Cancer: Quantitative Estimates of Avoidable Risks of Cancer in the United States Today.* 1981.

4.6 Challenges and Data Gaps

This chapter described key indicators for health and exposure. Many exposure indicators presented were measured by biomonitoring. Where biomonitoring data are not available, ambient exposure measures serve to describe human exposure to key environmental pollutants. Areas where strong associations have been demonstrated between environmental exposures and health outcomes were highlighted. However, in many areas those associations have not yet been demonstrated.

The success of environmental decisions in improving public health can be measured on a variety of levels:

- **National level** (e.g., U.S. Department of Health and Human Services' Healthy People 2010 initiative).
- **Geographic/regional level** (e.g., East Coast versus West Coast, CDC's state health reports).
- **Community level** (e.g., air and water quality monitoring).
- **Individual level** (e.g., screening programs for blood lead in children).

Many indicators may be used at a number or all of these levels. This report has focused on describing indicators and impacts at a national level. Future versions of this report may utilize indicators to evaluate success in reducing environmental health exposure and outcomes at some of the other levels as well.

Use of Health Outcome Measures to Evaluate Environmental Policy Decisions or Interventions

Mortality data were chosen as one of the major disease indicators because these are collected nationwide in every state, county, and community. These mortality data constitute a comprehensive database, since every death is presumed to be reported. This information has been collected for more than the past 50 years and has been used to document the success of major public health programs. For example, treatment of drinking water through filtration or chlorination eliminated diarrhea diseases as a major cause of death in the 20th century. More recently, anti-smoking campaigns aimed at men are believed to be responsible for the sudden downward trend in deaths due to lung cancer. In fact, an analysis of the key indicators of health for the country confirm that the health of the U.S. population is improving. The U.S. population is living longer (life expectancy) and death rates for major causes of death (cancer, cardiovascular disease) are declining. Except for those rare diseases that have a short survival period and 100 percent death rate, death represents only a small fraction of the true number of cases for a disease in the population (see Section 4.2).

Better information and insight into the health of the U.S. population can be obtained from evaluating incidence data (new cases of illness) or prevalence data (all existing cases of illness). At this time, no comprehensive nationwide systems for collecting incidence or prevalence data on disease are in place. The majority of morbidity data reported in this chapter are available either from national surveys that sample the U.S. and are assumed to be representative of the nation, or from data (e.g., birth defects and cancer registries) collected by the state-based centers around the country. The actual picture of health may differ from that suggested by the data, as in the case of childhood asthma prevalence that has been rising (as described in Section 4.3.4). CDC has launched an initiative to improve the nation's health tracking system. CDC recently awarded grants to state and local health departments to begin developing a national environmental health tracking network and to develop capacity in monitoring environmental health at the state and local levels (<http://www.cdc.gov/nceh/tracking/EPHTracking/EPHTracking.htm>).

Several emerging areas of health concern (e.g., Parkinson's disease, diabetes) and emerging areas of environmental exposure (e.g., endocrine disrupters) were recognized in this chapter. In many of these areas, either the link between environmental exposures and the disease has not been established or no systematic surveillance or established indicators currently exist. Future reports may well include many of the diseases and exposures identified as emerging issues and may establish associated indicators. Major efforts to address diabetes, asthma, and obesity also present a very promising opportunity to incorporate research on the role of environmental exposures into such plans.

Use of Exposure Measures to Evaluate Environmental Policy Decisions or Interventions

Most exposure indicators described in this chapter were biomonitoring indicators. Ambient exposure measures were described for a number of areas where, at present, biomonitoring data are not available (e.g., for certain air pollutants where there are no markers in blood or urine).

The NHANES data provide examples where biomonitoring data have reflected a public health benefit from EPA actions. For example, the decline in blood lead levels confirms that the removal of lead from gasoline, water, and paint has successfully reduced exposures. Similarly, the decline in urinary cotinine levels demonstrates that efforts to reduce smoking have led to public health improvements. However, interpretation of many of the other exposure indicators is difficult at this time. Either not enough is known about the exposure levels in the population, or data gathering at a national level has just begun. It will take time for a stable reference base to emerge.

Efforts to establish a national reference base are under way through the work of CDC's National Center for Environmental Health, which is developing the National Human Exposure to Environmental Chemicals Report. The first report was released in 2001 (<http://www.cdc.gov/nceh/dls/report/PDF/CompleteReport.pdf>) and a second one was released in January 2003 with data on 116 chemicals (<http://www.cdc.gov/humanexposure>). CDC is committed to expanding this database, and its recent *Federal Register* notice called for nominations of chemicals to consider for inclusion in the third report, to be published in 2005. The report will fill a critical need to describe exposure. Use of the report indicators for explanatory or predictive functions will require an understanding of pathways and sources that may have contributed to the exposure and the exposure's relationships to health effects. With this additional understanding the report ultimately could be used to guide exposure reduction programs.

Monitoring Environmental Health Status at the Community Level

Except for mortality data, many communities must look to their own local public health officials to monitor the health status of their community. This is true for a number of reasons, including:

- Current health surveys have limited application at the community level and often require extrapolation from a larger population (state or national).
- Current disease reporting systems, whether national sample or reporting systems (e.g., National Notifiable Diseases Reporting System), can rarely provide an answer for a specific community.
- Biomonitoring surveys that apply to specific communities are extremely rare. For example, blood lead screening programs, while common across the country, do not report in a systematic fashion to a centralized location for compilation and analysis of the data.

Until such systems are developed, communities will continue to rely on environmental monitoring programs to tell them about their exposure to air or water pollution. EPA is pursuing a number of activities to increase the capacity of information providers (e.g., states) and users (e.g., communities) to share information. This effort includes working closely with other federal agencies, such as CDC, to build compatible systems for linking health and environmental data bases. One potential outcome of such partnerships is an opportunity to revisit and refine current sampling designs such that future data collection efforts would provide better information for smaller units (community level) and would ensure better temporal and spatial congruence between environmental, biomonitoring, and surveillance programs.

Future Challenges

For EPA to make better use of more direct indicators of public health outcomes, the science underlying the Agency's key public health functions (describe, explain, predict, evaluate) will need to be strengthened. EPA will continue to work on providing a better understanding of the components of the source-dose-health continuum (Exhibit 4-1). Key among them will be establishing the necessary degree of predictive validity between indicators of each component (e.g., exposure versus dose). Such an understanding is critical to defining the degree to which one indicator can be successfully used as a surrogate for another. However, this may not be conducive to widespread use in surveys or may be difficult to ascertain in smaller populations (e.g., at a community level).

EPA also will continue to build collaborations with CDC and other federal agencies responsible for collecting health surveillance and human exposure data. Such partnerships are essential to any effort to describe the status and trends of exposure and disease in the U.S. with the eventual goal of every U.S. citizen understanding what the status is for his or her family and community. An important initiative along these lines is the interagency effort to develop the National Children's Study, in which EPA is a collaborator. The Children's Health Act of 2000 authorized the National Institutes of Child Health and Disease and a consortium of federal agencies "to conduct a national longitudinal study of environmental influences on children's health and development." The study will investigate the interaction of biologic, genetic, social, and environmental factors to better understand their role(s) in children's health.

EPA will also seek to develop and evaluate methodologies for understanding the contribution of other risk factors to a given health condition in comparison to the environmental exposure (i.e., partitioning out the risk attributable to the environmental exposure[s] of concern). Such measures will assist in prioritizing intervention/prevention programs and will allow the benefits and cost of environmental management to be placed in the context of the larger public health picture.

Other issues of emerging, or emerged, concern include:

- **Susceptible populations.** This chapter identified children as a susceptible population and described indicators relating specifically to them. EPA also recently announced an initiative to define the environmental risks associated with the ever-increasing aging population (<http://www.epa.gov/epahome/headline_103002.htm>) to be undertaken in partnership with other federal agencies and the many alliances for the aging. Many of the indicators in this report are particularly relevant to the elderly (e.g., cardiovascular disease, chronic obstructive pulmonary disease), and they are, or can be, reported by age group. As other susceptible populations are identified, EPA will need to continue working with its federal partners to see that the data are collected and analyzed to track those populations.

- **Aggregate and cumulative risks.** Individuals are not exposed to single chemicals, but rather to multiple pollutants and other stressors through multiple pathways and routes over the course of a day. The reality of aggregate and cumulative exposures further complicates attempts to attribute risk to a single environmental agent. EPA has begun to look at this issue, stimulated in part by mandates under the Food Quality Protection Act. The recently released Cumulative Risk Guidance report (EPA, 2003e) lays the groundwork for taking on this challenge and will help target the research to better understand the nature and impact of such "composite" exposures, especially as related to targeting regulatory and health prevention strategies.

Finally, the health and exposure indicators described in this chapter are only a portion of the story on the state of the environment. These indicators should be viewed in conjunction with the other indicators identified in the companion chapters on ecological condition, land, air, and water. As presented in Exhibit 4-1, that integration is vital to fully developing the understanding envisioned by the cascade of events from source to effects.

Chapter 5:
Ecological Condition

Indicators selected and included in this chapter were assigned to one of two categories:

- **Category 1** - The indicator has been peer reviewed and is supported by national level data coverage for more than one time period. The supporting data are comparable across the nation and are characterized by sound collection methodologies, data management systems, and quality assurance procedures.
- **Category 2** - The indicator has been peer reviewed, but the supporting data are available only for part of the nation (e.g., multi-state regions or ecoregions), or the indicator has not been measured for more than one time period, or not all the parameters of the indicator have been measured (e.g., data has been collected for birds, but not for plants or insects). The supporting data are comparable across the areas covered, and are characterized by sound collection methodologies, data management systems, and quality assurance procedures.

5.0 Introduction

As described in Chapter 4, Human Health, EPA is moving in the direction of measuring outcomes that reflect the actual impacts that result from environmental pollution. This chapter applies that approach to ecosystems. Previous chapters examined impacts on air, water, and land—all elements of the environment that EPA seeks to protect. This chapter links the state of the nation's air, water, land, and living organisms into a broad framework termed "ecological condition"—the sum total of the physical, chemical, and biological characteristics of the environment, and of the resulting processes and interactions among them.[1] Understanding ecological condition is crucial, because humans depend on ecosystems for food, fiber, flood control, and countless other critical "services" they provide to society (Daily, 1997). Many Americans also attribute deep significance and important intangible benefits to ecosystems and their diverse flora and fauna.

Ecological condition reflects the result of a complex array of factors, including natural disturbances, invasions of new species, resource management, planning and zoning, and pollution. EPA has statutory authority to regulate only a few of these factors, but it exerts policy leadership across a broad spectrum of public and private activities, including review of significant federal projects under the National Environmental Policy Act (NEPA). These efforts reflect the EPA's important role as one of many federal, tribal, state, and local government and private partners in protecting the nation's environment.

This chapter asks questions about our current understanding of the ecological condition of:

- Forests
- Farmlands
- Grasslands and shrublands
- Urban and suburban areas
- Fresh waters
- Coasts and oceans
- The entire nation[2]

Exhibit 5-1 is a depiction of the events that link environmental changes to ecological outcomes. "Stressors," indicated by arrows, represent factors such as insect outbreaks or pollutants affecting the system. These act directly on one or more of the "essential ecological attributes" shown in the circles in the center of the diagram. (These attributes are described in more detail below.) Each of these attributes can, in turn, act on and be acted on by others. The web of arrows among the indicators illustrates some of the possible interactions. Effects on ecological attributes can be direct or indirect. This diagram illustrates the fact that ecological processes have important feedbacks on the chemical and physical structure of the environment in which these changes occur. The overall changes in the attributes result in altered structure and function of the ecosystem, which in turn lead to outcomes (good or bad) about which society is concerned.

Exhibit 5-1 shows that monitoring only stressors or monitoring single ecosystem attributes–such as living things–in isolation cannot convey a full and accurate picture of ecological condition. Assessments of ecological condition must incorporate measures of different characteristics, potentially at different times and in different places within a system. EPA can build on decades of monitoring stressors to develop and appropriately monitor multidimensional and better-linked ecological condition indicators.

This chapter presents initial work toward identifying indicators that can help to answer the question "What is the ecological condition of the U.S.?" and it can help elucidate the sequence of events shown in Exhibit 5-1. The chapter is organized into nine sections that describe:

- The framework used in this report to identify indicators to assess ecological condition and outcomes (Section 5.1).
- The ecological condition of forests (Section 5.2), farmlands (Section 5.3), grasslands and shrublands (Section 5.4), urban and suburban areas (Section 5.5), fresh waters (Section 5.6), coasts and oceans (Section 5.7), and the entire nation (Section 5.8).
- The key challenges and data gaps for developing adequate indicators of ecological condition (Section 5.9).

Because ecological condition depends critically on the physical and chemical characteristics of land, air, and water, this chapter draws on indicators from Chapters 1 through 3 of this report, as shown in Exhibit 5-2. Those chapters should be consulted for the data sources for those indicators. Many of the indicators were drawn from The H. John Heinz III Center for Science, Economics, and the Environment (The Heinz Center) report, T*he State of the Nation's Ecosystems: Measuring Lands, Waters, and Living Resources of the United States*, 2002, which also presents more detail on data sources, as does Appendix B of this report.

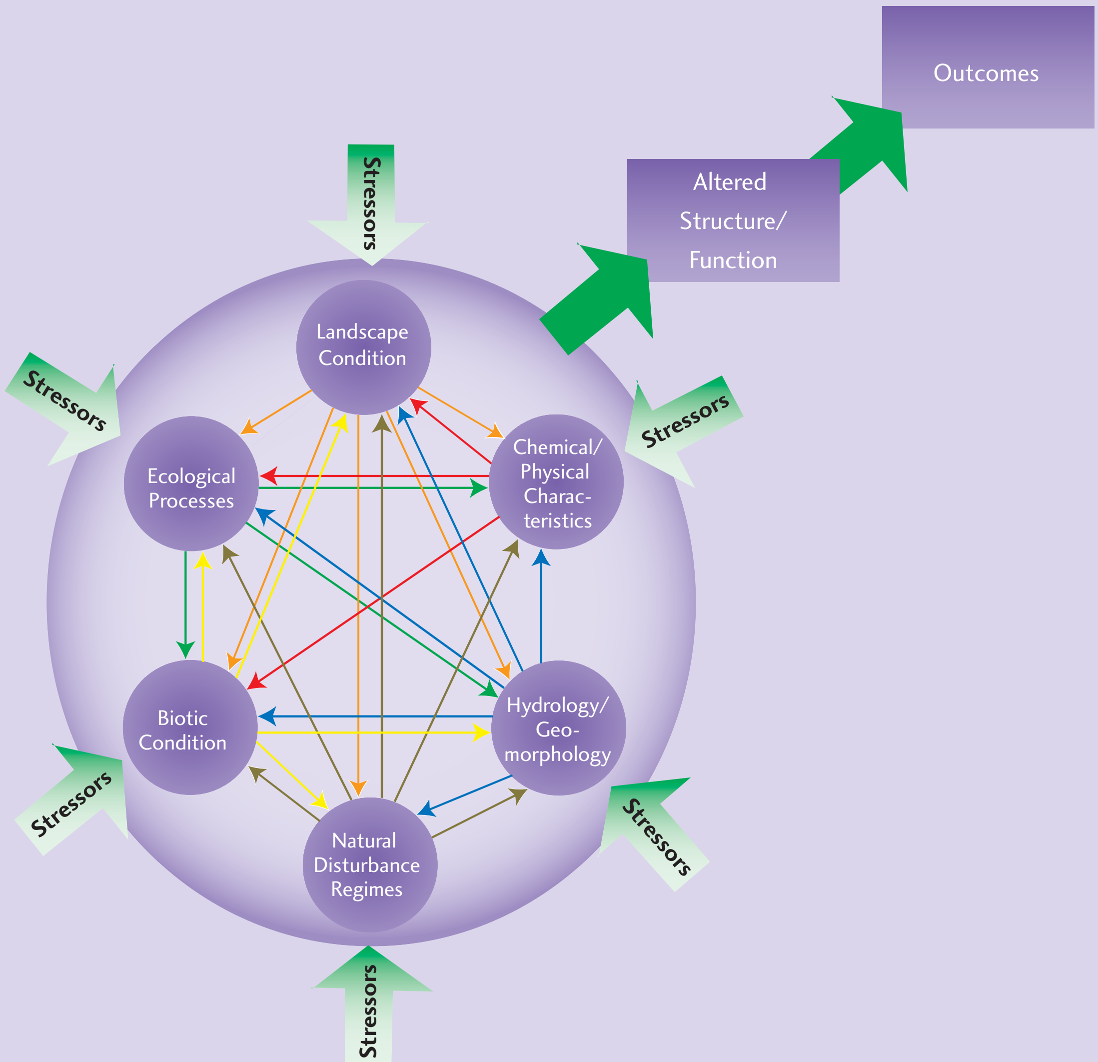
The key data sources reflect the fact that monitoring ecological condition is a multi-organizational task. Organizations in addition to EPA that are responsible for collecting the data to support indicators in this chapter include:

- The U.S. Department of Commerce (National Oceanic and Atmospheric Administration)
- National Aeronautics and Space Administration
- The U.S. Department of Agriculture (Forest Service, Agricultural Research Service, National Agricultural Statistics Service, and Natural Resource Conservation Service)
- The U.S. Department of Interior (U.S. Geological Survey and U.S. Fish and Wildlife Service)
- NatureServe, a private foundation

[1] The term *ecosystem* is used in its broadest sense as any interacting system of physical, chemical, and biological components and the associated flows of energy, material, and information (Odum, 1971).

[2] This seventh category refers to the overall condition of the complex, interconnected mosaic of different ecosystem types across the entire nation.

Exhibit 5-1: Ecological condition paradigm



Together, the six ecological attributes constitute "ecological condition."

Stressors (shown as ⇦) affect ecological attributes directly and also indirectly through feedback (interaction)among the attributes (↑)

Programs such as the U.S. Department of Agriculture Forest Inventory and Analysis (FIA) program and the Natural Resources Inventory (NRI) have a long history, because they measure aspects of the environment that are critical to multi-billion dollar industries (e.g., timber, crops, etc.). Programs with a strictly "ecological" focus (e.g., the USDA Forest Service Forest Health Monitoring [FHM] Program, the U.S. Geological Survey National Water Quality Assessment Program [NAWQA], the multi-agency Multi-Resolution Land Characterization Consortium [MRLC], and EPA's Environmental Monitoring and Assessment Program [EMAP]) are newer on the scene, and most have produced only Category 2 indicators as this report goes to press.

Like Chapter 4, Human Health, this chapter is not intended to be exhaustive. Rather, it provides a snapshot, at the national level, of current U.S. ecological condition indicators and status based on key data sources with sufficiently robust design, quality assurance, and maturity.

Exhibit 5-2: Ecological Condition - Questions and Indicators

Forests

Question	Indicator Name	Category	Section
What is the ecological condition of forests?	*Extent of forest area, ownership, and management*	*1*	*3.1.4*
	Nitrate in farmland, forested, and urban streams and ground water	*2*	*2.2.4.b*
	Deposition: wet sulfate and wet nitrogen	*2*	*1.2.2*
	Changing stream flows	*1*	*2.2.4.a*
	Extent of area by forest type	1	5.2
	Forest age class	2	5.2
	Forest pattern and fragmentation	2	5.2
	At-risk native forest species	2	5.2
	Populations of representative forest species	2	5.2
	Forest disturbance: fire, insects, and disease	1	5.2
	Tree condition	2	5.2
	Ozone injury to trees	2	5.2
	Carbon storage	2	5.2
	Soil compaction	2	5.2
	Soil erosion	2	5.2
	Processes beyond the range of historic variation	2	5.2

Farmlands

Question	Indicator Name	Category	Section
What is the ecological condition of farmlands?	*Extent of agricultural land uses*	*1*	*3.1.2*
	The farmland landscape	*1*	*3.1.2*
	Nitrate in farmland, forested, and urban streams and ground water	*2*	*2.2.4.b*
	Phosphorus in farmland, forested and urban streams	*2*	*2.2.4.b*
	Pesticides in farmland streams and ground water	*2*	*2.2.4.c*
	Potential pesticide runoff from farm fields	*2*	*3.2.4*
	Sediment runoff potential from croplands and pasturelands	*2*	*3.1.6*
	Pesticide leaching potential	2	5.3
	Soil quality index	2	5.3
	Soil erosion	2	5.3

Grasslands and Shrublands

Question	Indicator Name	Category	Section
What is the ecological condition of grasslands and shrublands?	*Extent of grasslands and shrublands*	*1*	*3.1.3*
	Number/duration of dry stream flow periods in grasslands and shrublands	*2*	*2.2.4.a*
	At-risk native grassland and shrubland species	2	5.4
	Population trends of invasive and native non-invasive bird species	1	5.4

Note: Italicized indicators are presented in other chapters.

Urban and Suburban Lands

Question	Indicator Name	Category	Section
What is the ecological condition of urban and suburban areas?	*Extent of urban and suburban lands*	*1*	*3.1.1*
	Ambient concentrations of ozone: 8-hour and 1-hour	*2*	*1.1.1.b*
	Nitrate in farmland, forested and urban streams, and ground water	*2*	*2.2.4.b*
	Phosphorus in farmland, forested, and urban streams	*2*	*2.2.4.b*
	Chemical contamination in urban streams and ground water	*2*	*2.2.4.c*
	Patches of forest, grassland, shrubland, and wetland in urban/suburban areas	2	5.5

Fresh Waters

Question	Indicator Name	Category	Section
What is the ecological condition of fresh waters?	*Wetland extent and change*	*1*	*2.2.2*
	Altered fresh water ecosystems	*2*	*2.2.1*
	Contaminants in fresh water fish	*2*	*2.5.1*
	Phosphorus in large rivers	*2*	*2.2.4.b*
	Lake Trophic State Index	*2*	*2.2.1*
	Chemical contamination in streams and ground water	*2*	*2.2.4.c*
	Acid sensitivity in lakes and streams	*2*	*2.2.4.c*
	Changing stream flows	*1*	*2.2.4.a*
	Sedimentation index	*2*	*2.2.4.a*
	Extent of ponds, lakes, and reservoirs	1	5.6
	At-risk native fresh water species	2	5.6
	Non-native fresh water species	2	5.6
	Animal deaths and deformities	2	5.6
	At-risk fresh water plant communities	2	5.6
	Fish Index of Biotic Integrity in streams	2	5.6
	Macroinvertebrate Biotic Integrity Index for streams	2	5.6

Coasts and Oceans

Question	Indicator Name	Category	Section
What is the ecological condition of coasts and oceans?	*Chlorophyll concentrations*	*2*	*2.2.3*
	Water clarity in coastal waters	*2*	*2.2.3*
	Total nitrogen in coastal waters	*2*	*2.2.4.b*
	Total phosphorus in coastal waters	*2*	*2.2.4.b*
	Dissolved oxygen in coastal waters	*2*	*2.2.3*
	Total organic carbon in sediments	*2*	*2.2.3*
	Sediment contamination of coastal waters	*2*	*2.2.4.c*
	Sediment toxicity in estuaries	*2*	*2.2.4.c*
	Extent of estuaries and coastline	1	5.7
	Coastal living habitats	2	5.7
	Shoreline types	2	5.7
	Benthic Community Index	2	5.7
	Fish diversity	2	5.7
	Submerged aquatic vegetation	2	5.7
	Fish abnormalities	2	5.7
	Unusual marine mortalities	2	5.7

Note: Italicized indicators are presented in other chapters.

The Entire Nation

Question	Indicator Name	Category	Section
What is the ecological condition of the entire nation?	Ecosystem extent	2	5.8
	At-risk native species	2	5.8
	Bird Community Index	2	5.8
	Terrestrial Plant Growth Index	1	5.8
	Movement of nitrogen	1	5.8
	Chemical contamination	2	5.8

Note: Italicized indicators are presented in other chapters.

5.1 Links Between Stressors and Ecological Outcome: A Framework for Measuring Ecological Condition

The primary reasons to monitor ecological condition are similar to those for monitoring air, water, and land;

- To establish baselines against which to assess the current and future condition.
- To provide a warning that action may be required.
- To track the outcomes of policies and programs, and adapt them as necessary.

Measuring ecological condition is not as straightforward as monitoring water or air to determine whether temperatures or concentrations of pollutants exceed a legal standard, however. Ecosystems are dynamic assemblages of organisms that have more or less continuously adapted to a variety of natural stresses over shorter (e.g., fire, windstorms) and longer (climate variations) periods of time, taking on new and different characteristics. This makes determination of the condition of a "natural" system difficult (Ehrenfeld, 1992). In addition, people have altered natural ecosystems to increase their productivity of food, timber, fish, and game, and to provide the infrastructure needed to support a modern society. How should the ecological condition of these altered ecosystems be measured, and against what reference points? Several recent reports by experts in the field have provided advice to guide current and future efforts.

The National Research Council (NRC) report, *Ecological Indicators for the Nation* (NRC, 2000), provides an introduction to recent national efforts to measure ecological condition and a thoughtful discussion of the rationale for choosing indicators. EPA's Science Advisory Board (SAB) also proposed a *Framework for Assessing and Reporting on Ecological Condition* (EPA, SAB, 2002). The framework identifies six "essential ecological attributes" (EEAs) of ecosystems:

- Landscape condition
- Biotic condition
- Chemical and physical characteristics
- Ecological processes
- Hydrology and geomorphology
- Natural disturbance regimes

The EEAs, along with reporting categories and examples of associated indicators, are displayed in Exhibit 5-3. Neither report identifies specific methodologies, network designs, or actual datasets corresponding to the examples.

The H. John Heinz III Center for Science, Economics, and the Environment (The Heinz Center) led a nationwide effort by government, academia, and the private sector to develop a report entitled T*he State of the Nation's Ecosystems: Measuring Lands, Waters, and Living Resources of the United States* (The Heinz Center, 2002). According to the introduction, the report "provides a prescription for 'taking the pulse' of the lands and waters. It identifies what should be measured, counted, and reported, so that decision-makers and the public can understand the changes that are occurring in the American landscape." The Heinz Center report identified 103 specific indicators, of which 33 were judged by the authors to have adequate data for national reporting.

The Heinz Center report provides an important core of indicators for this chapter. The Heinz Center report uses a somewhat different categorization of indicators than the Category 1 and 2 designations, and indicators identified by The Heinz Center that have inadequate data or need further development have not been included here. The Heinz Center indicators in this chapter are organized around the SAB framework, but given the similarities among the NRC, SAB, and Heinz Center approaches, this choice does not affect the final result. This chapter also includes, in addition to The Heinz Center national indicators, some Category 2 indicators from regional monitoring studies that

Exhibit 5-3: Essential ecological attributes and reporting categories

Landscape Condition

- Extent of Ecological System/Habitat Types
- Landscape Composition
- Landscape Pattern and Structure

Biotic Condition

- Ecosystems and Communities
  - Community Extent
  - Community Composition
  - Trophic Structure
  - Community Dynamics
  - Physical Structure
- Species and Populations
  - Population Size
  - Genetic Diversity
  - Population Structure
  - Population Dynamics
  - Habitat Suitability
- Organism Condition
  - Physiological Status
  - Symptoms of Disease or Trauma

Chemical and Physical Characteristics (Water, Air, Soil, and Sediment)

- Nutrient Concentrations
  - Nitrogen
  - Phosphorous
  - Other Nutrients
- Trace Inorganic and Organic Chemicals
  - Metals
  - Other Trace Elements
  - Organic Compounds
- Other Chemical Parameters
  - pH
  - Dissolved Oxygen
  - Salinity
  - Organic Matter
  - Other
- Physical Parameters

Ecological Processes

- Energy Flow
  - Primary Production
  - Net Ecosystem Production
  - Growth Efficiency
- Material Flow
  - Organic Carbon Cycling
  - N and P Cycling
  - Other Nutrient Cycling

Hydrology/Geomorphology

- Surface and Ground Water Flows
  - Pattern of Source Flows
  - Hydrodynamics
  - Pattern of Ground Water Flows
  - Salinity Patterns
  - Water Storage
- Dynamic Structural Characteristics
  - Channel/Shoreline Morphology, Complexity
  - Extent/Distribution of Connected Floodplain
  - Aquatic Physical Habitat Complexity
- Sediment and Material Transport
  - Sediment Supply/Movement
  - Particle Size Distribution Patterns
  - Other Material Flux

Natural Disturbance Regimes

- Frequency
- Intensity
- Extent
- Duration

Source: EPA, Science Advisory Board. *A Framework for Assessing and Reporting on Ecological Condition.* June 2002.

show promise for implementation on a national scale. Regardless of whether the indicators are Category 1 or 2, all indicators were drawn directly from scientifically defensible studies published in peer-reviewed reports and journals.

One of the most critical data quality objectives of monitoring for EPA is representativeness, the degree to which monitoring data accurately and precisely represent the variations of a characteristic over an entire population (e.g., all streams or forests)[3]. *Sampling design*[4] approaches the problem of representativeness and the effects of sampling and measurement error on environmental management policies and decisions. Sampling designs fall into two main categories, *probability designs and judgmental designs*. Probability designs apply sampling theory, so that any sampling unit (e.g., a stream of a stand of trees in a forest) has a known probability of selection. This important attribute allows the characteristics of the entire population of streams or forest stands to be estimated with known uncertainty, ensures that the results are reproducible within that uncertainty, and enables one to calculate the probability of decision-error based on the uncertainty in the data. Probability designs do not provide information on the precise conditions at any location where measurements are not made, or of the populations during times when measurements are not made,[5] or of populations not included in the sampling design.

Judgmental designs rely on expert knowledge or judgment to select sampling units. They can be easier and less expensive to implement than probability sampling. Monitoring sites selected at random can be difficult or even impossible to access, and some monitoring programs require sites that are easy to access repeatedly, or remote sites from which to search for faint signals such as climate change or long-range transport of pollutants. The accuracy of the results of judgment designs depends on the quality of the professional judgment, but in the best of cases quantitative estimates of uncertainty cannot be made. In this report, Category 1 indicators were required to be based on indicators collected using probability designs or "wall-to-wall" coverage by remote sensing, unless a strong case could be made that the data were representative of the population being sampled.

This chapter follows The Heinz Center (2002) in reporting on six major ecosystem types.[6] With a few exceptions, environmental and natural resource monitoring programs currently are structured to track the condition of individual natural resources (e.g., trees, crops, soil, water, or air) represented by the first six ecosystem types. Though some of this

[3]Like the U.S. Census, which strives to collect data on every person in the U.S., an ecological census could attempt to collect data on every plant, animal, stream, etc. This is generally impossible or cost-prohibitive, except for data collected on land cover or other features of the environment that can be measured by satellite.

[4]Olsen, et al., 1999, and Yoccoz, et al., 2001, provide useful discussions of sampling oriented toward ecological monitoring.

[5]For example, if estuaries are sampled only in the fall, the sample reveals nothing about estuaries in the spring or winter.

monitoring takes place on a national level, it still focuses on discrete resources or ecosystem types. For this reason, most available indicators can help answer questions about the condition of individual ecosystem types, but cannot track the overall ecological condition of an area comprising different interconnected and interacting ecosystem types. Therefore, this chapter includes a seventh category representing indicators potentially suitable for the entire nation.

A few indicators are available to help provide a more holistic assessment of ecological condition at the national level. For example, large or migratory organisms (e.g., bears or neotropical birds, respectively) depend on many ecosystem types over large areas for their continued survival. As another example, all of the terrestrial ecosystems types may contribute nitrogen, carbon, or sediment to streams and rivers in watersheds. Even the arrangement of ecosystems in the landscape and the composition of patterns of land cover and land use have been identified as critical components in the way ecosystems function (Forman and Godron, 1986; Naiman and Turner, 2000; Winter, 2001; EPA, SAB, 2002). Section 5.8 corresponds approximately to the core national indicators in The Heinz Center report.

Ideally, the indicators in this chapter would be presented in a way that spoke to the success of our efforts to protect and restore the ecological condition of the types of ecosystems considered in this chapter. Trends in biotic condition and ecological functions and in the physical, chemical, hydrological, landscape, and disturbance regimes of each ecosystem would provide keys to stories involving acid rain, or landscape fragmentation, or changing climate. The resulting "stories" would establish baselines, provide warnings, and track the effectiveness of management actions by EPA and its partners, as envisioned by the NRC (2000). Because so few reliable data exist on trends for any indicators at the national level, however, such a presentation is not yet possible. Instead, the chapter presents a disturbingly fragmentary picture of what little is known reliably and nationally based on Category 1 indicators. It also anticipates what could reasonably be known if monitoring of Category 2 indicators were to be expanded.

Sections 5.2 through 5.8 below describe the ecological condition of the seven ecosystem types. Each section begins with an introduction that summarizes data on the indicators that appear in the previous chapters of this report on air, water, and land. Indicators presented for the first time then are described in detail. Each section ends with a summary of what the available indicators, taken together, reveal about the ecological condition of that ecosystem type.

5.2 What is the Ecological Condition of Forests?

Forests, as defined by the U.S. Department of Agriculture (USDA) Forest Service (FS), are any lands that are at least 10 percent covered by trees of any size and at least 1 acre in extent (Smith, et al., 2001). Some forested ecosystems are rich sources of biodiversity and recreational opportunities, while others are managed intensively for timber production. All are important for carbon storage, hydrologic buffering, and fish and wildlife habitat. Forested ecosystems are under pressure in the U.S. from a number of non-native insects and pathogens and from deviations from natural fire regimes (The Heinz Center, 2002). They also are becoming increasingly fragmented by urbanization and other human activities (Noss and Cooperrider, 1994).

Under its statutory programs, EPA has particularly focused on the effects of air pollution on forest ecosystems, including the effects of acid rain on forests and forest streams. Such impacts might affect not only the health and productivity of trees, but also biodiversity in forest ecosystems (Barker and Tingey, 1992). Under the Clean Air Act, EPA must promulgate secondary standards for criteria air pollutants that present unreasonable risks to plants, animals, and visibility. EPA also has statutory authority to control the effects of forest management practices on aquatic communities; safe use of herbicides and pesticides in forest systems; and significant federal activities in forested ecosystems subject to EPA's review under NEPA.

Forests are possibly the best monitored of the six ecosystem types in this report. The Forest Service has long monitored standing timber volume and production, as well as damage from fire and pests, in its Forest Inventory and Analysis (FIA) program (Smith, et al., 2001). This program relies on probability sampling to ensure that the results are statistically representative, and there is complete long-term national coverage. This results in two Category 1 indicators relating to forest extent and one to biotic condition. In the early 1990s, the Forest Service in collaboration with EPA's Environmental Monitoring and Assessment Program (EMAP) developed the Forest Health Monitoring (FHM) program to monitor additional indicators of the ecological condition of forests (see Stolte, et al., 2002), also using a probability design. Over the course of the 1990s, forests in a growing number of states were sampled in the FHM program, and many of the FHM indicators were merged into the FIA program in 1999. Although data on these indicators are now being collected in 47 states, with all 50 expected to be covered by 2005, at the time this report was being prepared, coverage was not yet sufficiently complete for these to reach Category 1 status.

[6]The concept of an ecosystem, while extremely useful and relevant, is a somewhat vague classification for purposes of environmental monitoring. See O'Neill, et al. (1986); Turner (1989); Suter (1993), pp. 275-308; and Knight and Landres (1998) for highly relevant discussions.

Exhibit 5-4: Forest Indicators

Essential Ecological Attribute	Indicators	Category 1	Category 2	Source
Landscape Condition		1	2	
Extent of Ecological System/ Habitat Types	Extent of forest area, ownership, and management	■		USDA
	Extent of area by forest type	■		USDA
Landscape Composition	Forest age class		■	USDA
Landscape Pattern/Structure	Forest pattern and fragmentation		■	USDA
Biotic Condition				
Ecosystems and Communities	At-risk native forest species		■	NatureServe
Species and Populations	Populations of representative forest species		■	NatureServe
Organism Condition	Forest disturbance: fire, insects, and disease	■		USDA
	Tree condition		■	USDA
	Ozone injury to trees		■	USDA
Ecological Processes				
Energy Flow				
Material Flow	Carbon storage		■	USDA
Chemical & Physical Characteristics				
Nutrient Concentrations	Nitrate in farmlands, forested, and urban streams and ground water		■	DOI
Other Chemical Parameters	Wet sulfate deposition		■	EPA
	Wet nitrogen deposition		■	EPA
Trace Organic and Inorganic Chemicals				
Physical Parameters	Soil compaction		■	USDA
Hydrology and Geomorphology				
Surface and Ground Water Flows	Changing streamflows	■		DOI
Dynamic Structural Conditions				
Sediment and Material Transport	Soil erosion		■	USDA
Natural Disturbance Regimes				
Frequency	Processes beyond the range of historic variation		■	USDA
Extent				
Duration				

Many of the indicators monitored by the FIA and FHM (Smith, et al., 2001) were included in the Heinz report (2002) and formed the original core of this chapter. As this chapter was being completed, however, the Forest Service published its *Final Draft National Report on Sustainable Forests–2003* (USDA, FS, 2002) under the Montreal Process. Several of the indicators contained in this 2002 report (all Category 2) were included in this chapter to demonstrate the kinds of data that will be available nationwide for a range of the forest EEAs as the FIA achieves data collection and analysis on a national basis. Data for several of these indicators (e.g., air quality, atmospheric deposition, and the chemistry and biology of forest streams) are contributed by national monitoring programs operated by other government and private sector organizations.

The forest indicators used in this report are displayed in Exhibit 5-4, grouped according to the EEAs. Some indicators relating to the EEAs of forest landscape condition, the chemical and physical attributes of forest streams, and the hydrology of forest watersheds are discussed in the chapters on Cleaner Air, Purer Water, and Better Protected Land, because they also relate to questions about those media. This section briefly summarizes the data for these indicators as they relate to the ecological condition of forests. This section then introduces additional indicators that relate to the EEAs of forest landscape condition, biotic condition, ecological processes, physical condition of forest soils, and natural disturbances in forests.

The following indicators presented in the previous chapters relate to the ecological condition of forests:

- The indicator *Extent of Forest Area, Ownership, and Management* (Chapter 3, Better Protected Land), is important for assessing trends in how forests are managed and protected. Forested ecosystems cover some 749 million acres in the U.S., or about one-third of the total land area. While approximately 25 percent lower than the pre-settlement acreage in the 1600s, the total acreage has held steady for the past century, although regional and local patterns have changed (USDA, FS, April 2001). Since the 1950s, forest land has increased by 10 million acres in the Northeast and North Central states, and decreased by 11 million acres in the Southeast (USDA, FS, April 2001).

  About 55 percent of all U.S. forests are in private ownership, with 83 percent of forests in the East being privately held (USDA, FS, 2002). About 9 percent of forest lands are managed by private industry to produce timber. Although 503 million acres of forests are classified as "timberland," the rest receive less intensive management. Harvest on public lands declined nearly 50 percent from 1986 to 2 billion cubic feet per year in 2001, but increased on private land by 1 billion cubic feet per year, to 14 billion cubic feet per year during the same period (USDA, FS, 2002). About 38 percent of harvesting is by clearcut, mostly in the South (USDA, FS, 2002). About 76 million acres of forests are "reserved" and managed as national parks or wilderness areas, an almost threefold increase since 1953 (USDA, FS, 2002). Much of the protected forest in the West is in stands more than 100 years old.

- The indicator *Nitrate in Farmland, Forested, and Urban Streams and Ground Water* (Chapter 2, Purer Water) is important for tracking the loss of nitrate from forested watersheds, which often indicates the effects of acid rain or insect infestation. In 36 forested streams monitored by the National Water Quality Assessment (NAWQA) program, almost 50 percent had concentrations of nitrate less than 0.1 parts per million; 75 percent had concentration of less than 0.5 ppm; and only one had a concentration of more than 1.0 ppm. By comparison, of 107 agricultural watersheds, almost half of the streams had nitrate concentrations greater than 2.0 ppm.

- According to the indicator *Deposition–Wet Sulfate and Wet Nitrogen* (Chapter 1, Cleaner Air), wet sulfate deposition decreased substantially throughout the Midwest and Northeast between 1989-1991 and 1999-2001 (Chapter 1, Cleaner Air). By 2001, wet sulfate deposition had decreased by more than 8 kilograms per hectare per year (kg/ha/yr) from 30-40 kg/ha/yr in 1990 in much of the Ohio River Valley and northeastern U.S. The greatest reductions occurred in the mid-Appalachian region. Wet nitrate deposition levels remained relatively unchanged in most areas during the same period and even increased up to 3 kg/ha in the Plains, eastern North Carolina, and southern California.

  Using National Atmospheric Deposition Program data, a USDA report on sustainable forests observed that annual wet sulfate deposition decreased significantly between 1994 and 2000, especially in the North and South Resource Planning Act (RPA) regions, where deposition was the highest. Nitrate deposition rates were lowest in the Pacific and Rocky Mountain RPAs, where approximately 84 percent of the regions experienced deposition rates of less than 4.7 kg/ha/yr (4.2 pounds per acre per year). Only 2 percent of the sites in the eastern U.S. received less than that amount (USDA, FS, 2002).

- The indicator *Changing Stream Flows* (Chapter 2, Purer Water) addresses altered stream flow and timing, which are critical aspects of hydrology in forest streams. Low flows define the smallest area available to stream biota during the year, and high flows shape the stream channel and clear silt and debris from the stream. Some fish depend on high flows for spawning, and the timing of the high and low flows also can influence many ecological processes. Changes in flow can be caused by dams, water withdrawal, and changes in land use and climate. This indicator reveals that 10 percent of predominantly forested watersheds showed decreased minimum flow rates during the period 1940 through 2000 compared to the period before 1940, while 25 percent had increased minimum flow rates (USDA, FS, 2002). Five percent of the watersheds had lower maximum flow rates, and 25 percent had higher maximum flow rates compared to the earlier period. There were no obvious trends in maximum flow rates in the decades since 1940, but minimum flow rates increased over the period. Increased flows were generally found in the East, but decreased flows were found in the West.

The other 12 forest indicators in Exhibit 5-4, described on the following pages, appear for the first time in this report in this chapter. Most of these indicators are from the *Final Draft National Report on Sustainable Forests-2003* (USDA, FS,2002) which became available after The Heinz Center report went to press. All are Category 2 indicators because the data are not yet available for the entire country.

Indicator | Extent of area by forest type - Category I

Trends in the distribution of forest types ultimately control the different types of communities that they support. The data for this indicator were collected by the FIA program, which currently updates the assessment data every 5 years. This indicator compares current conditions to those in 1977.

What the Data Show

Oak-hickory forest is the most common forest type in the U.S., covering 132 million acres—an increase of 18 percent since 1977 (Exhibit 5-5). Maple-beech-birch forest covers 55 million acres and has increased 42 percent since 1977. Pine forest of various types covers 115 million acres; spruce-birch forests cover 61 million acres (mostly in Alaska); and Douglas fir covers 40 million acres, mostly in the Pacific Northwest. Mixed forests (e.g., oak-pine and oak-gum-cypress) cover 64 million acres, mostly in the South (USDA, FS, 2002).

In the East, longleaf-slash pine and lowland hardwoods (elm-ash-cottonwood and oak-gum-cypress) had the largest decreases in acreage (12 million and 17 million acres, respectively). In the West, hemlock-sitka spruce, ponderosa pine, and lodgepole pine decreased the most (by 9 million, 8 million, and 6 million acres, respectively). In both regions, "non-stocked" land, on which trees have been cut but that has not yet regrown as forest, has declined steadily.

Indicator Gaps and Limitations

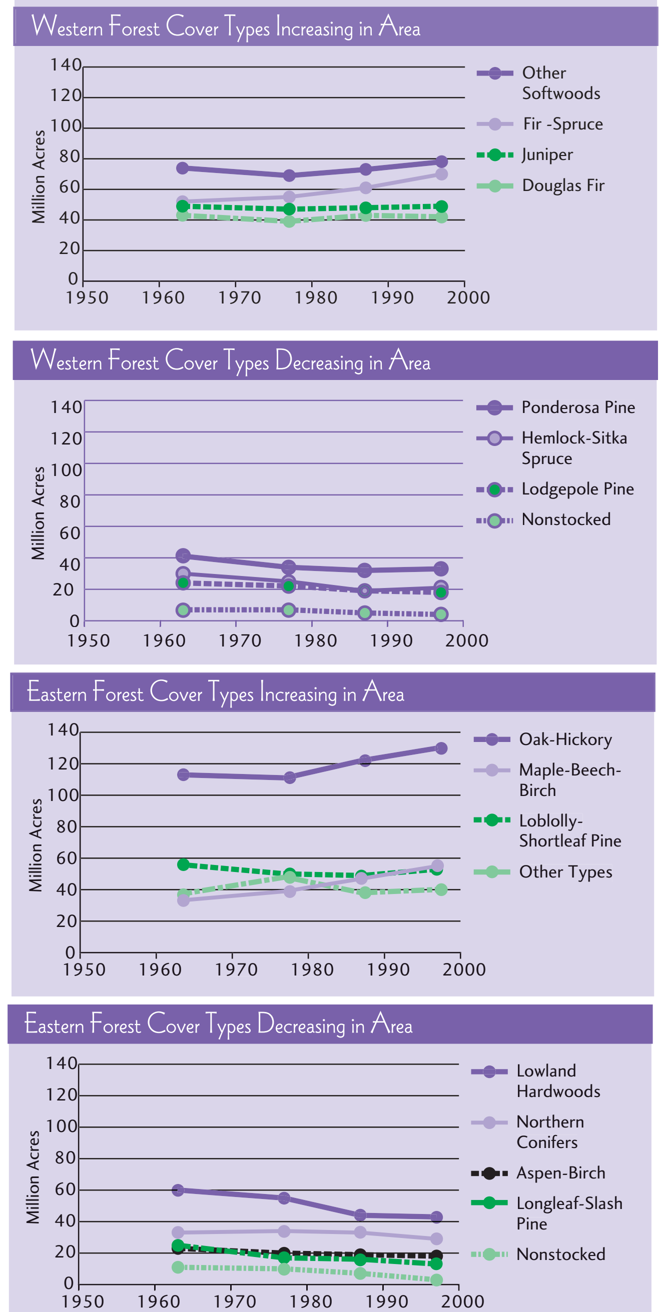
Limitations of this indicator include the following:

- Since the late 1940s, field data on species composition have been collected on a probability sample of 450,000 sites, nationwide (Smith, et al., 2001). The resulting estimates of area by forest type have an uncertainty of 3 to 10 percent per million acres of area sampled (The Heinz Center, 2002).
- The data do not include information on private lands that are legally reserved from harvest, such as lands held by private groups for conservation purposes. Other forest lands are at times reserved from harvest because of administrative or other restrictions. Data on these lands would provide a more complete picture of U.S. forest lands.

Data Source

The data source for this indicator was *Forest Resources of the United States*, 1997, Smith, et al., 2001. (See Appendix B, page B-36, for more information.)

Exhibit 5-5: Forest types in the United States, 1963-1997



Coverage: All 50 states.

Source: The Heinz Center. *The State of the Nations Ecosystems.* 2002. Data from the USDA, Forest Service.

Indicator Forest age class - Category 2

Maintaining forest cover with a wide age range and a variety of successional stages sustains habitats for a variety of forest-dependent species and provides for the sustainable yield of a range of forest products. This indicator reports the percentage of forest area, with stands in each of several age classes.[7]

What the Data Show

In the eastern U.S., 35 percent of forests classified as "timberlands" are more than 60 years old, and 10 percent are more than 100 years old; in the West, the corresponding numbers are 70 percent and 35 percent, respectively (Exhibit 5-6). Softwood age distributions are skewed slightly toward younger age classes due to their management for timber. Hardwoods have a more normal distribution, with a peak in the 40 to 79 year age class, reflecting maturing second and third growth forests in the East. Stands averaging 0 to 5 inches and those over 11 inches are increasing, while intermediate stands in the 6 to 10 inch range are decreasing, indicating a rise in selective harvesting in the U.S. (USDA, FS, 2002).

Indicator Gaps and Limitations

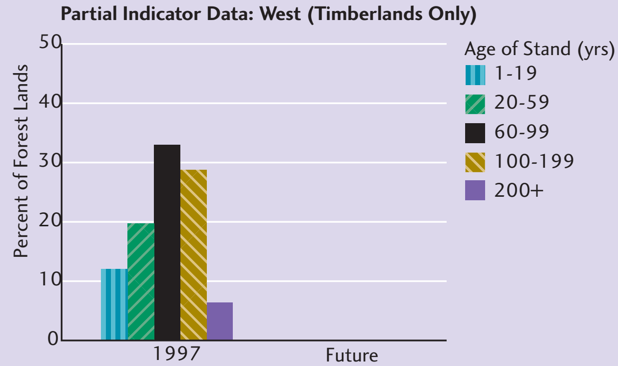
Data for national parks and wilderness areas and other forested land are not available at this time, but will be in the future (The Heinz Center, 2002).

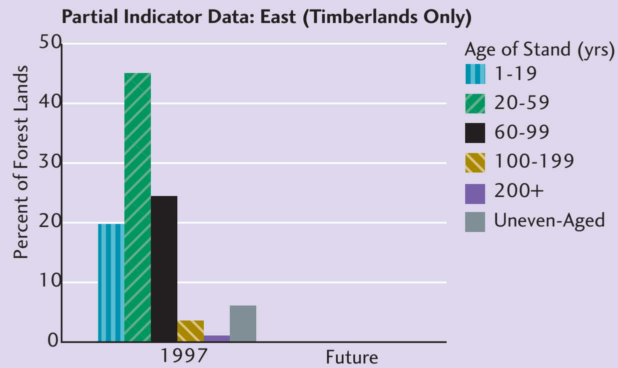
Data Source

The data source for this indicator was *Forest Resources of the United States, 1997,* Smith, et al., 2001. (See Appendix B, page B-36, for more information.)

Exhibit 5-6: Forest age class, 1997

Data Not Adequate for Reporting on Forest Lands Other Than Those Classified as Timberlands





Coverage: all 50 states (timberlands only.)

Note: "Timberlands" is a USDA Forest Service designation for lands that grow at least 20 cubic feet of wood per acre per year, which is considered be sufficient to support commercial harvest under current economic conditions. Lands on which harvest is prohibited by statute are not included as "timberlands." Note also that the term "uneven-age" is being phased out; such stands are composed of intermingled trees that differ considerably in age.

Source: The Heinz Center. *The State of the Nation's Ecosystems.* 2002. Data from the USDA, Forest Service.

[7] Age class is defined by the mean age of the dominant or codominant crowns in the upper layer of the tree canopy.

Indicator

Forest pattern and fragmentation - Category 2

Forest pattern and fragmentation affect the plant and animal species that live in forests. Large blocks of contiguous forest support interior forest species. Partial forest cover creates forest edge habitat, which supports birds and other animals that nest in forests but forage in nearby fields (Ritters, et al., 2002). Fragmentation also creates areas that concentrate airborne nutrients and pollutants by increasing the amount of unprotected forest edge (Weathers, et al., 2001). This indicator captures some of these features.

What the Data Show

Fragmentation in forests in the U.S. is significant. Based on 1992 data (The Heinz Center, 2002), two-thirds of all points within forests were surrounded by land that was at least 90 percent forest in their "immediate neighborhood" (i.e., a radius of 250 feet) (Exhibit 5-7). However, only one-fourth of the points within forests were surrounded by land that was at least 90 percent forest within their "larger neighborhood" (i.e., to a radius of 2.5 miles) (The Heinz Center, 2002). Approximately half of the fragmentation consists of "holes" in otherwise continuous forest cover. About three-quarters of all forest land is found in or near the boundaries of these large (greater than 5,000 hectares), but heavily fragmented, forest patches (Ritters, et al., 2002). In short, most forest is near other forest, and "holes" in forest cover caused by development, agriculture, harvesting, etc., tend to be isolated from each other.

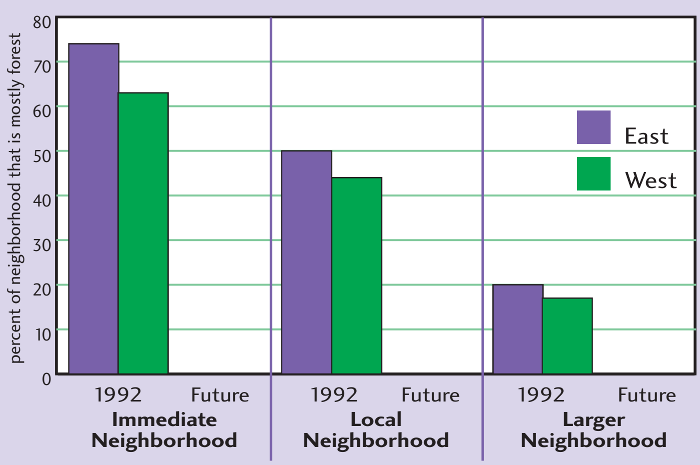
Indicator Gaps and Limitations

Although this indicator was calculated for the conterminous U.S., it has been categorized as a Category 2 indicator because it is only one of many potentially important fragmentation indicators. The exact impact of the amount and type of fragmentation on biotic structure and ecological processes is poorly known, and is likely to vary from one species and process to another (Ritters, et al., 2002). The FHM program is developing additional landscape fragmentation indicators, but the data have not been fully evaluated as this report was being finalized.

Data Sources

The data source for this indicator was *Forest Health Monitoring National Technical Report, 1991 to 1999*, U.S. Department of Agriculture, Forest Service, Southern Research Station, 2002; and *Fragmentation of Continental United States Forests*, Ritters, et al., 2002. (See Appendix B, page B-37, for more information.)

Exhibit 5-7: Forest cover and neighborhood size, 1992



Immediate neighborhood: land within a radius of about 250 ft from each forest point.
Local neighborhood: land within a radius of about 1/4 mile from each forest point.
Larger neighborhood: land within a radius of about 2 1/2 miles from each forest point
Mostly forest: land that is at least 90% forested (less than 10% nonforest)

Coverage: lower 48 states
Source: The Heinz Center. *The State of the Nation's Ecosystems.* 2002. Data from the Multi-Resolution Characterization Consortium and the USDA, Forest Service.

Indicator At-risk native forest species - Category 2

Species richness is considered to be an important indicator of ecological condition by both the National Research Council (2000) and the Science Advisory Board (2002). Although the role of species richness in maintaining a stable ecosystem is debated, greater species richness (i.e., greater number of species) is generally accepted as desirable. Species richness could be altered by air pollution, fragmentation, and forest disturbance by fire, insects, or disease.

What the Data Show

Based on an assessment of 12 factors, NatureServe and its member programs in the Natural Heritage program determined that 5 percent of forest animal species are imperiled, 3.5 percent are critically imperiled, and 1.5 percent are or might be extinct (The Heinz Center, 2002) (Exhibit 5-8). This indicator includes reports on mammals, amphibians, grasshoppers, and butterflies; too little is known about other groups, including plants, to assign risk categories. NatureServe data reveal that of the 1,642 species of terrestrial animals associated with forests, 88 percent still occupy their full historical geographic range on a state-by-state basis (USDA, FS, 2002).

The Natural Heritage Program uses standard ranking criteria and definitions, making the ranks comparable across groups. This means that "imperiled" has the same basic meaning whether applied to a salamander, a moss, or a forest community. Ranking is a qualitative process, however, taking into account several factors that function as guidelines rather than arithmetic rules. The ranker's overall knowledge of the element allows him or her to weigh each factor in relation to the others and to consider all pertinent information for a particular element. The factors considered in ranking species include population size, range extent and area of occupancy, short- and long-term trends in the foregoing factors, threats, and fragility (Stein, 2002).

The information gathered by Natural Heritage data centers also provides support for official designations of endangered or threatened species. However, because Natural Heritage lists of vulnerable species and official lists of endangered or threatened species have different criteria, evidence requirements, purposes, and taxonomic coverage, they normally do not coincide completely with the official designations of "rare and endangered" species.

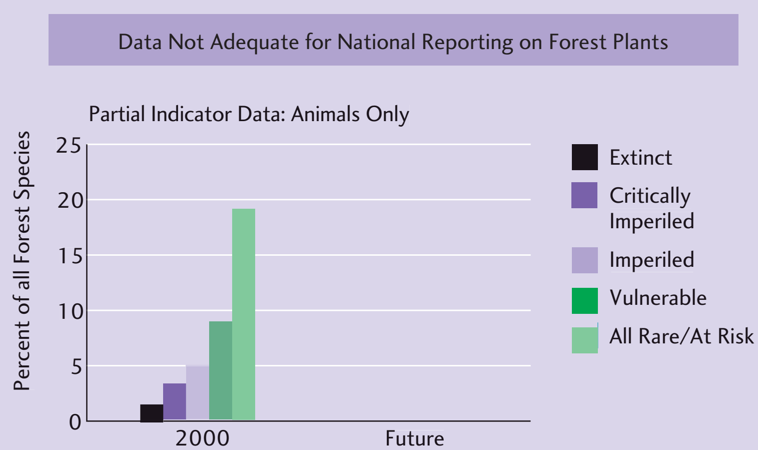
Indicator Gaps and Limitations

The data for this indicator are not from a site-based monitoring program, but rather from a census approach that focuses on the location and distribution of at-risk species. Determining whether species are naturally rare or have been depleted is currently not possible. It is not clear that trends can be quantified with any precision.

Data Source

The data source for this indicator was *The State of the Nation's Ecosystems,* The Heinz Center, 2002, using data from the NatureServe Explorer Database. (See Appendix B, page B-37, for more information.)

Exhibit 5-8: At-risk native forest species, by risk category, 2000



Coverage: all 50 states.

Source: The Heinz Center. *The State of the Nation's Ecosystems.* 2002. Data from NatureServe and its Natural Heritage member programs.

Indicator Populations of representative species - Category 2

The abundance of species representative of particular forest types is a more sensitive and less dramatic measure of ecological condition than species richness alone. Species richness reflects the net number of species invading an area and species going extinct, whereas species abundance also includes the numbers of individuals in each species (USDA, FS, 2002). The FHM program has collected abundance data on bird and tree species.

What the Data Show

Between 1966 and 1979, 21 percent of bird species associated with forests experienced population declines. This figure rose to 26 percent between 1980 and 2000 (USDA, FS, 2002). Areas with the greatest population declines were along the coasts and in the Appalachians. Between 1966 and 2000, 26 percent of bird species associated with forests showed population increases.

In the majority of tree species groups, the number of trees with trunk diameters greater than 1 foot increased by more than 50 percent between 1970 and 2002, indicating a more abundant community of older trees (USDA, FS, 2002) (Exhibit 5-9).

Indicator Gaps and Limitations

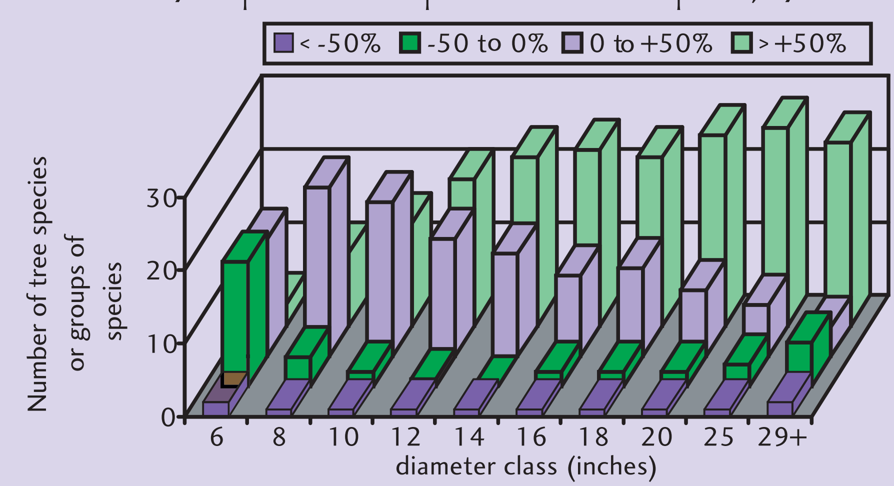
Several limitations are associated with this indicator:

- Population data are available only for birds and trees. Data for big game are reported by the states, but generally very few systematic measures of animal population density exist.
- The data from the Breeding Bird Survey (BBS) are based on a volunteer observer program and might not be statistically reliable.

Data Sources

The data sources for this indicator were the Breeding Bird Survey, U.S. Geologic Survey (1966-2000); and U.S. Department of Agriculture, Forest Service. *Draft Resource Planning and Assessment Tables*, 2002; and *National Report on Sustainable Forests-2003, Final Draft*, U.S. Department of Agriculture, Forest Service, 2002. (See Appendix B, page B-38, for more information.)

Exhibit 5-9: Populations of representative forest species, 1970-2002



Coverage: 37 states.

Source: USDA, Forest Service. Draft Resource Planning Act Assessment Tables. May 3, 2002 (updated August 12, 2002). (September 2002; *http://www.ncrs.fs.fed.us/4801/FIADB/rpa_tabler/Draft_RPA_2002_Forest_Resource_Tables.pdf.*)

Indicator Forest disturbance: fire, insects, and disease - Category I

Fires, insects, and disease often occur naturally in forests. Their impact on forest ecosystems can be influenced by their interaction with other variables such as management decisions, air pollutants, and variations in climate. For example, trees weakened by pollutants might be more susceptible to attack by pathogens. When ecological processes are altered beyond a critical threshold, significant changes to forest conditions might result.

What the Data Show

Wildfire acreage has declined from a peak of more than 50 million acres per year in the 1930s to 2 to 7 million acres per year, largely due to fire suppression policies (The Heinz Center, 2002).[8] However, there has been a slight increase in fires in national forests in recent decades, with 8.4 million acres burned in 2000 (Exhibit 5-10).

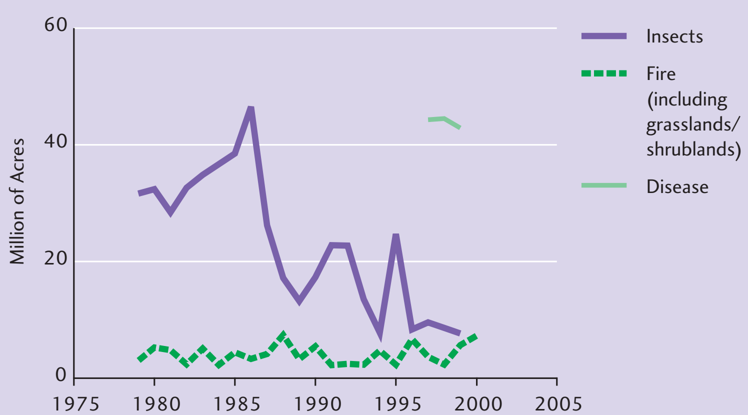
Insect damage fluctuates from year to year, mostly as a result of population cycles of the gypsy moth and southern pine beetle, affecting between 8 and 46 million acres per year. Data for two major parasites, fusiform rust and mistletoe, are available only for the past several years, but the total acreage affected is 43 to 44 million acres (The Heinz Center, 2002).

Indicator Gaps and Limitations

Limitations of this indicator include the following:

- This indicator does not distinguish between forest fires, other wildfires, and prescribed burns. It also does not track the intensity of the fires.
- Data are not available on forests affected by diseases other than those listed above.
- Some insects can cause widespread damage before it is apparent from aerial surveys.

Exhibit 5-10: Forest disturbance: fire, insects, and disease, 1979-2000



Insects: gypsy moth, spruce budworm, southern pine beetle, mountain pine beetle, western spruce budworm (all but the gypsy moth are native to the United States.)

Diseases: fusiform rust, dwarf mistletoe

Coverage: all 50 states

Note: Data are not limited to national forests.

Source: The Heinz Center. *The State of the Nation's Ecosystems.* 2002. Data from the USDA, Forest Service Health Protection/Forest Health Monitoring Program (insects, disease) and the National Forest System (fire).

Data Sources

The data sources for this indicator were *The State of the Nation's Ecosystems,* The Heinz Center, 2002, using data from *Western National Forests: Nearby communities are increasingly threatened by catastrophic wildfires,* U.S. General Accounting Office, 1999; *Forest Health Monitoring National Technical Report, 1991-1999,* U.S. Department of Agriculture, Forest Service, Southern Research Station, 2002; and National Fire Statistics, the National Interagency Fire Center, (See Appendix B, page B-38, for more information.)

[8]These data include wildfires in grasslands and shrublands.

Indicator Tree condition - Category 2

Changes in tree condition reflect the sum total of factors acting on the tree, including stress due to pollutants, climate, nutrient status, soil condition, and disease. This indicator (called "diminished biological components" in USDA, FS, 2002), reports on the percentage of trees in each region of the conterminous U.S. states that exhibit significant changes in three measures: mortality volume, crown condition, and the area in fire Current Condition Class 3. A Resource Planning Act region (shown in Exhibit 5-11) was considered to have poor tree condition (designated as diminished biological components in the exhibit) if (1) average annual mortality volume was more than 60 percent of gross annual growth volume, or (2) the ZB-index, an indicator of crown condition, was increasing at a rate of 0.015 or more per year, or (3) more than half of the forest area was in fire Current Condition Class 3. Fire condition Class 3 represents a major deviation from the ecological conditions compatible with historic fire regimes and might require management activities such as harvesting and replanting to restore the historic fire regime.

What the Data Show

According to the data for this indicator, 20 percent of forests in the U.S. were observed to exhibit poor tree condition, 40.9 percent were in fair or good condition, and 38.8 percent had no or insufficient data (USDA, FS, 2002) (Exhibit 5-11). Mortality was highest in the Pacific Northwest and northern Minnesota, and a large portion of these forests was in fire Current Condition Class 3, indicating that mortality might be producing a high fuel load. The South and Rocky Mountain regions had the smallest areas of poor tree condition, but more than half of those areas had insufficient data or no data at all.

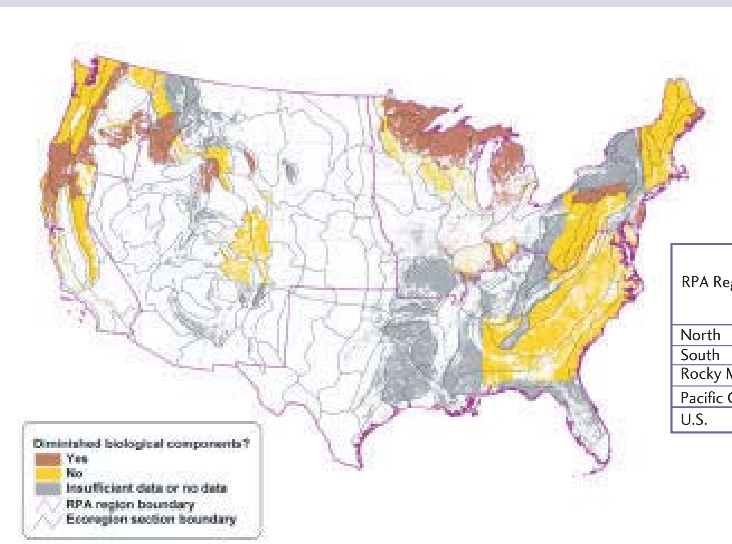
Indicator Gaps and Limitations

The data used to calculate this indicator were available at the time for only 32 states; more than half of the South and Rocky Mountain regions had insufficient or no data at all.

Data Sources

The data sources for this indicator were *Forest Health Monitoring National Technical Report,* 1991-1999, U.S. Department of Agriculture, Forest Service, Southern Research Station, 2002, and *National Report on Sustainable Forests-2003, Final Draft*, U.S. Department of Agriculture, Forest Service, 2002. (See Appendix B, page B-39, for more information.)

Exhibit 5-11: Tree condition, 1990-1999



RPA Region	Diminished Biological Components? Yes	No	No or Insufficient Data
	percent		
North	33.1	37.1	29.8
South	0.0	43.1	56.9
Rocky Mtn.	18.5	29.2	52.3
Pacific Coast	40.5	59.5	0.0
U.S.	20.3	40.9	38.8

Coverage: 32 states.

Forest area having diminished biological components that may indicate changes in fundamental ecological processes and/or ecological continuity. Percentages based on forest area in conterminus 48 States.

Source: Conkling, B., et al. *Forest Health Monitoring National Technical Report 1991-1999*. 2002.

Indicator | Ozone injury to trees - Category 2

Ozone injury to trees can be diagnosed by examination of plant leaves (Skelly, et al., 1987; Bennet, et al., 1994). Foliar injury is the first visible sign of injury of plants from ozone exposure and indicates impairment of physiological processes in the leaves.

What the Data Show

Little or no ozone injury was reported at 97 percent of Pacific Coast sites and 100 percent of Rocky Mountain sites (Exhibit 5-12). In the North and South regions, however, 23 percent of biomonitoring sites showed at least low levels of injury, with severe levels observed at about 5 percent of the plots (USDA, FS, 2002).

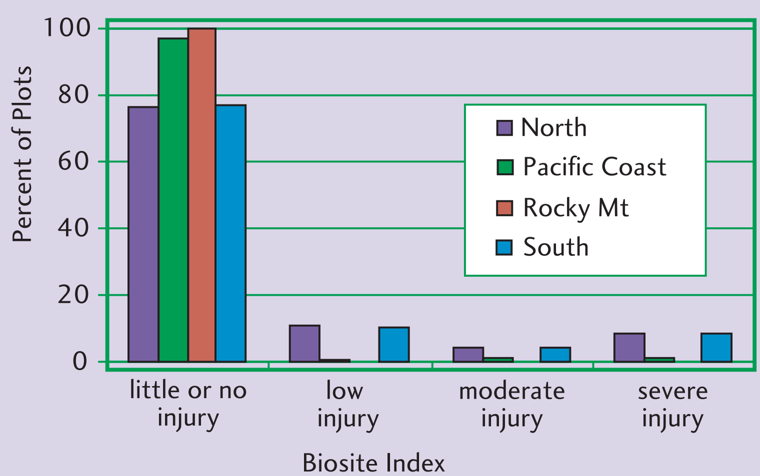
Indicator Gaps and Limitations

- Any further injury to the plant (beyond injury to the leaves) requires that ozone penetrate through the stomata into the leaf interior, which is regulated by a variety of environmental processes; some plants that show foliar damage show no further damage, and some plants show damage without concurrent signs of leaf damage (EPA, ORD, July 1996).
- Biomonitoring site data were available for only 32 states at the time the data for this indicator were analyzed.

Data Sources

The data sources for this indicator were the Forest Health Monitoring Program, U.S. Department of Agriculture (1991-2000) and *National Report on Sustainable Forests-2003, Final Draft*, U.S. Department of Agriculture, Forest Service, 2002. (See Appendix B, page B-39, for more information.)

Exhibit 5-12: Ozone injury to trees, 1994-2000



Coverage: 32 states.

Source: USDA, Forest Service. *National Report on Sustainable Forests - 2003. Final Draft.* 2002.

Indicator | Carbon storage - Category 2

As a result of photosynthesis, carbon is stored in forests for a period of time in a variety of forms before it is ultimately returned to the atmosphere through the respiration and decomposition of plants and animals. A substantial pool of carbon is stored in woody biomass (roots, trunks, and branches). Another portion eventually ends up as dead organic matter in the upper soil horizons. Carbon storage in forest biomass and forest soils is essential for stable forest ecosystems, and it reduces atmospheric concentrations of a carbon dioxide, a greenhouse gas (see Chapter 1, Cleaner Air).

What the Data Show

For the period 1953 to 1996, the average annual net storage of non-soil forest carbon pools was 175 million tonnes of carbon per year (MtC/yr). The rate of storage for the last period of record (1987-1996) declined to 135 MtC/yr (Exhibit 5-13). The decrease in sequestration in the last period is thought to be due to more accurate data, increased harvests relative to growth, and better accounting of emissions from dead wood. The Northern region is sequestering the greatest amount of carbon, followed by the Rocky Mountain region. The trend of decreasing sequestration in the South is due to the increase in harvesting relative to growth. Some of the harvested carbon is sequestered in wood products (USDA, FS, 2002).

Indicator Gaps and Limitations

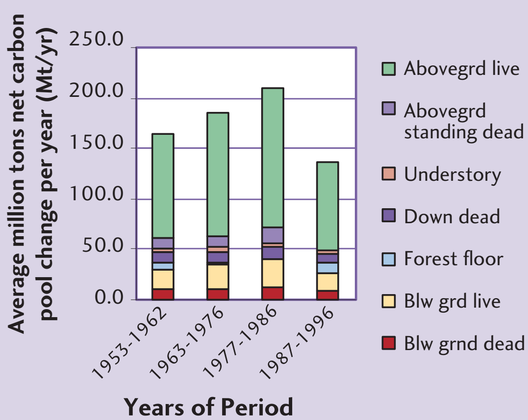
Limitations of this indicator include the following:

- The data only cover forest classified as "timberland," which excludes about one-third of U.S. forests.
- Carbon stored in soil is not included.
- Several of the carbon pools are not measured, but are estimated based on inventory-to-carbon relationships developed with information from ecological studies.

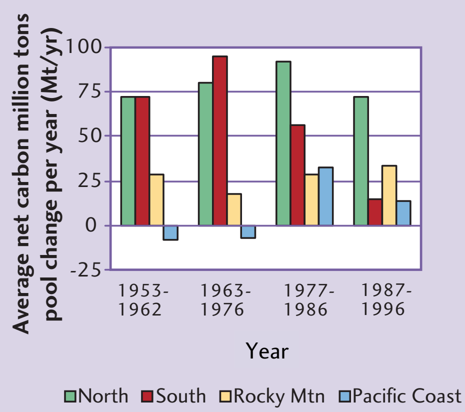
Data Sources

The data sources for this indicator were the Forest Inventory and Analysis, U.S. Department of Agriculture (1979-1995); and *National Report on Sustainable Forests, 2003, Final Draft*, U.S. Department of Agriculture, Forest Service, 2002.
(See Appendix B, page B-39, for more information.)

Exhibit 5-13: Contribution of forest ecosystems to the total global carbon budget, 1953-1996



Average annual net forest carbon change (Mt/yr), 1953-1996



Average annual net forest carbon change (Mt/yr) by region, 1953-1996

Coverage: lower 48 states.

Source: USDA, Forest Service. *National Report on Sustainable Forests - 2003. Final Draft.* 2002.

Indicator Soil compaction - Category 2

This indicator measures the extent of changes to the physical properties of forested soils resulting from forest harvesting, road construction, or other human impacts that are of sufficient magnitude to lower soil fertility or cause significant reductions in site productivity. Compaction can have a variety of negative effects on soil fertility by causing changes in both physical and chemical properties (Sutton, 1991; Fisher and Binkley, 2000). Reduction in pore space makes the soil more dense and difficult to penetrate and thus can constrain the size, reach, and extent of root systems. Reduction in soil aeration and water movement can reduce the ability of roots to absorb water, nutrients, and oxygen, resulting in shallow rooting and stunted trees. Destruction of soil structure can limit water infiltration and increase rates of runoff and soil loss from erosion.

What the Data Show

Soil compaction is primarily a local phenomenon. More than 86 percent of the plots measured showed less than 5 percent of the plot area exhibitng of soil compaction (Exhibit 5-14) (USDA, FS, 2003). Only a small fraction of plots (1.6 percent) showed compaction on more than 50 percent of the plot.

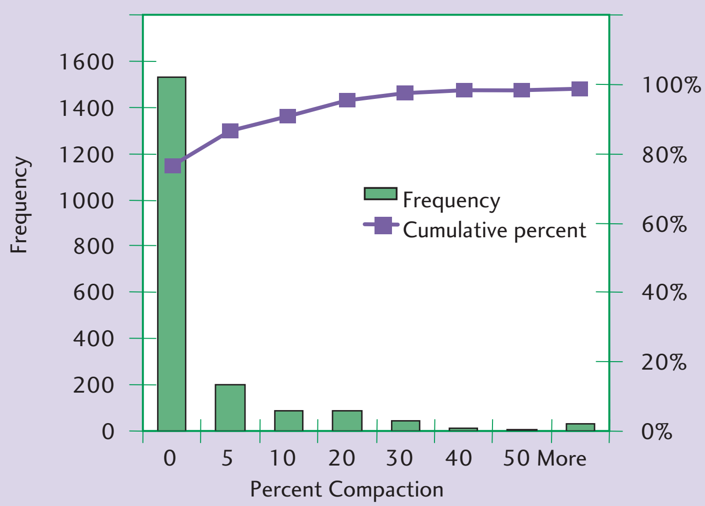
Indicator Gaps and Limitations

Soil physical properties (e.g., bulk density) are not conventionally monitored in a way that facilitates national reporting, and the current approach relies heavily on visual inspection and the State Soil Geographic Database (STATSGO) state soil maps (USDA, FS, 2003). No measurements were made of the degree or intensity of compaction. Physical disturbances that are not readily visible from the surface might be under-reported. Therefore the national maps thus far are only indicative of the *potential* for soil compaction on a regional basis. The FIA program has begun monitoring actual soil physical properties at the FIA sites, to be used in conjunction with the current method, but the data were not available nationally for development of the indicator in 2002 (USDA, FS, 2003).

Data Source

The data sources for this indicator were the Forest Health Monitoring Program, U.S. Department of Agriculture (1999-2000); and State Soil Geographic Database (STATSGO) state soil maps. (See Appendix B, page B-40, for more information.)

Exhibit 5-14: Frequency distribution of percent of plot area exhibiting evidence of surface compaction reported on Forest Health Monitoring (FHM) Program plots, 1999-2000



Coverage: 37 states.

Source: USDA, Forest Service. *National Report on Sustainable Forests-2003*. 2003.

Indicator Soil erosion - Category 2

Erosion is a term used to describe various mechanisms that wear away the land surface. Soil erosion is caused naturally by running water, wind, ice, and other geologic processes, but forest harvesting and road construction can increase erosion beyond natural levels. Erosion in excess of soil formation decreases the long-term productivity of forest systems and contributes to siltation of streams, lakes, and reservoirs. The Water Erosion Prediction Project (WEPP) model is commonly used in conjunction with the STATSGO state soil maps to estimate and predict the amount of soil loss based on several factors influencing erosion (Liu, et al., 1997).

What the Data Show

Modeled erosion rates on undisturbed forest lands were less than 0.05 ton per acre per year, on nearly 90 percent of the measured plots, compared to 3.1 tons per acre per year in agricultural ecosystems (USDA, FS, 2003) (Exhibit 5-15). Exposed mineral soil is a substantial contributor to erosion in the regions of the country sampled, and about 65 percent of the measured forest plots showed bare soil on less than five percent of the plot.

Indicator Gaps and Limitations

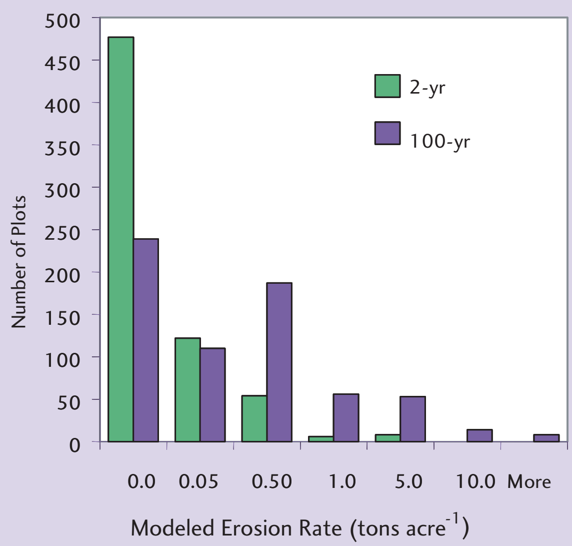
Limitations of this indicator include the following:

- The modeling approach (WEPP) was originally designed for agricultural systems. It might overestimate erosion from well-managed forest plots and underestimate erosion on plots that have been harvested and mechanically prepared (USDA, FS, 2003).
- The erosion indicator was calculated for only 37 states by 2002.

Data Sources

The data sources for this indicator were the Forest Health Monitoring Program, U.S. Department of Agriculture (1991-2000); and State Soil Geographic Database (STATSGO) state soil maps. (See Appendix B, page B-40, for more information.)

Exhibit 5-15: Frequency distribution for modeled erosion rates on Forest Health Monitoring (FHM) Program plots (1999-2000) following a 2-year (average) and 100-year storm event



Coverage: 23 states, excluding Alaska and Hawaii

Note: As an initial step in this analysis, model runs assume an undisturbed forest.

Source: USDA, Forest Service. *National Report on Sustainable Forests-2003*. 2003.

Indicator Processes beyond the range of historic variation - Category 2

The Forest Health Monitoring (FHM) program (USDA, FS, 2002) provided one of the few examples of an indicator that considers the essential ecological attribute of natural disturbance. The FHM program analyzed Forest Inventory and Analysis (FIA) data on climatic events, fire frequency, and insect and disease outbreaks between 1996 and 2000. These data were compared to anecdotal data from 1800 to 1850 to determine whether recent patterns in such incidents were beyond the range of historic variation. The FIA data were also compared to data from between 1978 and 1995 to determine if they were beyond the range of "recent" variation.

What the Data Show

A number of incidents were determined to be outside the range of recent variation in natural disturbance:

- El Niño during 1997 to 2000.
- A 1998 ice storm in the Northeast.
- Total area burned in the West during 1996, 1998, and 2000, and the total area burned nationwide in 2000.
- Outbreaks of spruce beetle in 1996, spruce budworm in 1997, and southern pine beetle in 2000.

Indicator Gaps and Limitations

Several limitations are associated with this indicator:

- This analysis was limited by the lack of metric data (actual measurements) available to describe conditions from 1800 to 1850.
- A relatively complete data set for major forest insects and diseases exists for the period 1979 to 2000, but these data are too recent for establishing a historical baseline.

Data Sources

The data sources for this indicator were the Forest Inventory and Analysis, U.S. Department of Agriculture (1979-1995); and *National Report on Sustainable Forests-2003-Final Draft,* U.S. Department of Agriculture, Forest Service, 2002. (See Appendix B, page B-41, for more information.)

Summary: The Ecological Condition of Forests

The available data are not, at this point, sufficient to track the progress of EPA's programs as they relate to the ecological condition of forest ecosystems. When the FHM/FIA program indicators are measured nationwide and repeatedly, they will form an important baseline against which to monitor the response of forests and their associated fauna to air pollutants, climate change, and management practices that impact forest ecosystems. At this point, the results of the leaf injury indicator suggest that research and assessment of the actual effects of ozone on forest ecosystems should be continued. The increasing acreage of older forests stands and changes in forest stream hydrology might bear watching inasmuch as these factors alter responses of forest systems to air and water pollutants.

Landscape condition

The total acreage of forests has remained steady over the past century and, although the acreage of some of the types of forests have changed, none are currently at risk of being lost. Over the past 50 years, the amount of non-stocked forest has decreased, while the amount of forest with older trees has increased. Forests are highly fragmented, but most forest land exists in or near the boundaries of large tracts of forest land.

Biotic condition

Most forest-related species continue to occupy a large portion of their original range. Eleven percent of species dependent on forest land are imperiled (5.7 percent are mammals, 2.3 percent are amphibians, and 1.4 percent are birds). Twenty-five percent of forest bird species have declined since 1975 (mostly in the Southeast), 25 percent have increased (mostly in the North), and 50 percent have stayed approximately the same. These results indicate that some forest habitats may not be supporting all the species they did historically. Currently no reliable data exist on the condition of biota in forest streams nationally or regionally. Our understanding of the relationship between indicators and biological conservation strategies remains weak (Lindenmeyer, et al., 2000).

According to available data, 20 percent of forests monitored in the U.S. were observed to exhibit poor tree condition, and 23 percent of biomonitoring plots in the eastern U.S. showed more than a small amount of ozone impact on plant leaves. Severe ozone damage to leaves was observed at 5 percent of the plots.

Ecological Processes

Annual rates of carbon storage in timberland increased over the three decades between 1953 and 1986 due to increasing age of timber stands and growth of woodlots on what was once farmland. However, annual storage declined in the decade 1987 to 1996, in part because of harvesting in Southeastern forests.

Chemical and physical characteristics

Nitrate loss from most forests does not appear to be resulting in high nitrate concentrations in forest streams, but few streams are monitored in areas where nitrate deposition is high (the East), and the baseline is too short to determine whether there are trends in the data.

Hydrology and geomorphology

With respect to forest streams, there has been a tendency toward decreased minimum flow rates in 10 percent of forest streams during the period 1940 through 2000 compared to pre-1940, while 25 percent of forest streams had increased minimum flow rates. Five percent of the watersheds had lower maximum flow rates and 25 percent had higher maximum flow rates. There were no obvious trends in maximum flow rates in the decades since 1940, but there was an increase in the minimum flow rates during that period. Increased flows were generally found in the East, and decreased flows were found in the West. Soil compaction is a problem on more than 10 percent of the plots in only 10 percent of monitored forest land.

Natural disturbance regimes

A number of events were determined to be outside the range of recent variation in natural disturbance, including two El Niño events, a severe ice storm in the Northeast, total area burned in the West during three years and the total area burned nationwide in 2000, and several tree pest outbreaks. The ecological consequences of these events are undoubtedly significant, but have not been systematically analyzed.

Many indicators currently being evaluated by the FIA and FHM programs are not included in this section because the results were not included in the Forest Service's most recent report on sustainable forests (USDA, FS, 2002). Because most of these measurements are made in a way that allows unbiased estimates and known uncertainty bounds, the ecological condition of forests will be even better known in the coming years.

5.3 What Is the Ecological Condition of Farmlands?

Agricultural practices using high-yielding crop varieties, fertilization, irrigation, and pesticides have contributed substantially to increased food production over the past 50 years (Matson, et al., 1997). These same practices also have altered the biotic interactions in farmlands, with local, regional, and global ecological consequences (Matson, et al., 1997). This report (following The Heinz Center, 2002) defines a farmland as consisting of not only of the lands used to grow crops, but also the field borders, windbreaks, small woodlots, grassland and shrubland areas, wetlands, farmsteads, small villages, and other built-up areas within or adjacent to croplands. These land covers/uses both support agricultural production and provide habitat for a variety of wildlife species. Farmlands include lands that grow perennial and annual crops as well as lands that are used to produce forage for livestock. This definition overlaps with other ecosystems; most notably, pastures are considered croplands, but are also considered part of grassland/shrubland ecosystems.

Among ecologists concerned with ecological condition, farmlands are often referred to as "agroecosystems." EPA is interested not only in the ecological condition of farmlands, but also in their effects on adjacent ecosystems. Developing and implementing agricultural practices that integrate crop and livestock production with ecologically

Exhibit 5-16: Farmland indicators

Essential Ecological Attribute	Indicators	Category 1	Category 2	Source
Landscape Condition		1	2	
Extent of Ecological System/Habitat Types	Extent of agricultural land uses	■		USDA
Landscape Composition	The farmland landscape	■		DOI
Landscape Structure/Pattern				
Biotic Condition				
Ecosystems and Communities				
Species and Populations				
Organism Condition				
Ecological Processes				
Energy Flow				
Material Flow				
Chemical and Physical Characteristics				
Nutrient Concentrations	Nitrate in farmland, forested, and urban streams and ground water		■	DOI
	Phosphorus in farmlands, forested and urban streams		■	DOI
Other Chemical Parameters				
Trace Organics and Inorganics	Pesticides in farmland streams and ground water		■	DOI
	Potential pesticide runoff from farm fields		■	USDA
	Pesticide leaching potential		■	USDA
	Soil quality index		■	EPA
Physical Parameters				
Hydrology and Geomorphology				
Surface and Ground Water Flows				
Dynamic Structural Conditions				
Sediment and Material Transport	Soil erosion		■	EPA
	Sediment runoff potential from croplands and pasturelands		■	USDA
Natural Disturbance Regimes				
Frequency				
Extent				
Duration				

based management practices has become the key for sustainable agriculture (NRC, 1999).

Some of the data on farmlands are available through the National Agricultural Statistics Service (NASS). Over the past 80 years, NASS has administered the USDA's program of collecting and publishing national and state agricultural statistics. NASS currently publishes more than 400 reports a year covering virtually every facet of U.S. agriculture—production and supplies of food and fiber, prices paid and received by farmers, farm labor and wages, and farm aspects of the industry. These estimates are based on a statistical area sampling frame that represents the entire land mass of the U.S. The biological indicators currently measured by NASS are primarily related to crop or animal production. However, NASS does not report on indicators of ecological condition. Physical or chemical indicators usually provide information relevant for agronomic production, but also can provide limited information on potential stressors to adjacent terrestrial and aquatic ecosystems such as soil erosion; nitrogen, phosphorus and pesticide runoff; and phosphorus and nitrate concentrations in farmland streams.

In 1990, EPA and the USDA Agricultural Research Service (ARS) undertook an interagency effort to assess the ecological condition of agroecosystems as part of the Environmental Monitoring and Assessment Program (EMAP). In 1994 and 1995, EMAP piloted a regional-scale assessment in the mid-Atlantic region (Hellkamp, et al., 2000). Some of the resulting indicators used in that pilot are included as Category 2 indicators in this report. These indicators could be measured in other regions and eventually across the nation in conjunction with the NASS annual surveys.

The farmland indicators used in this report are displayed in Exhibit 5-16, grouped according to the essential ecological attributes (EEAs). Some indicators relating to the EEAs of farmland landscape condition, the chemical and physical attributes of farmland streams, and the hydrology of farmland watersheds have been presented in the previous chapters on Better Protected Land and Purer Water, because these indicators also relate to questions about those media. Below, this section briefly summarizes the data for these indicators as they relate to the ecological condition of farmlands. The section then introduces additional indicators that relate to the EEAs of physical and chemical properties of farmland soils and the hydrology and geomorphology contributing to loss of soil from farmlands. Data are insufficient for national reporting on indicators in three of the six categories of EEAs: biotic condition, ecological processes, and natural disturbance regimes (The Heinz Center, 2002).

The following indicators presented in previous chapters relate to the ecological condition of farmlands:

- According to the indicator *Extent of Agricultural Land Uses* (Chapter 3, Better Protected Land), croplands total 377 million acres. As of 1997, Conservation Reserve Program (CRP) lands totaled 32 million acres, excluding Alaska (USDA, NRCS, 2000). Between 1982 and 1997, cropland decreased 10.4 percent, from about 421 million acres to nearly 377 million acres. Of this 44-million acre decrease, however, 32.7 million acres are now enrolled in the CRP, leaving an 11.3 million acre loss as a result of conversion of croplands to other land uses (USDA, NRCS, 2000).

  Unfortunately, there is no single, definitive, accurate estimate of the extent of cropland. Cropland is a flexible resource that is constantly being taken in and out of production. In addition, estimates of the amount of land devoted to farming differ because different programs use different methods to acquire, define, and analyze their data. For example, The Heinz Center report assesses total cropland (including pasture and hayland) as covering between 430 and 500 million acres in 1997, or about a quarter of the total land area in the U.S. (excluding Alaska). This report does not reconcile these differences, but does acknowledge that there are different estimates.

- The *Farmland Landscape* indicator (Chapter 3, Better Protected Land) describes the degree to which croplands dominate the landscape and the extent to which other land uses are intermingled (The Heinz Center, 2002). Croplands comprise about half of the larger farmland ecosystems in the East and Southeast and almost three-quarters of the farmland ecosystems in the Midwest (The Heinz Center, 2002). The remainder of the farmland ecosystems are forests in the East, wetlands in the Southeast, and both forests and wetlands in the Midwest. In the West, about 60 percent of farmland ecosystems are cropland, with grasslands and shrublands dominating the remainder in the western and northern Plains areas. Forests and grasslands/shrublands are about equal in the farmland landscape for the non-cropland area of the South Central region. In many areas of the U.S., other land cover types are almost as prevalent as croplands and can provide habitat for non-agronomic species.

- The indicator *Nitrate in Farmland, Forested, and Urban Streams and Ground Water* (Chapter 2, Purer Water) shows the loss of nitrate from agricultural watersheds, usually indicating the extent to which nitrogen fertilizer is lost or animal manure reaches streams via runoff or ground water. Sampling in areas where agriculture is the primary land use found that about 50 percent of the 52 stream sites sampled and 45 percent of the ground water wells sampled had nitrate concentrations greater than 2 ppm. About 20 percent of the ground water sites and 10 percent of the stream sites sampled had nitrate concentrations exceeding the drinking water nitrate standard of 10 ppm. These figures are much higher than the nitrate concentrations in forest streams (The Heinz Center, 2002).

- The indicator *Phosphorus in Farmland, Forested, and Urban Streams* (Chapter 2, Purer Water), shows the loss of phosphorus from agricultural watersheds, again usually indicating losses from fertilizer and animal manures. Total phosphorus concentrations in farmland streams were reported in four classes in the Heinz report: < 0.1 ppm, 0.1-0.3 ppm, 0.3-0.5 ppm, and > 0.5 ppm (The Heinz Center, 2002). EPA has set new regional criteria for phosphorous concentration, ranging from 0.023 to 0.076 ppm, to protect streams in agricultural ecosystems from eutrophication. The criteria vary according to differences in ecoregions, soil types, climate, and land use. The Heinz Center (2002) reports that about 75 percent of farmland streams had phosphorous concentrations greater than 0.1 ppm, thus exceeding any of EPA's criteria for eutrophication. Fifteen percent had phosphorous concentrations equal to or exceeding 0.5 ppm (The Heinz Center, 2002). Average phosphorous concentrations in farmland streams were similar to phosphorous concentrations measured in urban streams. As with nitrate concentrations, forest streams had lower phosphorous concentrations than farmland or urban streams.

- The indicator *Pesticides in Farmland Streams and Ground Water* (Chapter 2, Purer Water), captures the extent to which chemical conditions in streams may exceed the tolerance limits for aquatic communities. All streams monitored by the National Water Quality Assessment (NAWQA) program in farmland areas had at least one pesticide at detectable levels throughout the year (The Heinz Center, 2002). About 75 percent of these streams had an average of five or more pesticides at detectable levels, and more than 80 percent of the streams had at least one pesticide whose concentration exceeded the applicable aquatic life guideline. About 60 percent of ground water wells sampled in agricultural areas had at least one pesticide at detectable levels. A relatively small number of these chemicals—specifically the herbicides atrazine (and its breakdown product desethylatrazine), metalachlor, cyanazine, and alachlor—accounted for most detections.
- The *Potential Pesticide Runoff from Farm Fields* indicator (Chapter 3, Better Protected Land) identifies the potential for movement of agricultural pesticides by surface water runoff in watersheds nationwide, based on factors known to be important determinants of pesticide loss. These factors include: 1) soil characteristics, 2) historical pesticide use, 3) chemical properties of the pesticides used, 4) annual rainfall and its relationship to runoff, and 5) major field crops grown. The indicator uses 1992 as a baseline. Watersheds with high scores (i.e., the 4th quartile of runoff estimates) have a greater risk of pesticide contamination of surface water than do those with low scores (i.e., the 1st quartile of runoff estimates). The highest potential for pesticide runoff is projected for the central U.S., primarily in the upper and lower Mississippi River valley and the Ohio River valley. These areas are part of the "breadbasket" of the U.S., where pesticide application is highest. Many of the western watersheds have not been assessed.
- The hydrologic attribute indicator *Sediment Runoff Potential from Croplands and Pasturelands* (Chapter 3, Better Protected Land), captures the loss of valuable soil from the farmland, sediment impacts to the physical habitat of farmland streams, and transport of many pollutants to downstream lakes, reservoirs, and estuaries. This indicator combines land cover, weather patterns, and soils information in a process model that incorporates hydrologic cycling, weather, sedimentation, crop growth, and agricultural management to estimate the amount of sediment that could potentially be delivered to rivers and streams in each watershed. The highest potential for sediment runoff is concentrated in the central U.S., predominately associated with the upper Mississippi River valley and the Ohio River valley. Most of the western U.S. region is characterized by low runoff potential.

The other three indicators in Exhibit 5-16, described on the following pages, appear for the first time in this chapter.

Indicator Pesticide leaching potential - Category 2

Retention of pesticides in their target areas maximizes pesticide efficiency and minimizes off-site contamination (Hellkamp, et al., 2000). Pesticide leaching not only can contaminate surface and ground water, but also can have both chronic and acute toxic effects on non-target organisms, such as fish, birds, and other wildlife. This leaching potential is affected by soil properties, rainfall and runoff, pesticide chemistry, and other factors. The indicator was used as part of the NASS survey approach, so it has the potential for national application.

What the Data Show

During the 1994-1995 period, there were about 13.5 million acres of cropland in the MId-Atlantic region (Hellkamp et al, 2000). Although a large proportion of these 13.5 million acres had soils with properties conducive to pesticide leaching, the authors estimate that 50 percent (6.75 million acres) of the cropland received no pesticide application. Also, pesticides with moderately high to high leaching potentials were seldom applied to croplands with highly to very highly leachable soils. Consequently, only about 1 million acres (less than 10 percent of the total cropland acreage) was at moderately high to high risk for loss of pesticides from the on-farm target area (Hellkamp, et al., 2000).

Indicator Gaps and Limitations

The limitations of this indicator include the following:

- The pesticide leaching potential indicator has only been applied in the mid-Atlantic region and has not been tested or applied in other regions. It has the potential to be applied in other areas, but it will have to be adjusted for regional differences.
- Data collection occurred only during 1994 and 1995.

Data Source

The data source for this indicator was the Mid-Atlantic Integrated Assessment Program, U.S. Environmental Protection Agency (1994-1995). (See Appendix B, page B-41, for more information.)

Indicator | Soil quality index - Category 2

A Soil Quality Index (SQI) was developed and measured for agroecosystems in the mid-Atlantic region in 1994 and 1995 (Hess, et al., 2000; Hellkamp, et al., 2000). The SQI includes indicators of soil attributes, including physical (i.e., clay content, cation exchange capacity, base saturation), chemical (i.e., pH, sodium adsorption ratio, total nitrogen, total carbon, organic carbon/clay), and biological (i.e., microbial biomass). The SQI score is an average of eight numerical ratings (McQuaid and Olson, 1998) (Hellkamp, et al., 2000). The high soil quality range begins at SQI scores of 2.4, while the range of low SQI scores is from 0.0 to 1.6. While the SQI is an indicator of the capacity of the soil to support plant growth and is related primarily to agricultural productivity, it can also provide information on the capacity of the site to support non-agronomic plants.

This indicator was used as part of the NASS survey approach, so it has the potential for national application.

What the Data Show

SQI scores were obtained for the five-state mid-Atlantic region in 1994 and 1995 (Hellkamp, et al., 2000) (Exhibit 5-17). In 1994, the mean SQI score was 2.23 (CI[9] = 2.17 to 2.29); in 1995, the mean SQI was 1.98 (CI = 1.73 to 2.23). The difference in SQI scores between 1994 and 1995 was due to different index calculation procedures and sampling variability. SQI scores were lower in tilled soils compared with untilled soils, such as hay fields, in both 1994 and 1995. Untilled sites had higher microbial biomass values than conventional or reduced tillage sites in both years

Evaluation of the individual factors related to the moderate SQI scores indicated that cation exchange capacity (1994), carbon (total 1994, organic 1995), and microbial biomass (1995) had the lowest values (Hellkamp, et al., 2000).

Increasing the carbon content of soils might increase their capacity to support plant growth. Retaining or adding crop residues to the soils could increase both the carbon content and substrate for microbial activity. Crop residues can also reduce soil erosion and associated transport of nutrients and pesticides off the field. Nutrients and pesticides contribute to negative effects on aquatic receiving systems.

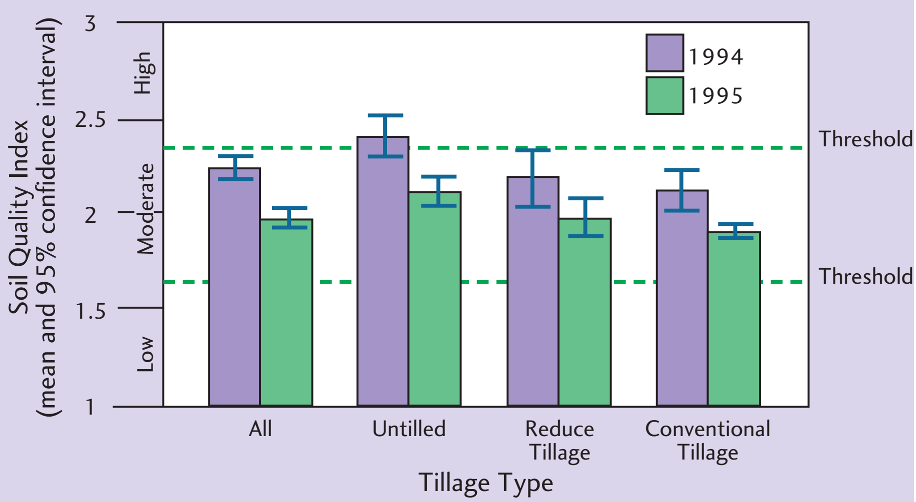
Indicator Gaps and Limitations

Data are available only for the mid-Atlantic region for 2 years. The indicator has the potential to be applied in other areas, but it will have to be adjusted for regional differences.

Data Source

The data source for this indicator was the Mid-Atlantic Integrated Assessment Program, U.S. Environmental Protection Agency (1994-1995). (See Appendix B, page B-41 for more information.)

Exhibit 5-17: Soil quality index for different tillage systems in the mid-Atlantic states, 1994 and 1995



Dashed lines represent thresholds between low, moderate, and high ranges in soil quality for supporting plant growth.

Coverage: Mid-Atlantic states.

Source: Hellkamp et al. *Assessment of the Condition of Agricultural Lands in Six Mid-Atlantic States. 2000.*

[9]The confidence interval (CI) of the mean is a range of values (interval) with a known probability (confidence, in this case 95 percent) of containing the true population mean. The 1994 measured SQI scores are only a sample of the entire population of SQI scores for the region. While the mean of the measured SQI scores was 2.23, there is a 95 percent probability that the mean for the entire population would be between 2.17 and 2.29.

Indicator | Soil erosion - Category 2

Sediment resulting from soil erosion and transport is the greatest pollutant in aquatic ecosystems, both by mass and volume (EPA, OW, August 2002). Soil particles also can transport sorbed nutrients and pesticides and carry these into aquatic systems where these constituents contribute to water quality problems. Agricultural soil erosion decreases soil quality and can reduce soil fertility, and soil movement can make normal cropping practices difficult (The Heinz Center, 2002). Soil erosion and transport can occur both by wind and by water.

Soil erosion estimates were calculated using the U.S. Geological Survey hydrologic unit codes watersheds (8-digit HUCs), National Resources Inventory soils data, the Universal Soil Loss Equation (Renard, et al., 1997), and the Wind Erosion Equation (Bondy, et al., 1980; Skidmore and Woodruff, 1968). Soil parameters were obtained from the USDA Natural Resources Conservation Service database.

What the Data Show

The acreage of U.S. farmland with the greatest potential for wind erosion decreased by almost 33 percent to about 63 million acres from 1982 to 1997 (The Heinz Center, 2002) (Exhibit 5-18). This acreage represents about 15 percent of the total cropland in the U.S. The acreage with the greatest potential for water erosion also decreased by about 33 percent to 89 million acres, which represents about 22 percent of U.S. cropland (The Heinz Center, 2002). Reductions in erosion can occur through improved tilling or management practices, taking marginal land out of production, participation in the Conservation Reserve Program, or similar activities. These reductions not only can contribute to increased soil quality, but also improved water quality in adjacent and downstream aquatic ecosystems.

Indicator Gaps and Limitations

This indicator provides estimates for the initiation of soil movement, not sediment transport or delivery off farmlands, which would require additional measurements and calculations. The distance the soil particles are moved might be considerable or minimal and cannot be determined from soil erosion estimates.

Data Sources

The data sources for this indicator were the National Resources Inventory, U.S. Department of Agriculture (1982-1997); and the State Soil Geographic Database (STATSGO), U.S. Department of Agriculture (1982-1997). (See Appendix B, page B-42, for more information.)

Exhibit 5-18: Croplands most prone to erosion, 1997

Croplands most prone to wind erosion, 1997

Croplands most prone to water erosion, 1997

Coverage: lower 48 states.

Note: data cover cropland and Conservation Reserve Program lands, but not pasture.

Source: The Heinz Center. *The State of the Nation's Ecosystems.* 2002. Data from the USDA, Natural Resources Conservation Service.

Summary: The Ecological Condition of Farmlands

Farmlands represent a significant portion of the landscape, but their ecological condition nationally, or even for most regions, is unknown. In a limited number of watersheds in which agricultural lands are the predominant land use, data indicate that concentrations of nitrate, phosphorus, and many contaminants are above levels of concern, but these data are not available for a representative sample of streams that could serve as a baseline for water quality management decisions for the entire U.S. No data for national indicators are available for three of the six essential ecological attributes, and many of the indicators for the other EEAs relate primarily to crop or livestock production. Habitat alteration and constituent loading from farmlands represent some of the major stressors on other ecosystems (see Chapter 2, Purer Water, and Chapter 3, Better Protected Land, for discussion of specific stressors.)

Landscape condition

While there is no single, definitive, accurate estimate of the extent of cropland, it has been estimated to have decreased by 10.4 percent between 1982 and 1997, from about 421 million acres to nearly 377 million acres. Of this 44-million acre decrease, 32.7 million acres are now enrolled in the CRP, leaving an 11.3 million acre loss as a result of conversion of croplands to other land uses. The Heinz report assesses total cropland (including pasture and hayland) as covering between 430 and 500 million acres in 1997, or about a quarter of the total land area in the U.S. (excluding Alaska). In many areas of the U.S., other land cover types within croplands are almost as prevalent as croplands themselves and can provide habitat for non-agronomic species. For example, croplands comprise only half of the larger farmland ecosystems in the East and Southeast and about three-quarters of the farmland ecosystems in the Midwest. This situation suggests that much of the farmland in the country supports more biodiversity and associated ecological processes than if it were more completely monoculture. Indicators for fragmentation of farmland landscapes by development and the shape of "natural" patches in farmland landscapes would be helpful additional indicators of landscape condition (The Heinz Center, 2002).

Chemical and physical characteristics

The physical and chemical characteristics of farmlands could provide information to measure national progress in controlling and managing non-point source pollutant transport to receiving waters under EPA's clean water Government Performance and Results Act (GPRA) goal. Unfortunately, many of the indicators for physical and chemical characteristics are estimated based on land use, rather than on measurements of water quality. The National Water Quality Assessment (NAWQA) program provides consistent and comparable information on nutrient and pesticide concentrations in streams in agricultural areas. The data show that nitrate and phosphorus concentrations in farmland streams are generally higher than in urban and suburban streams, and that more than 80 percent of the streams sampled had at least one pesticide whose concentration exceeded guidelines for protection of aquatic life. The sites sampled do not represent a probability sample and are too few to ensure that these data are representative of farmlands nationwide. Additional stream monitoring networks are required to assess the physical and chemical characteristics of streams in agricultural areas and the effectiveness of agricultural management practices for protecting or improving stream quality. A *pesticide leaching potential* indicator and a *soil quality index* indicate that only 10 percent of the soils in the mid-Atlantic region were highly leachable with respect to pesticides, and that soil quality was in the "moderate" range, but the indicator has not been widely applied elsewhere.

Hydrology and geomorphology

Sediment Runoff results in loss of valuable soil from the farmland, sediment impacts to the physical habitat of farmland streams, and transport of many pollutants to downstream lakes, reservoirs, and estuaries. The highest potential for sediment runoff is concentrated in upper Mississippi River valley and the Ohio River valley. Most of the western U.S. region is characterized by low runoff potential. Between 1982 and 1997, the acreage with the greatest potential for water erosion decreased by about 33 percent to 89 million acres, which represents about 22 percent of U.S. cropland. Wind can also erode soil. The acreage of U.S. farmland with the greatest potential for wind erosion decreased by almost 33 percent to about 63 million acres from 1982 to 1997, about 15 percent of the total cropland in the U.S. There were no indicators of hydrology available for either surface or ground water associated with agricultural ecosystems. Modification or elimination of wetlands and riparian areas contributes to hydrologic alteration of farmlands, as does agricultural irrigation, primarily in the western states. This consumption affects not only surface water through irrigation return flows, but also ground water through depletion of aquifers. Both water quantity and quality can be affected in farmlands. No national, representative monitoring programs exist for either the quantity or quality of water in farmlands.

No Category 1 or 2 indicators were available for this report for *biotic condition, ecological processes,* or *natural disturbance regimes.* The Heinz Center (2002) suggested that several indicators could be promising: soil biological condition, status of animal species in farmland areas, native vegetation in areas dominated by cropland, and stream habitat quality. An indicator of ant diversity and wildlife habitat also was developed and tested in the mid-Atlantic region by the Mid-Atlantic Integrated Assessment Program (MAIA). Data are insufficient, however, to report on agroecosystems nationally for any of these indicators (Hellkamp, et al., 2000; The Heinz Center, 2002). A particular problem in farmlands is establishing appropriate reference conditions for biological structure and ecosystem function measures (The Heinz Center, 2002). Agricultural systems are highly managed ecosystems, so no natural reference exists. It would be unrealistic to expect fish and invertebrate communities in farmlands to be comparable to relatively undisturbed forest or grassland ecosystems.

5.4 What Is the Ecological Condition of Grasslands and Shrublands?

Grasslands and shrublands include lands in which the dominant vegetation is grasses or other non-woody vegetation, or where shrubs and scattered trees are typical (The Heinz Center, 2002). This ecosystem type includes chaparral, deserts, mountain shrublands, range lands, Florida grasslands, and non-cultivated pastures. Grasslands and shrublands also can be used for grazing, so some land use summaries may include them in estimates of farmlands. Grasslands and shrublands include lands revegetated naturally or artificially to provide a non-crop plant cover that is managed like native vegetation. The vast majority of grasslands and shrublands occur in the western U.S. Collectively, these ecosystems constitute over one-third of the area in the conterminous U.S.

Environmental issues associated with grassland and shrubland ecosystems include introduction of non-native and invasive species, desertification, ground water depletion, and overgrazing. Several federal agencies (e.g., Bureau of Land Management, Forest Service, National Park Service) have responsibility for the majority of publicly owned grasslands and shrublands.

Ecological indicators used in this report for grassland and shrubland ecosystems are listed in Exhibit 5-19. The Heinz report serves as the primary source of information for this ecological resource (The Heinz Center, 2002). The following indicators presented in previous chapters relate to the ecological condition of grasslands and shrublands:

- The *Extent of Grasslands and Shrublands* indicator (Chapter 3, Better Protected Land) reveals that grasslands and shrublands occupy about 861 million acres or just over one-third of the land area in the conterminous U.S. states. Alaska contains about 205 million acres of grasslands and shrublands.
- *Number/Duration of Dry Stream Flow Periods in Grasslands and Shrublands* (Chapter 2, Purer Water) is an important indicator of the hydrology of grasslands and shrublands. This indicator shows that the percentage of no-flow periods has decreased in all grassland and shrubland regions of the West (The Heinz Center, 2002). The percentage of no-flow periods was similar in 1950 and 1960 and then decreased in the 1970s, 1980s, and 1990s. The 1980s was a relatively wet period and experienced some of the smallest percentages of no-flow periods over the 50-year period on record. The duration of zero-flow periods also decreased during the period from the 1970s through the 1990s, compared to the 1950s and 1960s (The Heinz Center, 2002).

The two biotic structure indicators in Exhibit 5-19, described on the following pages, appear for the first time in this chapter: *At-Risk Native Species* and *Population Trends of Invasive and Native, Non-invasive Birds*.

Exhibit 5-19: Grasslands and shrublands indicators

Essential Ecological Attribute	Indicators	Category		Source
Landscape Condition		1	2	
Extent of Ecological System/Habitat Types	Extent of grasslands and shrublands	■		DOI
Landscape Composition				
Landscape Structure/Pattern				
Biotic Condition				
Ecosystems and Communities	At-risk native grassland and shrubland species		■	NatureServe
	Population trends in invasive and native non-invasive bird species	■		DOI
Species and Populations				
Organism Condition				
Ecological Processes				
Energy Flow				
Material Flow				
Chemical and Physical Characteristics				
Nutrient Concentrations				
Other Chemical Parameters				
Trace Organics and Inorganics				
Physical Parameters				
Hydrology and Geomorphology				
Surface and Ground Water Flows	Number/duration of dry stream flow periods in grasslands/shrublands	■		DOI
Dynamic Structural Conditions				
Sediment and Material Transport				
Natural Disturbance Regimes				
Frequency				
Extent				
Duration				

Indicator

At-risk native grassland and shrubland species - Category 2

Native species contribute substantially to the goods and services provided by grasslands and shrublands. These species have evolved in and adapted to the reange of environmental conditions that has occurred in grassland and shrubland ecosystems over thousands of years. While species extinction is a natural geologic phenomenon, the extinction of species has increased over the past 100 years (Vitousek, et al., 1997), and many ecologists believe that ecosystem function and resilience is related to biodiversity (Naeem, et al., 1999), so that preserving biodiversity is critical for sustainable ecosystems. Whether or not this is always the case[10] many people believe that more species is preferable to fewer species.

What the Data Show

About 3.5 percent of native grassland and shrubland animal species are critically imperiled, 6 percent are imperiled, and 0.5 percent are or might be extinct (The Heinz Center, 2002) (Exhibit 5-20). When vulnerable species (7 percent) are counted, about 17 percent of grassland and shrubland animal species are considered "at risk."

Indicator Gaps and Limitations

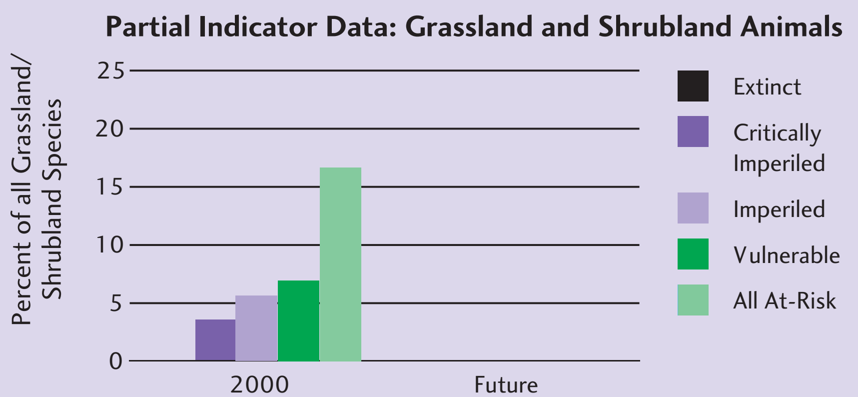
The data for this indicator are not from a site-based monitoring program, but rather from a census approach that focuses on the location and distribution of at-risk species. Determining whether species are naturally rare or have been depleted is currently not possible. It is not clear that trends can be quantified with any precision.

Data Source

The data source for this indicator was *The State of the Nation's Ecosystems,* The Heinz Center, 2002, using data from NatureServe Explorer database. (See Appendix B, page B-42, for more information.)

Exhibit 5-20: At-risk native grassland and shrubland species, by risk category, 2000

Data Not Adequate for National Reporting on Grassland and Shrubland Plants



Coverage: all 50 states.

Source: The Heinz Center. *The State of the Nation's Ecosystems.* 2002. Data from NatureServe and its Natural Heritage member programs.

[10] An ongoing debate exists within the scientific community on the importance of species diversity in sustaining ecosystem functoin (Tilman and Downing, 1994; Grime, 1997; Hodgson, et al., 1998; Wardle, et al., 2000)

Indicator Population trends of invasive and native, non-invasive birds - Category 1

Bird species are mobile and can respond quickly to environmental change (The Heinz Center, 2002). The Heinz report uses an indicator of population trends in invasive and non-invasive birds to determine if invasive bird species are increasing more than other bird populations (The Heinz Center, 2002). Invasive species are defined as non-native species (species that are not native to North America or that are now found outside their historic range) that spread aggressively. Some invasive bird species increase when the landscape becomes more fragmented or stress on the ecological system increases. The invasive species considered for grassland and shrublands are believed to be indicative of agricultural conversion, landscape fragmentation due to suburban and rural development, and the spread of exotic vegetation (The Heinz Center, 2002). Native, non-invasive species are considered to reflect relatively intact, high-quality native grasslands and shrublands (The Heinz Center, 2002).

What the Data Show

Since the late 1960s, invasive and non-invasive bird species increased in similar proportions until the period 1996 to 2000, when invasive species increased significantly (The Heinz Center, 2002) (Exhibit 5-21). This increase might represent a short-term fluctuation in bird populations, or it could be a sign of changing ecosystem condition. Continued monitoring of bird populations and indicators in other essential ecological attributes is required to evaluate these changes.

Indicator Gaps and Limitations

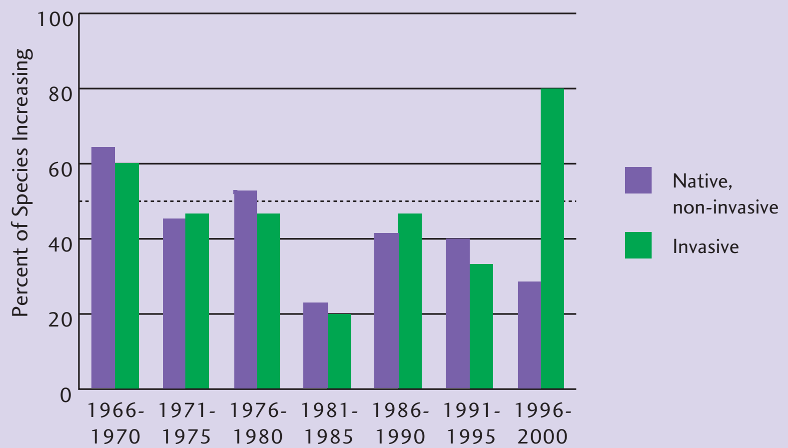
The limitations of this indicator include the following:

- The calculation method could mask increases or decreases in particular species. The two groups of birds contain species that differ in their habitats, relative abundance, and range, and bird populations normally fluctuate from year to year. If half the species in one of the groups were to increase and the other half to decrease over a given period, no consistent change would appear for that group (The Heinz Center, 2002).
- The recent period of change is too short to provide an indication of a possible increasing trend in invasive bird species.

Data Source

The data source for this indicator was the Breeding Bird Survey, U.S. Geological Service (1966-2000). (See Appendix B, page B-42, for more information.)

Exhibit 5-21: Population trends of invasive and native, non-invasive birds, 1966-2000



Coverage: selected grassland and shrubland areas.

Source: The Heinz Center. *The State of the Nation's Ecosystems.* 2002. Data from the U.S. Geological Survey, Breeding Bird Survey; analysis by W. Mark Roberts.

Summary: The Ecological Condition of Grasslands and Shrublands

Grassland and shrubland ecosystems are at risk from the introduction of non-native and invasive species, desertification, ground water depletion, and overgrazing. Few ecological indicators are currently being measured at a national or regional scale, and this situation is unlikely to change in the near future, so the overall ecological condition of the nation's grasslands and shrublands is and will remain effectively unknown.

Landscape condition

The extent of grasslands and shrublands can be estimated from National Land Cover Database (NLCD) information. Grasslands and shrublands occupy about 861 million acres or just over one-third of the land area in the conterminous U.S. Alaska contains about 205 million acres of grasslands and shrublands. This is a diverse group of ecosystems, however, ranging from Florida grasslands to the Mohave desert, and land use information is not readily available for all of them.

Biotic condition

At-risk native species and population trends in invasive and non-invasive birds are two indicators that can provide information on the status of, and change in, biotic condition. About 3.5 percent of native grassland and shrubland animal species are critically imperiled, 6 percent are imperiled, and 0.5 percent are or might be extinct. When vulnerable species (7 percent) are counted, about 17 percent of grassland and shrubland animal species are considered "at risk." However, there is no context in which to interpret the at-risk native species data. The proportion of species that would naturally be rare is unknown. Invasive species are believed to be indicative of agricultural conversion, landscape fragmentation due to suburban and rural development, and the spread of exotic vegetation, whereas native, non-invasive species are considered to reflect relatively intact, high-quality native grasslands and shrublands. Until recently, invasive and non-invasive bird species have changed in similar proportions, but from 1996 to 2000, invasive species increased significantly. This might be a short-term fluctuation in bird populations, or it could be a sign of changing ecosystem condition. Information on stream biota in grasslands and shrublands are needed to be able to assess the condition of grassland and shrubland streams, especially as it may be affected by grazing.

Hydrology and geomorphology

Periods of no flow can certainly be stressful to aquatic communities of grasslands and shrublands, and may indicate harm to the vegetation during drought periods. *The Number/Duration of Dry Stream Flow Periods* indicator has decreased in all grassland and shrubland regions of the West. The percentage of no-flow periods was similar in 1950 and 1960 and then decreased in the 1970s, 1980s, and 1990s. The duration of zero-flow periods also decreased during the period from the 1970s through the 1990s, compared to the 1950s and 1960s. Currently, dry stream flow periods are not monitored nationally.

There were no Category 1 or 2 indicators available for this report f*or ecological processes, physical and chemical characteristics,* or *natural disturbance regimes* for grasslands and shrublands.

5.5 What Is the Ecological Condition of Urban and Suburban Areas?

Urban and suburban ecosystems are areas where the majority of the land is devoted to or dominated by buildings, houses, roads, concrete, grassy lawns, or other elements of human use and construction (The Heinz Center, 2002). Urban ecosystems are highly built-up and paved over, resulting in more rapid changes in temperature, runoff, and other variables than in more natural ecosystems. Plant and animal life is heavily influenced by species introduced in horticulture and as pets, and native plant species might be more or less completely removed from large areas and replaced by lawns, gardens, and ornamentals (WRI, 2000). These areas generally show high levels of many air and water pollutants because of the concentration of pollutant sources in small areas. Nonetheless, substantial biodiversity

Exhibit 5-22: Urban and suburban indicators

Essential Ecological Attribute	Indicators	Category		Source
Landscape Condition		1	2	
Extent of Ecological System/Habitat Types	Extent of urban and suburban lands	■		USDA
Landscape Composition	Patches of forest, grassland, shrubland, and wetland in urban/suburban areas		■	DOI
Landscape Structure/Pattern				
Biotic Condition				
Ecosystems and Communities				
Species and Populations				
Organism Condition				
Ecological Processes				
Energy Flow				
Material Flow				
Chemical and Physical Characteristics				
Nutrient Concentrations	Nitrate in farmland, forested and urban streams and ground water		■	DOI
	Phosphorus in farmland, forested and urban streams		■	DOI
Other Chemical Parameters				
Trace Organics and Inorganics	Chemical contamination in urban streams and ground water		■	DOI
	Ambient concentrations of ozone, 8-hour and 1-hour	■		EPA
Physical Parameters				
Hydrology and Geomorphology				
Surface and Ground Water Flows				
Dynamic Structural Conditions				
Sediment and Material Transport				
Natural Disturbance Regimes				
Frequency				
Extent				
Duration				

can remain in these systems; for example, a 1993 survey identified 115 bird species in Washington, DC (Hadidian, et al., 1997).

There is substantial interest in understanding urban and suburban ecosystems, as evidenced by two urban National Science Foundation long-term ecological research sites (Phoenix and Baltimore), a professional journal, *Urban Ecosystems* and a number of recent writings on the subject (Pickett, et al., 2001; Kinzig and Grove, 2001; Grimm, et al., 2002). Much of urban ecosystems research is aimed not at preserving natural ecosystems, but at "smart growth" and understanding how to enhance ecosystem services in a highly built environment. Despite the growing amount of research, the entire science of urban ecosystem ecology is not sufficiently developed to have a substantial number of ecological indicators. In addition, there may be a lack of understanding regarding what to expect when applying indicators typically used in less built-up land cover classes to urban and suburban ecosystems. The Heinz report lists eight indicators for urban and suburban ecosystems, only two of which have adequate data for national reporting.

Indicators for urban and suburban ecosystems used in this report are listed in Exhibit 5-22, grouped according to essential ecological attributes. Extent and chemical and physical condition data are the most widely available. There were no indicators for biotic condition, ecological processes, hydrology and geomorphology, or natural disturbance regimes for urban and suburban ecosystems suitable for national or even regional reporting (The Heinz Center, 2002).

This section summarizes data related to urban and suburban ecosystems for five indicators, most of them relating to pollutant concentrations, that appear in earlier chapters. The section then introduces one indicator that appears for the first time in this report—*Patches of Forest, Grassland, Shrubland, and Wetland in Urban/Suburban Areas*—which relates to the landscape essential ecological attribute.

The following indicators presented in previous chapters relate to the ecological condition of urban and suburban areas:

- The indicator *Extent of Urban and Suburban Lands* (Chapter 3, Better Protected Land) was assessed using the National Land Cover Database and estimating the proportion of the area in 1,000 foot pixels that fell into one of four developed land cover types: low-intensity residential; high-intensity residential; commercial-industrial-transportation; or urban and recreational grasses (The Heinz Center, 2002). In 1992, urban and suburban areas occupied about 32 million acres in the conterminous U.S. or about 1.7 percent of the total land area (The Heinz Center, 2002). As with the estimate of the extent of farmlands, urban and suburban areas are defined differently by different organizations, sometimes using different data sources, thus affecting the area estimates. For example, the Extent of Developed Lands indicator in Chapter 3, Better Protected Land is based on USDA National Resources Inventory delineation of developed lands, which is about 98 million acres in the conterminous U.S., or about 4.3 percent of the total land area of the U.S., not including Alaska (see Chapter 3, Better Protected Land).
- The indicator A*mbient Concentrations of Ozone, 8-hour and 1-hour* (Chapter 1, Cleaner Air) revealed that in 1999, about 55 percent of the urban and suburban monitoring stations had high ozone concentrations on 4 or more days, and that the percentage fluctuated between 35 percent and 60 percent during the 1990s (The Heinz Center, 2002). The number of sites with 10 days or more of high ozone fluctuated between 20 and 30 percent of the sites, with no apparent trend, but the number of sites with high ozone on 25 days or more decreased from about 10 percent to around 5 percent over the decade. Fluctuations are caused in part by changes in the weather. As noted in the section on forests, biomonitoring plots frequently reveal at least some ozone damage to tree leaves.
- The indicator *Nitrate in Farmland, Forested, and Urban Streams and Ground Water* (Chapter 2, Purer Water), shows that 40 percent of 21 streams in which the predominant land use was urban and suburban had nitrate concentrations above 1.0 ppm; 25 percent had concentrations below 0.5 ppm; and 3 percent had concentrations below 0.1 ppm (The Heinz Center, 2002). Concentrations of nitrate in these urban streams were generally lower than those of agricultural watersheds, but higher than those in forested watersheds.
- The indicator *Phosphorus in Farmland, Forested, and Urban Streams (*Chapter 2, Purer Water) showed that two-thirds of 21 urban streams sampled had phosphorus concentrations of at least 0.1 ppm, a level usually associated with excess algal growth (The Heinz Center, 2002). About 10 percent of the urban streams had concentrations of at least 0.5 ppm.
- According to the indicator *Chemical Contamination in Streams and Ground Water* (Chapter 2, Purer Water), 85 percent of 21 urban streams sampled had an average of about five detectable contaminants throughout the year (The Heinz Center, 2002). All of the streams had at least one chemical that exceeded guidelines for the protection of aquatic life. For many urban and suburban streams, the nutrient and contaminant signature is similar to the signatures from agroecosystems (The Heinz Center, 2002; Wickham, et al., 2002).

The following indicator, *Patches of Forest, Grassland, Shrubland, and Wetland in Urban/Suburban Areas,* provides data on landscape condition in urban and suburban areas.

Indicator Patches of forest, grassland, shrubland, and wetland in urban/suburban areas - Category 2

Patches of forest, grassland, shrubland, and wetland in urban/suburban areas provide habitat for birds, amphibians, and small mammals. They also increase water infiltration and reduce temperature by evapotranspiration. Patches of urban and suburban vegetation generally reduce particulate matter, and they can increase or decrease ozone concentrations, relative to built surfaces (Nowak, et al., 2000). According to The Heinz Center (2002), the size of patches of undeveloped land in urban and suburban areas is important, with smaller patches generally considered to provide poorer quality habitat. Recent studies have indicated a significant loss of forest patch coverage in Atlanta and Baltimore in the last several decades (American Forests, 2001, 2002).

What the Data Show

Around half of the undeveloped land in urban and suburban areas occurs in patches smaller than 10 acres (Exhibit 5-23). Urban and suburban areas in the Northeast have the largest percentage of large (1,000 to 10,000 acres) patches of undeveloped land. Patches of undeveloped land larger than 10,000 acres occur only in urban and suburban areas of the West.

Indicator Gaps and Limitations

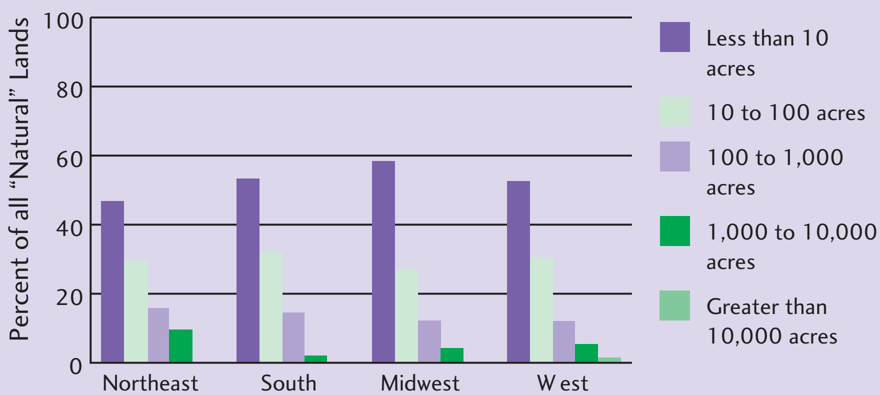
Several limitations are associated with this indicator:

- Natural patches may extend beyond the boundary of the "urban and suburban area" land use class, which would cause the size of the patches to be underestimated.
- Very small patches are difficult to distinguish if they are mixed with developed classes, which also leads to underestimates.
- Remote sensing cannot distinguish between land that has always been "non-urban" and patches, such as landfills, that have reverted to grasslands or forest.
- Patch size is not the only factor that contributes to habitat quality (The Heinz Center, 2002).

Data Source

The data source for this indicator was the National Land Cover Database, Multi-Resolution Land Characterization Consortium (1990s). (See Appendix B, page B-43, for more information.)

Exhibit 5-23: Patches of forest, grassland, shrubland, and wetland in urban and suburban areas, 1992



Coverage: lower 48 states

Source: The Heinz Center. *The State of the Nation's Ecosystems.* 2002. Data from Multi-Resolution Land Characteristics Consortium, and the USGS Earth Resources Observations Systems Data Center.

Summary: The Ecological Condition of Urban and Suburban Ecosystems

Urban and suburban systems have been the subject of increasing ecological interest, but their overall condition, nationally or even regionally, is virtually unknown.

Landscape condition

Within the technical limitations of using remote sensing data to define urban and suburban ecosystems and the landscape patches they contain, The Heinz Center (2002) has established a baseline against which to judge current trends in urbanization. In 1992, urban and suburban areas occupied about 32 million acres in the conterminous U.S. or about 1.7 percent of the total land area, but different organizations, sometimes using different data sources, produce different estimates. For example, USDA National Resources Inventory delineation of developed lands, estimates there to be about 98 million acres in the conterminous U.S., or about 4.3 percent of the total land area of the U.S., not including Alaska (see Chapter 3, Better Protected Land). However, there is currently no firm plan in place to collect the remote sensing data in the future to allow trends to be calculated. Although the land use indicators identified provide some useful information on extent, they do not address the actual condition of those lands. Given the concentration of the human population in developed areas of the country, a better understanding of the interaction among humans and their developed environment could help improve human health and the effects of developed lands on ecological condition.

Chemical and physical characteristics

Chemical data from the NAWQA program used to develop the stream quality indicator in this report and the Heinz report (2002) include only 21 urban streams across the entire U.S. Nitrate and phosphorus concentrations in these streams were intermediate between farmlands and forest streams, but all of them had at least one chemical that exceeded guidelines for the protection of aquatic life. Given the numerous factors that can affect these systems, 21 streams are not likely to be an adequate baseline against which to track the progress of environmental protection activities, including stormwater management, controls on non-point source pollution from lawns, golf courses, and septic systems, with any statistical certainty. An indicator of the extent of impervious surfaces might be useful for inferring non-point source pollution impacts.

There were no Category 1 or 2 indicators available for this for *biotic condition, ecological processes,* or *natural disturbance regimes.* The Heinz Center (2002) identified several indicators that could be promising but for which there are not even regional data:

- An indicator that would report on the percentage of urban and suburban areas in which <25 percent, 25 to 50 percent, 50 to 75 percent, and >75 percent of the original species had been lost or displaced.
- An indicator that would report on the number of nuisance species in urban and suburban areas (e.g., white-tailed deer, kudzu).
- Fish Index of Biotic Integrity (IBI) and Macroinvertebrate Biotic Integrity Index (MBII) indicators in urban/suburban streams.
- An indicator that would report on the coverage of stream bank vegetation.

The lack of national biotic indicators for urban fresh water systems makes it particularly difficult to measure national progress in maintaining balanced communities in urban streams.

A particular problem in urban and suburban systems is establishing appropriate reference conditions for biological structure and ecosystem function measures (The Heinz Center, 2002). For example, expecting fish and invertebrate communities in urban streams to be typical of relatively undisturbed forest or grassland ecosystems would be unrealistic. Data are insufficient on both the current status of species and the original species present to calculate the number of native species lost. As another example, an indicator tracking national trends in urban stream buffers would be particularly helpful to states tracking the effectiveness of watershed management programs. However, a decision would be needed on a threshold for buffer strips of adequate width to protect stream channels, and further development of satellite measurements would be needed before such an indicator could be used for national reporting.

A potentially useful hydrology/geomorphology indicator would be the percentage of impervious area (The Heinz Center 2002). Impervious areas generally increase runoff from rain events, leading to modified stream channels, increased stream temperatures, decreased infiltration, and pollutants carried into ecosystems (e.g., Booth and Jackson, 1997). According to The Heinz Center, however, although some local governments collect data on impervious surfaces, it is difficult to measure (Arnold and Gibbons, 1996), and there are insufficient data on this indicator for national reporting. Tracking impervious surface changes may be important for measuring progress in reducing the impact of stormwater runoff on the quality of receiving streams.

Another potentially useful indicator is the urban heat island (The Heinz Center 2002). Urban heat islands raise the ambient temperature surrounding both terrestrial and aquatic ecosystems. Because chemical and biological reaction rates are temperature dependent, increased heating and temperatures can increase the stress on all biological species, both directly and indirectly. Dissolved oxygen saturation is lower in warmer water, so aquatic organisms, with higher metabolic rates and the need for greater oxygen supplies, have less oxygen available in the water because of lower oxygen saturation in warm water. The heat island effect can also have important impacts on air quality in urban and downwind areas (Nowak, et al., 2000). Again, the data may be available to calculate this indicator, but it has not been developed nationally.

5.6 What Is the Ecological Condition of Fresh Waters?

Fresh waters include wetlands, lakes and reservoirs, and streams and rivers. Wetlands are areas where saturation with water is the dominant factor determining the types of plant and animal communities. Wetlands vary widely because of differences in soils, topography, climate, hydrology, water chemistry, vegetation, and other factors. Two general categories of wetlands are recognized: coastal (tidal) wetlands and inland (non-tidal) wetlands. Wetlands have been threatened by outright loss and conversion from one type to another, but programs designed to restore or enhance wetlands, such as the Wetlands Reserve Program, as well as state, local, and private initiatives on agricultural lands, have resulted in reduced losses (see Chapter 2, Purer Water).

The U.S. contains more than 3.7 million miles of streams and rivers. About 60 percent of all these stream miles are found in small, head-

Exhibit 5-24: Fresh water indicators

SAB Framework	Indicators	Category		Source
Landscape Condition		1	2	
Extent of Ecological System/Habitat Types	Wetland extent and change	■		DOI
	Extent of ponds, lakes, and reservoirs	■		DOI
Landscape Composition	Altered fresh water ecosystems		■	DOI
Landscape Structure/Pattern				
Biotic Condition				
Ecosystems and Communities	Non-native fresh water fish species		■	DOI
	Animal deaths and deformities		■	DOI
	At-risk fresh water plant communities		■	NatureServe
	Fish Index of Biotic Integrity in streams		■	EPA
	Macroinvertebrate Biotic Integrity Index for streams		■	EPA
Species and Populations	At-risk native fresh water species		■	NatureServe
Organism Condition	Contaminants in fresh water fish		■	DOI
Ecological Processes				
Energy Flow				
Material Flow				
Chemical and Physical Characteristics				
Nutrient Concentrations	Phosphorus in large rivers		■	DOI
	Lake Trophic State Index		■	EPA
Trace Organic and Inorganic Chemicals	Chemical contamination in streams		■	DOI
Other Chemical Parameters	Acid sensitivity in lakes and streams		■	EPA
Physical Parameters				
Hydrology and Geomorphology				
Surface and Ground Water Flows	Changing stream flows	■		DOI
Dynamic Structural Conditions				
Sediment and Material Transport	Sedimentation index		■	EPA
Natural Disturbance Regimes				
Frequency				
Extent				
Duration				

water streams. The U.S. also contains more than 60 million acres of lakes, ponds, and reservoirs. Natural lakes are generally located in previously glaciated areas of the Northeast and Midwest, in mountainous areas, and as sinkholes or seepage lakes in Florida. Oxbow lakes are associated with former meanders of river systems. Reservoirs predominate in the West and in the unglaciated areas of the South and Southeast. Ponds, both manmade and natural, are found throughout the U.S. (see Chapter 2).

Many of the problems facing fresh water systems are similar: low dissolved oxygen, eutrophication, acidification, toxic materials in air deposition (e.g., mercury), point and non-point discharges and sediments, siltation, hydrologic modification, temperature modification, effects of Ultraviolet-B (UV-B) radiation, invasive species, overfishing, and more recently, endocrine-disrupting chemicals (e.g., Naiman and Turner, 2000). According to the most recent 305(b) report required bi-annually under the Clean Water Act, approximately one-half of the lakes and slightly more than one-half of the streams assessed by the states do not meet the designated use assigned to them by the state in which they are located (EPA, OW, August 2002).[11]

There have been several systematic efforts over the past three decades to report on the condition of lakes and stream ecosystems with respect to some of these issues:

- The U.S. Fish and Wildlife Service (USFWS) conducted the National Fisheries Survey to determine the condition of fish communities in the nation's streams (Judy, et al., 1984). The survey used a probability design, and fish community condition was based on expert opinion, rather than collection of field data.
- The National Surface Water Survey (NSWS) used a probability design to assess the acidity of lakes and streams in all areas of the U.S. sensitive to acid deposition (NAPAP, 1991; Baker, et al., 1991; Kaufmann, et al., 1991).
- The Temporally Integrated Monitoring of Ecosystems (TIME) program has continued monitoring a representative sample of acid sensitive lakes and streams, in the Northeast and Appalachians (Stoddard, et al., 1999).
- The National Water Quality Assessment (NAWQA) network samples surface fresh water ecosystems in 50 watersheds, and makes measurements of chemistry and biota (<http://water.usgs.gov/nawqa/>).
- The Environmental Monitoring and Assessment Program (EMAP) conducted a pilot survey of streams in the mid-Atlantic states, measuring chemistry and biota (Herlihy, et al., 2000). Surveys are ongoing in the western states and have just begun in large river systems of the mid-continent.

This substantial experience has contributed progress in monitoring ecological condition in lakes and streams, but there are still few Category 1 indicators.

Exhibit 5-24 shows the fresh water indicators used in this report, grouped according to the essential ecological attributes. Nine of these indicators are discussed in the previous chapters. This section briefly summarizes those indicators, and then introduces seven new ones. There are no indicators available for national or regional reporting for ecological processes or natural disturbance regimes (The Heinz Center, 2002). Indicators presented in previous chapters include:

- The indicator *Wetland Extent and Change* (Chapter 2, Purer Water) shows that since European settlement of the conterminous U.S., more than half of the original 220 million acres of wetlands have been drained and filled. Wetland types include fresh water forested, shrub, and emergent wetlands, plus open water ponds. By 1997, total wetland acreage was estimated to be 105.5 million acres (Dahl, 2000). Of that total, nearly 95 percent or 100.2 million acres were fresh water, and about 5 percent or 5.3 million acres were intertidal marine and estuarine. Rates of annual wetland losses have been dropping from almost 500,000 acres a year three decades ago to less than 100,000 acres averaged annually since 1986. The loss rate between 1986 and 1997 was estimated to be 58,500 acres per year, an 80 percent reduction in the rate of loss from the previous decade.

  A related ecological impact has been the conversion of one wetland type to another, such as clearing trees from a forested wetland or excavating a shallow marsh to create an open water pond. Open water ponds, which have more than doubled in area since the 1950s, are not the ecological equivalent of fresh water emergent marshes. Such conversions change habitat types and community structure in watersheds and impact the animal communities that depend on them.

  Urban development accounted for an estimated 30 percent of all wetland losses. Estimates for the other loss categories included 26 percent to agriculture, 23 percent to silviculture, and 21 percent to rural development. An estimated 98 percent of all wetlands converted to other uses were fresh water wetlands (Dahl, 2000).

  Forested and emergent wetlands make up over 75 percent of all fresh water wetlands. Since the 1950s, fresh water emergent wetlands have declined by nearly 24 percent, more than any other fresh water wetland type. Fresh water forested wetlands have sustained the greatest overall losses—10.4 million acres since the 1950s.
- Physically altering a fresh water body to increase some other benefit (e.g., flood control, navigation, reduced erosion, or increased area for farming or development) also may change fish

[11] While these statistics are reported biannually, because the states use different measures and monitoring designs, the results do not provide a comparable and consistent picture of the condition of lakes and streams nationally (USGAO, 2000). See Section 2.2.1 for a discussion of recent progress on this issue.

and wildlife habitat, disrupt patterns and timing of water flows, act as barriers to animal movement, or reduce or increase natural filtering of sediment and pollutants. The indicator *Altered Fresh Water Ecosystems* (Chapter 2, Purer Water), reveals that 23 percent of the banks of both rivers and streams (riparian areas) and lakes and reservoirs have either croplands or urban development in the narrow area immediately adjacent to the stream. Data on the degree to which streams and rivers are channelized, leveed, or impounded are not available. According to Dahl (2000), 78,100 acres (31,600 hectares) of forested wetlands were converted to fresh water ponds. Conversions of forested wetlands to deep water lakes resulted from human activities by either creating new impoundments or raising the water levels on existing impoundments, thus killing the trees.

- The indicator *Contaminants in Fresh Water Fish* (Chapter 2, Purer Water) reported on contaminants in fish tissue for the entire U.S., including polychlorinated biphenyls (PCBs), organochlorine pesticides, and trace elements (The Heinz Center, 2002). The presence of contaminants can be harmful to the organisms themselves, or can affect reproduction, and they can make fish unsuitable for consumption. Half of the fish tested had at least five contaminants at detectable levels, and approximately the same number had one or more contaminants at levels that exceeded the aquatic life guidelines.

  For Mid-Atlantic Highland streams with sufficient fish tissue for analysis (44 percent of stream miles did not have sufficient quantities of fish tissue), about 4 percent of the stream miles had fish tissue mercury concentrations that exceeded wildlife criteria (EPA, ORD, Region 3, August 2000).

- For the the indicator *Phosphorus in Large Rivers* (Chapter 2, Purer Water), The Heinz Center (2002) reports that half of the rivers tested had total phosphorus concentrations of 100 ppb or higher. This concentration (100 ppb) is EPA's recommended goal for preventing excess algal growth in streams that do not flow directly into lakes. None of the rivers had concentrations below 20 ppb, a level generally held to be free of negative effects (EPA, OW, November 1986). Data were insufficient to report on lakes and reservoirs nationally.

- The indicator *Lake Trophic State Index* (Chapter 2, Purer Water) assessed the nutrient or total phosphorus (TP) concentrations in northeast lakes (Peterson, et al., 1998). Once phosphorus enters lakes, it frequently serves as the nutrient that limits the growth of nuisance blooms of phytoplankton (algae). National data on lake trophic condition are not available. However, regional patterns of lake trophic condition were assessed for a target population of 11,076 Northeast lakes sampled as part of the EPA EMAP during summers from 1991 to 1994 using the Lake Trophic State Index. It was found that 37.9 percent (±8.4 percent)[12] of the lakes were oligotrophic (TP<10 ppb), 40.1 percent (±. 9.7 percent) were mesotrophic (10<TP<30 ppb), 12.6 percent (±.7.9 percent) were eutrophic (30<TP<60 ppb), and 9.3 percent (±.6.3 percent) were hypertrophic (TP>60 ppb) (Peterson, et al., 1998).

- The indicator *Chemical Contamination in Streams and Ground Water* (Chapter 2, Purer Water), revealed that all the streams sampled by the NAWQA program had one or more contaminants at detectable levels throughout the year, and 85 percent had five or more (The Heinz Center, 2002).[13] Three-fourths of the streams tested had one or more contaminants that exceeded aquatic life guidelines. One-fourth of the streams exceeded the standards for four or more contaminants. Nearly all of the stream sediments tested had an average of five or more contaminants (PCBs, polycyclic aromatic hydrocarbons [PAHs], other industrial chemicals and trace elements) at detectable levels, and half had one or more contaminants that exceeded aquatic life guidelines. Half of the fish tested had at least five contaminants (PCBs, organochlorine pesticides, and trace elements) at detectable levels, and approximately the same number had one or more contaminants at levels that exceeded the aquatic life guidelines (The Heinz Center, 2002).[14]

- The indicator *Acid Sensitivity in Lakes and Streams* (Chapter 2, Purer Water) is affected by the natural buffering capacity of the soil and the rate of acid deposition from the atmosphere. The National Surface Water Survey (NSWS) (Landers, et al., 1988; Linthurst, et al., 1986; Messer, et al., 1986, 1988) determined that 4.2 percent of the NSWS lakes and 2.7 percent of NSWS streams were acidic (Acid Neutralizing Capacity <0 µeq/L) (Baker, et al., 1991). Almost 20 percent (19.1 percent) of NSWS lakes and 11.8 percent of NSWS streams were susceptible to acidic deposition (ANC < 50 µeq/L) (Baker, et al., 1991).[15] Of the acidic NSWS lakes, 75 percent were classified as acidic from acid deposition, 22 percent were organic acid dominated, and 3 percent were acidic from watershed sulfur sources. Of the acidic stream reaches, 70 percent were acidic from acid deposition, 29 percent were organic acid dominated, and 1 percent were acidic from watershed sulfur sources (Baker, et al., 1991).

  These surveys have been repeated periodically for smaller probability samples of lakes in the Northeast, the Adirondacks, and streams in the Appalachians (Stoddard, et al., 1996). More intensive monitoring also has been conducted on lakes in the Northeast, the Appalachians, and the Midwest, and on streams in the Appalachian Plateau and Blue Ridge to assess long-term acidification trends (Stoddard, et al., 1998). Based on these

[12] Concentrations in parentheses represent the 95 percent confidence interval.

[13] Nitrate, ammonium, and trace metals were not included in the occurrence analysis, because they occur naturally (Heinz(The HeinzCenterHeinz Center, 2002, p.50).

[14]Additional information on chemical contamination in all waters of the U.S. is provided in the technical notes, pp. 210-214, of the Heinz report (2002).

[15]There were regional differences in these percentages: only 0.1 percent of NSWS lakes in the West and Florida were sensitive, but 22.7 percent of Northern Appalachian streams were sensitive.

programs, EPA estimated that in three regions, one-quarter to one-third of lakes and streams previously affected by acid rain were no longer acidic, although they were still highly sensitive to future changes in deposition (EPA, ORD, January 2003). Specifically:

- Eight percent of lakes in the Adirondacks are currently acidic, down from 13 percent in the early 1990s.
- Less than 2 percent of lakes in the Upper Midwest are currently acidic, down from 3 percent in the early 1980s.
- Nine percent of the stream length in the Northern Appalachian Plateau region is currently acidic, down from 12 percent in the early 1990s.

Lakes in New England registered insignificant decreases in acidity, and streams in the Ridge and Blue Ridge regions of Virginia were unchanged. The Ridge and Blue Ridge regions are expected to show a lag time in their recovery due to the nature of their soils, and immediate responses to decreasing deposition were neither seen nor expected. The NSWS has not been repeated nationwide, so no data exist to assess trends in surface water acidification in other sensitive areas of the country.

- The indicator *Changing Stream Flows* is one of two indicators presented in Chapter 2, Purer Water that are associated with fresh water hydrology and geomorphology and relate to the ecological condition of fresh water. Changes in stream flow can result in significant effects on fish habitat and chemical concentrations in streams. According to The Heinz Center (2002), the percentage of streams and rivers with major changes in the high or low flows or timing of those flows increased slightly from the 1970s to the 1990s, but the number with high flows well above the high flows between 1930 and 1949 increased by approximately 30 percent in the 1990s. The earlier 1930 through 1949 period included some droughts, but much of it also preceded widespread dam-building and irrigation projects.
- The greatest stressor to mid-Atlantic streams, and many other streams throughout the U.S., is altered instream habitat (EPA, ORD, Region 3, August 2000). A *Sedimentation Index* (Chapter 2, Purer Water) was developed for Mid-Atlantic Highland streams to assess the quality of instream habitat for supporting aquatic communities (Kaufmann, et al., 1999). The amount of fine sediments on the bottom of each stream was compared with expectations based on each stream's ability to transport fine sediments downstream (a function of the slope, depth and complexity of the stream). When the amount of fine sediments exceeds expectations, it suggests that the supply of sediments from the watershed to the stream is greater than what the stream can naturally process. Streams with levels of fine particles at least 10 percent below the predicted value were rated to be in "good" condition relative to the sedimentation criteria. Those with levels from 10 percent below to 20 percent above the predicted value were rated "fair." Those with levels more than 20 percent above regional mean expectations were rated "poor." Based on the Sedimentation Index, about 35 percent of the stream miles had good instream habitat, 40 percent had fair instream habitat, and 25 percent of the stream miles had poor instream habitat (EPA, ORD, Region 3, August 2000).

Several indicators presented for the first time in this report are described below. They include a Category 1 indicator related to landscape condition and six Category 2 indicators relating to biotic condition. There were no indicators for ecological processes or natural disturbance regimes.

Indicator Extent of ponds, lakes, and reservoirs - Category I

This indicator reports the area of ponds, lakes, and reservoirs in the conterminous U.S., excluding the Great Lakes. Over the long term, changes in this indicator reflect the effects of climate on water levels in existing lakes, ponds, and reservoirs, and of reservoir construction, destruction, and management.

What the Data Show

The Heinz Center (2002) reports that, excluding the Great Lakes, the conterminous U.S. contains 21 million acres of lakes, ponds, and reservoirs. The number of ponds (small water bodies usually less than 20 acres and 6 feet deep) increased by 100 percent since the 1950s (Exhibit 5-25). For unknown reasons, the rate of lake and reservoir creation declined 43 percent from the 1970s to 1980s; deep water lakes and reservoirs showed a modest but statistically unreliable increase between the 1980s and 1990s (Dahl, 2000).

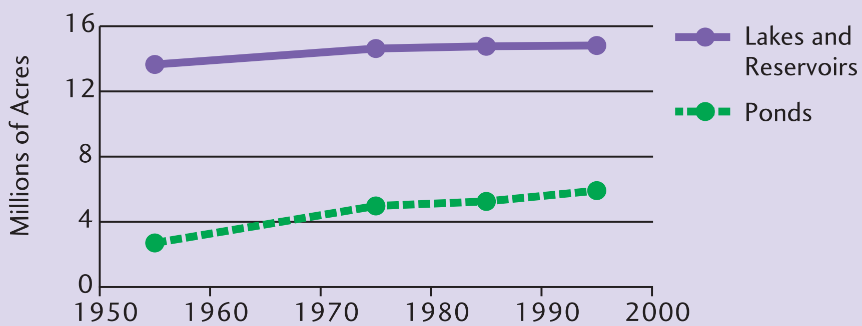
Indicator Gaps and Limitations

The USGS National Hydrography Dataset identifies a considerably larger area of lakes, reservoirs, and ponds at least 6 acres in size (26.8 million acres), and the cause of the discrepancy is unknown (The Heinz Center, 2002).

Data Source

The data source for this indicator was the National Wetlands Inventory, U.S. Fish and Wildlife Service (1970-2000). (See Appendix B, page B-43 for more information.)

Exhibit 5-25: Extent of ponds, lakes, and reservoirs, 1950s-1990s



Coverage: lower 48 states.

Note: Lake area does not include the Great Lakes, which cover about 60.2 million acres within the United States.

Source: The Heinz Center. *The State of the Nation's Ecosystems.* 2002. Data from the U.S. Fish and Wildlife Service's National Wetlands Inventory.

Indicator | At-risk fresh water native species - Category 2

The U.S. was sufficiently concerned about preserving species to enact the Endangered Species Act in 1973 to provide legal protection for species that were endangered or threatened. Many of these species depend on lakes, streams, and adjoining wetlands for their continued existence. It is impossible to monitor all freshwater species, but this indicator reports on species of fish, amphibians, reptiles, aquatic mammals, butterflies, mussels, snails, crayfish, fresh water shrimp, dragonflies, damselflies, mayflies, stoneflies, and caddisflies that are at various degrees of risk of extinction (The Heinz Center, 2002).

What the Data Show

According to The Heinz Center (2002), approximately 13 percent of native fresh water species are critically imperiled, 8 percent are imperiled, 11 percent are vulnerable, and 4 percent are or might be extinct (Exhibit 5-26). Critically imperiled species are typically found at no more than five places, and may have suffered steep declines or very high risk. Vulnerable species may be found in 20 to 80 locations and show widespread declines or moderate levels of risk (Stein, 2002). Mussels and fish are particularly at risk. Hawaii and the Southeast have significantly higher percentages of at-risk species than other regions, but this condition may be partially the result of Hawaii and parts of the Southeast having a higher number of naturally rare species (The Heinz Center, 2002).

Indicator Gaps and Limitations

The data underlying this indicator are not from a site-based monitoring program, but rather from a census approach that focuses on the location and distribution of at-risk species. The data do not distinguish species that are naturally rare from species that have become rare because of human actions, making it difficult to distinguish actual trends in this indicator.

Data Source

The data source for this indicator was *The State of the Nation's Ecosystems,* The Heinz Center, 2002, using data from NatureServe Explorer database. (See Appendix B, page B-43, for more information.)

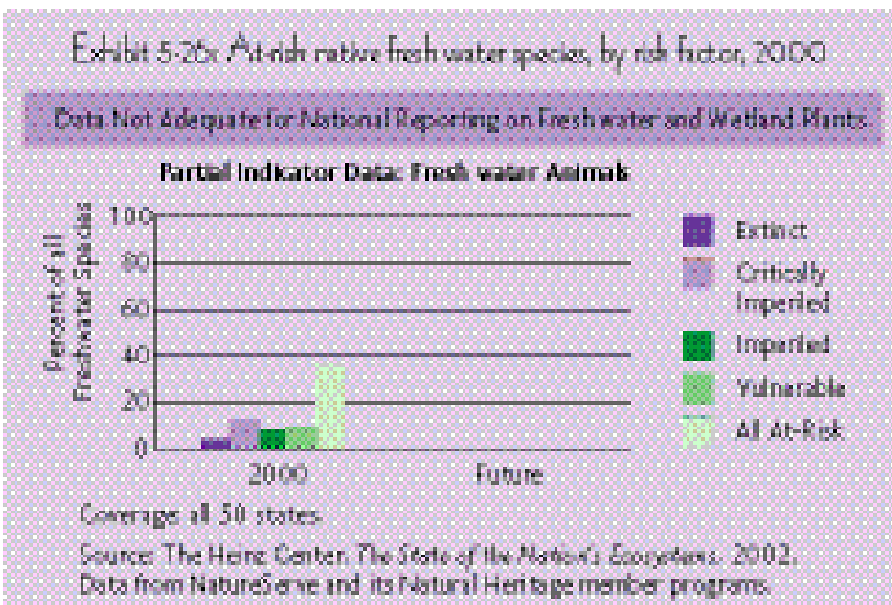


Exhibit 5-26: At-risk native fresh water species, by risk factor, 2000

Source: The Heinz Center. *The State of the Nation's Ecosystems.* 2002. Data from NatureServe and its Natural Heritage member programs.

Indicator Non-native fresh water fish species - Category 2

This indicator reports on the percentage of watersheds with different numbers of non-native species with established breeding populations (The Heinz Center, 2002). Non-native species include species not native to North America and species that are native to this continent but are now found outside their historic range. Such species, once introduced from some other location, often lack predators or parasites that kept them in check in their native habitats, and expand to cause a degree of ecological and economic disruption. Some non-native species are introduced intentionally (e.g., rainbow trout).

What the Data Show

Data are currently available nationally only for fish: of 350 watersheds (6-digit HUCs) in the U.S., only five have no non-native fish (The Heinz Center, 2002). Sixty percent have 1 to 10 non-native species, and two watersheds have 41 to 50 non-native fish species (Exhibit 5-27).

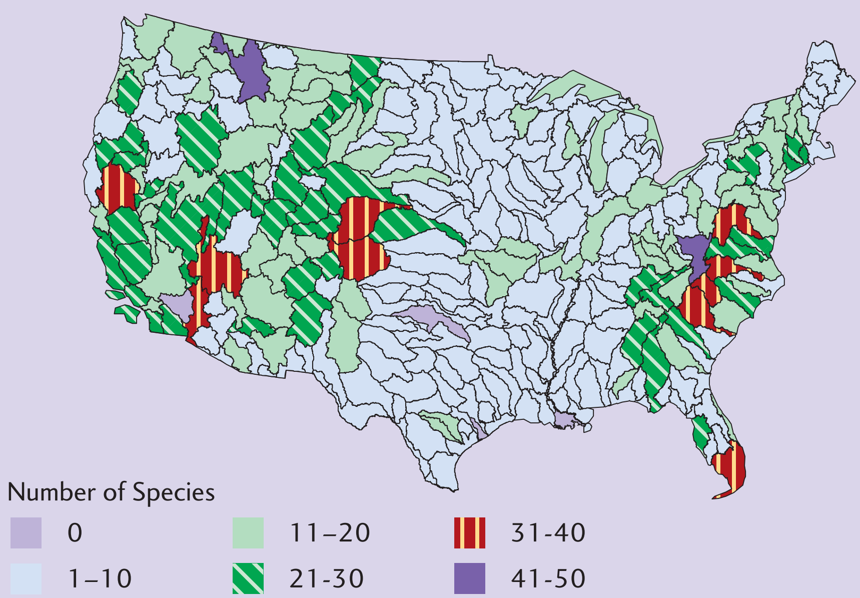
Indicator Gaps and Limitations

The data are not from a site-based monitoring program; they rely for the most part (90 percent) on the published literature and (10 percent) direct reporting by governmental and private biologists. New discoveries are not always reported (The Heinz Center, 2002).

Data Source

The data source for this indicator was The *State of the Nation's Ecosystems,* The Heinz Center, 2002, using data from the Non-indigenous Aquatic Species database. (See Appendix B, page B-44, for more information.)

Exhibit 5-27: Non-native fresh water fish species, 2000



Coverage: lower 48 states.

Source: The Heinz Center. *The State of the Nation's Ecosystems.* 2002. Data from the U.S. Geological Survey.

Indicator: Animal deaths and deformities - Category 2

Unusual mortality events (e.g., fish kills) or deformities (e.g., frog deformities) can have economic consequences, and they are also seen as evidence that something is wrong (e.g., a contaminant is present, or the organisms are under stress from some other source). Although data are collected on die-offs of mammals, fish, and amphibians, and on amphibian deformities, data are insufficient for national reporting (The Heinz Center, 2002). This indicator reports on unusual mortality events for waterfowl only.

What the Data Show

From 1995 to 1999, approximately 500 incidents of unusual waterfowl mortality were reported (The Heinz Center, 2002) (Exhibit 5-28). In slightly more than 20 percent of the incidents, more than 1,000 birds died, and in 15 of the incidents, more than 10,000 birds died. The total number of die-offs reported from 1995 to 1999 was 20 percent lower than the numbers reported in two earlier periods (1985 to 1989 and 1990 to 1994) (The Heinz Center, 2002). A larger number of events were reported in the Pacific and Midwest regions; fewer were reported in the Southwest and Southeast.

Indicator Gaps and Limitations

The data are not from a defined site-based monitoring program, but are provided by various sources such as state and federal personnel, diagnostic laboratories, wildlife refuges, and published reports, as they are discovered or reported (The Heinz Center, 2002). This makes it hard to distinguish real trends from trends in reporting.

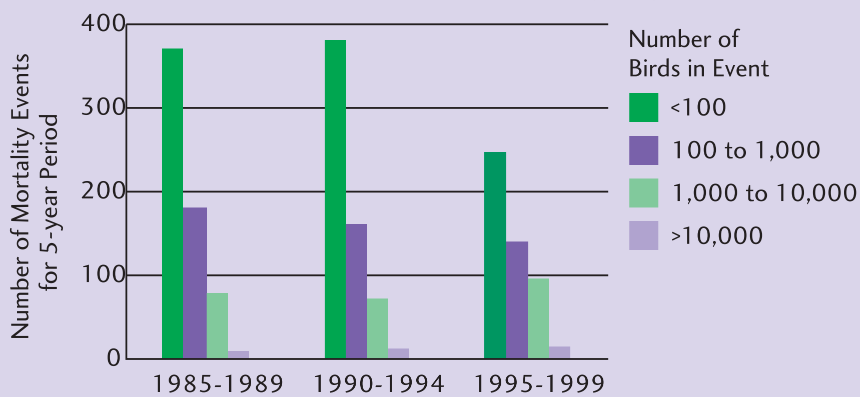
Data Source

The data source for this indicator was *The State of the Nation's Ecosystems,* The Heinz Center, 2002, using data from the National Wildlife Health Center database.
(See Appendix B, page B-44, for more information.)

Exhibit 5-28: Animal deaths and deformities, 1985-1999

Data Not Adequate for National Reporting on:
- Fish Die-offs
- Mammal Die-offs
- Amphibian Die-offs
- Amphibian Deformities

Partial Indicator Data: Waterfowl Mortality Only



Coverage: all 50 states, Puerto Rico, and the U.S. Virgin Islands

Source: The Heinz Center. *The State of the Nation's Ecosystems.* 2002. Data from the U.S. Geological Survey.

Indicator At-risk fresh water plant communities - Category 2

The Heinz report employs an indicator of the threat of elimination of wetland and riparian area plant communities. This indicator uses an expert assessment conducted by NatureServe (Stein, 2002) of factors such as the remaining number and condition of the community, the remaining acreage, and the severity of threats to the community type.

What the Data Show

According to this indicator, 12 percent of the 1,560 wetland communities ranked are critically imperiled, 24 percent are imperiled, and 25 percent are vulnerable (The Heinz Center, 2002) (Exhibit 5-29).

Indicator Gaps and Limitations

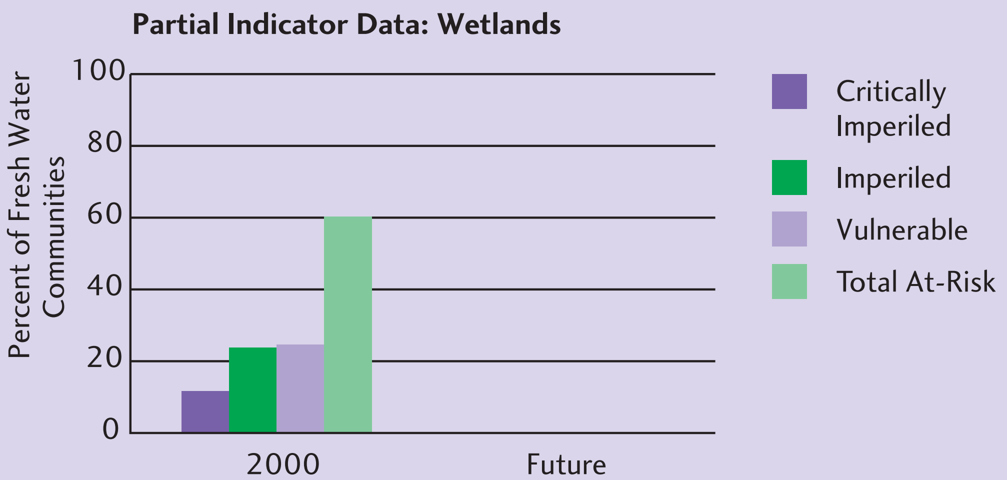
The Heinz report states that data are not adequate for national reporting (The Heinz Center, 2002). The report concludes that technical challenges in classifying riparian communities prevent national estimates for stream bank plant communities. In addition, interpreting the data is complicated because some species are naturally rare, and the total number of species for any ecosystem is unknown.

Data Source

The data source for this indicator was *The State of the Nation's Ecosystems,* The Heinz Center, 2002, using data from NatureServe Explorer database. (See Appendix B, page B-44, for more information.)

Exhibit 5-29: At-risk fresh water plant communities, 2000

Data Not Adequate for National Reporting on Riparian Communities



Coverage: excludes Alaska.

Source: The Heinz Center. *The State of the Nation's Ecosystems.* 2002. Data from NatureServe and its Natural Heritage member programs.

Indicator — Fish Index of Biotic Integrity in streams - Category 2

Fish communities integrate the effects of the physical, chemical, and biological stressors in the environment. The Heinz Center (2002) listed the status of fresh water animal communities as an indicator in need of development. Karr, et al. (1986, 1997) developed a Fish Index of Biotic Integrity (IBI) that incorporates species richness, trophic composition, reproductive composition, and abundance and individual health of fish communities in streams. This index, modified by McCormick, et al. (2001), was applied to a regional survey of streams in the mid-Atlantic states, and provides an example of an indicator that could be applied nationally.

A sample of reference sites that represented the best conditions observable today in the mid-Atlantic region (e.g., sites free of influences from mine drainage, nutrients, habitat degradation) provided a frame of reference for ranking the condition of streams overall. The IBI scores calculated for the reference sites ranged from 57 to 98. The 25th percentile of this distribution (IBI=72) was used to distinguish sites that were in good condition from those in fair condition. The first percentile value (IBI=57) separated sites in fair condition from those in poor condition. A statistical way to describe this setting of thresholds is to say that any IBI score of less than 57 in a sampled stream is 99 percent certain to be below the range of values seen in reference sites (McCormick, et al., 2001).

What the Data Show

Fish were collected at probability sites that represent about 90,000 miles of streams in the mid-Atlantic. The fish IBI indicated that 27 percent of the streams were in good condition and 14 percent were in poor condition in the Mid-Atlantic Highlands (see Exhibit 5-30). About 38 percent of the streams were scored in fair condition. No fish were caught in about 21 percent of the streams. The estimates of stream condition have a confidence interval of about ±.8 percent (McCormick, et al., 2001).

Indicator Gaps and Limitations

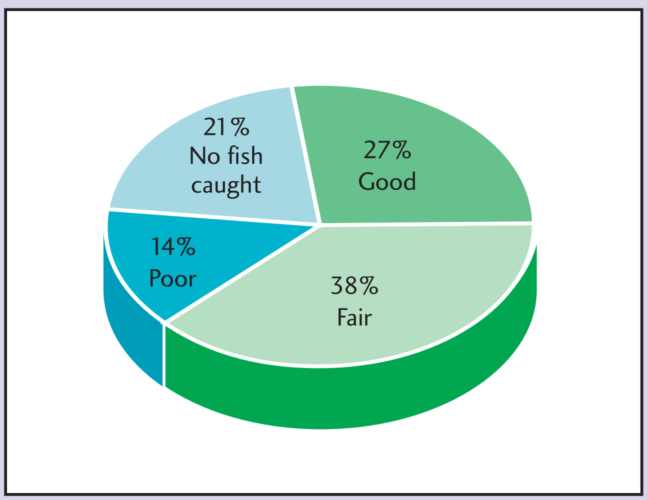
The limitations of this indicator include the following:

- Condition cannot be assessed in streams where no fish were caught. Poor condition cannot be inferred from no fish caught, because some streams were likely too small to support a fishery. Data were insufficient to indicate if the stream had poor quality or simply no fish (EPA, ORD, Region 3, August 2000).
- The data are available only for a limited geographic region, and no repeated sampling is available to estimate trends.

Data Source

The data source for this indicator was the Mid-Atlantic Highlands Streams Assessment, Environmental Protection Agency, August 2000, using data from the Mid-Atlantic Integrated Assessment. (See Appendix B, page B-45, for more information.)

Exhibit 5-30: Fish Index of Biotic Integrity (IBI) indicators used to assess stream condition in the Mid-Atlantic Highlands, 1993-1996



Coverage: Mid-Atlantic Highlands

Note: No fish caught does not indicate poor condition. Some streams naturally do not have fish.

Source: McCormick, F. H. et al. *Development of an Index of Biotic Integrity for the Mid-Atlantic Highlands Region.* 2001.

Indicator Macroinvertebrate Biotic Integrity Index for streams - Category 2

Like fish, macroinvertebrate communities integrate physical, chemical, and biological stressors, but because many of them are more sedentary than fish and occupy different ecological niches, they provide a complementary picture of ecological condition.

A Macroinvertebrate Biotic Integrity Index (MBII) was developed for mid-Atlantic streams by Klemm, et al. (2002, 2003). The MBII incorporates taxa richness, assemblage composition, pollution tolerance (includes all maroinvertebrates, not just insects), and functional feeding groups (Klemm, et al., 2002). Similar to the approach used to separate the Fish IBI scores (McCormick, et al., 2001), the 25th percentile of the reference site MBII scores was used to distinguish sites in good condition from those in fair condition. The first percentile was used to separate sites in fair condition from those in poor condition (McCormick, et al., 2001).

What the Data Show

The MBII scores indicated that 17 percent of the streams in the mid-Atlantic were in good condition, 57 percent were in fair condition, and 26 percent were in poor condition (Exhibit 5-31).

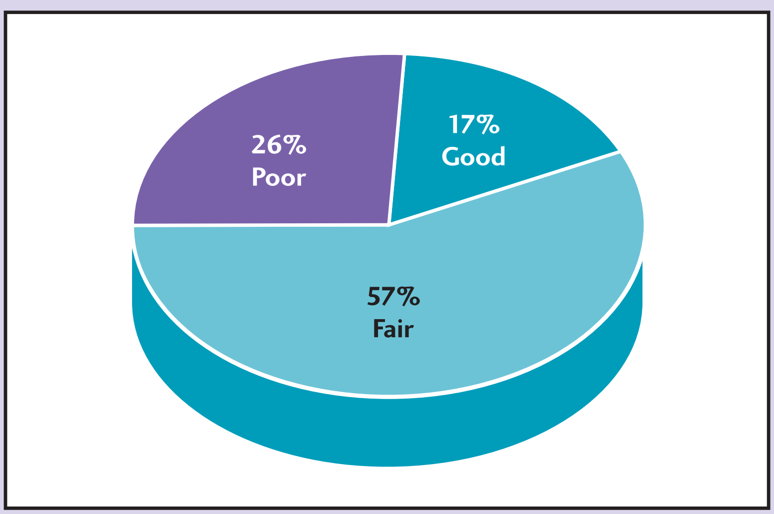
Indicator Gaps and Limitations

The data are available only for a limited geographic region, and no repeated sampling is available to estimate trends.

Data Source

The data source for this indicator was *Development and Evaluation of a Macroinvertebrate Biotic Integrity Index (MBII) for Regionally Assessing Mid-Atlantic Highlands Streams.* 2003, Klemm, et al., using data from the Mid-Atlantic Integrated Assessment. (See Appendix B, page B-45, for more information.)

Exhibit 5-31: Macroinvertebrate Biotic Integrity Index (MBII), Mid-Atlantic Highlands, 1993-1996



Coverage: Mid-Atlantic Highlands

Source: Klemm, D.J., et al. *Development and Evaluation of a Macroinvertebrate Biotic Integrity Index (MBII) for Regionally Assessing Mid-Atlantic Highlands Streams.* 2003.

Summary: The Ecological Condition of Fresh Waters

Fresh water systems are under pressure from point and non-point pollution, atmospheric deposition, altered habitat, and invasive species. A review of Exhibit 5-24, however, indicates that there are virtually no Category 1 indicators or monitoring programs that provide a national picture of the ecological condition of fresh waters. No national condition data are available on ecological processes, not are there any nationally or regionally reported indicators of natural disturbance regimes.

Landscape condition

The National Wetlands Inventory provides unbiased statistical estimates of the extent of wetlands, ponds, lakes, and reservoirs in the conterminous U.S. at decadal scales since the 1970s. There is no similar effort for the extent of streams (losses can occur because of mining, damming, water withdrawal, or climate change). Chapter 2, Purer Water, estimates that the U.S. has more than 3.7 million miles of streams and rivers (EPA, OW, June 2000a, 2000b). About 60 percent of all these stream miles are found in small, headwater streams. The Heinz Center reports, however, that because there is no agreed-upon system to classify streams (e.g., by discharge, drainage area, or stream order), there are no national data sets for reporting on stream size.

Biotic condition

At this time, no national condition data are available on lake, wetland, or stream biota. The USGS National Water Quality Assessment (NAWQA) program has collected data on the biota in rivers and streams in the network, but no analysis has been performed on the data at a national level (USGS, 2002; <http://water.usgs.gov/nawqa/>). Surveys of stream benthos and fish communities have been conducted for the mid-Atlantic region that provide unbiased estimates of the condition of 90 percent of the streams in the region. Both surveys showed only 17 percent (±8 percent) of the streams to be in good condition, but there is no indication of whether they are the same streams or of the likely cause(s) of impairment. No fish were caught in 16 percent of the streams, so their condition could not be judged based on this criterion. Similar regional studies have been conducted in the western states, but the data have not yet been reported. There are no nationally or regionally representative data on the aquatic communities of lakes. Based on NatureServe data, 36 percent of aquatic biota in several categories are either extinct or at some risk of extinction, but because this database relies on voluntary reporting, future trends might not be discernable with statistical reliability. NAWQA collected contaminant data from fish tissue in 223 streams, and almost half showed concentrations that exceeded aquatic life guidelines for at least one contaminant. However, these data have not been related to the condition of the fish communities in the corresponding streams, so ecological condition cannot be determined. There are no specific plans to re-sample in any of these programs, and so there is no assurance that trend data will be available in the future.

Chemical and physical characteristics

Better data are available for chemical and physical characteristics of streams, less for lakes, and none for wetlands. The NAWQA program reports data on total phosphorus concentrations in more than 140 large rivers nationwide, but there are no corresponding national data on either lake or reservoir concentrations (where algal blooms are likely to develop), nor on the corresponding biological communities. Reliable regional estimates have been made of total phosphorus concentrations in 11,076 lakes in the Northeast states. These estimates showed with a high degree of confidence that fewer than 22 percent of the lakes were estimated to be eutrophic or hypertrophic. While a relationship exists between total phosphorus concentrations and algal biomass or productivity (Carlson, 1977), lake-to-lake variation is considerable, so none of these data truly express the known ecological condition of these lakes or rivers with respect to eutrophication. Nitrate is not often a limiting nutrient in fresh waters, so it provides little ecological information on fresh waters themselves (although it does provide useful information on the watershed, as discussed in the sections on forests and farmlands).

The NAWQA program reports on contaminants in stream waters from 109 streams, and sediments from 558 stream sites across the U.S. At least half of the streams had concentrations that exceeded wildlife criteria, but there are as yet no analyses relating these to the condition of fish or invertebrate communities in the streams naturally. Incorporation of water quality data monitored by the states could improve the coverage, if care is given to representative sampling and comparable methods and indicators.

A national survey in the 1980s provided estimates of the sensitivity of all lakes and all streams in the eastern U.S. to acidic deposition (Landers, et al., 1988; Kaufmann, et al., 1991). Periodic resurveys and intensive sampling of representative lakes and streams have allowed EPA to conclude that, because of reductions in sulfate emissions under its acid rain regulations, one-quarter to one-third of lakes and streams in three regions affected by acid rain are no longer acidic (EPA, ORD, Region 3, August 2000). Corresponding biological community data exist only for streams in the Mid-Atlantic Highlands.

Hydrology and geomorphology

There are nationally reported data on only one hydrologic/geomorphological indicator: changing stream flow. This indicator is reported on all rivers and streams for which the record of data is adequate, and it shows that high flows have increased during the past decade. There are no corresponding data to indicate why, however, nor are there data on any accompanying change in the fish communities, so ecological condition cannot be assessed with any reliability.

There were no Category 1 or 2 indicators available for *ecological processes* or *natural disturbance regimes* for fresh waters. Limnologists have long measured primary productivity in lakes, and nutrient spiraling and leaf-pack decomposition in streams, but no systematic data were available in the form of an indicator for this report. Phenomena involved in natural disturbance regimes in fresh waters include hydrology (e.g., low-flow frequencies, floods), time of ice-out in lakes, and fires and other factors that affect watersheds.

5.7 What Is the Ecological Condition of Coasts and Oceans?

The coasts and oceans of the United States extend from the shoreline out approximately 200 miles into the open ocean. The indicators in this report, however, focus on estuaries and coastal waters within 25 miles of the coast. Coastal ecosystems are productive and diverse, and include estuaries, coastal wetlands, coral reefs, mangrove forests, and upwelling areas. Critical coastal habitats provide spawning grounds, nurseries, shelter, and food for finfish, shellfish, birds, and other wildlife. Coastal areas are also sinks for pollutants transported through surface water, ground water, and atmospheric deposition.

Coastal areas are among the most developed areas in the nation. Coastal areas comprise 17 percent of total conterminous U.S. land area, yet these areas are home to 53 percent of the U.S. human population. The coastal population is increasing by about 3,600 people per day, giving rise to a projected total increase of 27 million people between 2000 and 2015 (U.S. Census Bureau, 2002).

Coastal areas also contribute significantly to the U.S. economy. Almost 31 percent of the Gross National Product is produced in coastal counties (EPA, ORD, OW, September 2001). Almost 85 percent of commercially harvested fish depend on estuaries and adjacent coastal waters at some stage in their life cycle (NRC, 1997). About 180 million people use coastal beaches each year (Cunningham and Walker, 1996). Estuaries supply water, receive discharge from municipal and industrial sources, and support agriculture, commercial and sport fisheries, and recreational uses such as swimming, and boating.

National estuarine and coastal monitoring programs have been in place for 15 to 20 years. A number of agencies and programs provide information on the condition of coastal waters and wetlands, including the National Oceanic and Atmospheric Administration's (NOAA) National Status and Trends Program, National Estuarine Research Reserve System, and National Marine Fisheries Service National Habitat Program; EPA's National Estuary Program and Environmental Monitoring and Assessment Program; and the Fish and Wildlife Service National Wetlands Inventory and Coastal Program.

In 2000, EPA, NOAA and USGS, in cooperation with all 24 U.S. coastal states, initiated the National Coastal Assessment (also known as Coastal 2000 or C2000). Using a compatible, probabilistic design and a common set of survey indicators, each state conducted

Exhibit 5-32: Coasts and oceans indicators

Essential Ecological Attribute	Indicators	Category		Source
Landscape Condition		I	II	
Extent of Ecological System/Habitat Types	Extent of estuaries and coastline	■		EPA
Landscape Composition	Coastal living habitats		■	DOI
	Shoreline types		■	DOC
Landscape Structure/Pattern				
Biotic Condition				
Ecosystems and Communities	Benthic Community Index		■	EPA
	Fish diversity		■	EPA
	Submerged aquatic vegetation		■	EPA
Species and Populations	Chlorophyll concentrations		■	EPA
Organism Condition	Fish abnormalities		■	EPA
	Unusual marine mortalities		■	DOC
Ecological Processes				
Energy Flow				
Material Flow				
Chemical and Physical Characteristics				
Nutrient Concentrations	Total nitrogen in coastal waters		■	EPA
	Total phosphorous in coastal waters		■	EPA
Other Chemical Parameters	Dissolved oxygen in coastal waters		■	EPA
	Total organic carbon in sediments		■	EPA
Trace Organics and Inorganics	Sediment contamination of coastal waters		■	EPA
	Sediment toxicity in estuaries		■	EPA
Physical Parameters	Water clarity in coastal waters		■	EPA
Hydrology and Geomorphology				
Surface and Ground Water Flows				
Dynamic Structural Conditions				
Sediment and Material Transport				
Natural Disturbance Regimes				
Frequency				
Extent				
Duration				

Note: MAIA indicators included pending completion of peer review the survey and independently assessed the condition of their coastal resources. These estimates currently are being aggregated to assess the condition of the nation's coastal waters. While the first complete assessment of the nation's coastal waters will be available in 2003, a preliminary assessment of selected estuarine systems was published in 2001 (EPA, ORD, OW, September 2001).

Exhibit 5-32 lists the ecological indicators of coastal condition used in this report. Eight indicators are discussed in Chapter 2, Purer Water. The indicator *Chlorophyll Concentrations* deals with biotic structure of phytoplankton communities, and the rest are associated with the chemical and physical characteristics of coastal ecosystems. These eight indicators are summarized below. The section then presents nine indicators that appear for the first time in this report. Two involve the coastal landscape, and the rest involve the biotic structure of coastal ecosystems. There are no indicators of ecological processes, hydrology and geomorphology, or natural disturbance regimes with data suitable for national or regional reporting.

The following indicators presented in previous chapters relate to the ecological condition of coasts and oceans:

- The indicator *Chlorophyll Concentrations* is a measure of the abundance of phytoplankton. Excessive growth of phytoplankton, as measured by chlorophyll concentrations, can lead to degraded water quality, such as noxious odors, decreased water clarity, andoxygen depletion. Excess phytoplankton growth is usually associated with increased nutrient inputs (e.g., watershed or atmospheric transport, upwelling) or a decline in filtering organisms such as clams, mussels, or oysters (The Heinz Center, 2002).

  Average seasonal ocean chlorophyll concentrations (within 25 miles of the coast) ranged from 0.1 to 6.5 ppb (The Heinz Center, 2002). The highest ocean chlorophyll concentrations (4.8 to 6.5 ppb) were in the Gulf of Mexico with the lowest concentrations in Hawaiian waters (0.1 ppb). Southern California had the next lowest chlorophyll concentrations, between 1.1 and 1.5 ppb. Other ocean waters (e.g., north, mid-, and south Atlantic, and Pacific Northwest) had chlorophyll concentrations ranging from 2 to 4.5 ppb.

  Estuarine chlorophyll concentrations were not available for national reporting in the Heinz report, but chlorophyll concentrations in the mid-Atlantic estuaries ranged from 0.7 to 95 ppb in 1997 and 1998 (EPA, ORD, May 2003). EPA established three categories: good <15 ppb; fair 15-30 ppb; and poor >30 ppb. The lower threshold of 15 ppb chlorophyll is equal to the restoration goal recommended for the survival of submerged aquatic vegetation (SAV) in the Chesapeake Bay (Batiuk, et al., 2000). About 33 percent of the mid-Atlantic estuarine area had chlorophyll concentrations exceeding 15 ppb. The Delaware Estuary showed a wide range of chlorophyll concentrations, from low in the Delaware Bay (<15 ppb) to intermediate in the Delaware River (15 to 30 ppb) to very high (>80 ppb) in the Salem River. The western tributaries to the Chesapeake Bay were consistently high in chlorophyll, with more than 25 percent of the area showing >30 ppb chlorophyll concentrations. Chlorophyll concentrations in the coastal bays were generally low (< 15 ppb), even though nutrients were elevated, because of increased turbidity and low light penetration.

- The *Water Clarity in Coastal Waters* (Chapter 2, Purer Water) indicator is important for maintaining productive systems in good condition and is affected by chlorophyll concentrations. Light penetration is important for submerged aquatic vegetation (SAV), which serves as food, nursery, shelter, and refugia habitat (areas that provide protection from predators) for aquatic organisms. EMAP measured water clarity using a light penetrometer, which recorded the amount of surface light that penetrated to a depth of 1 meter (EPA, ORD, OW, September 2001). Water clarity was considered poor if less than 10 percent of surface radiation penetrated to 1 meter. Water clarity was considered fair if there was between 10 and 25 percent penetration, and clarity was considered good if there was greater than 25 percent penetration. Data were collected for all conterminous estuaries in the U.S. The 10 percent light penetration at 1 meter is required to support SAV, which is an ecological endpoint in several estuarine ecosystems. Overall, 64 percent of the nation's estuarine area had light penetration of at least 25 percent at 1 meter (EPA, ORD, OW, September 2001). Only 4 percent of the nation's estuarine area had poor light penetration (less than 10 percent).

- Nitrogen, and less often phosphorus, control the chlorophyll concentrations in coastal ecosystems. The indicator *Total Nitrogen in Coastal Waters* (Chapter 2, Purer Water), was calculated for the mid-Atlantic estuaries by summing the concentrations of total dissolved nitrogen and particulate organic nitrogen (EPA, ORD, May 2003). Assessment categories were determined based on the 25th and 75th percentiles because there are no total nitrogen (TN) criteria for estuaries. The categories are: low < 0.5 ppm N; intermediate 0.5 to 1.0 ppm N; and high > 1.0 ppm N. About 35 percent of the mid-Atlantic estuarine area had low TN concentrations, 47 percent had intermediate TN concentrations, and 18 percent had high TN concentrations. About 50 percent of the mainstem area of the Chesapeake Bay had low TN concentrations, with only about 5 percent having high TN concentrations. The coastal bays, in contrast, had about 5 percent of their area with low TN concentrations and about 35 percent with high TN concentrations. The Delaware River estuary portion of Delaware Bay had 100 percent of its area with high TN concentrations.

- The indicator *Total Phosphorus in Coastal Waters* (Chapter 2, Purer Water) assessment categories were based on the 25th and 75th percentile concentrations measured throughout the mid-Atlantic. These categories are: low < 0.05 mg P/L; intermediate 0.05 to 0.1 mg P/L; and high > 0.1 mg P/L. Total phosphorus (TP) concentrations ranged from 0 to 0.34 mg P/L. About 58 percent of the mid-Atlantic estuarine area had low TP concentrations, 30 percent had intermediate, and 12 percent had high TP concentrations (EPA, ORD, May 2003). About 85 percent of the mainstem area of the Chesapeake Bay had low TP concentrations, with no areas having high TP concentrations. The coastal bays, in contrast, had no areas with low TP concentrations and about 35 percent with high TP concentrations. The Delaware River estuary portion of Delaware Bay had 100 percent of its area with high TP concentrations.

- Dissolved oxygen is depleted when phytoplankton in estuaries die and decompose. Data on the *Dissolved Oxygen in Coastal Waters* indicator (Chapter 2, Purer Water) were reported primarily for estuaries in the Virginian, Carolinian, and Louisianian Provinces[16]. Dissolved oxygen in these estuaries was reported as good because 80 percent of estuarine waters assessed were estimated to exhibit dissolved oxygen at concentrations greater than 5 ppm (EPA, ORD, OW, September 2001). Hypoxia resulting from anthropogenic activities is a relatively local occurrence in Gulf of Mexico estuaries; only 4 percent of the combined bottom areas in these estuaries is hypoxic. The occurrence of hypoxia in the shelf waters of the Gulf of Mexico is more significant. The Gulf of Mexico hypoxic zone is the largest area of anthropogenic coastal hypoxia in the western hemisphere (CAST, 1999). Since 1993, mid-summer bottom water hypoxia in the Northern Gulf of Mexico has been larger than 3,860 square miles and in 1999, it reached over 7,700 square miles (CENR, 2000).

- *Total Organic Carbon in Sediments* (Chapter 2, Purer Water) is often an indicator of organic pollution (e.g., from decomposing phytoplankton blooms or waste disposal). Total organic carbon (TOC) values are calculated as percent carbon in dried sediments. Values ranged from 0.02 to 13 percent carbon (Paul, et al. 1999). Assessment categories for the mid-Atlantic estuaries were tentatively set at: low 1 percent; intermediate 1 to 3 percent, and high >3 percent, but they are still under evaluation. For the mid-Atlantic region, about 60 percent of the sediments had low TOC values, about 24 percent had intermediate TOC values, and 16 percent had high sediment TOC values (EPA, ORD, May 2003). Values ranged from those of Delaware Bay, with about 95 percent of its sediments having low TOC values, to those of the Chowan River in the Albemarle-Pamlico Estuary with 65 percent of its sediments having high TOC values (EPA, ORD, May 2003). The Chesapeake Bay mainstem had about 65 percent of its sediments with low TOC values and about 15 percent with high TOC values.

- The *Sediment Contamination of Coastal Waters* indicator (Chapter 2, Purer Water) was analyzed in estuaries primarily along the Atlantic Coast and Gulf of Mexico as part of the EPA EMAP Estuaries Program. Results from these analyses indicated that 40 percent of estuarine sediments in these areas were enriched in metals from human sources, 45 percent were enriched in PCBs, and 75 percent were enriched in pesticides (EPA, ORD, OW, September 2001). The highest concentrations of all three constituents were found in South Florida sediments with 53 percent, 99 percent, and 93 percent of the sediment area enriched in metals, PCBs, and pesticides, respectively.

- The EPA EMAP Estuaries Program, in conjunction with the NOAA Status and Trends Program, developed the indicator S*ediment Toxicity in Estuaries* (Chapter 2, Purer Water). The EMAP Estuaries Program found that about 10 percent of the sediments in the Virginian, Carolinian, Louisianian, West Indian, and Californian Province estuaries were toxic to the marine amphipod *Ampelisca abdita* over a 10-day period (EPA, ORD, OW, September 2001). The NOAA Status and Trends Program also used a sea urchin fertility test and a microbial test to evaluate chronic toxicity in selected estuaries. NOAA found that 43 to 62 percent of the sediment samples from the selected estuaries showed chronic toxicity (EPA, ORD, OW, September 2001).

On the following pages, several indicators are introduced for the first time in this report that relate to the essential ecological attributes of landscape condition and biotic condition of estuaries.

[16] Provinces are biogeographical regions with distinct faunas.

Indicator Extent of estuaries and coastline - Category 1

Estuarine areas provide habitat for organisms which contribute significantly to the national economy. These areas also are under pressure from the 53 percent of the U.S. population that lives within 75 miles of the coast. Estuarine areas and coastline include brackish water bays and tidal rivers, which are influenced by the mixing of fresh water and ocean salt water in these areas. Extent estimates were provided by the coastal states as part of the EPA National Water Quality Inventory - 2000 Report (EPA, OW, August 2000).

What the Data Show

EPA estimates that the U.S. and its territories have 95.9 million acres of estuarine surface area and about 58,618 miles of coastline (EPA, OW, August 2002).

Indicator Gaps and Limitations

These data were compiled from inventories performed by the states. Differences in how each state defines estuaries are likely, so the consistency of the inventory is unknown.

Data Source

The data source for this indicator was the *2000 National Water Quality Inventory,* U.S. Environmental Protection Agency, August 2002. (See Appendix B, page B-45, for more information.)

Indicator Coastal living habitats - Category 2

This indicator provides the acreage of vegetative habitat such as submerged aquatic vegetation (SAV), mangrove forests, and coastal wetlands. Vegetation not only stabilizes the habitat, but also provides food, shelter, nursery areas, and refugia for other aquatic organisms. Loss of coastal habitat is a major contributor to the loss of both economic and non-marketable aquatic species (The Heinz Center, 2002).

What the Data Show

The USFWS National Wetlands Inventory (NWI) estimates more than 5 million acres of coastal wetlands contribute to the diversity of coastal habitat (Exhibit 5-33). Wetland acreage declined about 8 percent from the mid-1950s to the mid-1990s (The Heinz Center, 2002). Out of 5 million total acres, 400,000 acres of coastal wetland were lost over this period, although the loss rate declined in the 1990s (The Heinz Center, 2002).

Indicator Gaps and Limitations

Data for coral reefs and seagrasses and other SAV are available for many areas, but these data have not been integrated to produce a national estimate. Different approaches have been used to estimate some of these coastal habitats which make make integration difficult. For example, estimates of the extent of SAV are noted in some regions only as presence/absence, while the area is estimated quantitatively in other regions. Data for vegetated wetlands are available for only the East and Gulf Coasts.

Data Source

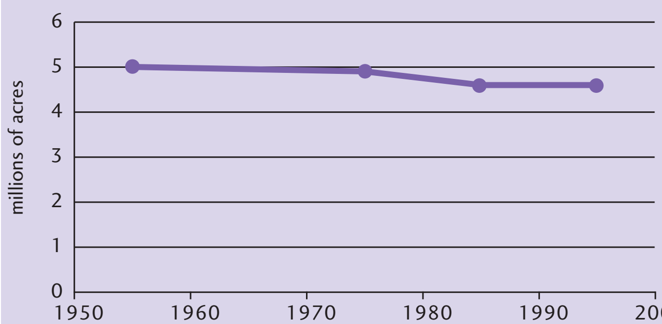
The data source for this indicator was *Status and Trends of Wetlands in the Conterminous United States 1986 to 1997*, Dahl, 2000, utilizing data from the National Wetlands Inventory. (See Appendix B, page B-45, for more information.)

Exhibit 5-33: Coastal living habitats, 1950s-1990s

Data Not Adequate for National Reporting on:

- Seagrasses/Submerged Vegetation
- Shellfish Beds
- Coral Reefs
- Wetlands in Other Regions

Partial Indicator Data: Coastal Vegetated Wetlands



Coverage: Atlantic and Gulf Coasts Only

Source: The Heinz Center. *The State of the Nation's Ecosystems.* 2002. Data from the U.S. Fish and Wildlife Service.

Indicator Shoreline types - Category 2

This indicator includes the miles of coastline in different categories, such as beaches, mud or sand flats, rock or clay cliffs, and wetlands. It also includes coastline that is protected with engineered structures such as armoring or riprap. Loss or conversion of shoreline habitat to armoring or riprap can eliminate the habitat required by various organisms for spawning, gestation, nursery area, feeding, or refugia.

What the Data Show

Over two-thirds of the mapped shoreline in the south Atlantic, southern California, and Pacific Northwest is coastal wetlands, with most of the coastal wetlands occurring in the South Atlantic (The Heinz Center, 2002) (Exhibit 5-34). Three-quarters of the south Atlantic shoreline is wetlands (The Heinz Center, 2002). Beaches account for about 33 percent of the shoreline in both southern California and the Pacific Northwest. Southern California, however, has a much lower percentage of wetlands and mud or sand flats than the Pacific Northwest. Steep shorelines, mud flats, and sand flats each make up the smallest portion of the total in all three regions. Armored shorelines, which inclde bulkheads and rip rap, account for about 11 percent of miles of the total coastline.

Indicator Gaps and Limitations

Estimates of shoreline types are not available for the entire U.S., including much of the Atlantic and Gulf Coast areas. Some of the atlases used to compile this information are more than 15 years old. Coastal areas are dynamic and change over time, so the accuracy of available estimates is unknown.

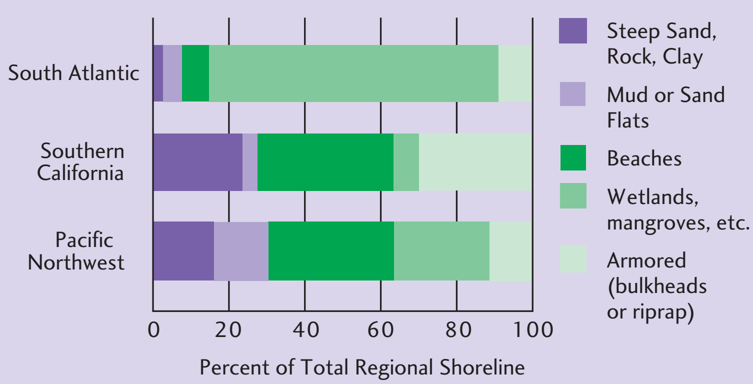
Data Source

The data source for this indicator was the *Environmental Sensitivity Index Atlases,* National Oceanic and Atmospheric Administration (1984-2001). (See Appendix B, page B-46, for more information.)

Exhibit 5-34: Coastal shoreline types, 2000

Data Not Adequate for National Reporting on:
- North Atlantic
- Mid-Atlantic
- Gulf of Mexico
- Gulf of Alaska
- Bering Sea
- Hawaii

Partial Indicator Data: Shoreline Types by Region



Coverage: Pacific Northwest, Southern California, and South Atlantic Regions only

Source: The Heinz Center. *The State of the Nation's Ecosystems.* 2002.
Data from the National Oceanic and Atmospheric Administration.

Indicator Benthic Community Index - Category 2

EMAP Estuaries Program has developed indices of benthic condition for estuaries in the conterminous U.S. (Engle and Summers, 1999; Engle, et al., 1994; Van Dolah, et al., 1999; Weisberg, et al., 1997). Benthic macroinvertebrates include annelids, mollusks, and crustaceans that inhabit the bottom substrates of estuaries. These organisms play a vital role in maintaining sediment and water quality, and are an important food source for bottom-feeding fish, invertebrates, ducks, and marsh birds. Measures of biodiversity and species richness, species composition, and relative abundance or productivity of functional groups are among the assemblage attributes that can be used to characterize benthic community composition and abundance. The Heinz report refers to this indicator as Condition of Bottom-Dwelling Organisms (The Heinz Center, 2002).

Assemblages of benthic organisms are sensitive to pollutant exposure (Holland, et al., 1987, 1988; Rhoads, et al., 1978; Pearson and Rosenberg, 1978; Sanders, et al., 1980; Boesch and Rosenberg, 1981), and they integrate responses to disturbance and exposure over relatively long periods of time (months to years). Their sensitivity to pollutant stress is, in part, because they live in sediment that accumulates environmental contaminants over time (Nixon, et al., 1986), and because they are relatively immobile.

Reference sites were used to calibrate the indices similar to the approach used to calibrate fish IBI scores in fresh water ecosystems. The references cited above describe the approaches used for calibration and scoring in various estuarine provinces. These indices were calibrated for the respective estuarine province in which they were developed. While the development and calibration process was similar among provinces, the specific thresholds reflect the estuarine conditions within that province. In general, good condition means that less than 10 percent of the coastal waters have low benthic index scores. Fair condition means that between 10 and 20 percent of the coastal waters have low benthic index scores. Poor condition means that greater than 20 percent of the coastal waters have low benthic index scores.

What the Data Show

Benthic community index scores have been assessed for the Northeast, Southeast, and Gulf Coastal Areas. For the Northeast, Southeast, and Gulf Coastal areas, 56 percent of the coastal waters were assessed in good condition, 22 percent in fair condition, and 22 percent in poor condition based on benthic index scores (Exhibit 5-35).

Associations of biological condition with specific stressors indicate that, of the 22 percent of coastal areas with poor benthic condition, 62 percent had sediment contamination, 11 percent had low dissolved oxygen concentrations, 7 percent had low light penetration, and 2 percent showed sediment toxicity (EPA, ORD, OW, September 2001).

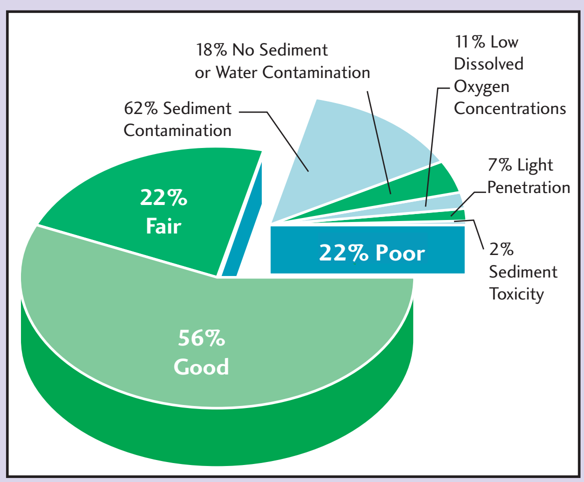
Indicator Gaps and Limitations

Benthic community index scores have been assessed only for the Northeast, Southeast, and Gulf Coastal areas. Samples have been collected in all coastal areas, including Alaska, Hawaii, and Island Territories, but these data have not been assessed. A complete assessment of coastal condition is anticipated in 2003.

Data Source

The data source for this indicator was *National Coastal Condition Report*, U.S. Environmental Protection Agency, September 2001, using data from the Environmental Monitoring and Assessment Program, Estuaries Program. (See Appendix B, page B-46, for more information.)

Exhibit 5-35: Benthic Community Index (BCI) scores for coastal waters in good, fair, or poor condition, 2000



Coverage: Northeast, Southeast, and Gulf Coastal areas

Source: EPA, Office of Research and Development and Office of Water. *National Coastal Condition Report.* September 2001.

Indicator Fish diversity - Category 2

Fish diversity is considered to be an indicator of ecological condition because fish integrate effects of environmental stress over space and time (EPA, ORD, September 1998). For this indicator, fish collected by trawling are identified, enumerated, and measured, allowing assessment of native and non-native species, diversity, abundance, pollution-tolerant/intolerant, and size class (e.g., young-of-year and adults).

This indicator provides data for the mid-Atlantic estuaries. Because fish catch data are sensitive to different sampling gear, no critical thresholds were established for the mid-Atlantic estuaries. High and low diversity were arbitrarily established as: high > 3 fish species in a standard trawl; low ≤ 3 fish species in a standard trawl (EPA, ORD, May 2003).

What the Data Show

In 1998, out of 110 sampling sites selected for the mid-Atlantic estuaries in 1998, fish trawls were conducted at 80 sites (the others were too shallow to trawl). The fish species count ranged from 0 to 13, with an average of 4.6 species per site (Exhibit 5-36). For the mid-Atlantic estuaries in general, more fish species were found in upper Delaware Bay, the coastal bays, and in the upper portions of tributaries. Fewer species were evident in the Chesapeake Bay mainstem and lower tributaries.

Indicator Gaps and Limitations

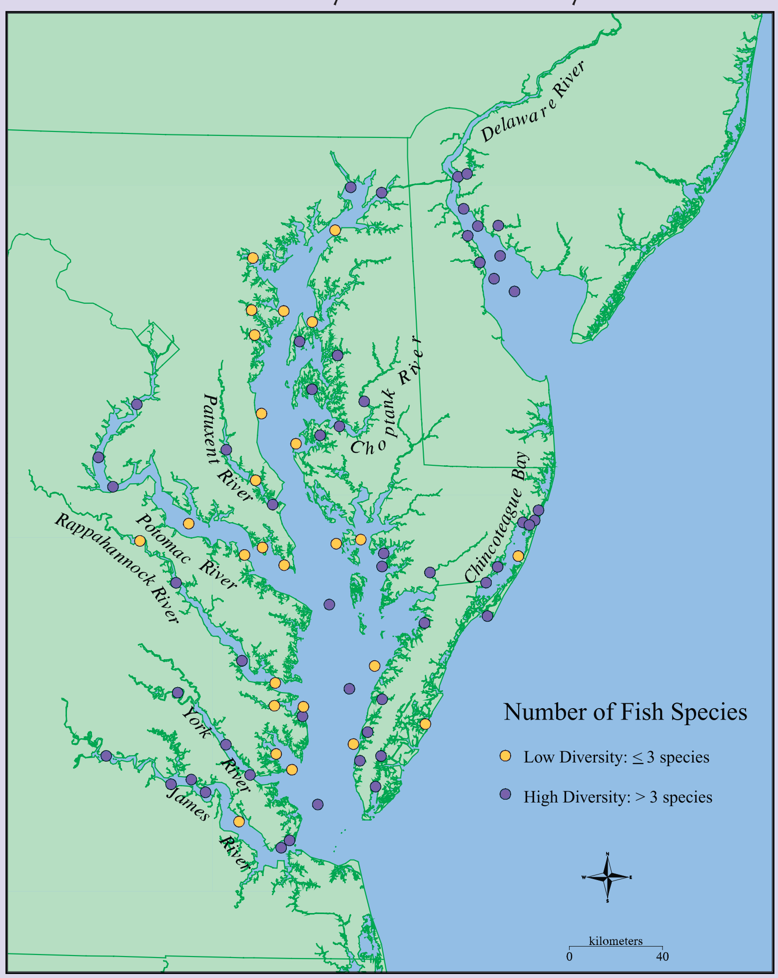
The limitations of this indicator include the following:

- Fish diversity estimates are available only for the mid-Atlantic estuaries.
- While fish diversity can be determined for each sampling site, currently no context exists for interpreting the condition of estuaries from fish diversity numbers because there are no criteria or thresholds for relating fish diversity estimates to estuarine condition.
- Fish populations are highly mobile, so caution must be used in interpreting low diversity estimates for measurements observed at any individual site may not be representative of the condition of the estuary.

Data Source

The data source for this indicator was the *Mid-Atlantic Integrated Assessment, MAIA-Estuaries, 1997-1998 Summary Report,* U.S. Environmental Protection Agency, May 2003. (See Appendix B, page B-46, for more information.)

Exhibit 5-36: Fish diversity in mid-Atlantic bays, 1997-1998



Coverage: Mid-Atlantic bays (Delaware, Maryland, New Jersey, Virginia).

Source: EPA, Office of Research and Development, Atlantic Ecology Division. *Mid-Atlantic Integrated Assessment, MAIA - Estuaries 1997-98, Summary Report.* May 2003.

Indicator Submerged aquatic vegetation - Category 2

Many estuarine systems contain submerged aquatic vegetation (SAV), which provides habitat and refugia for fish and invertebrates, helps protect shorelines from erosion, contributes to sediment accretion, and provides food for aquatic organisms. The vegetation also stabilizes shifting sediments and adds oxygen to the water. SAV is sensitive to pollution and shading by turbid water.

In the mid-Atlantic region, Mid-Atlantic Integrated Assessment (MAIA) field crews noted the presence or absence of SAV at their sampling stations as an ancillary measurement, but no attempt was made to estimate the extent of SAV. For the Chesapeake Bay, however, SAV extent is an ecological endpoint, and restoration of SAV is one of the goals of the Chesapeake Bay Program (Batiuk, et al., 2000).

What the Data Show

Scientists estimated that historically there were about 600,000 acres of SAV in the Chesapeake Bay. A 1978 aerial survey estimated that this SAV acreage had decreased to 41,000 acres, but total acreage had increased to over 69,000 acres by 2000 (Moore, et al., 2000). Extent measures are not currently available for the rest of the nation's estuarine systems.

Indicator Gaps and Limitations

The limitations of this indicator include the following:

- SAV estimates have been analyzed and reported only for the mid-Atlantic estuaries but not for the entire U.S.
- These SAV estimates are for presence/absence only and do not indicate the density or abundance of the vegetation. More quantitative approaches using remote sensing are being used, but this information is not currently available for the entire U.S. coastline.

Data Source

The data sources for these indicators were *Chesapeake Bay Submerged Aquatic Vegetation Water Quality and Habitat-Based Requirements and Restoration Targets: A Second Technical Synthesis*, U.S. Environmental Protection Agency, Chesapeake Bay Program, 2000; and *Mid-Atlantic Integrated Assessment, MAIA-Estuaries, 1997-1998 Summary Report*, U.S. Environmental Protection Agency, May 2003. (See Appendix B, page B-47, for more information.)

Indicator Fish abnormalities - Category 2

External abnormalities in fish can include lumps, growths, ulcers, fin rot, gill erosion, and gill discoloration. The cause of an abnormality is not always chemical contamination—it could also result from an injury or disease. A high incidence of such conditions could, however, indicate an environmental problem.

What the Data Show

The EPA EMAP Estuaries Program examined more than 100,000 fish from estuaries in the Virginian, Carolinian, Lousianian, and West Indian Province estuaries for evidence of disease, parasites, tumors and lesions on the skin, malformations of the eyes, gill abnormalities, and skeletal curvatures. Of all the fish examined, only 0.5 percent (454 fish) had external abnormalities (EPA, ORD, OW, September 2001). Of the fish examined, bottom-feeding fish had the highest incidence of disease, but this incidence was still low. There is no criterion for what constitutes a high or low number of fish abnormalities.

Indicator Gaps and Limitations

The limitations of this indicator include the following:

- Fish abnormality estimates are not available nationally for U.S. estuaries.
- Fish abnormalities can result from both natural causes such as injury and from chemical contamination, and the cause cannot be readily assessed.

Data Source

The data source for this indicator was *National Coastal Condition Report*, U.S. Environmental Protection Agency, September 2001, using data from the Environmental Monitoring and Assessment Program, Estuaries Program. (See Appendix B, page B-47, for more information.)

Indicator Unusual marine mortalities - Category 2

Unusual marine mortalities are characterized by an abnormal number of dead animals in locations or at times of the year that are not typical for that species. For animals such as turtles, whales, dolphins, seals, sea lions, or similar vertebrates, where small numbers of deaths can be significant, this indicator reports the actual number of dead animals. For other more abundant animals such as fish, sea birds, and shellfish, the number of mortality events is recorded. The cause of these unusual events might include infectious disease, toxic algae, pollutants, or natural events.

What the Data Show

More than 2,500 California sea lions were involved in unusual marine mortalities in 1992, which is more than 10 times the number of seals, sea lions, sea otters, or manatees lost in similar events since 1992 (The Heinz Center, 2002) (Exhibit 5-37). The next two largest events were the deaths of 150 manatees off the Florida coast in 1996 and the deaths of 185 California sea lions in 1997 (The Heinz Center, 2002). No causes for these events were cited in the Heinz report (The Heinz Center, 2002).

Indicator Gaps and Limitations

The limitations of this indicator include the following:

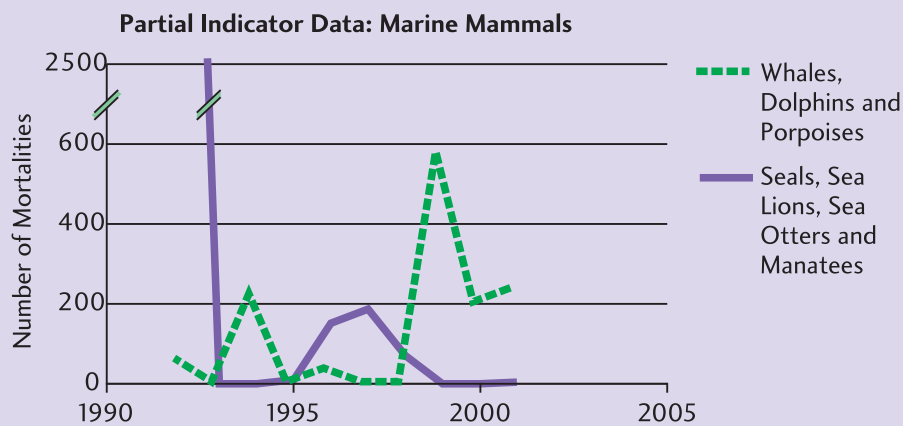
- This indicator represents only unusual events; it does not represent all observed mortalities of marine organisms.
- Criteria or thresholds do not exist for assessing the importance of unusual mortalities.
- It is not possible to determine if the event was caused by natural phenomena such as El Nino or was the result of anthropogenic influences.
- The data are not available on a national basis.

Data Source

The data source for this indicator was *The State of the Nation's Ecosystems,* The Heinz Center, 2002, using data from the U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries, Office of Protected Resources, Marine Mammal Health, Stranding Response Program, *CRC Handbook of Marine Mammal Medicine: Health, Disease, and Rehabilitation, 2nd edition* (Dierauf and Gulland, eds., 2001). (See Appendix B, page B-47, for more information.)

Exhibit 5-37: Unusual marine mortalities, 1992-2001

Data Not Adequate for National Reporting on Sea Turtles



Coverage: all U.S. waters.

Source: The Heinz Center. *The State of the Nation's Ecosystems.* 2002.
Data from the National Marine Fisheries Service and Dierauf and Gulland (2001).

Summary: The Ecological Condition of Coasts and Oceans

Coasts and oceans are subject to the same pressures as fresh waters, especially because they represent the endpoint for most fresh water drainage networks. Problems are exacerbated by the hydrology of estuaries, which tends to create conditions ideal for concentration of pollutants entering from upstream.

Landscape condition

The extent of this resource has been described by EPA and NOAA, and the landscape composition of much of the nation's coastline is known, providing a baseline against which to monitor future changes. As an example, 400,000 of 5,000,000 acres of coastal wetland were lost since the mid-1950s, although the loss rate declined in the 1990s (The Heinz Center, 2002). The baseline information is inadequate, however, for coral reefs, shellfish beds, and SAV, although a survey in Chesapeake Bay indicates that the acreage of SAV there increased from 41,000 to 69,000 acres since 1978 (Moore, et al., 2000). The estuarine landscape structure and pattern, and their contribution to ecological condition, remain inadequately measured or understood.

Biotic condition

The National Coastal Assessment, a joint federal and state interagency national monitoring program implemented to assess the ecological condition of the nation's estuaries, has developed regional data on several biotic condition indicators, including fish, benthic communities, and SAV. The program is also monitoring abnormalities and tissue contaminants. Results from three regions (Northeast, Southeast, and Gulf) indicate that, on average, 44 percent of the bottom community was in fair or poor condition, but this number varies among regions. Chlorophyll concentrations, which reflect the amount of phytoplankton growing in the water column, were over the recommended limit of 15 ppm (to protect SAV beds) over one-third of the estuarine area in the mid-Atlantic states. No similar estimates are yet available nationwide. Of more than 100,000 fish in random trawls from Maine to Texas, less than 0.5 percent showed visible evidence of disease, parasites, tumors or lesions of the skin, malformation of the eyes or gills, or skeletal curvature. Fish tissue contamination (other than non-toxic arsenic) was found in about 4 percent of fish.

Chemical and physical characteristics

A number of physical and chemical indicators are being monitored in estuarine systems to help diagnose and interpret biotic condition information. Data are available only for estuaries on the Atlantic or Gulf coasts, but 18 percent of mid-Atlantic estuaries were judged to have high nitrogen concentrations (which can lead to harmful algal blooms), and 12 percent had high concentrations of phosphorus. Twenty percent of Atlantic and Gulf estuaries had low dissolved oxygen concentrations (<5 ppm). On average, 75 percent of the sediments had elevated pesticide concentrations, and 40 percent had elevated concentrations of heavy metals, again with significant variation from region to region. Ten percent of the sediments showed a positive response to toxicity tests using a marine amphipod. Only 4 percent of the estuaries had poor light penetration.

There were no Category 1 or 2 indicators of *ecological processes, hydrology and geomorphology,* or *natural disturbance regimes* available for this report. The dearth of indicators for ecological processes is likely due, in part, to the fact that these indicators typically require repeated visits over several days, which makes systematic sampling in estuaries time-consuming and expensive. Procedures using remote sensing to assess ecological processes are being developed, but these are not ready for national or regional implementation. Hydrologic indicators may be similar to those for fresh water systems, but are complicated by the complex flows caused by tides and other phenomena in estuaries. An indicator of sea level change also may be useful. Storms, hurricanes, and similar disturbances are monitored globally, nationally, regionally, and locally, but this information has not been developed in the form of an indicator.

Information on disturbance regimes could also be used to partition observed estuarine system responses into portions attributable to natural versus anthropogenic disturbances.

5.8 What Is the Ecological Condition of the Entire Nation?

The previous sections asked questions about the ecological condition of forests, coasts and oceans, fresh water ecosystems, urban and suburban areas, farmlands, and grasslands and shrublands nationally. Because ecosystems are hierarchical (O'Neill, et al., 1986) some important questions about ecological condition cannot be answered in terms of these land cover classes. Examples of large-scale issues include the following:

- The relative distribution of forests, grasslands, farmlands, and urban/suburban areas across the entire nation.
- Neotropical migratory birds and other species do not depend on one ecosystem type, but many, often spread over large regions.
- The condition of forest streams, and of other low-order streams across regions, was considered in Section 5.6, but processes in very large watersheds (e.g., the Mississippi or Columbia River basins) reflect the sum total of contributions from many ecosystem types.
- Typically, large systems are slower to change and to respond to management actions (O'Neill, et al., 1986; Messer, 1992). Global climate change and changes in stratospheric ozone are examples of stressors of this type (Rosswall, et al., 1988).

Because EPA's regulatory programs, both alone and in combination, typically impact many kinds of ecosystems, such large-scale questions are an important part of tracking the overall effectiveness of these programs in protecting the entire nation.

Exhibit 5-38 shows the indicators for the entire nation used in this report. All seven of the indicators are taken from the core national indicators in *The State of the Nation's Ecosystems* (The Heinz Center, 2002). There are indicators for four of the six essential ecological attributes with at least regional data, but no indicators on hydrology and geomorphology or natural disturbance regimes with data available on a national or regional level (The Heinz Center, 2002).

Exhibit 5-38: Indicators covering the entire nation

Essential Ecological Attribute	Indicators	Category		Source
Landscape Condition		1	2	
Extent	Ecosystem extent	■		USDA, DOI, DOC
Landscape Composition				
Landscape Pattern/Structure				
Biotic Condition				
Ecosystems and Communities	At-risk native species		■	NatureServe
Species and Populations	Bird Community Index		■	EPA
Organism Condition				
Ecological Processes				
Energy Flow	Terrestrial Plant Growth Index	■		DOI, DOC
Material Flow	Movement of nitrogen	■		DOI
Chemical and Physical Characteristics				
Nutrient Concentrations				
Other Chemical Parameters				
Trace Organic and Inorganic Chemicals	Chemical contamination		■	DOI, EPA
Physical Parameters				
Hydrology and Geomorphology				
Surface and Ground Water Flows				
Dynamic Structural Conditions				
Sediment and Material Transport				
Natural Disturbance Regimes				
Frequency				
Extent				
Duration				

Indicator | Ecosystem extent - Category 2

Extent provides basic information on how much of an ecosystem exists, where it is, and whether it is changing over time. Changes in the extent of various cover types in the U.S. have been driven primarily by human land and water uses over the past 400 years. The total amount and relative distribution of land-cover types at the regional and national level are important, because ultimately they affect many of the ecological attributes such as biodiversity. For example, not only do forest species depend on forests, but many forest species also depend on adjacent wetlands or grasslands.

What the Data Show

Estimates show that before European settlement, the U.S. had 1 billion acres of forests (USDA, FS, 2002), 900 to 1,000 million acres of grasslands and shrublands (Klopatek, et al., 1979) and 221 million acres of wetlands (Dahl, 2000). Today, the U.S. has 749 million acres of forests (USDA, FS, 2002), 861 million acres of grasslands and shrublands (The Heinz Center, 2002), and 106 million acres of wetlands (Dahl, 2000). About 530 million acres of croplands (USDA, NRCS, 2000) and 90 million acres of urban and suburban land uses (USDA, NRCS, 2001) have been added.

The acreage of forest and fresh water wetlands have each declined by about 10 million acres in the decades since the 1950s; the acreage of croplands has fluctuated, but it is currently about 35 million acres less than in the 1950s; and urban areas have grown by 40 million acres during the same period (The Heinz Center, 2002) (Exhibit 5-39).

Indicator Gaps and Limitations

According to The Heinz Center (2002), the National Land Cover Database (NLCD) produced different estimates of area for forests and farmlands from those mentioned above, because of differences in the definitions of these systems in the Forest Inventory and Analysis (FIA) and the USDA Economic Research Service (ERS). In addition, current indicators of extent do not provide information about fragmentation and landscape patterns.

Data Sources

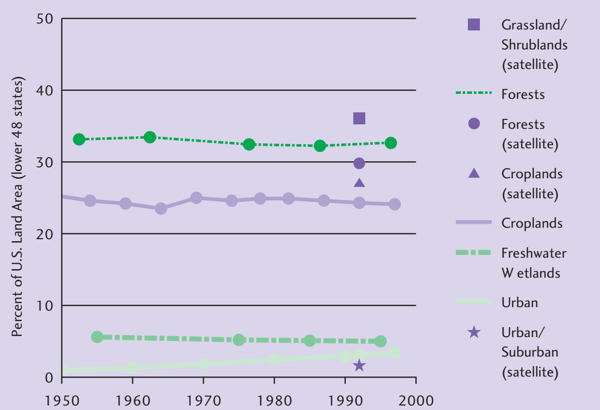
The data sources for these indicators were Forest Inventory and Analysis, U.S. Department of Agriculture (1979-1995); National Land Cover Database, Multi-Resolution Land Characteristics Consortium (1990s); National Wetlands Inventory, U.S. Fish and Wildlife Service (1970-2000); and Economic Research Service, U.S. Department of Agriculture (1982-1997). (See Appendix B, page B-48, for more information.)

Exhibit 5-39: Change in ecosystem extent, long-term and recent trends, 1950s-1990s

Data Not Adequate for National Reporting on Extent of brackish coastal waters

Partial Indicator Data: Long-term Changes for For Forests, Croplands, Grasslands/Shrublands, Urban/Suburban

Partial Indicator Data: Recent Trends for Forests, Croplands, Grasslands/Shrublands, Urban/Suburban, Freshwater Wetlands



Coverage: lower 48 states.

Note: Because these estimates are from different sources, they do not sum to 100% of U.S. land area. Approximately 5% of lands are not accounted for by these data sources. They include some wetlands, some non-suburban developed areas, disturbed areas such as mines and quarries and the like. In addition, freshwater wetlands currently occupy approximately 5% of the area of the lower 48 states, a reduction of about 50% since presettlement times. Because they are found within forests, grasslands, and shrublands, or croplands, freshwater wetlands from those ecosystems are shown as aggregated data on the graph. Finally, the "urban" trend line in this graph is based on a different definition from the one in this report and is presented here to illustrate general trends. The definition used in this report was used to generate the "urban/suburban (satellite)" area estimate.

Source: The Heinz Center. *The State of the Nation's Ecosystems.* 2002. Data from the USDA Forest Service (forests, current area, recent trends), USDA Economic Research Service (croplands trends, urban area trends), Multi-Resolution Land Characterization Consortium (MRLC; all satelite data, including current estimate of grass/shrub and urban/suburban area in top graph). Presettlement estimates are from Klopatek et al. 1979.

Indicator | At-risk native species - Category 2

Scientists are engaged in considerable discussion about the importance of rare and at-risk species for the sustainability of ecosystems (e.g., Grime, 1997; Hodgson, et al., 1998; Naeem, et al., 1999; Tilman and Downing, 1994; Wardle, et al., 2000). There are at least 200,000 native plant, animal, and microbial species in the U.S., but according to The Heinz Center (2002), "little is known about the status and distribution of most of these." This indicator represents what is known about 22 species groups, including 16,000 plant species and 6,000 animal species. It includes all higher plants; all terrestrial and fresh water vertebrates (i.e., mammals, birds, reptiles, amphibians, and fish); select invertebrate groups, including fresh water mussels and snails, crayfishes, butterflies and skippers; and about 2,000 species of grasshoppers, moths, beetles, and other invertebrates (The Heinz Center, 2002). The Heinz Center believes that this indicator is a powerful—yet manageable—snapshot of the condition of U.S. species. No data are available for marine species, which led The Heinz Center to rank this as an indicator equivalent to a Category 2. Special groupings of these species have been used as indicators in specific ecosystem categories. This indicator includes all of them, but The Heinz Center has not analyzed species dependent on large or multiple ecosystems.

What the Data Show

One-third of species native species are at risk, and 1 percent of plant and 3 percent of animal species might already be extinct (The Heinz Center, 2002) (Exhibit 5-40). Approximately 19 percent of native animal species and 15 percent of native plant species are ranked as imperiled or critically imperiled. There are large differences among plant and animal groups and among regions. For example, the percentage of at-risk fresh water species such as mussels and crayfish is much higher than that for birds or mammals, and more at-risk species are found in California, Hawaii, the southern Appalachians, and Florida than elsewhere (Stein, 2002).

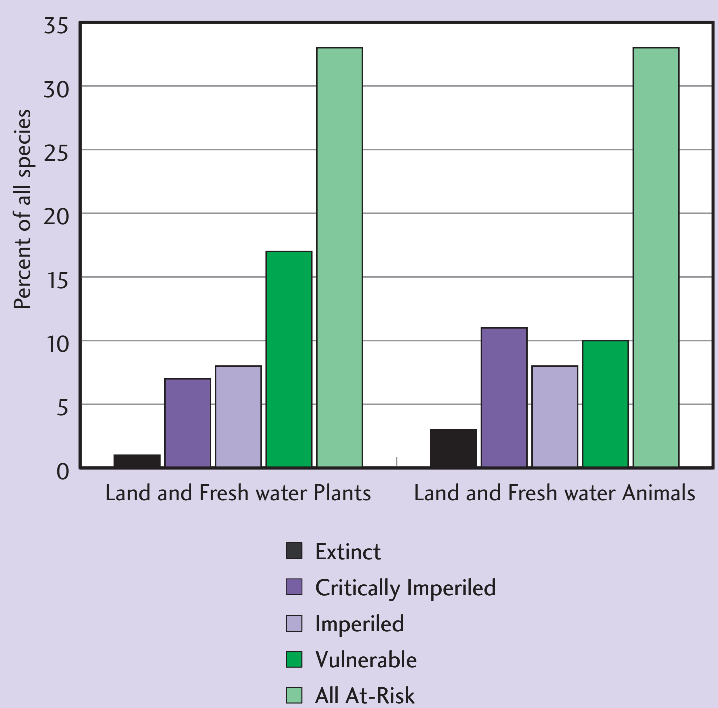
Indicator Gaps and Limitations

The data are from a census approach that focuses on the location and distribution of at-risk species. Therefore, distinguishing trends in the indicator is difficult.

Data Source

The data for this indicator was *The State of the Nation's Ecosystems,* The Heinz Center, 2002, using data from the NatureServe Explorer database. (See Appendix B, page B-48, for more information.)

Exhibit 5-40: At-risk land and fresh water plant and animal native species, 2000



Coverage: all 50 states.

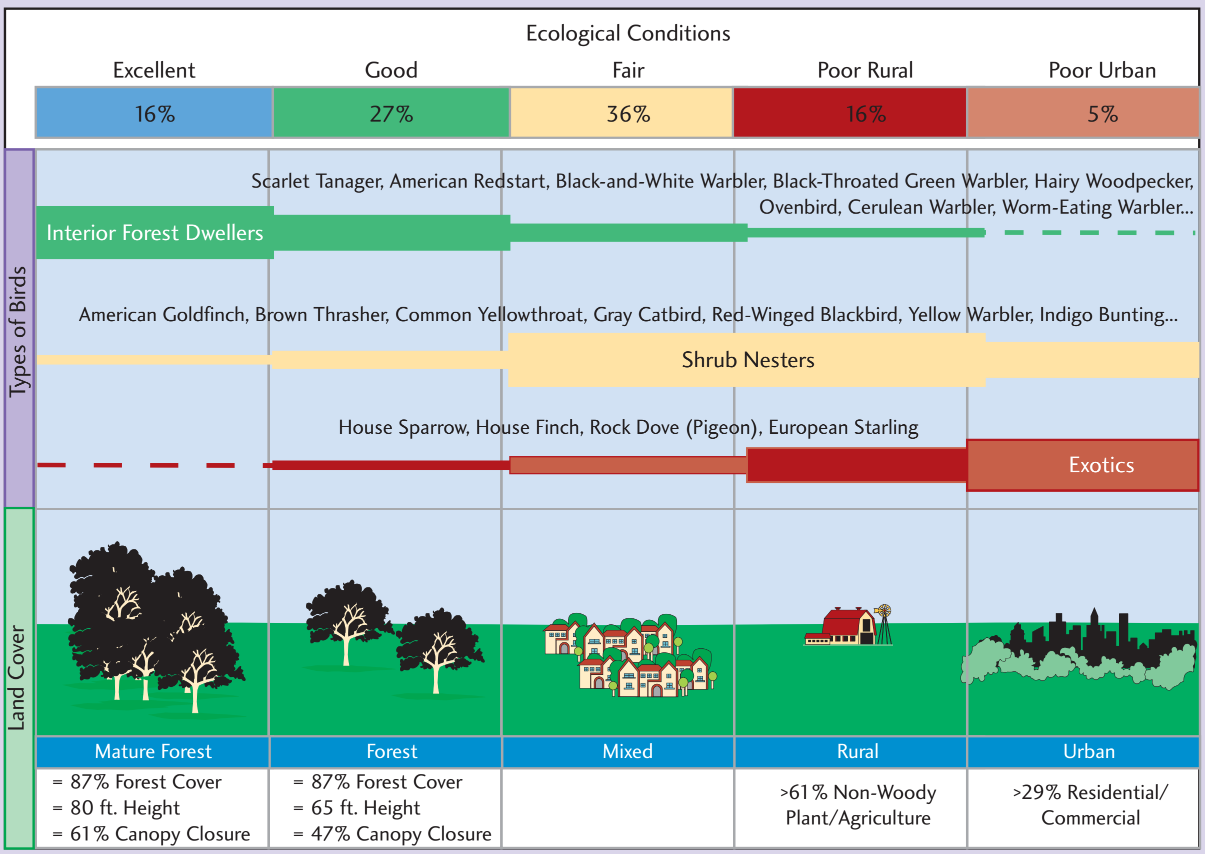
Source: The Heinz Center. *The State of the Nation's Ecosystems.* 2002. Data from NatureServe and its Natural Heritage member programs.

Indicator Bird Community Index - Category 2

The types of birds observed in an area have been shown to serve as an indicator of the overall characteristics of the landscape. Species vary in their sensitivity to physical, chemical, and biological threats, and different species require different habitats for food, shelter, and reproduction. Some species need extensive areas of interior forest, others prefer the edges between different types of land cover or mixed areas, and still others prefer disturbed or highly managed areas. Consequently, the composition of the bird community reflects the overall mix, pattern, and condition of the mosaic of forest, agriculture, grasslands and shrublands, wetlands, streams, and urban/suburban areas that makes up most of the U.S. landscape.

The Bird Community Index (BCI) was developed by O'Connell, et al. (1998, 2000) for songbirds in the mid-Atlantic states. The index was developed based on data collected at 34 reference sites, with bird species classified into 16 functional groups according to the degree to which they specialized in using the native flora and fauna in an area (high BCI scores) versus being generalists and exotic or invasive species (low BCI scores). The BCI then was applied to a probability sample of bird data from 126 sites across the Mid-Atlantic Highlands.

Exhibit 5-41: Bird species as characteristics of landscape composition and pattern as an indicator of landscape condition, 1995-1996



Coverage: Mid-Atlantic Highlands (Maryland, Pennsylvania, Virginia, West Virginia).

Source : EPA, Office of Research and Development. *Birds Indicate Ecological Condition of the Mid-Atlantic Highlands.* June 2000.

Indicator Bird Community Index - Category 2 (continued)

What the Data Show

Good-to-excellent BCI scores (diverse communities of birds characterized by many specialists and native species) were associated with at least 87 percent forest cover and a minimum of 47 percent canopy closure. Poor BCI scores (low diversity communities characterized by generalists and exotic species) were associated with either rural agricultural or urban areas where almost 30 percent of the landscape was in residential or commercial land use.

The BCI was calibrated across a range of landscape conditions from least disturbed to significantly degraded. Based on this calibration, 43 percent of the Mid-Atlantic Highlands was estimated to be in good to "excellent" condition (in other words, containing large tracts of interior forest), 36 percent was estimated to be in "fair" condition, and 21 percent (5 percent urban and 16 percent rural) was estimated to be in "poor" condition (Exhibit 5-41). Forested sites in good and excellent condition supported different bird communities and ground-level vegetation attributes, but could not be separated by land cover composition alone. As the proportion of the landscape in forested areas decreased or the proportion of canopy closure decreased, so did the BCI scores (O'Connell, et al., 1998, 2000).

Indicator Gaps and Limitations

The limitations of this indicator include the following:

- This indicator depends on a value judgement common among ecologists that communities associated with the native vegetation of a region are "better" than exotic, generalist species associated with human modification of the environment.
- The BCI has been calibrated and assessed only for the Mid-Atlantic Highlands, and may not apply to areas where shoreline birds or migratory waterfowl are a larger component of the bird community.
- The BCI relates primarily to land cover estimates, and does not explicitly include the condition of any particular land cover type.

Data Source

The data sources for this indicator were *A Bird Community Index of Biotic Integrity for the Mid-Atlantic Highlands,* O'Connell, et al., 1998; and *Bird Guilds as Indicators of Ecological Condition in the Central Applachians,* O'Connell, et al., 2000, using data from U.S. Environmental Protection Agency Mid-Atlantic Highlands Program and the National Land Cover Database. (See Appendix B, page B-48, for more information.)

Indicator Terrestrial Plant Growth Index - Category I

Both the National Research Council and Science Advisory Board reports suggest that primary productivity (the amount of solar energy captured by plants through photosynthesis) is a key indicator of ecosystem function (NRC, 2000; SAB, 2002). Generally, ecosystems will maximize their primary productivity through adaptation (Odum, 1971), so primary productivity can increase under favorable conditions (e.g., increased nutrients or rainfall) or decrease under unfavorable conditions (e.g., plant stress caused by toxic substances or disease). Changes in primary productivity can result in changes in the way ecosystems function, in the yield of crops or timber, or in the animal species that live in the ecosystems.

Gross primary productivity is related to the standing crop of the photosynthetic pigment chlorophyll and can be thought of in simple terms as plant growth. The Terrestrial Plant Growth Index indicator is based on the Normalized Difference Vegetation Index (NDVI), which measures the amount of chlorophyll, using satellite data (The Heinz Center, 2002). While the standing crop of chlorophyll is not identical to primary productivity, EPAs Science Advisory Board (EPA, SAB, 2002) lists it as an example of an indicator under the ecological processes EEA.

What the Data Show

No overall trend in plant growth is observed for the 11-year period from 1989 through 2000, for any land cover type or any region of the U.S., although year-to-year measurements can fluctuate by up to 40 percent of the 11-year average (The Heinz Center, 2002) (Exhibit 5-42). Over a sufficiently long period, regional trends in NDVI could be an important indicator of increasing or decreasing plant growth resulting from changing climate, UV-B exposure, air pollution, or other stressors.

Indicator Gaps and Limitations

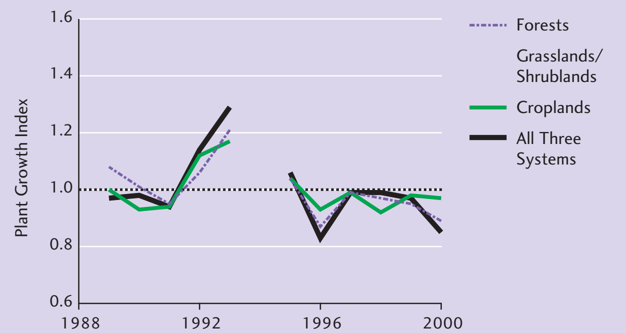
There were no calculations for phytoplankton or submerged vegetation growth in fresh water or coastal systems.

Data Source

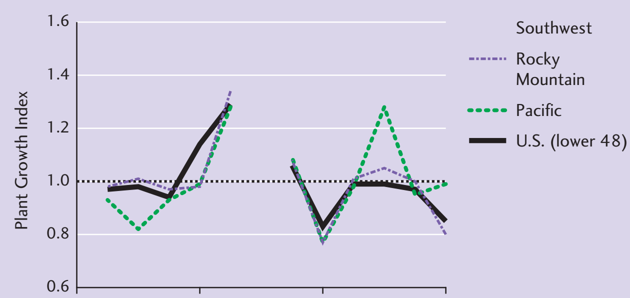
The data source for this indicator was *The State of the Nation's Ecosystems*, The Heinz Center, 2002, using data on visible and near-infrared wavelengths collected by the National Oceanic and Atmospheric Administration's Advanced Very High Resolution Radiometer and converted into a Normalized Difference Vegetation Index (Reed and Young, 1997). (See Appendix B, page B-49, for more information.)

Exhibit 5-42: Plant Growth Index, 1989-2000

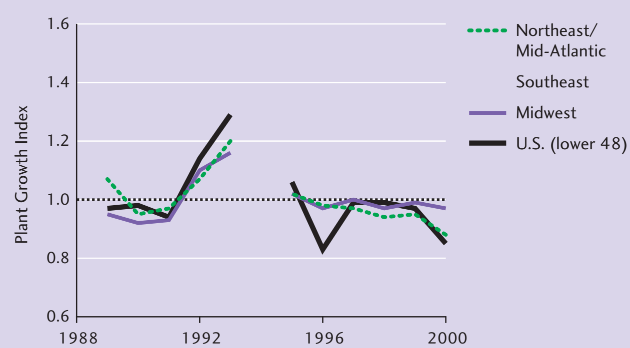
Terrestrial Plant Growth Index for lower 48 states



Plant Growth Index: southwest, rocky mountain, pacific regions



Plant Growth Index: northeast, southeast, midwest regions



Coverage: Lower 48 states.

Note: Because of satellite problems, no data are available for 1994.

Source: The Heinz Center. *The State of the Nation's Ecosystems*. 2002.
Data from the U.S. Geological Survey; Multi-Resolution Land Characterization Consortium.

Indicator | Movement of nitrogen - Category I

Nitrogen is a critical nutrient for plants, and "leakage" of nitrogen from watersheds can signal a decline in ecosystem function (Vitousek, et al., 2002). It also may signal the failure of watershed management efforts to control point, non-point, and atmospheric sources of nitrogen pollutants, and the resulting nitrogen may have "cascading" harmful effects as it moves downstream to coastal ecosystems (Galloway and Cowling, 2002). Nitrate concentration in streams has served as an indicator of chemical condition in the other ecosystems in this section. This indicator, however, deals with nitrogen export from large watersheds, and is an indicator of ecosystem function.

What the Data Show

Nitrate export from the Mississippi River has been monitored since the mid-1950s and from the Susquehanna, St. Lawrence, and Columbia Rivers since the 1970s, and is reported in The State of the Nation's Ecosystems in tons per year. The load in the Mississippi River has fluctuated from year to year, but it has increased from approximately 250,000 tons per year in the early 1960s to approximately 1,000,000 tons per year during the 1980s and 1990s (The Heinz Center, 2002) (Exhibit 5-43). The Mississippi River drains the agricultural "breadbasket" of the nation and contains a large percentage of the growing population, so the increases likely reflect failure to control nitrogen pollution, rather than a breakdown in ecosystem function (e.g., Rabalais and Turner, 2001). Nitrate loads in the other three rivers have fluctuated around 50,000 tons per year since the 1970s, although the Columbia River spiked to 100,000 tons per year in the late 1990s.

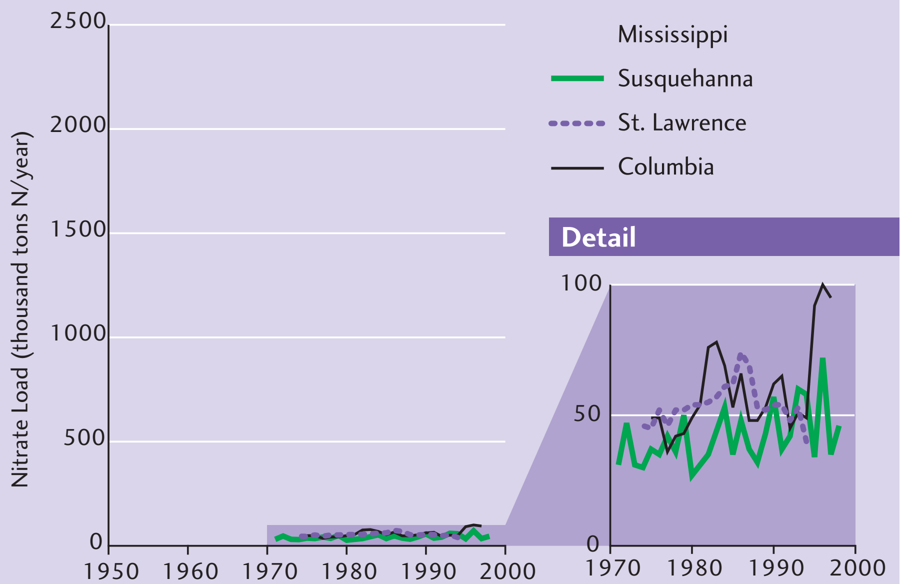
Indicator Gaps and Limitations

The indicator does not include data from numerous coastal watersheds whose human populations are rapidly increasing and are therefore estimated to have high nitrogen loss rates (e.g., Valigura, et al., 2000). It also does not include other forms of nitrogen besides nitrate, which may constitute a substantial portion of the nitrogen load.

Data Source

The data source for this indicator was *The State of the Nation's Ecosystems,* The Heinz Center, 2002, using data collected by the U.S. Geological Survey, National Stream Quality Accounting Network and National Water Quality Assessment Program, and by the U.S. Army Corps of Engineers. (See Appendix B, page B-49, for more information.)

Exhibit 5-43: Nitrate load carried by major rivers, 1970-1999



Coverage: selected major rivers.

Source: The Heinz Center. *The State of the Nation's Ecosystems.* 2002.
Data from the U.S. Geological Survey's National Stream Quality Network (NASQAN), National Water Quality Assessment (NAWQA), and Federal-State Cooperative Program.

Indicator Chemical contamination - Category 2

This indicator has been discussed for the individual ecosystems, but here it is reported for all media, regardless of land-cover type. The following is a summary of the key findings; the Heinz report (2002) should be consulted for further details.

What the Data Show

Three-fourths of all streams in the National Water Quality Assessment (NAWQA) network had one or more contaminants that exceeded guidelines for the protection of aquatic life, and one-fourth had four or more contaminants over those levels. One-fourth of ground water wells sampled had one or more contaminants above human health standards. One-half of all streams had one or more contaminants in sediments that exceeded wildlife protection guidelines (usually more stringent than criteria to protect human health). One-half of all fish tested had one or more contaminants that exceeded wildlife protection guidelines. Approximately 60 percent of estuarine sediments tested had concentrations of contaminants expected to lead to "possible effects" in aquatic life, and 2 percent had concentrations exceeding levels expected to have "likely effects."

Indicator Gaps and Limitations

The limitations of this indicator include the following:

- While these data represent a comparison of a standard to the respective contaminant concentration, they do not represent assessments of risk posed to humans or ecosystems.
- Different standards also reflect different levels of protection, so these data should be interpreted cautiously.
- Media contamination, such as water or sediment contamination, does not necessarily indicate exposure to the contaminant for either humans or other biological populations.

Data Source

The data source for this indicator was *The State of the Nation's Ecosystems,* The Heinz Center, 2002, using data from the National Water Quality Assessment Program and the Environmental Monitoring and Assessment Program, Estuaries Program. (See Appendix B, page B-50, for more information.)

Summary: The Ecological Condition of the Entire Nation

The idea of monitoring indicators that could include the entire nation, irrespective of the type of land cover, has not been a main topic of ecological monitoring. The main idea is that pressures acting over large areas may have effects that transcend a land cover type, or may depend on the interaction of land cover types. The issue of scale has not been well-articulated with respect to these indicators (issues of national scope may not operate at national scales). This is an area of attention for future reports.

Landscape condition

The National Land Cover Database (NLCD) now provides a consistent national picture of the extent of the various ecosystem types at 30 meter (about 100 foot) resolution (Vogelmann, et al., 2001). A consortium of federal agencies performs the interpretation of the satellite data necessary for development of the NLCD. Much of the data in this indicator come from the Forest Inventory and Analysis (FIA) or the National Resources Inventory (NRI), which allows trends to be estimated during periods prior to the first NLCD coverage. Unfortunately, these data are not comparable to the NLCD, because of differences in the definitions of the land cover categories (see Chapter 3, Better Protected Land).

Biotic condition

With respect to the at-risk native species indicator, the NatureServe database is an invaluable resource for identifying these species. Because the resulting data are developed without an underlying statistical design, however, it will be difficult to determine whether future trends are the result of more thorough field work and reporting by researchers and resource managers, or actual trends in the number of at-risk species. An effort has begun to identify all species in the Smoky Mountain National Park (Kaiser, 1999), and an international effort, called Species 2000, is being developed by a multinational project team associated with the United Nations (U.N.) Convention of Biological Diversity. Recent research expanding the bird diversity index to the entire mid-Atlantic region shows that it has promise as a national indicator (O'Connell, et al., 2002). Analysis of the biological data from the first 20 National Water Quality Assessment (NAWQA) study units, and similar analyses of Environmental Monitoring and Assessment Program (EMAP) data from the national estuaries and streams in the West and Midwest, should shed some light on the feasibility of a national indicator for estuarine and stream benthic communities. Because the plankton communities of lakes do not exhibit a high degree of biogeographical variation (independent of natural factors such as hardness or the presence of organic color), a national plankton index would seem feasible if the necessary data were collected.

Ecological processes

The *Terrestrial Plant Growth Index* is probably the best example of the indicator of primary productivity called for by both the NRC (2000) and SAB (2002). Comparable data exist on trends for a decade, with census coverage (at the resolution of the AVHRR sensor) for the conterminous U.S. Examination of the trends data for this indicator in The Heinz Center (2002) report shows large (±40 percent) excursions from the 11-year average in the Southwest, and ±20 percent excursions in the Pacific region. The amount of time necessary to separate changes caused by air pollutants (e.g., ozone, nitrogen deposition, carbon dioxide) from those caused by natural climatic factors and insect and disease outbreaks is unknown.

The Movement of Nitrogen indicator certainly captures trends in this important nutrient in the nation's largest river basins. The indicator would be improved if it included total nitrogen, including an accurate estimate of nitrogen carried in the bed load of sediments as it moves into coastal waters, and if it were extended to the many smaller coastal watersheds that are experiencing large increases in population. An indicator of sediment runoff potential would be a useful large-ecosystem indicator if it were extended to non-farmland ecosystems (see Chapter 3, Better Protected Land).

Chemical and physical characteristics

The *Chemical Contamination* indicator raises a serious question about how representative the streams in the NAWQA study units are. There were 119 NAWQA sites with surface water monitoring data, located in 20 geographically well-dispersed watersheds across the U.S. Eventually, NAWQA plans to expand to 60 such units, and presumably all will include water sampling. On a national basis, this might be an adequate number to represent the range of factors affecting ecological condition of the streams and watersheds. The number of streams characterizing forest, farmland, or urban/suburban watersheds seems too small, however, given the very wide range of nutrient and contaminant concentrations presented in the Heinz report.

More important, however, is whether the streams sampled are representative of the range of streams in the entire nation. The ecological condition of fresh waters (and their watersheds) reflects the sum total of natural factors (including disturbances), conscious and unconscious decisions about land-use management (e.g., what crops to grow, whether and when to cut timber, urban planning and zoning), and the presence and control of pollutants. A particular stream might be representative of a watershed with respect to geomorphology and hydrology, and even land use (e.g., corn or tree farming, urban or suburban). But resource management decisions and the presence or control of pollutants are particular to a specific watershed, and so the streams must be chosen to be representative of the full range of possibilities, and of their relative frequencies. With respect to pollution control, assuming that the full set of environmental controls are working as envisioned by EPA is particularly risky. In fact, this risk is one of the primary reasons for monitoring progress toward national goals under GPRA; to determine if the programs, as implemented and enforced by the states are really protecting and restoring the biological integrity of fresh waters. In this context, identifying representative streams or watersheds is not as reasonable as identifying representative samples of streams or watersheds. Until the NAWQA streams can be compared to a statistically representative sample of streams, great care must be taken in assuming that the data accurately reflect the national condition of fresh waters and watersheds.

There were no Category 1 or 2 indicators available for this report for *hydrology and geomorphology* or *natural disturbance regimes,* but developing them does not seem to be a particularly daunting challenge, given the widely available data on geology, flow, and paleological methods to indicate the regional occurrence of climatic events and fire.

5.9 Challenges and Data Gaps

The availability of indicators across ecosystem types is summarized in Exhibit 5-44. Indicators that currently can provide national information on ecological condition are available for only 14 of the possible 126 indicator categories in the framework. More than half of the Category 1 indicators provide information only on ecosystem extent and landscape composition, with a few exceptions:

- The Forest Inventory and Analysis (FIA) and Forest Health Monitoring (FHM) programs together have achieved representative national coverage for both the present status and historical trends in the occurrence of fire, insect damage, and disease for forests.
- Satellite data provide continent-wide status and trends in the Normalized Difference Vegetation Index (NDVI), which serves as a surrogate for primary productivity, or the amount of energy available at the base of the ecosystems.[17]
- Historical hydrology data were analyzed for The Heinz Center report to determine trends in high and low-flows for more than 800 streams with no specified land cover and more than 500 forest streams across the U.S., and the number and duration of dry periods were calculated for 152 streams in grasslands, shrublands, and dry areas. These analyses could presumably have been performed for urban/suburban, agricultural, and very large watersheds, but they have not been performed to date.
- The current status and historical trends in the potential for sediment transport from farmland can be calculated from existing data (though not the amount of sediment actually lost).

For the rest of the essential ecological attributes, only partial data exist, at best (e.g., regional data or data for only part of the resource), for one or more indicators. For more than one-half of the major indicator categories in the seven ecosystem types, not even one indicator was identified for this report. For many more, only one existed, though several would be necessary. This situation will improve slightly in the next year or two. A number of active research programs are collecting and analyzing relevant ecological condition data at the national or regional level, but the results had not yet met the criterion for peer review at the time this report was finalized. Two years from now, research on indicators from the FIA program, FHM program, the National Water Quality Assessment (NAWQA) program, and the Environmental Monitoring and Assessment Program (EMAP) Western Streams Pilot should provide new Category 2, and a few Category 1 indicators, primarily biotic condition and ecological process indicators. As of now, the gaps are substantial.

[17]There is some debate as to whether standing crop chlorophyll can really be a surrogate for primary productivity, so this might be more appropriate as an ecosystem condition indicator.

What the Available Indicators Reveal about Some Ecological Issues of Recent Concern to EPA

The introduction to this chapter identified three reasons to monitor ecological condition:

- To establish baselines against which to assess the current and future condition of ecosystems.
- To provide a warning that action may be required.
- To track the outcomes of policies and programs, and adapt them as necessary.

This section addresses the question of how well the available indicators of ecological condition, notwithstanding the gaps evident in Exhibit 5-44, serve these purposes for some ecological issues that have been of concern to EPA over the past decade. These do not reflect all such issues, or signify EPA's priorities, but simply typify a diverse set of challenges for national ecological monitoring:

- Forest dieback
- Vertebrate deformities
- Harmful algal blooms
- Eutrophication
- Loss of biodiversity
- Non-target organism effects from pesticides and herbicides
- Issues related to ozone, UV-B, mercury, acidic deposition, and persistent bioaccumulative toxics (PBTs)

For the first five issues listed above, biota were harmed before the cause was known. For the other two, a perceived risk exists, but the extent of actual harm or exposure is unknown. In either case, data on the extent or trends in ecological condition is needed to inform how research is targeted or regulatory programs adjusted. Identifying indicators of the appropriate essential ecological attribute also should help to identify some of the factors that might be contributing to the extent of and trends in harm to biota and ecosystem function (EPA, SAB, 2002).

Forest dieback

Forest dieback can be exacerbated, if not caused, by some combination of acid deposition, air pollution, UV-B radiation, disease, insects, and unusual climate events (USDA, FS, 2002). Currently, the forest indicators provide a baseline for the extent of poor tree condition in 37 states; soon, these indicators will provide a baseline and future trends for the conterminous U.S. NDVI data are available as a surrogate for primary productivity in forests. FIA program plots are being examined for indications of harm to ozone-sensitive species. Relevant soil data (exchangeable base cations) are being measured, even though that indicator cannot yet be reported. A UV-B monitoring network has been collecting data for less than 2 years, and the data are currently being evaluated. Data for ozone and acid deposition in high elevation forests remain poor, as do climate data. Most of these indicators are being monitored using a probability design, so continued FIA monitoring can provide a national baseline for assessing the extent and trends in forest dieback, and some of the EEAs that may contribute to it.

Vertebrate deformities

The ability of exogenous chemicals to interfere with normal endocrine functioning and related processes of an organism has raised increasing concerns for human health and the environment. Studies have reported that both synthetic and naturally occurring compounds interfere with normal endocrine function of invertebrates, fish, amphibians, reptiles, birds, and mammals causing effects such as birth defects, impaired fertility, masculinization of female organisms, feminization of male organisms, or organisms with both male and female reproductive organs. Two recent reports summarize available data from field and laboratory studies and provide an assessment of the state of the science (EPA, RAF, 1997; IPCS, 2002). The existing challenge is to further elucidate the cause-and-effect relationships for the observed adverse effects, determine which chemicals are of greatest concern, and the extent to which these chemicals negatively impact populations of fish and/or wildlife.

The only indicator identified in this chapter that tracks the extent or trends in animal deformities (irrespective of the cause) is a Category 2 indicator, Fish Deformities, collected by EMAP in coast and ocean ecosystems. Data are being collected on amphibian deformities by the USGS, using reports from a wide array of sources. A new national survey, the Amphibian Research and Monitoring Initiative, was established by USGS in 2000. However, it may be several years before USGS and EPA can detect national and/or regional trends from this initiative. Until there is a better understanding of which chemicals are of greatest concern, there is also some question about which chemi-

Exhibit 5-44: Distribution of available ecological condition indicators across the ecosystem types

Essential Ecological Attribute	Forests	Farmlands	Grasslands/ Shrublands	Urban/ Suburban	Fresh Waters	Coasts and Oceans	The Nation
Landscape Condition							
Extent of Ecological System/Habitat Types	1 1	1	1	1	1 1	1	1
Landscape Composition	2	1		2	2	2 2	
Landscape Pattern/Structure	2						
Biotic Condition							
Ecosystems and Communities	2		1 2		2 2 2 2 2	2 2 2	2
Species and Populations	2				2	2	2
Organism Condition	1 2 2				2	2 2	
Ecological processes							
Energy Flow							1
Material Flow	2						1
Chemical & Physical Characteristics							
Nutrient Concentrations	2	2 2		2 2	2 2	2 2	
Other Chemical Parameters	2 2				2	2 2	
Trace Organic /Inorganic Chemicals		2 2 2 2		1 2	2	2 2	2
Physical Parameters	2					2	
Hydrology and Geomorphology							
Surface and Ground Water Flows	1		1		1		
Dynamic Structural Conditions							
Sediment and Material Transport	2	2 2			2		
Natural Disturbance Regimes							
Frequency	2						
Extent							
Duration							

Note: Numbers correspond to indicator categories presented in this report.

cals to monitor in the fish and wildlife habitat. Additional information on chemicals will become available once EPA has fully implemented an Endocrine Disruptor Screening Program to test a chemical for its potential endocrine disruption activity.

Harmful algal blooms

Scientists have also been concerned about the condition of the nation's estuaries and in particular, about a perceived increase in harmful algal blooms (HABs); loss of submerged aquatic vegetation (SAV), which serves as habitat for fish; and sediment toxicity, which might limit the productivity of an important component of the estuarine food chain (Anderson and Garrison, 2000; Gallagher and Keay, 1998). EMAP, working with the states, has collected data on the condition of SAV, estuarine fish communities, estuarine benthic communities, sediment toxicity, and nutrient concentrations that should provide representative status and trends data for these indicators. The sampling design does not allow tracking of the frequency and extent of HABs or nutrient levels in estuaries, but USGS does monitor nutrient loads to coastal systems from four of the largest U.S. rivers. Continued monitoring of the estuaries is subject to state-by-state availability of funding.

Eutrophication

EPA has recently focused substantial attention on the listing by the states of their waters that do not meet their designated uses (usually expressed in terms of their ability to support aquatic life), and developing total maximum daily loads of pollutants that would allow the designated use to be achieved. Concern over eutrophication of lakes and reservoirs has prompted EPA to begin developing regional standards for the nutrients nitrogen and phosphorus. At present, there is no indicator monitoring suitable to track progress in reducing the number of eutrophic lakes and streams or the condition of the biotic communities in rivers and streams at the national or even regional level. Indicators monitored by the states are not comparable, the same waters are not necessarily sampled over time, and their representativeness is unknown and questionable. NAWQA uses comparable methods and intends to monitor the same streams over time, but the number of such streams in the various ecosystem types is too small to adequately represent all the factors that contribute to water quality at the national level. While the data are likely to be broadly representative of certain types of streams, they cannot be expanded to all streams with known statistical reliability. This fact is particularly important if the combination of factors affecting water quality in the study units (which depend on a variety of factors, including water quality management by the states, national patterns of air pollution and acid rain, geology and land use, and climate) is not statistically representative of these factors nationally. EMAP has demonstrated regional approaches to statistically representative sampling that include both biology and chemistry, but has not yet reported on relationships between them, nor is there any long-term commitment to repeating the pilot studies or expanding them to other regions. EPA is currently working with the states to rectify this situation, and some progress is reported in Chapter 2, Purer Water.

Loss of biodiversity

EPA is concerned generally about biodiversity, and this is one of the primary areas on which EPA comments in Environmental Impact Statements for significant projects involving federal funding under NEPA. The NatureServe indicator reported for many of the ecosystems is invaluable in indicating species at risk in the vicinity of such projects. Because the database is not based on a systematic survey of plots over time, however, it is not clear how to interpret data that are not reported. For example, the current data cannot distinguish naturally rare species from species whose numbers have been reduced. It is not clear how to determine whether future trends are the result of better (or less) field work or the actual status of the species in question. The answer likely depends on the species, but at this point the data seem less than ideal for national reporting.

Non-target organism effects from pesticides and herbicides

EPA is concerned about non-target organism effects from pesticides and herbicides. Pesticides and herbicides (including those incorporated into the genomes of crops) are registered for use by EPA such that their use in accordance with the registration is not expected to pose unnecessary risks to non-target organisms. Nonetheless, neither the models nor the compliance are likely to be perfect, so tracking any residues of such pesticides in non-target organisms would be useful, as would identifying any harm or mortality of organisms that might be caused by improper use of pesticides. There are Category 2 indicators for pesticide application and leaching pesticides in stream biota, and pesticides in sediment and fish tissue for fresh waters. There are no indicators in The Heinz Center report for pesticides in terrestrial organisms. Another indicator that might provide presumptive evidence of harm—animal die-off in fresh waters—is adequate for national reporting only for waterfowl.

Issues related to ozone, UV-B, mercury, acidic deposition, and persistent bioaccumulative toxics (PBTs)

In air, a number of pollutants travel regionally or even globally (e.g., ozone, acid deposition, PBTs [including mercury], ozone-depleting substances, greenhouse gases). What do the indicators reveal about baselines and trends in the levels of these pollutants in various ecosystems, or possible harm to biota as a result of exposure to these pollutants or their secondary effects? The chemical and physical characteristic EEA in Exhibit 5-44 contains many Category 2 indicators, but no indicators are available that provide a representative baseline for the nation.

For water, the NAWQA program samples sediment chemistry in more than 500 streams for many PBTs. Repeated sampling should provide an invaluable picture of trends, unless the variability is too high or there are important local sources that make these streams non-representative of streams in general. A smaller number of streams have been sampled for contaminants in fish tissue. A national monitoring network for mercury currently exists, with sampling sites primarily on the East coast and in the upper Midwest (see Chapter 2, Purer Water), but it is not adequate for establishing a national baseline for mercury or other PBTs. Monitoring for UV-B exposure is under development by USDA. EMAP has collected fish tissue residues for many of the PBTs, but there is no commitment to re-sample in the future.

To the extent that these factors affect tree growth, FHM will provide national trends information in the future, but at this point, there is no prospect for establishing trends in either exposure or effects for most of these chemicals.

Future Challenges

When the indicators available for this report are arrayed against the essential attributes in Exhibit 5-44, it is clear that indicators and adequate data are available to address only a portion of the information needed to describe ecological condition for the nation. Data for a few more indicators have been collected once, or for limited geographic regions, but the clear message is that more data are needed to describe and track ecological condition. This situation will improve over the next few years, but most of the gaps in Exhibit 5-44 are likely to remain for some time to come.

There are several challenges to developing adequate indicators of ecological condition for the nation:

- Indicators must be tied to conceptual models that capture how ecosystems respond to single and multiple stressors at various scales.
- Federal, state, and local monitoring organizations must find a way to coordinate and integrate their activities to meet multiple, potentially conflicting, data needs.
- Mechanisms must be found to ensure long-term commitments to measuring selected indicators over long periods and in standardized ways, to establish comparable baselines and trends.
- Indicators must simplify complex data in ways that make them meaningful and useful to decision-makers and the public.

None of these challenges appear insurmountable, but the gaps in Exhibit 5-44 indicate the work that remains to allow measurement of ecological condition at the national scale.

Appendix A: Databases and Reports Supporting Major Clusters of Indicators Used in the Report with Links for Additional Information

Appendix A: Databases and Reports Supporting Major Clusters of Indicators Used in the Report with Links for Additional Information

The databases that serve as the underlying datasets and the reports that provide the majority of indicators used in the Draft Report on the Environment Technical Document are listed by human health and environmental categories in alphabetical order below. In the interests of providing complete and accurate information, rather than provide summary descriptions of the databases, links to the primary home pages of the databases are noted as starting points for further investigation by interested readers.

Human Health Databases

Database: National Center for Health Statistics (NCHS), National Health and Nutrition Examination Survey (NHANES)
Web site: *http://www.cdc.gov/nchs/nhanes.htm (NHANES)*

Database: National Center for Health Statistics (NCHS), National Health Interview Survey (NHIS)
Web site: *http://www.cdc.gov/nchs/nhis.htm*

Database: Environmental Protection Agency, Office of Research and Development (ORD), National Human Exposure Assessment Survey (NHEXAS)
Web sites: *http://www.epa.gov/nerl/research/nhexas/nhexas.htm* (NHEXAS) and *http://www.epa.gov/heds/* (NHEXAS data in EPA's Human Exposure Database System)

Database: Centers for Disease Control and Prevention, Epidemiology Program Office, National Notifiable Disease Surveillance System
Web sites: *http://www.cdc.gov/mmwr/* (Morbidity and Mortality Weekly Report) *http://www.cdc.gov/epo/dphsi/annsum/* (Summary of Notifiable Diseases)

Database: National Center for Health Statistics (NCHS), National Vital Statistics Systems (NVSS)
Web site: *http://www.cdc.gov/nchs/nvss.htm*

Database: National Institutes of Health (NIH), National Cancer Institute (NCI), Surveillance, Epidemiology, and End Results (SEER) Program
Web site: *http://seer.cancer.gov/*

Environmental Databases and Reports

Database: Environmental Protection Agency, Office of Air and Radiation, Aerometric Information Retrieval System (AIRS)
Web site: AIRS and the Air Quality System—*http://www.epa.gov/ttnairs1/airsaqs/index.htm*

Database: Environmental Protection Agency, Office of Research and Development, Environmental Monitoring and Assessment Program (EMAP)
Web site: *http://www.epa.gov/emap/*

Database: U.S. Department of Agriculture, U.S. Forest Service, Forest Health Monitoring (FHM) Program
Web site: *http://www.na.fs.fed.us/spfo/fhm/index.htm*

Database: U.S. Department of Agriculture, U.S. Forest Service, Forest Inventory and Analysis (FIA)
Web site: *http://fia.fs.fed.us*

Report: Environmental Protection Agency, *Office of Air and Radiation, Latest Findings on National Air Quality: 2001 Status and Trends*
Web site: *http://www.epa.gov/oar/aqtrnd01/*

Database: Multi-Resolution Land Characterization (MLRC) Consortium, National Land Cover Dataset (NLCD)
Web sites: MRLC: *http://www.epa.gov/mrlc/*
NLCD: *http://www.epa.gov/mrlc/nlcd.html*

Database: U.S. Department of Agriculture, Natural Resources Conservation Service, National Resources Inventory (NRI)
Web site: *http://www.nhq.nrcs.usda.gov/NRI/1997/*

Database: U.S. Department of the Interior, U.S. Geological Survey, National Stream Water Quality Accounting Network (NASQAN)
Web site: *http://water.usgs.gov/nasqan/*

Database: U.S. Department of the Interior, U.S. Geological Survey, National Water Quality Assessment (NWAQA)
Web site: *http://water.usgs.gov/nawqa/*

Database: U.S. Department of the Interior, U.S. Fish and Wildlife Service, National Wetlands Inventory (NWI)
Web site: NWI: *http://www.nwi.fws.gov/*

Database: NatureServe
Web site: *http://www.natureserve.org*

Report: U.S. Department of the Interior, U.S. Fish and Wildlife Service, *Status and Trends of Wetlands in the Conterminous United States 1986 to 1997*
Web site: *http://www.nwi.fws.gov/bha/SandT/SandTReport.html*

Report: The H. John Heinz III Center for Science, Economics, and the Environment, *The State of the Nation's Ecosystems: Measuring the Lands, Waters, and Living Resources of the United States*
Web site: *http://www.heinzctr.org/ecosystems*

Database: Environmental Protection Agency, Office of Environmental Information, Toxics Release Inventory (TRI)
Web site: *http://www.epa.gov/tri/*

Appendix B: Indicator Metadata

Terms Used in the Indicator Metadata Appendix

Indicator names are those presented in the text report of this.

Indicator type (status or trend) - Indicators are designated **status** if the indicator is supported by a single data point or study, a snapshot in time. Indicators are designated **trends** if there are at least three data points.

Indicator category. Indicators were assigned to one of two categories:

- **Category 1**—The indicator has been peer reviewed and is supported by national level data coverage for more than one time period. The supporting data are comparable across the nation and are characterized by sound collection methodologies, data management systems, and quality assurance procedures.
- **Category 2**—The indicator has been peer reviewed, but the supporting data are available only for part of the nation (e.g., multi-state regions or ecoregions), or the indicator has not been measured for more than one time period, or the not all the parameters of the indicator have been measured (e.g., data has been collected for birds, but not for plants or insects). The supporting data are comparable across the areas covered, and are characterized by sound collection methodologies, data management systems, and quality assurance procedures.

All category designations for the indicators and associated data are relative to the specific associated question.

Spatial coverage is scale and geographic information about where monitoring and sampling have taken place.

Temporal coverage is the time period in which the data has been collected and includes information about seasonality of collection activity where relevant.

Characterization of supporting data set(s) is descriptive information about the history of the database and its collection methodologies, data management systems, and quality assurance procedures.

Indicator source information, including **derivation** and **web sites**, are provided for readers who want additional information.

Chapter 1: Cleaner Air

Outdoor Air Quality

Indicator name: Number and percentage of days that metropolitan statistical areas (MSAs) have Air Quality Index (AQI) values greater than 100

Indicator type (status or trend): Trend

Indicator category (1 and 2): 2

Associated question: What is the quality of outdoor air in the United States?

Spatial coverage: National. Based on the measurements, EPA designates geographical areas of attainment (meeting standards) and nonattainment for specific criteria air pollutants.

Temporal coverage: 1988-2001.

Characterization of supporting data set(s): The National Air Monitoring Stations (NAMS) and the State and Local Air Monitoring Stations network measures air quality at 5,200 monitors operating at 3,000 sites across the country, mostly in urban areas. Measurements, taken on both a daily and continuous basis to assess both peak concentrations and overall trends, are reported in the Aerometric Information Retrieval Systems (AIRS). Trends are derived by averaging direct measurements from these monitoring stations on a yearly basis. Not all sites monitor all of the six criteria air pollutants. The Air Quality System (AQS) database contains measurements of criteria air pollutant concentrations in the 50 United States, plus the District of Columbia, Puerto Rico, and the Virgin Islands.

EPA uses the AQI for five major air pollutants regulated by the Clean Air Act (CAA): ground-level ozone, particulate matter, carbon monoxide, sulfur dioxide, and nitrogen dioxide. In large metropolitan areas (more than 350,000 people), state and local agencies are required to report the AQI to the public daily. In 1976, EPA developed the Pollutant Standards Index (PSI), a consistent and easy to understand way of stating air pollutant concentrations and associated health implications. In June 2000, EPA updated the index and renamed it AQI. PSI and AQI are similar as they both focus on health risks of brief exposure to pollutants (a few hours or days); involve air pollutants regulated by the CAA (criteria pollutants); use the same method to calculate index values; and use an index value of 100 to represent pollutant concentration at the level of the national ambient standard set by EPA National Ambient Air Quality Standards (NAAQS). Beginning in 2000, the AQI included new features including a new health risk category, unhealthy for sensitive groups; two additional pollutants (ozone averaged over 8 hours and fine particulate matter less than 2.5 micrometers in size ($PM_{2.5}$); and a specific color associated with each of the health risk categories.

Indicator derivation (project, program, organization, report): For 1988 through 1991, data were drawn from U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards. *National Air Quality and Emissions Trends Report*, 1997. Table A-15. EPA 454-R-98-016. Research Triangle Park, NC: EPA. December, 1998. For 1992 through 2001, data were drawn from U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards. Air trends: Metropolitan area trends, Table A-17. 2001. (February 25, 2003; *http://www.epa.gov/airtrends/metro.html*).

Web sites: *AIRS and AQS*
http://www.epa.gov/ttnairs1/airsaqs/index.htm;
1997 air quality trends report
http://www.epa.gov/oar/aqtrnd97/tables.html;
2000 air quality trends tables
http://www.epa.gov/airtrends/metro.html/;
AQI background
http://www.epa.gov/airnow/aqibroch/

Indicator name: Number of people living in areas with air quality levels above the National Ambient Air Quality Standards (NAAQS) for particulate matter (PM) and ozone

Indicator type (status or trend): Trend

Indicator category (1 and 2): 1

Associated question: How many people are living in areas with particulate matter and ozone levels above the National Ambient Air Quality Standards (NAAQS)?

Spatial coverage: National. Based on the measurements, EPA designates geographical areas of attainment (meeting standards) and nonattainment for specific criteria air pollutants.

Temporal coverage: 2001

Characterization of supporting data set(s): The National Air Monitoring Stations (NAMS) and the State and Local Air Monitoring Stations (SLAMS) network measure air quality at 5,200 monitors operating at 3,000 sites across the country, mostly in urban areas. Measurements, taken on both a daily and continuous basis to assess both peak concentrations and overall trends, are reported in the Aerometric Information Retrieval Systems (AIRS). Trends are derived by averaging direct measurements from these monitoring stations on a yearly basis. Not all sites monitor all of the six criteria air pollutants.

Indicator derivation (project, program, organization, report): Aerometric Information Retrieval System (AIRS), the repository of data collected from the NAMS and the SLAMS is reported in U.S. Environmental Protection Agency, *Latest Findings on National Air Quality: 2001 Status and Trends*, EPA 454-K-02-001, Washington, DC: EPA., Office of Air Quality and Standards, September 2002.

Web sites: *AIRS and AQS*
http://www.epa.gov/ttnairs1/airsaqs/index.htm;
Air quality trends report http://www.epa.gov/oar/aqtrnd01/

Indicator name: Ambient concentrations of particulate matter ($PM_{2.5}$ and PM_{10})

Indicator type (status or trend): Status

Indicator category (1 and 2): 1

Associated question: What are the concentrations of some criteria air pollutants: $PM_{2.5}$, PM_{10}, ozone, and lead?

Spatial coverage: National. Based on the measurements, EPA designates geographical areas of attainment (meeting standards) and nonattainment for specific criteria air pollutants.

Temporal coverage: 1982-2001

Characterization of supporting data set(s): The National Air Monitoring Stations (NAMS) and the State and Local Air Monitoring Stations (SLAMS) network measure air quality at 5,200 monitors operating at 3,000 sites across the country, mostly in urban areas. Measurements, taken on both a daily and continuous basis to assess both peak concentrations and overall trends, are reported in the Aerometric Information Retrieval Systems (AIRS). Trends are derived by averaging direct measurements from these monitoring stations on a yearly basis. Not all sites monitor all of the six criteria air pollutants. In 1999, EPA and its state, tribal, and local air pollution control agency partners deployed a monitoring network to begin measuring $PM_{2.5}$ concentrations nationwide. The $PM_{2.5}$ data presents was drawn from AIRS as of July 8, 2002. 770 sites have sufficient PM10 to assess trends from 1992-2001.

Indicator derivation (project, program, organization, report): Aerometric Information Retrieval System (AIRS), the repository of data collected from the NAMS and the SLAMS is reported in U.S. Environmental Protection Agency, *Latest Findings on National Air Quality: 2001 Status and Trends,* EPA 454-K-02-001, Washington, DC: EPA., Office of Air Quality and Standards, September 2002.

Web sites: *AIRS and AQS*
http://www.epa.gov/ttnairs1/airsaqs/index.htm;
Air quality trends report http://www.epa.gov/oar/aqtrnd01/

Indicator name: Ambient concentrations of ozone, 8-hour and 1-hour

Indicator type (status or trend): Status

Indicator category (1 and 2): 1

Associated question: What are the concentrations of some criteria air pollutants: $PM_{2.5}$, PM_{10}, ozone, and lead?

Spatial coverage: National. Based on the measurements, EPA designates geographical areas of attainment (meeting standards) and nonattainment for specific criteria air pollutants.

Temporal coverage: 1982-2001

Characterization of supporting data set(s): The National Air Monitoring Stations (NAMS) and the State and Local Air Monitoring Stations (SLAMS) network measure air quality at 5,200 monitors operating at 3,000 sites across the country, mostly in urban areas. Measurements, taken on both a daily and continuous basis to assess both peak concentrations and overall trends, are reported in the Aerometric Information Retrieval Systems (AIRS). Trends are derived by averaging direct measurements from these monitoring stations on a yearly basis. Not all sites monitor all of the six criteria air pollutants. 379 sites have sufficient data to assess trends from 1992-2001 for both 8-hour and 1-hour measurements.

Indicator derivation (project, program, organization, report): Aerometric Information Retrieval System (AIRS), the repository of data collected from the NAMS and the SLAMS is reported in U.S. Environmental Protection Agency, *Latest Findings on National Air Quality: 2001 Status and Trends,* EPA 454-K-02-001, Washington, DC: EPA., Office of Air Quality and Standards, September 2002.

Web sites: *AIRS and AQS*
http://www.epa.gov/ttnairs1/airsaqs/index.htm;
Air quality trends report http://www.epa.gov/oar/aqtrnd01/

Indicator name: Ambient concentrations of lead

Indicator type (status or trend): Trend

Indicator category (1 and 2): 1

Associated question: What are the concentrations of some criteria air pollutants: PM2.5, PM10, ozone, and lead?

Spatial coverage: National. Based on the measurements, EPA designates geographical areas of attainment (meeting standards) and nonattainment for specific criteria air pollutants.

Temporal coverage: 1982-2001

Characterization of supporting data set(s): The National Air Monitoring Stations (NAMS) and the State and Local Air Monitoring Stations (SLAMS) network measure air quality at 5,200 monitors operating at 3,000 sites across the country, mostly in urban areas. Measurements, taken on both a daily and continuous basis to assess both peak concentrations and overall trends, are reported in the Aerometric Information Retrieval Systems (AIRS). Trends are derived by averaging direct measurements from these monitoring stations on a yearly basis. Not all sites monitor all of the six criteria air pollutants. EPA has over 200 lead monitoring sites for lead nationally in addition to special purpose monitors near smelters and other lead emitters. The lead trend is based on 39 monitors that have a full 20 years of complete data.

Indicator derivation (project, program, organization, report): Aerometric Information Retrieval System (AIRS), the repository of data collected from the NAMS and the SLAMS is reported in U.S. Environmental Protection Agency, *Latest Findings on National Air Quality: 2001 Status and Trends*, EPA 454-K-02-001, Washington, DC: EPA., Office of Air Quality and Standards, September 2002.

Web sites: *AIRS and AQS*
http://www.epa.gov/ttnairs1/airsaqs/index.htm;
http://www.epa.gov/oar/aqtrnd01/

Indicator name: Visibility

Indicator type (status or trend): Trend

Indicator category (1 and 2): 1

Associated question: What are the impacts of air pollution on visibility in national parks and other protected lands?

Spatial coverage: National. 30 sampling sites located in national parks and wilderness areas through 1999; 110 sites after 2000 in the monitoring network with an additional 20 sites using the monitoring protocol. Applicable to 156 Class I areas, mostly national parks and wilderness areas in the eastern and western U.S.

Temporal coverage: 1992-1999 and 1990-1999

Characterization of supporting data set(s): Data are presented by mean visual range as measured in kilometers respectively by worst, mid-range, and best visibility. The Interagency Monitoring of Protected Visual Environments (IMPROVE) network was established in 1987 as a cooperative effort among EPA, states, the National Park Service, the U.S. Forest Service, the Bureau of Land Management, and the U.S. Fish and Wildlife Service. Data are collected and analyzed from this network to determine the type of pollutants primarily responsible for reduced visibility and to track progress toward the Clean Air Act's national goal.

Indicator derivation (project, program, organization, report): U.S. Environmental Protection Agency, *Latest Findings on National Air Quality: 2001 Status and Trends*, EPA 454-K-02-001, Washington, DC: EPA., Office of Air Quality and Standards, September 2002.

Web site: *Air quality trends report*
http://www.epa.gov/oar/aqtrnd01/

Indicator name: Ambient concentrations of selected air toxics

Indicator type (status or trend): Trend

Indicator category (1 and 2): 2

Associated question: What are the concentrations of toxic air pollutants in ambient air?

Spatial coverage: National, but no formal monitoring network in place limiting information.

Temporal coverage: 1994-2000

Characterization of supporting data set(s): Selected air toxics only, not all 188 identified in the Clean Air Act (CAA). Ambient concentrations are based on annual averages from the reporting sites. EPA and the states do not maintain an extensive nationwide monitoring network for air toxics as they do for the criteria air pollutants. While EPA, states, tribes, and local air regulatory agencies collect monitoring data for a number of toxic air pollutants, both the chemicals monitored and the geographic coverage of the monitors vary from state to state. Measurements of benzene were taken from 95 urban monitoring sites around the country. These urban areas generally have higher levels of benzene than other areas of the country.

Indicator derivation (project, program, organization, report): The data come from a combination of several monitoring networks, including: Photochemical Assessment Monitoring Stations Program; Urban Air Toxics Monitoring Program; Non-Methane Organic Compound Monitoring Program; Interagency Monitoring of Protected Visual Environments (IMPROVE) Network. Reported in U.S. Environmental Protection Agency, *Latest Findings on National Air Quality: 2001 Status and Trends*, EPA 454-K-02- 001, Washington, DC: EPA., Office of Air Quality and Standards, September 2002.

Web site: *Air quality trends report*
http://www.epa.gov/oar/aqtrnd01/

Indicator name: Emissions: particulate matter ($PM_{2.5}$ and PM_{10}), sulfur dioxide, nitrogen oxides, and volatile organic compounds

Indicator type (status or trend): Trend

Indicator category (1 and 2): 2

Associated question: What are contributors to particulate matter, ozone, and lead in ambient air?

Spatial coverage: National

Temporal coverage: 1992-2001

Characterization of supporting data set(s): Actual emissions data are not presented and estimates are used. EPA estimates nationwide emissions of ambient pollutants and their precursors based on actual monitored readings or engineering calculations of the amounts and types of pollutants emitted by vehicles, factories, and other sources. Emission estimates are based on many factors, including the level of industrial activity, technology developments, fuel consumption, vehicle miles traveled, and other activities that cause air pollution (EPA, OAQPS, September 2002). Consistent estimation methods have been developed to provide trend data. Estimation is particularly necessary for mobile sources and area-wide sources. The methodology for estimating emissions is continually reviewed and is subject to revision. EPA is currently conducting such an evaluation of emissions data, and emissions estimates may be updated. Trend data prior to revisions must be considered in the context of those changes. Emission estimates also reflect changes in air pollution regulations and installation of emission controls.

Indicator derivation (project, program, organization, report): The National Emissions Inventory (NEI) for Criteria and Hazardous Air Pollutants (HAPs) is a composite of many data sources reported in U.S. Environmental Protection Agency, *Latest Findings on National Air Quality: 2001 Status and Trends*, EPA 454-K-02-001, Washington, DC: EPA., Office of Air Quality and Standards, September 2002. In the NEI, EPA divides emissions into four types of sectors: 1) major (large industrial) sources; 2) area and other sources, which include smaller industrial sources like small dry cleaners and gasoline stations, as well as natural sources like wildfires; 3) onroad mobile sources, including highway vehicles; and 4) nonroad mobile sources like aircraft, locomotives, and construction equipment (EPA, OAQPS, September 2002).

Web site: *Air quality trends report*
http://www.epa.gov/oar/aqtrnd01/

Indicator name: Lead emissions

Indicator type (status or trend): Trend

Indicator category (1 and 2): 2

Associated question: What are contributors to particulate matter, ozone, and lead in ambient air?

Spatial coverage: National

Temporal coverage: 1982-2001

Characterization of supporting data set(s): EPA estimates nationwide emissions of ambient pollutants and their precursors based on actual monitored readings or engineering calculations of the amounts and types of pollutants emitted by vehicles, factories, and other sources. Emission estimates are based on many factors, including the level of industrial activity, technology developments, fuel consumption, vehicle miles traveled, and other activities that cause air pollution (EPA, OAQPS, September 2002). Consistent estimation methods have been developed to provide trend data. Estimation is particularly necessary for mobile sources and area-wide sources. The methodology for estimating emissions is continually reviewed and is subject to revision. EPA is currently conducting such an evaluation of emissions data, and emissions estimates may be updated. Trend data prior to revisions must be considered in the context of those changes. Emission estimates also reflect changes in air pollution regulations and installation of emission controls.

Indicator derivation (project, program, organization, report): The National Emissions Inventory (NEI) for Criteria and Hazardous Air Pollutants (HAPs) is a composite of many data sources reported in U.S. Environmental Protection Agency, *Latest Findings on National Air Quality: 2001 Status and Trends*, EPA 454-K-02-001, Washington, DC: EPA., Office of Air Quality and Standards, September 2002.

Web site: *Air quality trends report*
http://www.epa.gov/oar/aqtrnd01/

Indicator name: Air toxics emissions

Indicator type (status or trend): Trend

Indicator category (1 and 2): 2

Associated question: What are contributors to toxic air pollutants in ambient air?

Spatial coverage: National

Temporal coverage: 1990-1993, 1996

Characterization of supporting data set(s): Hazardous air pollutant estimates are currently available for 1990-1993 (a mix of years depending on data availability on various source types) and 1996. EPA compiles an air toxics inventory as part of the National Emissions Inventory (NEI, formerly the National Toxics Inventory) to estimate and track national emissions trends for the 188 toxic air pollutants regulated under the CAA. In the NEI, EPA divides emissions into four types of sectors: 1) major (large industrial) sources; 2) area and other sources, which include smaller industrial sources like small dry cleaners and gasoline stations, as well as natural sources like wildfires; 3) onroad mobile sources, including highway vehicles; and 4) nonroad mobile sources like aircraft, locomotives, and construction equipment. The data presented are based on the data in the NEI (EPA, OAQPS, September 2002).

Indicator derivation (project, program, organization, report): The NEI for Criteria and Hazardous Air Pollutants (HAPs) is a composite of many data sources reported in U.S. Environmental Protection Agency, *Latest Findings on National Air Quality: 2001 Status and Trends*, EPA 454-K-02-001, Washington, DC: EPA., Office of Air Quality and Standards, September 2002.

Web site: *Air quality trends report*
http://www.epa.gov/oar/aqtrnd01/

Acid Deposition

Indicator name: Deposition: wet sulfate and wet nitrogen

Indicator type (status or trend): Status comparison

Indicator category (1 and 2): 2

Associated question: What are the deposition rates of pollutants that cause acid rain?

Spatial coverage: NADP/NTN consists of over 250 sites in the continental U.S., Alaska, Puerto Rico, and the Virgin Islands.

Temporal coverage: 1989-1991, 1999-2001

Characterization of supporting data set(s): 1) The data is collected by uniform methods/protocol under the National Atmospheric Deposition Program (NADP)/National Trends Network (NTN) and the Clean Air Status and Trends Network (CASTNet). The NADP is a cooperative program among federal and state agencies, universities, electric utilities, and other industries that has measured precipitation chemistry in the U.S. since 1978. The NADP/NTN is a nationwide network of precipitation monitoring sites designed to measure regional levels of atmospheric deposition. The NADP/NTN measures wet acid deposition that occurs in rain, snow, or sleet) weekly at about 250 monitoring stations throughout the U.S. The data are subject to strict quality assurance and completeness screening in the field, in the laboratory, and during analysis. 2) Presented total sulfur and total nitrogen data are derived from CASTNet, a nationwide network of over 70 sites concentrated in the eastern continental U.S. that measure ambient air concentrations of pollutants, including ozone. CASTNet has not yet completed its expansion into the Great Plains and western states. CASTNet also measures dry deposition (the process through which particles and gases are deposited in the absence of precipitation) of acidic compounds. CASTNet data are also subject to strict quality assurance and completeness criteria (EPA, OAR, November 2002).

Indicator derivation (project, program, organization, report): NADP/NTN and CASTNet data are reported in U.S. Environmental Protection Agency, *EPA Acid Rain Program: 2001 Progress Report*, EPA 430-R-02-009, Washington, DC: EPA, Office of Air and Radiation, November, 2002.

Web site: *NADP/NTN Data Access* http://nadp.sws.uiuc.edu/

Indicator name: Emissions (utility): sulfur dioxide and nitrogen oxides

Indicator type (status or trend): Trend

Indicator category (1 and 2): 2

Associated question: What are the emissions of pollutants that form acid rain?

Spatial coverage: Over 2000 facilities nationally.

Temporal coverage: 1980, 1985, 1990, 1995, 2000, 2001

Characterization of supporting data set(s): Data collected by regulated facilities using certified continuous emissions monitors or equivalent, beginning in 1994-95 with quarterly and annual totals tabulated for each facility and aggregated for plants, states, and the U.S.

Indicator derivation (project, program, organization, report): U.S. Environmental Protection Agency. *EPA Acid Rain Program: 2001 Progress Report*, EPA 430-R-02-009. Washington, DC: U.S. Environmental Protection Agency, Office of Air and Radiation, November 2002. Appendix A: Acid Rain Program - Year 2001 SO_2 Allowance Holdings and Deductions. (April 8, 2003; *http://www.epa.gov/airmarkets/cmprpt/arp01/appendixa.pdf*) and Appendix B1: 2001 Compliance Results for NO_X Affected Units. (April 8, 2003; *http://www.epa.gov/airmarkets/cmprpt/arp01/ appendixb1.pdf*).
Web site: http://www.epa.gov/airmarkets/emissions/index.html

Indoor Air Quality

Indicator name: U.S. homes above EPA's radon action levels

Indicator type (status or trend): Status

Indicator category (1 and 2): 2

Associated question: What is the quality of the air in buildings in the United States?

Spatial coverage: National

Temporal coverage: 1989-1990

Characterization of supporting data set(s): The National Radon Residential Study of 1989-1990 was a survey of the nation's housing that estimated that 6 percent of U.S. homes (5.8 million in 1990) had an annual average radon level greater than 4 picocuries per liter (pCi/L) in indoor air. Data viability is limited given its age and subsequent changes as a result of education efforts and new housing stock.

Indicator derivation (project, program, organization, report): U.S. Environmental Protection Agency. *National Residential Radon Survey: Summary Report*, EPA 402-R-92-011. Washington, DC: EPA, Office of Air and Radiation, October 1992.

Web site: Report is not available online.

Indicator name: Percentage of homes where young children are exposed to environmental tobacco smoke

Indicator type (status or trend): Status

Indicator category (1 and 2): 2

Associated question: What is the quality of the air in buildings in the United States?

Spatial coverage: National

Temporal coverage: The National Center for Health Statistics (NCHS), National Health Interview Survey (NHIS) has been conducted continuously since 1957, the content of the survey has been updated about every 10-15 years. In 1996 a substantially revised NHIS content began field testing. This new questionnaire, described in detail below, began in 1997 and improves the ability of the NHIS to provide important health information. 1998 data is cited.

Characterization of supporting data set(s): The NHIS is a continuous nationwide survey in which data are collected through personal household interviews. Self-reported information is obtained on personal and demographic characteristics, illnesses, injuries, impairments, chronic conditions, utilization of health resources, and other health topics. The sample scheduled for each week is representative of the target population, and the weekly samples are additive over time. Response rates for special health topics (supplements) have generally been lower. Because of the extensive redesign of the questionnaire in 1997 and introduction of the computer-assisted personal interviewing (CAPI) method of data collection, data from 1997 and later years may not be comparable with earlier years. The indicator numerator was the number of children 6 years and under living in households with a resident who smoked inside the home 4 or more days each week. The denominator was the number of households with children ages 6 years and under.

Indicator source (project, program, organization, report): U.S. Department of Health and Human Services, National Center for Health Statistics. *Healthy People 2000 Final Review*, DHHS Publication No. 01-0256. Hyattsville, MD: Public Health Service, October 2001.

Web site: http://www.cdc.gov/nchs/data/hp2000/hp2k01.pdf

Stratospheric Ozone

Indicator name: Ozone levels over North America

Indicator type (status or trend): Status (two separate data points, not a trend)

Indicator category (1 and 2): 1

Associated question: What is the trends in the Earth's ozone layer?

Spatial coverage: Daily images of North America.

Temporal coverage: Begun in 1978, ongoing with a gap in coverage from December 1994 through June 1996.

Characterization of supporting data set(s): High-resolution spectrographic images taken daily from National Aeronautics and Space Administration (NASA) satellite platforms.

Indicator derivation (project, program, organization, report): National Aeronautics and Space Administration. Ozone Levels Over North America - NIMBUS-7/TOMS. March 1979 and March 1994. (January 24, 2003; *http://epa.gov/ozone/science/glob_dep.html*).

Web site: The graphic images referenced by the indicator can be found at http://www.epa.gov.ozone/science/glob_dep.html

Indicator name: Worldwide and U.S. production of ozone-depleting substances

Indicator type (status or trend): Trend

Indicator category (1 and 2): 2

Associated question: What are causing changes to the ozone layer?

Spatial coverage: Global and national

Temporal coverage: Worldwide1986 and 1999; U.S.1958-1993

Characterization of supporting data set(s): Global—The present report contains additional and updated data on the production and consumption of ozone-depleting substances (ODS), as reported to the United Nations Secretariat during the period 1986-2000, by 167 of the 183 parties to the Montreal Protocol on Substances that

Deplete the Ozone Layer. The Secretariat has arranged the data provided by the Parties into the groups for which control measures are prescribed in the protocol. To calculate the figures for each group, the quantities in metric tons reported by the parties for each substance of the group were multiplied by the ozone-depleting potential (ODP) of that substance and added together. All the data in this report is therefore presented in ODP tons. National–Methodology uncertain.

Indicator derivation (project, program, organization, report): Global: United Nations Environment Programme. *Production and Consumption of Ozone Depleting Substances under the Montreal Protocol 1986-2000*, Nairobi, Kenya: United Nations Environment Programme, Secretariat for The Vienna Convention for the Protection of the Ozone Layer and The Montreal Protocol on Substances that Deplete the Ozone Layer, April 2002. National: Historical data (1958-1993) is drawn from the report U.S. International Trade Commission. *1993. Synthetic Organic Chemicals; U.S. Production and Sales*, Washington DC: Government Printing Office, 1994.

Web site: *EPA report* http://www.epa.gov/globalwarming/publications/emissions/index.html;
U.S. ITC report http://www.epa.gov/ozone/science/indicat/index.html

Indicator name: Concentrations of ozone-depleting substances (equivalent effective chlorine)

Indicator type (status or trend): Trend

Indicator category (1 and 2): 2

Associated question: What are causing changes to the ozone layer?

Spatial coverage: Global

Temporal coverage: 1992-2002

Characterization of supporting data set(s): Approximately 250 scientists from many countries of the developed and developing world participated in the 2002 assessment as lead authors, coauthors, contributors, and reviewers.

Indicator derivation (project, program, organization, report): 1) Scientific Assessment Panel of the Montreal Protocol on Substances that Deplete the Ozone Layer. *Scientific Assessment of Ozone Depletion: 2002, Executive Summary,* Report No. 47. Geneva, Switzerland: World Meteorological Organization, Global Ozone Research and Monitoring Project, 2003. 2) Montzka, S.A., J.H. Butler, J.W. Elkins, T.M. Thompson, A.D. Clarke, and L.T. Lock. Present and future trends in the atmospheric burden of ozone- depleting halogens. *Nature* 398: 690-694 (1999). 3) National Oceanic and Atmospheric Administration, Climate Monitoring & Diagnostics Laboratory. Halocarbons and other Atmospheric Trace Species (HATS). 2002. March 18, 2003; *http://www.cmdl.noaa.gov/hats/graphs/graphs.html*).

Web site: WMO report http://www.unep.ch/ozone/sap2002.shtml; Global Equivalent Effective Chlorine graphic
http://www.cmdl.noaa.gov/hats/graphs/graphs

Chapter 2: Purer Water

Waters and Watersheds

Indicator name: Altered fresh water ecosystems

Indicator type (status or trend): Status

Indicator category (1 or 2): 2

Associated question: What is the condition of fresh surface waters and watersheds in the U.S.?

Spatial coverage: Lower 48 states. Applies to rivers, streams, lakes, ponds and reservoirs, and does not account for all types of alteration.

Temporal coverage: 1992

Characterization of supporting data set(s): 1) The U.S. Geological Survey's National Hydrography Dataset (NHD) and the Multi-Resolution Land Characterization (MRLC) Consortium's National Land Cover Database (NLCD) were used to identify alteration. NLCD uses remote-sensed image data. 2) Data on altered wetlands are available through the U.S. Fish and Wildlife Service's (USFWS) National Wetlands Inventory (NWI). NWI counts all wetlands, lakes, reservoirs, and ponds regardless of land ownership, but recognizes only wetlands that are at least 3 acres, and ponds that are at least 1 acre. At present, these data are not available in electronic form for the entire U.S.

Indicator derivation (project, program, organization, report): 1) MRLC Consortium's NLCD and the USGS's NHD, processed by U.S. Environmental Protection Agency's Office of Research and Development, National Exposure Research Laboratory, Environmental Sciences Division plus the 2) USFWS's NWI. Presented in *The State of the Nation's Ecosystems*, pages 140 and 247 (The Heinz Center, 2002).

Web site: *NHD* http://nhd.usgs.gov/;
NLCD http://www.epa.gov/mrlc/about.html;
NWI http://www.nwi.fws.gov

Indicator name: Lake Trophic State Index

Indicator type (status or trend): Status

Indicator category (1 or 2): 2

Associated question: What is the condition of fresh surface waters and watersheds in the U.S.?

Spatial coverage: Northeast United States

Temporal coverage: 1991-1994

Characterization of supporting data set(s): The EPA Environmental Monitoring and Assessment (EMAP) program conducted variable probability sampling on 344 lakes throughout the northeastern United States. The EMAP trophic state characterization is based primarily on the total phosphorus indicator. Descriptions of total nitrogen, chlorophyll-a, total suspended solids, and Secchi disk transparency were used to support the total phosphorus characterization.

Indicator derivation (project, program, organization, report): Peterson, Spencer A., David P. Larsen, Steven G. Paulsen, and N. Scott Urquhart. Regional Lake Trophic Patterns in the Northeastern United States: Three Approaches. *Environmental Management* 22 (5): 789-801 (1999).

Web site: Full article not available on noncommercial website.

Indicator name: Wetland extent and change

Indicator type (status or trend): Status and trends

Indicator category (1 or 2): 1

Associated question: What is the extent and condition of wetlands?

Spatial coverage: Lower 48 states

Temporal coverage: 1950s to 1997 (1954-1974, 1974-1983, 1986-1997)

Characterization of supporting data set(s): An interagency group of statisticians developed the design for the U.S. Fish and Wildlife Service's (USFWS) national status and trends study. The basic sampling design and study objectives have remained constant for each wetland status and trends report. The study design consists of 4,375 randomly selected sample plots (4-square-miles in area) that are examined and characterized using aerial imagery provided by the National Aerial Photography Program in combination with field verification to determine wetland change. Estimates of change in wetlands were made over a specific time period. To make the three studies used comparable, the USFWS authors of the 2000 report adjusted the estimate of wetland area for the mid-1980s in the 1991 report to be in the same statistical range. Other factors contributing to this adjustment were corrections to the wetland data set, and improved data capture and measurement techniques (Dahl, 2000).

Indicator derivation (project, program, organization, report): 1) Dahl, T.E. *Status and Trends of Wetlands in the Conterminous United States 1986 to 1997*, Washington DC: U.S. Department of the Interior, U.S. Fish and Wildlife Service, 2000. 2) Frayer, W.E., T.J. Monahan, D.C. Bowden, and F.A. Graybill. *Status and Trends of Wetlands and Deepwater Habitats in the Conterminous United States, 1950's to 1970's*, Ft. Collins, CO: Colorado State University, 1983. 3) Dahl, T.E., and C.E. Johnson. *Status and Trends of Wetlands in the Conterminous United States, Mid-1970's to Mid-1980's*, Washington DC: U.S. Department of the Interior, U.S. Fish and Wildlife Service, 1991.

Web site: *Dahl, 2000*
http://wetlands.fws.gov/bha/SandT/SandTReport.html

Indicator name: Sources of wetland change/loss

Indicator type (status or trend): Status and trend

Indicator category (1 or 2): 2

Associated question: What is the extent and condition of wetlands?

Spatial coverage: Non-federal lands, lower 48 states, Puerto Rico and the Virgin Islands

Temporal coverage: U.S. Department of Agriculture (USDA), National Resources Inventory (NRI) data are collected every five years, 1982-1997.

Characterization of supporting data set(s): Data collected for the 1997 NRI were based on a statistical design to sample 800,000 sample points, using photo-interpretation and other remote sensing methods and standards. Data gatherers utilized a variety of ancillary materials; extensive use was made of USDA field office records, information provided by local Natural Resources Conservation Service (NRCS) field personnel, soil survey and wetland inventory maps and reports, and tables and technical guides developed by local field office staffs.

Indicator derivation (project, program, organization, report): U.S. Department of Agriculture. *Summary Report: 1997 National Resources Inventory (Revised December 2000)*, Washington, DC: Natural Resources Conservation Service and Ames, Iowa: Iowa State University, Statistical Laboratory, 2000.

Web site:
http://www.nrcs.usda.gov/technical/NRI/1997/summary_report/table16.html

Indicator name: Water clarity in coastal waters

Indicator type (status or trend): Status

Indicator category (1 or 2): 2

Associated question: What is the condition of coastal waters?

Spatial coverage: U.S. east coast south of Cape Cod, Gulf of Mexico, and west coast.

Temporal coverage: 1990-1997 variable by region

Characterization of supporting data set(s): Data collected using a statistically based random design from estuaries by transmissometer at 1 meter below the water surface.

Geographic location/applicability: U.S. east coast south of Cape Cod, Gulf of Mexico, and west coast

Indicator derivation (project, program, organization, report): U.S. Environmental Protection Agency (EPA) Environmental Monitoring and Assessment Program (EMAP) Estuaries database as presented in U.S. Environmental Protection Agency. *National Coastal Condition Report*, EPA 620-R-01-005. Washington DC: U.S. Environmental Protection Agency, Office of Research and Development and Office of Water, September 2001.

Web site: *EMAP data*
http://www.epa.gov/emap/html/dataI/estuary/data/index.html;
NCCR http://epa.gov/owow/oceans/nccr/downloads.html

Indicator name: Dissolved oxygen in coastal waters

Indicator type (status or trend): Status

Indicator category (1 or 2): 2

Associated question: What is the condition of coastal waters?

Spatial coverage: U.S. east coast south of Cape Cod, Gulf of Mexico, and west coast

Temporal coverage: 1990-1997 variable by region

Characterization of supporting data set(s): Data collected using a statistically-based random design from estuaries by point-in-time or continuously recording dissolved oxygen meter a 1 meter above the bottom.

Indicator derivation (project, program, organization, report): U.S. Environmental Protection Agency (EPA) Environmental Monitoring and Assessment Program (EMAP) Estuaries database as presented in U.S. Environmental Protection Agency. *National Coastal Condition Report*, EPA 620-R-01-005. Washington DC: EPA, Office of Research and Development and Office of Water, September 2001.

Web site: *EMAP data*
http://www.epa.gov/emap/html/dataI/estuary/data/index.html;
NCCR http://epa.gov/owow/oceans/nccr/downloads.html

Indicator name: Total organic carbon in sediments

Indicator type (status or trend): Status

Indicator category (1 or 2): 2

Associated question: What is the condition of coastal waters?

Spatial coverage: Mid-Atlantic estuaries

Temporal coverage: 1997-1998

Characterization of supporting data set(s): The EPA Mid-Atlantic Integrated Assessment (MAIA) Estuaries Summary Database contains water quality, sediment, benthic community, and fish data collected by several partners in MAIA Region estuaries in 1997 and 1998. The MAIA program conducted regular fish surveys during the summer of 1998 to characterize the structure and health of the fish communities. The stations sampled were selected according to a probabilistic design. These stations were not identical with the stat ons sampled for water and sediment quality analyses conducted primarily in 1997; therefore, it is not possible to directly compare these different analyses station by station. However, it is statisticallyvalid to compare results among *classes* of estuaries, (e.g., large versus small estuaries, Delaware Estuary versus Chesapeake Estuary).

Indicator source (project, program, organization, report): U.S. Environmental Protection Agency. *Mid- Atlantic Integrated Assessment, MAIA - Estuaries 1997-98, Summary Report*, EPA 620-R-02-003. Narragansett, RI: EPA, Office of Research and Development, Atlantic Ecology Division, May 2003.

Web site: *MAIA Estuaries data* http://www.epa.gov/emap/maia/html/data/estuary/9798/xport.html

Indicator name: Chlorophyll concentrations

Indicator type (status or trend): Trend

Indicator category: 2

Associated question: What is the condition of coastal waters?

Spatial coverage: National in scope, selected ocean regions

Temporal coverage: 1998-2000

Characterization of supporting data set(s): Data from the National Aeronautical and Space Administration's (NASA) Sea viewing Wide Field-of-view Sensor (Sea WiFS) were analyzed for nine ocean regions by the National Ocean Service (NOS), National Oceanographic and Atmospheric Administration (NOAA). Reflectance, or light reflected from the sea surface is used to estimate chlorophyll concentrations at the surface using a series of assumptions accepted by the scientific community (The Heinz Center, 2002).

Indicator derivation (project, program, organization, report): NASA Sea WiFS data analyzed by the NOS. Presented in *The State of the Nation's Ecosystems*, pages 80 and 226 (The Heinz Center, 2002).

Web site: http://seawifs.gsfc.nasa.gov

Indicator name: Percent urban land cover in riparian areas

Indicator type (status or trend): Status

Indicator category (1 or 2): 2

Associated question: What are pressures to water quality?

Spatial coverage: National, excluding Alaska

Temporal coverage: NLCD, 1992 imagery; C-CAP, mid-1990s imagery; NHD, 1999.

Characterization of supporting data set(s): Riparian zones defined as 30-meter buffer around streams, extent and locations extracted from the National Hydrography Dataset (NHD). Urban land cover defined as sum of low-intensity residential, high-intensity residential, and commercial/industrial/transportation land cover types in National Land Cover Database (NLCD) and sum of high-intensity developed and low- intensity developed land cover types in the Coastal Change Analysis Program (C-CAP). Cover identified by aerial imagery.

Indicator derivation (project, program, organization, report): NHD, NLCD, and C-CAP data processed by the U.S. Environmental Protection Agency, Office of Research and Development, National Exposure Research Laboratory, Environmental Sciences Division.

Web sites: *NLCD* http://www.epa.gov/mrlc/about.html;
C-CAP http://www.csc.noaa.gov/crs/lca/index.html;
NHD http://nhd.usgs.gov/index.html;
HUC http://water.usgs.gov/GIS/huc.html

Indicator name: Agricultural lands in riparian areas

Indicator type (status or trend): Status

Indicator category (1 or 2): 2

Associated question: What are pressures to water quality?

Spatial coverage: National, excluding Alaska

Temporal coverage: NLCD, 1992 imagery; C-CAP, mid-1990s imagery; NHD, 1999.

Characterization of supporting data set(s): Riparian zones defined as 30-meter buffer around streams, extent and locations extracted from the National Hydrography Dataset (NHD). Total agriculture is defined as the sum of row crops and pasture land cover types in the National Land Cover Database (NLCD) and as the amount of cultivated land in the Coastal Change Analysis Program (C-CAP). Cover identified by aerial imagery.

Indicator derivation (project, program, organization, report): NHD, NLCD, and C-CAP data processed by U.S. EPA National Exposure Research Laboratory, Environmental Sciences Division.

Web sites: *NLCD* http://www.epa.gov/mrlc/about.html;
C-CAP http://www.csc.noaa.gov/crs/lca/index.html;
NHD http://nhd.usgs.gov/index.html;
HUC http://water.usgs.gov/GIS/huc.html

Indicator name: Population density in coastal areas

Indicator type (status or trend): Trend

Indicator category (1 or 2): 2

Associated question: What are pressures to water quality?

Spatial coverage: National

Temporal coverage: 1790 to 1994 population data

Characterization of supporting data set(s): Various Bureau of the Census publications were used in preparing the article. NPA Data Services, Inc. provided the population projection data for this paper. The Bureau of the Census, U.S. Department of the Interior, provided historical information on coastal counties.

Indicator source (project, program, organization, report): Culliton, Thomas J. "Population: Distribution, Density and Growth." In NOAA's *State of the Coast Report*. Silver Spring, MD: National Oceanic and Atmospheric Administration. 1998. (February 2003; *http://state-of- coast.noaa.gov/bulletins/html/pop_01/pop.html*).

Web site: http://state-of-coast.noaa.gov/bulletins/html/pop_01/pop.html

Indicator name: Changing stream flows

Indicator type (status or trend): Trend

Indicator category (1 or 2): 1

Associated question: What are pressures to water quality?

Spatial coverage: National

Temporal coverage: Since end of the 19th century focusing on period from 1970s to 1990s

Characterization of supporting data set(s): Data are from the U.S. Geological Survey (USGS) stream gauge network using standard USGS protocols. Data are available in the form of daily streamflow values reported as the average volume of water per second over a 24-hour period. Gauge placement by the USGS is not a random process as gauges are generally placed on larger, perennial streams and rivers, and changes seen in these larger systems may differ from those seen in smaller streams and rivers (The Heinz Center, 2002).

Indicator source (project, program, organization, report): USGS stream gauging network. Presented in *The State of the Nation's Ecosystems*, pages 142 and 249 (The Heinz Center, 2002).

Web site: http://www.water.usgs.gov.nwis.discharge

Indicator name: Number/duration of dry stream flow periods in grassland/shrublands

Indicator type (status or trend): Trend

Indicator category: 2

Associated question: What are pressures to water quality?

Spatial coverage: National

Temporal coverage: 1950s to 1990s

Characterization of supporting data set(s): Data are from the U.S. Geological Survey (USGS) stream gauge network using standard USGS protocols. Data are available in the form of daily streamflow values reported as the average volume of water per second over a 24-hour period. Gauge placement by the USGS is not a random process as gauges are generally placed on larger, perennial streams and rivers, and changes seen in these larger systems may differ from those seen in smaller streams and rivers (The Heinz Center, 2002). The number of sites with at least one no-flow day in a year was determined for each water year from 1950 to 1999. The correspon-ding percentage value for that year was also calculated as 100 x (number of sites/total sites). The percentage values were then aver-aged over each decade (i.e., 1950s, 1960s, 1970s, 1980s, and 1990s). This procedure was followed for all sites with greater than 50% grassland/shrubland cover as well as for each ecoregion (The Heinz Center, 2002).

Indicator derivation (project, program, organization, report): USGS stream gauge network. Presented in *The State of the Nation's Ecosystems*, pages 166 and 259 (The Heinz Center, 2002).

Web site: http://water.usgs.gov/nwis/discharge

Indicator name: Sedimentation index

Indicator type (status or trend): Status

Indicator category (1 or 2): 2

Associated question: What are pressures to water quality?

Spatial coverage: Statistically selected stream sites in the Mid-Atlantic states (parts of Virginia, Maryland, Pennsylvania, and New York and all of West Virginia)

Temporal coverage: 1993-1994 sampling years

Characterization of supporting data set(s): About 450 stream reaches were sampled in the Mid-Atlantic Highlands. To describe the condition of all streams within the Highlands without sampling all of them EMAP worked with EPA Region 3 and the states to develop a regional statistical survey of streams. A sedimentation index was developed for streams in the Mid-Atlantic Highlands to assess the quality of instream habitat to support aquatic communities. Stream sedimentation was defined as an increase or excess in the amount of fine substrate particles (smaller than 16mm diameter) relative to an expected reference value that is based on the region and the

Indicator derivation (project, program, organization, report): U.S. Environmental Protection Agency. *Mid-Atlantic Highlands Streams Assessment*, EPA 903-R-00-015. Philadelphia, PA: U.S. Environmental Protection Agency Region 3, Office of Research and Development, August 2000.

Web site: MAIA Report http://www.epa.gov/maia/html/maha.html

Indicator name: Atmospheric deposition of nitrogen

Indicator type (status or trend): Status and trend

Indicator category (1 or 2): 2

Associated question: What are pressures to water quality?

Spatial coverage: NADP/NTN consists of over 250 sites in the continental U.S., Alaska, Puerto Rico, and the Virgin Islands.

Temporal coverage: 2001

Characterization of supporting data set(s): 1) The data is collected by uniform methods/protocol under the National Atmospheric Deposition Program (NADP)/National Trends Network (NTN) and the Clean Air Status and Trends Network (CASTNet). The NADP is a cooperative program among federal and state agencies, universities, electric utilities, and other industries that has measured precipitation chemistry in the U.S. since 1978. The NADP/NTN is a nationwide network of precipitation monitoring sites designed to measure regional levels of atmospheric deposition. The NADP/NTN measures wet acid deposition that occurs in rain, snow, or sleet) weekly at about 250 monitoring stations throughout the U.S. The data are subject to strict quality assurance and completeness screening in the field, in the laboratory, and during analysis. 2) CASTNet is a nationwide network of over 70 sites concentrated in the eastern continental U.S. that measure ambient air concentrations of pollutants. CASTNet has not yet completed its expansion into the Great Plains and western states. CASTNet also measures dry deposition (the process through which particles and gases are deposited in the absence of precipitation) of acidic compounds. CASTNet data are also subject to strict quality assurance and completeness criteria (EPA, OAR, November 2002).

Indicator derivation (project, program, organization, report): NADP/NTN and CASTNet

Web site:
http://nadp.sws.uiuc.edu/isopleths/maps2001/no3dep.pdf and
http://nadp.sws.uiuc.edu/isopleths/maps2001/nh4dep.pdf

Indicator name: Nitrate in farmland, forested, and urban streams and ground water

Indicator type (status or trend): Status

Indicator category (1 or 2): 2

Associated question: What are pressures to water quality?

Spatial coverage: National. Major river basins and watersheds across U.S.

Temporal coverage: 1992-1998

Characterization of supporting data set(s): Nitrate data were collected annually from 105 stream sites and 1,190 wells in agricultural areas from 36 major river basins in the conterminous U.S. 1992-1998. The U.S. Geological Survey's (USGS) National Water Quality Assessment (NAWQA) program samples watersheds with relatively homogeneous land use/land cover to better illuminate the effect of land use on water quality. All sample were collected and analyzed by USGS according to the overall NAWQA design. The data are highly aggregated and should be interpreted mainly as an indication of general national patterns (The Heinz Center, 2002).

Indicator derivation (project, program, organization, report): USGS, NAWQA. Presented in *The State of the Nation's Ecosystems*, pages 95 and 232 (The Heinz Center, 2002)

Web site: http://water.usgs.gov/nawqa

Indicator name: Total nitrogen in coastal waters

Indicator type (status or trend): Status

Indicator category (1 or 2): 2

Associated question: What are pressures to water quality?

Spatial coverage: Mid-Atlantic estuaries

Temporal coverage: 1997-1998

Characterization of supporting data set(s): The EPA Mid-Atlantic Integrated Assessment (MAIA) Estuaries Summary Database contains water quality, sediment, benthic community, and fish data collected by several partners in MAIA Region estuaries in 1997 and 1998. The MAIA program conducted regular fish surveys during the summer of 1998 to characterize the structure and health of the fish communities. The stations sampled were selected according to a probabilistic design. These stations were not identical with the stat ons sampled for water and sediment quality analyses conducted primarily in 1997; therefore, it is not possible to directly compare these different analyses station by station. However, it is statistically valid to compare results among *classes* of estuaries, (e.g., large versus small estuaries, Delaware Estuary versus Chesapeake Estuary).

Indicator source (project, program, organization, report): U.S. Environmental Protection Agency. *Mid- Atlantic Integrated Assessment, MAIA - Estuaries 1997-98, Summary Report*, EPA 620-R-02-003. Narragansett, RI: U.S. Environmental Protection Agency, Office of Research and Development, Atlantic Ecology Division, May 2003.

Web site: MAIA Estuaries data
http://www.epa.gov/emap/maia/html/data/estuary/9798/xport.html

Indicator name: Phosphorus in farmland, forested, and urban streams

Indicator type (status or trend): Status

Indicator category (1 or 2): 2

Associated question: What are pressures to water quality?

Spatial coverage: National. Major river basins and watersheds across U.S.

Temporal coverage: 1992-1998

Characterization of supporting data set(s): Phosphorus data were collected annually from 105 stream sites in agricultural areas from 36 major river basins in the conterminous U.S. 1992-1998. The U.S. Geological Survey's (USGS) National Water Quality Assessment (NAWQA) program samples watersheds with relatively homogeneous land use/land cover to better illuminate the effect of land use on water quality. All sample were collected and analyzed by USGS according to the overall NAWQA design. The data are highly aggregated and should be interpreted mainly as an indication of general national patterns (The Heinz Center, 2002).

Indicator derivation (project, program, organization, report): USGS, NAWQA. Presented in *The State of the Nation's Ecosystems*, pages 96 and 232 (The Heinz Center, 2002)

Web site: http://water.usgs.gov/nawqa

Indicator name: Phosphorus in large rivers

Indicator category (1 or 2): 2

Associated question: What are pressures to water quality?

Spatial coverage: National. Major river basins and watersheds across U.S.

Temporal coverage: 1992-1998

Characterization of supporting data set(s): Phosphorus data were collected annually from 140 stream sites in agricultural areas from 36 major river basins in the conterminous U.S. 1992-1998. The U.S. Geological Survey's (USGS) National Water Quality Assessment (NAWQA) and National Stream Water Quality Accounting Network (NASQAN) program sampling efforts from 1992 to 1998. NAWQA samples watersheds with relatively homogeneous land use/land cover to better illuminate the effect of land use on water quality. All sample were collected and analyzed by USGS according to the overall NAWQA design. The data are highly aggregated and should be interpreted mainly as an indication of general national patterns (The Heinz Center, 2002).

Indicator derivation (project, program, organization, report): USGS, NAWQA. Presented in , pages 141 and 248 (The Heinz Center, 2002)

Web site: http://water.usgs.gov/nawqa

Indicator name: Total phosphorus in coastal waters

Indicator category (1 or 2): 2

Associated question: What are pressures to water quality?

Spatial coverage: Mid-Atlantic estuaries

Temporal coverage: 1997-1998

Characterization of supporting data set(s): The EPA Mid-Atlantic Integrated Assessment (MAIA) Estuaries Summary Database contains water quality, sediment, benthic community, and fish data collected by several partners in MAIA Region estuaries in 1997 and 1998. The MAIA program conducted regular fish surveys during the summer of 1998 to characterize the structure and health of the fish communities. The stations sampled were selected according to a probabilistic design. These stations were not identical with the stat ons sampled for water and sediment quality analyses conducted primarily in 1997; therefore, it is not possible to directly compare these different analyses station by station. However, it is statistically valid to compare results among classes of estuaries, (e.g., large versus small estuaries, Delaware Estuary versus Chesapeake Estuary).

Indicator source (project, program, organization, report): U.S. Environmental Protection Agency. *Mid-Atlantic Integrated Assessment, MAIA-Estuaries 1997-98, Summary Report*, EPA 620-R-02-003. Narragansett, RI: EPA, Office of Research and Development, Atlantic Ecology Division, May 2003.

Web site: MAIA Estuaries data
http://www.epa.gov/emap/maia/html/data/estuary/9798/xport.html

Indicator name: Atmospheric deposition of mercury

Indicator type (status or trend): Status and trend

Indicator category (1 or 2): 2

Associated question: What are pressures to water quality?

Spatial coverage: National with limited coverage related to mercury emission sources

Temporal coverage: 2001

Characterization of supporting data set(s): The National Atmospheric Deposition Program (NADP), Mercury Deposition Network (MDN) is a cooperative program among federal and state agencies, universities, electric utilities, and other industries. Samples were collected from 50 sites across the U.S. related to mercury emissions. The network uses standardized methods for collection and analyses. Weekly precipitation samples are collected and analyzed by cold vapor atomic fluorescence. The MDN provides data for total mercury, but also includes methylmercury if desired by a site sponsor.

Indicator derivation (project, program, organization, report): NADP, MDN

Web site:
http://nadp.sws.uiuc.edu/mdn/maps/2001/01MDNdepo.pdf

Indicator name: Chemical contamination in streams and ground water

Indicator type (status or trend): Status

Indicator category (1 or 2): 2

Associated question: What are pressures to water quality?

Spatial coverage: Lower 48 states

Temporal coverage: 1992-1998

Characterization of supporting data set(s): The data for freshwater streams and ground water were collected and analyzed by the U.S. Geological Survey's (USGS), National Water Quality Assessment (NAWQA) in 36 major river basins and aquifers across the U.S.

Indicator derivation (project, program, organization, report): USGS, NAWQA. Presented in *The State of the Nation's Ecosystems*, pages 48-51 and 210 (The Heinz Center, 2002).

Web site: http://water.usgs.gov/nawqa

Indicator name: Pesticides in farmland streams and ground water

Indicator type (status or trend): Status

Indicator category (1 or 2): 2

Associated question: What are pressures to water quality?

Spatial coverage: National in scope, 20 hydrologic basins

Temporal coverage: 1992-1998

Characterization of supporting data set(s): Data collection from 1992-1996 included analyses for 76 pesticides and 7 selected pesticide degradation products, in 8,200 samples of ground water/surface water in 20 of the nation's major hydrologic basins. The U.S. Geological Survey's (USGS) National Water Quality Assessment (NAWQA) program samples watersheds with relatively homogeneous land use/land cover to better illuminate the effect of land use on water quality. All sample were collected and analyzed by USGS according to the overall NAWQA design. The data are highly aggregated and should be interpreted mainly as an indication of general national patterns (The Heinz Center, 2002).

Indicator derivation (project, program, organization, report): USGS, NAWQA. Presented in *The State of the Nation's Ecosystems*, pages 97-98 and 234 (The Heinz Center, 2002)

Web site: http://water.usgs.gov/nawqa

Indicator name: Acid sensitivity in lakes and streams

Indicator type (status or trend): Status

Indicator category (1 or 2): 2

Associated question: What are pressures to water quality?

Spatial coverage: Eastern United States

Temporal coverage: 1984-1986

Characterization of supporting data set(s): In the mid-1980's, the U.S. Environmental Protection Agency (EPA) and other federal agencies commissioned a National Surface Water Survey (NSWS) to examine the effect of acid deposition in over 1,000 lakes 1,000 lakes larger than 10 acres and in thousands of miles of streams believed to be sensitive to acidification.

Indicator source (project, program, organization, report): 1) EPA, NSWS and 2) Baker, L.A., A. Herlihy, P. Kaufmann, and J. Eilers. Acid Lakes and Streams in the United States: the role of acid deposition. *Science* 252:1151-1154 (1991).

Web site: NSWS not available online and Baker, et al., not available on a noncommercial website.

Indicator name: Toxic releases to water of mercury, dioxin, lead, PCBs, and PBTs

Indicator type (status or trend): Status

Indicator category (1 or 2): 2

Associated question: What are pressures to water quality?

Spatial coverage: National

Temporal coverage: 2000

Characterization of supporting data set(s): The U.S. Environmental Protection Agency (EPA) Toxics Release Inventory (TRI) database consists of release and other waste management information from facilities. EPA requires facilities to use one or more of four general approaches to estimating/measuring releases, namely, monitoring, emission factors, mass balance, and engineering calculations. Facilities report release and other waste management information along with information about release estimation methods.

Indicator source (project, program, organization, report): U.S. Environmental Protection Agency. *2000 Toxics Release Inventory Public Data Release Report*, EPA 260-S-02-001. Washington, DC: U.S. Environmental Protection Agency, Office of Environmental Information, May 2002.

Web site: http://www.epa.gov/tri/

Indicator name: Sediment contamination of inland waters

Indicator type (status or trend): Status

Indicator category (1 or 2): 2

Associated question: What are pressures to water quality?

Spatial coverage: National, generally from sites targeted for contamination problems

Temporal coverage: 1980-1999

Characterization of supporting data set(s): Data are contained in the U.S. Environmental Protection Agency's (EPA) National Sediment Quality Inventory, comprehensive national survey of data about the quality of aquatic sediments in the United States mandated by Congress, and the forthcoming report of this data is an update of a 1997 report. The underlying data primarily are those reported to the EPA Storage and Retrieval (STORET) database. Data are from 19,470 sites evaluated. Limitations of the compiled data include: the mixture of data sets derived from different sampling strategies; incomplete sampling coverage; the age and quality of the data; and missing information, such as latitude and longitude. The limitations of the evaluation approach include uncertainties in the tools used to assess sediment quality. Because of these limitations, the draft report assesses locations in the U.S. where there is the probability of adverse effects to human health and the environment. Since the data in this report come from non-random sampling and do not cover the entire country, EPA states that it is not appropriate to come up with a national estimate of contaminated sediments. EPA also states that the results from the trend assessment should not be extrapolated to areas of the country where data were not available.

Indicator derivation (project, program, organization, report): U.S. Environmental Protection Agency. *The Incidence and Severity of Sediment Contamination in Surface Waters of the United States, National Sediment Quality Survey: Second Edition, DRAFT*, EPA 823-R-01-01. Washington, DC: EPA, Office of Water, December 2001.

Web site: http://www.epa.gov/waterscience/cs/surveyfs.html

Indicator name: Sediment contamination of coastal waters

Indicator type (status or trend): Status

Indicator category (1 or 2): 2

Associated question: What are pressures to water quality?

Spatial coverage: Eastern U.S. south of Cape Cod and Gulf of Mexico estuaries

Temporal coverage: 1990-1997

Characterization of supporting data set(s): The data for sediments and fish contamination in coastal waters were collected and analyzed by the U.S. Environmental Protection Agency's (EPA) Environmental Monitoring and Assessment Program (EMAP). The data were collected in a manner that allows conclusions to be drawn concerning the majority (approximately 76 percent) of the area of estuaries in the United States. The list of contaminants targeted in sediments by EMAP include pesticides, polychlorinated biphenyls (PCBs), polycyclic aromatic hydrocarbons (PAHs), and heavy metals. Samples collected from over 2,000 location for measurement of over 100 contaminants. Sample sites selected based upon statistically random design.

Indicator source (project, program, organization, report): EPA's EMAP Estuaries data set (EPA, 2001) implemented through partnerships with the National Oceanic and Atmospheric Administration (NOAA), the U.S. Geological Survey (USGS), coastal states, and academia as reported in U.S. Environmental Protection Agency. *National Coastal Condition Report*, EPA 620-R-01-005. Washington DC: EPA, Office of Research and Development and Office of Water, September 2001. Presented in *The State of the Nation's Ecosystems*, 72 and 220 (The Heinz Center, 2002).

Web site: *EMAP* http://www.epa.gov/emap/;
NCCR http://epa.gov/owow/oceans/nccr/downloads.html

Indicator name: Sediment toxicity in estuaries

Indicator type (status or trend): Status

Indicator category (1 or 2): 2

Associated question: What are pressures to water quality?

Spatial coverage: Eastern U.S. south of Cape Cod and Gulf of Mexico estuaries

Temporal coverage: 1990-1997 for EMAP and since 1986 for NOAA

Characterization of supporting data set(s): The data were collected and analyzed by the U.S. Environmental Protection Agency's (EPA) Environmental Monitoring and Assessment Program (EMAP) and the National Oceanic and Atmospheric Administration (NOAA) National Status and Trends (NS&T) Program. 1) The EMAP data from over 2,500 location were collected in a manner that allows conclusions to be drawn concerning the majority (approximately 76 percent) of the area of estuaries in the United States. Sample sites selected based upon statistically random design. 2) The NOAA NS&T bioeffects program collected toxicity data from 22 major estuaries of the United States.

Indicator derivation (project, program, organization, report): EPA's EMAP Estuaries data set (EPA, 2001) implemented in partnership with NOAA, as reported in U.S. Environmental Protection Agency. *National Coastal Condition Report*, EPA 620-R-01-005. Washington DC: U.S. Environmental Protection Agency, Office of Research and Development and Office of Water, September 2001.

Web site: *EMAP* http://www.epa.gov/emap/;
NCCR http://epa.gov/owow/oceans/nccr/downloads.html;
NOAA http://ccmaserver.nos.noaa.gov/NSandT/New_NSandT.html

Drinking Water

Indicator name: Population served by community water systems that meet all health-based standards

Indicator type (status or trend): Status and trends

Indicator category (1 or 2): 1

Associated question: What is the quality of drinking water?

Spatial coverage: National

Temporal coverage: 1993-2001

Characterization of supporting data set(s): Community water systems report monitoring violations quarterly to the states and data are compiled by the U.S. Environmental Protection Agency (EPA). The over 55,000 water systems that are required to report violations serve about 94% of the U.S. population. The Safe Drinking Water Information System (SDWIS) contains information about public water systems and their violations of EPA's drinking water regulations, as reported to EPA by states and EPA regions in conformance with reporting requirements established by statute, regulation and guidance. States report the following information to EPA:

- Basic information on each water system, including: name, ID number, number of people served, type of system (year-round or seasonal), and source of water (ground water or surface water);
- Violation information for each water system: whether it has followed established monitoring and reporting schedules, complied with mandated treatment techniques, or violated any Maximum Contaminant Levels (MCLs);
- Enforcement information: what actions states have taken to ensure that drinking water systems return to compliance if they are in violation of a drinking water regulation;
- Sampling results for unregulated contaminants and for regulated contaminants when the monitoring results exceed the MCL.

Indicator derivation (project, program, organization, report): EPA SDWIS Federal version.

Web site: http://www.epa.gov/safewater/sdwisfed/sdwis.htm

Recreation in and on the Water

Indicator name: Number of beach days that beaches are closed or under advisory

Indicator type (status or trend): Status

Indicator category (1 or 2): 2

Associated question: What is the condition of surface waters supporting recreational use?

Scale and coverage: National, coastal

Temporal coverage: 2001 reporting year, collected since 1997

Characterization of supporting data set(s): A questionnaire is sent to managers (usually health or environmental quality departments in states, counties, or cities) responsible for monitoring swimming beaches on the coasts or estuaries of the Atlantic Ocean, Pacific Ocean, and Gulf of Mexico, and the shoreline of the Great Lakes; information on some inland fresh water beaches has also been collected. Days that beaches are closed or under advisory are extracted from the survey and compiled by the U.S. Environmental Protection Agency (EPA). Respondents numbered 237 in 2001 reporting on 2,445 beaches.

Indicator derivation (project, program, organization, report): U.S. Environmental Protection Agency. *EPA's Beach Watch Program: 2001 Swimming Season*, EPA 823-F-02-006. Washington, DC: U.S. Environmental Protection Agency, Office of Water, May 2002.

Web site: http://www.epa.gov/waterscience/beaches/2001 surveyfs.pdf

Consumption of Fish and Shellfish

Indicator name: Percent of river miles and lake acres under fish consumption advisories

Indicator type (status or trend): Status and trend

Indicator category (1 or 2): 2

Associated question: What is the condition of waters that support consumption of fish and shellfish?

Spatial coverage: National

Temporal coverage: 1993-2001

Characterization of supporting data set(s): The National Listing of Fish and Wildlife Advisories (NLFWA) database includes all available information describing state-, tribal-, and federally-issued fish consumption advisories in the United States for the 50 States, the District of Columbia, and four U.S. Territories, and in Canada for the 12 provinces and territories. The database contains information provided to the U.S. Environmental Protection Agency (EPA) by the states, tribes, territories and Canada. The EPA has compiled these advisory data into a database which lists, among other things, species and size of fish or wildlife under advisory, chemical contaminants covered by the advisory, location and surface area of the waterbody under advisory, and population subject to the advisory.

Indicator derivation (project, program, organization, report): U.S. Environmental Protection Agency. *Update: National Listing of Fish and Wildlife Advisories*. EPA 823-F-02-007. Washington, DC: EPA, Office of Water, May 2002.

Web site: http://www.epa.gov/waterscience/fish/advisories/ factsheet.pdf

Indicator name: Contaminants in fresh water fish

Indicator type (status or trend): Status

Indicator category (1 or 2): 2

Associated question: What is the condition of waters that support consumption of fish and shellfish?

Spatial coverage: Lower 48 states

Temporal coverage: 1992-1998 (USGS)

Characterization of supporting data set(s): From 1992 to 1998, fish samples were collected and analyzed from 223 stream sites by the U.S. Geological Survey's (USGS) National Water Quality Assessment (NAWQA) program. Tissue composites from whole fish were analyzed for polychlorinated biphenyls (PCBs), organochlorine pesticides, and trace elements. The stream sites selected were r epresentative of a large range of stream sizes, land use practices and were not selected to be a statistical representation of U.S. streams (The Heinz Center, 2002).

Indicator derivation (project, program, organization, report): USGS, NAWQA; EPA, EMAP and GLNPO. Presented in *The State of the Nation's Ecosystems*, pages 48-51 and 210 (The Heinz Center, 2002).

Web site: NAWQA http://water.usgs.gov/nawqa

Indicator name: Number of watersheds exceeding health-based national water quality criteria for mercury and PCBs in fish tissue

Indicator type (status or trend): Status

Indicator category (1 or 2): 2

Associated question: What is the condition of waters that support consumption of fish and shellfish?

Spatial coverage: National; for mercury, 35 states (West coast and eastern two-thirds of the U.S.)

Temporal coverage: 2001 reporting year, collected 1993-2001

Characterization of supporting data set(s): The data set is a compilation of fish tissue quality data housed in the U.S. Environmental Protection Agency's (EPA) National Listing of Fish and Wildlife Advisories (NLFWA) fish tissue database. Mercury data represented in 696 watersheds and PCBs in 153 watersheds. Mercury map is based on 22,000 records of fish tissue mercury concentrations from the NLFWA where air deposition is the sole significant source of mercury. Watersheds are eliminated from the analysis if they contain potentially significant, but unquantified, runoff and effluent loads from mercury mines, large-producer gold mines, and mercury-cell chlor-alkali facilities. Watersheds are also eliminated when the total screening level effluent load estimates for municipal wastewater treatment plants and pulp and paper mills are above five percent of the estimated waterbody-delivered air deposition load (EPA, Office of Water, November 2001).

Indicator derivation (project, program, organization, report): EPA NLFWA Mercury Fish Tissue Database, June 2001 as presented in U.S. Environmental Protection Agency. *Mercury Maps: Linking Air Deposition and Fish Contamination on a National Scale*. EPA 823-F-01-026. Washington, DC: EPA, Office of Water, November 2001.

Web site: Mercury map
http://www.epa.gov/waterscience/maps/factsheet.pdf

Chapter 3: Better Protected Land

Land Use

Indicator name: Extent of developed lands

Indicator type (status or trend): Status and Trend

Indicator Category: 1

Associated question: What is the extent of developed lands?

Spatial coverage: National, statistical sample of non-federal lands. The U.S. Department of Agriculture (USDA) Natural Resources Conservation Service's (NRCS) National Resources Inventory (NRI) collects data at the same 800,000 sampling sites every five years in all 50 states, Puerto Rico, the U.S. Virgin Islands, and some Pacific Basin locations.

Temporal coverage: At each NRI sample point, information is available for 1982, 1987, 1992, and 1997 so that trends and changes in land use and resource characteristics over 15 years can be examined and analyzed.

Characterization of supporting data set(s): NRI is a statistical sampling of over 800,000 locations to collect data on land cover and use, soil erosion, prime farmland soils, wetlands, habitat diversity, conservation practices, and related resource attributes. NRI is a compilation of natural resource information on non-Federal land in the U.S.

Indicator derivation (project, program, organization, report): U.S. Department of Agriculture. *Summary Report: 1997 National Resources Inventory (Revised December 2000)*, Washington, DC: Natural Resources Conservation Service and Ames, Iowa: Iowa State University, Statistical Laboratory, 2000.

Web site: http://www.nrcs.usda.gov/technical/NRI/

Indicator name: Extent of urban and suburban lands

Indicator type (status or trend): Status

Indicator Category: 2

Associated question: What is the extent of developed lands?

Spatial coverage: Lower 48 states.

Temporal coverage: 1992 satellite land cover data.

Characterization of supporting data set(s): The National Land Cover Dataset (NLCD). In the 1990s, a federal interagency consortium (the Multi-Resolution Land Characterization (MRLC) consortium) was created to coordinate access to and use of land cover data from the Landsat 5 Thematic Mapper. Using Landsat data and a variety of ancillary data, the consortium processed data from a series of 1992 Landsat images, to create the NLCD on a square grid covering the lower 48 states. The MRLC NLCD with 21 land cover classes, was further processed by the USGS for the Heinz Center to estimate the urban and suburban area coverage for the U.S.

Indicator derivation (project, program, organization, report): U.S. Environmental Protection Agency, Office of Research and Development. Multi-resolution land characteristics consortium - national land cover data. 1992. (February 19, 2003; *http://www.epa.gov/mrlc/nlcd.html*). Presented in *The State of the Nation's Ecosystems*, pages 181 and 264 (The Heinz Center, 2002).

Web site: Data are available from http://www.usgs.gov/mrlcreg.html

Indicator name: Extent of agricultural land uses

Indicator type (status or trend): Status and Trend

Indicator Category: 1

Associated question: What is the extent of farmlands?

Spatial coverage: National, statistical sample of non-federal lands. The U.S. Department of Agriculture (USDA) Natural Resources Conservation Service's (NRCS) National Resources Inventory (NRI) collects data at the same 800,000 sampling sites every five years in all 50 states, Puerto Rico, the U.S. Virgin Islands, and some Pacific Basin locations.

Temporal coverage: At each NRI sample point, information is available for 1982, 1987, 1992, and 1997 so that trends and changes in land use and resource characteristics over 15 years can be examined and analyzed.

Characterization of supporting data set(s): NRI is a statistical sampling of over 800,000 locations to collect data on land cover and use, soil erosion, prime farmland soils, wetlands, habitat diversity, conservation practices, and related resource attributes. NRI is a compilation of natural resource information on non-Federal land in the U.S.

Indicator derivation (project, program, organization, report): U.S. Department of Agriculture. *Summary Report: 1997 National Resources Inventory (Revised December 2000)*, Washington, DC: Natural Resources Conservation Service and Ames, Iowa: Iowa State University, Statistical Laboratory, 2000.

Web site: http://www.nrcs.usda.gov/technical/NRI/

Indicator name: The farmland landscape

Indicator type (status or trend): Status

Indicator Category: 2

Associated question: What is the extent of farmlands?

Spatial coverage: Lower 48 states.

Temporal coverage: 1992 satellite land cover data.

Characterization of supporting data set(s): The National Land Cover Dataset (NLCD). In the 1990s, a federal interagency consortium (the Multi-Resolution Land Characterization (MRLC) consortium) was created to coordinate access to and use of land cover data from the Landsat 5 Thematic Mapper. Using Landsat data and a variety of ancillary data, the consortium processed data from a series of 1992 Landsat images, to create the NLCD on a square grid covering the lower 48 states. The MRLC NLCD with 21 land cover classes, was aggregated and reprocessed by the USGS for the Heinz Center to estimate the farmland landscape coverage for the U.S.

Indicator derivation (project, program, organization, report): U.S. Environmental Protection Agency, Office of Research and Development. Multi-resolution land characteristics consortium - national land cover data. 1992. (February 19, 2003; *http://www.epa.gov/mrlc/nlcd.html*). Presented in *The State of the Nation's Ecosystems*, pages 92 and 231 (The Heinz Center, 2002).

Web site: Data are available from http://www.usgs.gov/mrlcreg.html

Indicator name: Extent of grasslands and shrublands

Indicator type (status or trend): Status

Indicator Category: 2

Associated question: What is the extent of grasslands and shrublands?

Spatial coverage: The lower 48 states and Alaska.

Temporal coverage: 1992 satellite imagery

Characterization of supporting data set(s): The Multi-Resolution Land Characterization (MRLC) Consortium's National Land Cover Dataset (NLCD) with 21 land cover classes, was used to estimate the area coverage for the U.S. The NLCD is based on remotely sensed imagery from the Landsat 5 Thematic Mapper. Data for Alaska were estimated from a vegetation map of Alaska by Fleming (1996) based on Advanced Very High Resolution Radiometer (AVHRR) remote-sensing images with an approximate resolution of 1 km on a side (The Heinz Center, 2002).

Indicator derivation (project, program, organization, report): 1) U.S. Environmental Protection Agency, Office of Research and Development. Multi-resolution land characteristics consortium - national land cover data. 1992. (February 19, 2003; *http://www.epa.gov/mrlc/nlcd.html*). 2) Flemming, M.D. A *Statewide Vegetation Map of Alaska Using a Phenological Classification of AVHRR Data*. Anchorage, AK: 1996 Alaska Surveying and Mapping Conference, February 1996. Presented in *The State of the Nation's Ecosystems*, pages 161 and 256 (The Heinz Center, 2002).

Web site: Data are available from http://www.usgs.gov/mrlcreg.html

Indicator name: Extent of forest area, ownership, and management

Indicator type (status or trend): Status and Trend

Indicator Category: 1

Associated question: What is the extent of forest lands?

Spatial coverage: National

Temporal coverage: Data from late 1940s to present. Data since 1953 provided with a reliability of ± 3- 10 percent per 1 million acres (67 percent confidence limit). FIA provides updates of assessment data every five years.

Characterization of supporting data set(s): The USDA Forest Service Forest Inventory and Analysis (FIA) program is a survey-based program that has operated since the late 1940s, collecting information on a variety of forest characteristics. FIA has used a two-phase sample (generally, double sampling for stratification) to collect information on the nation's forests. Phase one establishes a large number of samples (more than 4 million, roughly every 0.6 miles). These are selected using aerial photographs or other remote-sensing images, which are then interpreted for various forest attributes. Phase two establishes a subset of approximately 450,000 phase-one points (roughly every 3 miles) for ground sampling. About 125,000 of these samples are permanently established on forest land. The forest characteristics measured include ownership, protection status, species composition, stand age and structure, tree growth, occurrences of mortality and removals, tree biomass, incidences of pathogens, natural and human-caused disturbances, and soil descriptors (The Heinz Center, 2002).

Indicator derivation (project, program, organization, report): U.S. Department of Agriculture, U.S. Forest Service. Draft Resource Planning Act assessment tables. August 12, 2002. (September 2003; *http://www.ncrs.fs.fed.us/4801/FIADB/rpa_tabler/Draft_RPA_2002_Forest_Resource_Tables.pdf*). Presented in *The State of the Nation's Ecosystems*, pages 117 and 239 (The Heinz Center, 2002).

Web site: http://www.fia.fs.fed.us/

Indicator name: Sediment runoff potential from croplands and pasturelands

Indicator type (status or trend): Status

Indicator Category: 2

Associated question: What are the ecological effects associated with land uses?

Spatial coverage: National, statistical sample of non-federal lands. The U.S. Department of Agriculture (USDA) Natural Resources Conservation Service's (NRCS) National Resources Inventory (NRI) collects data at the same 800,000 sampling sites every five years in all 50 states, Puerto Rico, the U.S. Virgin Islands, and some Pacific Basin locations.

Temporal coverage: At each NRI sample point, information is available for 1982, 1987, 1992, and 1997 so that trends and changes in land use and resource characteristics over 15 years can be examined and analyzed. NRI is a compilation of natural resource information on non-Federal land in the U.S.

Characterization of supporting data set(s): Data are from USDA/NRCS STATSGO Soils Data and NRI 1997 data (adjusted in 2000). The Soil and Water Assessment Tool (SWAT) is a public domain model actively supported by the USDA Agricultural Research Service (ARS) at the Grassland, Soil and Water Research Laboratory in Temple, Texas.

Indicator derivation (project, program, organization, report): Walker, Clive. Sediment Runoff Potential, 1990-1995. Hydrologic Unit Modeling of the United States (HUMUS) Project. Temple, TX: Texas Agricultural Experiment Station. August 24, 1999.

Web site: *Exhibit source* http://www.epa.gov/iwi/1999sept/iv12c_usmap.html;
NRI http://www.nrcs.usda.gov/technical/NRI/;
SWAT http://www.brc.tamus.edu/swat/

Chemicals in the Landscape

Indicator name: Quantity and type of toxic chemicals released and managed

Indicator type (status or trend): Status

Indicator Category: 2

Associated question: How much and what types of toxics are released into the environment?

Spatial coverage: National

Temporal coverage: 1998-2000

Characterization of supporting data set(s): The U.S. Environmental Protection Agency's (EPA) Toxics Release Inventory (TRI) database consists of release and other waste management information from facilities. EPA requires facilities to use one or more of four general approaches to estimating/measuring releases, namely, monitoring, emission factors, mass balance, and engineering calculations. Facilities report release and other waste management information along with information about release estimation methods.

Indicator derivation (project, program, organization, report): U.S. Environmental Protection Agency. *2000 Toxics Release Inventory Public Data Release Report*, EPA 260-S-02-001. Washington, DC: U.S. Environmental Protection Agency, Office of Environmental Information, May 2002.

Web site: http://www.epa.gov/tri/

Indicator name: Agricultural pesticide use

Indicator type (status or trend): Status

Indicator Category: 2

Associated question: What is the volume, distribution, and extent of pesticide use?

Spatial coverage: National

Temporal coverage: 1992 and 1997

Characterization of supporting data set(s): Data are based on the National Center for Food and Agricultural Policy (NCFAP) Pesticide Use Database, a database of information on pesticide applications to cropland for 220 active ingredients.

Indicator derivation (project, program, organization, report): Data from the NCFAP, a private, non-profit, non-advocacy research organization, as reported in Gianessi, L.P., and M.B. Marcelli. *Pesticide Use in U.S. Crop Production*. Washington D.C. November, 2000.

Web site: http://www.ncfap.org/ncfap/nationalsummary1997.pdf

Indicator name: Fertilizer use

Indicator type (status or trend): Status and Trend

Indicator Category: 2

Associated question: What is the volume, distribution, and extent of fertilizer use?

Spatial coverage: National

Temporal coverage: 1960-1998

Characterization of supporting data set(s): Data in the U.S. Department of Agriculture's (USDA) Agricultural Resources and Environmental Indicators Report is based on a variety of surveys, as well as the Census of Agriculture and the Natural Resources Inventory.

Indicator derivation (project, program, organization, report): Daberkow, S., H. Taylor, and W. Huang. "Agricultural Resources and Environmental Indicators: Nutrient Use and Management." September, 2000. In *Agricultural Resources and Environmental Indicators*, Agricultural Handbook No. AH722. U.S. Department of Agriculture, Economic Research Service, Washington, DC, February 2003, 4.4.1-4.4.49.

Web site: http://www.ers.usda.gov/publications/arei/arei2001/

Indicator name: Pesticide residues in food

Indicator type (status or trend): Trend

Indicator Category: 1

Associated question: What is the potential disposition of chemicals used on land?

Scale and coverage: National

Temporal coverage: 1997-2000

Characterization of supporting data set(s): The U.S. Department of Agriculture's (USDA) Pesticide Data Program (PDP) was started by USDA in May 1991 to provide data on pesticide dietary exposure, food consumption, and pesticide usage. PDP data are based on samples of approximately 50 different commodities tested for more than 290 different pesticides.

Indicator derivation (project, program, organization, report): Data from U.S. Department of Agriculture, Agricultural Marketing Service. *Pesticide Data Program: Annual Summary Calendar Year 2000*, Washington, DC: U.S. Department of Agriculture, February 2002. PDP is USDA's program to collect data on pesticide residues in food.

Web site: http://www.ams.usda.gov/science/pdp/

Indicator name: Potential pesticide runoff from farm fields

Indicator type (status or trend): Status

Indicator Category: 1

Associated question: What is the potential disposition of chemicals used on land?

Spatial coverage: National, statistical sample of non-federal lands. The U.S. Department of Agriculture (USDA) Natural Resources Conservation Service's (NRCS) National Resources Inventory (NRI) collects data at the same 800,000 sampling sites every five years in all 50 states, Puerto Rico, the U.S. Virgin Islands, and some Pacific Basin locations.

Temporal coverage: At each NRI sample point, information is available for 1982, 1987, 1992, and 1997 so that trends and changes in land use and resource characteristics over 15 years can be examined and analyzed. The data used in this analysis were from 1992.

Characterization of supporting data set(s): Using national-level databases, a simulation was conducted of potential pesticide losses from representative farm fields. About 170,000 Natural Resources Inventory (NRI) sample points were treated as "representative fields." Thirteen crops were included in the simulation: barley, corn, cotton, oats, peanuts, potatoes, rice, sorghum, soybeans, sugar beets, sunflowers, tobacco, and wheat. The potential for pesticide loss from each "representative field" was estimated using the state average pesticide application rate and percent acres treated from the National Pesticide Use Database. The maximum percent runoff loss over a 20-year simulation of rainfall from the Pesticide Loss Database was imputed to NRI sample points using match-ups by soil properties and proximity to 55 climate stations. The total loss of pesticides from each "representative field" was estimated by summing over the loss estimates for all the pesticides that the National

Pesticide Use Database reported for each State and crop. Watershed scores were determined by averaging the scores for the NRI sample points within each watershed.

Indicator derivation (project, program, organization, report): Data are from 1)1) National Resources Inventory, U.S. Department. of Agriculture, Natural Resources Conservation Service, 1992; 2) National Pesticide Use Database from Gianessi, Leonard P., and James Earl Anderson. *Pesticide Use in U.S. Crop Production: National Data Report*. National Center for Food and Agricultural Policy, Washington D.C., February 1995; and 3) Pesticide Loss Database from Don W. Goss, Texas Agricultural Experiment Station, Temple, Texas.

Web site: http://www.epa.gov/iwi/1999sept/iv12a_usmap.html

Indicator name: Risk of nitrogen export

Indicator type (status or trend): Status

Indicator Category: 2

Associated question: What is the potential disposition of chemicals used on land?

Spatial coverage: Lower 48 states

Temporal coverage: 1992 satellite imagery

Characterization of supporting data set(s): The Multi-Resolution Land Characterization (MRLC) Consortium's National Land Cover Dataset (NLCD) with 21 land cover classes, was used to estimate the area coverage for the U.S. The NLCD is based on remotely sensed imagery from the Landsat 5 Thematic Mapper.

Indicator derivation (project, program, organization, report): 1) U.S. Environmental Protection Agency, Office of Research and Development. Multi-resolution land characteristics consortium - national land cover data. 1992. (February 19, 2003; *http://www.epa.gov/mrlc/nlcd.html*). 2) Wickham, J.D., K.H. Riitters, R.V. O'Neill, K.H. Reckhow, T.G. Wade, and K.B. Jones. Land cover as a framework for assessing risk of water pollution. *Journal of the American Water Resources Association* 36 (6): 1-6 (2000).

Web site: Data are available from http://www.usgs.gov/mrlcreg.html

Indicator name: Risk of phosphorus export

Indicator type (status or trend): Status

Indicator Category: 2

Associated question: What is the potential disposition of chemicals used on land?

Spatial coverage: Lower 48 states

Temporal coverage: 1992 satellite imagery

Characterization of supporting data set(s): The Multi-Resolution Land Characterization (MRLC) Consortium's National Land Cover Dataset (NLCD) with 21 land cover classes, was used to estimate the area coverage for the US. The NLCD is based on remotely sensed imagery from the Landsat 5 Thematic Mapper.

Indicator derivation (project, program, organization, report): 1) U.S. Environmental Protection Agency, Office of Research and Development. Multi-resolution land characteristics consortium - national land cover data. 1992. (February 19, 2003; *http://www.epa.gov/mrlc/nlcd.html*). 2) Wickham, J.D., K.H. Riitters, R.V. O'Neill, K.H. Reckhow, T.G. Wade, and K.B. Jones. Land cover as a framework for assessing risk of water pollution. *Journal of the American Water Resources Association* 36 (6): 1-6 (2000).

Web site: Data are available from http://www.usgs.gov/mrlcreg.html

Waste and Contaminated Lands

Indicator name: Quantity of municipal solid waste (MSW) generated and managed

Indicator type (status or trend): Status and Trend

Indicator Category: 2

Associated question: How much and what types of waste are generated and managed?

Spatial coverage: National

Temporal coverage: Trends in MSW management from 1960 to 1999, including source reduction, recovery for recycling (including composting), and disposal via combustion and landfilling.

Characterization of supporting data set(s): The supporting data set addresses MSW in the U.S. that is generated, recycled, and disposed. More recently, estimates of waste prevention have been included as well. Data are provided both for specific materials (glass, plastic, paper, etc.) in MSW and specific products (newspaper, aluminum cans, etc.) in MSW.

Indicator derivation (project, program, organization, report): Data are from U.S. Environmental Protection Agency. *Municipal Solid Waste in the United States: 2000 Facts and Figures,* EPA 530-S-02-001. U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response, June 2002.

Web site: http://www.epa.gov/epaoswer/non-hw/muncpl/msw99.htm

Indicator name: Quantity of RCRA hazardous waste generated and managed

Indicator type (status or trend): Status

Indicator Category: 2

Associated question: How much and what types of waste are generated and managed?

Spatial coverage: National

Temporal coverage: Biennial

Characterization of supporting data set(s): Generators, transporters, treaters, storers, and disposers of hazardous waste are required to provide information about their activities to state environmental agencies. These agencies in turn pass on the information to regional and national EPA offices. This information is stored in EPA's RCRAInfo database.

Indicator derivation (project, program, organization, report): U.S. Environmental Protection Agency. *The National Biennial RCRA Hazardous Waste Report*, EPA 530-R-01-009. Washington DC: U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response, June 2001.

Web site: http://www.epa.gov/epaoswer/hazwaste/data/brs99/index.htm

Indicator name: Quantity of radioactive waste generated and in inventory

Indicator type (status or trend): Status

Indicator Category: 2

Associated question: How much and what types of waste are generated and managed?

Spatial coverage: National

Temporal coverage: Fiscal year 2000

Characterization of supporting data set(s): Summary data on the amounts (volume/mass) and location of the radioactive waste, spent nuclear fuel, and contaminated media managed by the U.S. Department of Energy (DOE). These data are provided in a publicly-available report (Summary Data Report) and are based on data in the DOE's Environmental Management (EM) Corporate Database (Central Internet Database).

Indicator derivation (project, program, organization, report): U.S. Department of Energy, Office of Environmental Management. Central Internet Database. 2002. (January 2003; *http://cid.em.doe.gov*).

Web site: http://cid.em.doe.gov

Indicator name: Number and location of municipal solid waste (MSW) landfills

Indicator type (status or trend): Status and Trend

Indicator Category: 2

Associated question: What is the extent of land used for waste management?

Spatial coverage: National

Temporal coverage: Trends in MSW management from 1960 to 1999, including source reduction, recovery for recycling (including composting), and disposal via combustion and landfilling.

Characterization of supporting data set(s): BioCycle magazine collects the MSW landfill data annually through a survey to state solid waste officers who relay the total number of landfills in each state (as reported by state agencies, counties, and/or municipalities). There is no quality review process for these data and there are differences in the ways data is collected and reported by the state programs.

Indicator derivation (project, program, organization, report): BioCycle Journal of Composting and Organics Recycling 41 (4), April 2000 as reprinted in U.S. Environmental Protection Agency. *Municipal Solid Waste in the United States: 2000 Facts and Figures*, EPA 530-S-02-001. U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response, June 2002.

Web site: http://www.epa.gov/epaoswer/non-hw/muncpl/msw99.htm

Indicator name: Number of RCRA hazardous waste management facilities

Indicator type (status or trend): Trend

Indicator Category: 2

Associated question: What is the extent of land used for waste management?

Spatial coverage: National

Temporal coverage: 1999

Characterization of supporting data set(s): RCRAInfo is EPA's comprehensive information system, providing access to data supporting the Resource Conservation and Recovery Act (RCRA) of 1976 and the Hazardous and Solid Waste Amendments (HSWA) of 1984. RCRAInfo replaces the data recording and reporting abilities of the Resource Conservation and Recovery Information System (RCRIS) and the Biennial Reporting System (BRS). The RCRAInfo system allows tracking of many types of information about the regulated universe of RCRA hazardous waste handlers. RCRAInfo characterizes facility status, regulated activities, and compliance histories and captures detailed data on the generation of hazardous waste from large quantity generators and on waste management practices from treatment, storage, and disposal facilities.

Indicator derivation (project, program, organization, report): U.S. Environmental Protection Agency. *The National Biennial RCRA Hazardous Waste Report*, EPA 530-R-01-009. Washington DC: U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response, June 2001.

Web site: http://www.epa.gov/epaoswer/hazwaste/data/index.htm

Indicator name: Number and location of Superfund National Priorities List sites

Indicator type (status or trend): Status and Trend

Indicator Category: 2

Associated question: What is the extent of contaminated land?

Spatial coverage: National

Temporal coverage: 1990-2002

Characterization of supporting data set(s): CERCLIS is the Comprehensive Environmental Response, Compensation, and Liability Information System. CERCLIS contains information on hazardous waste sites, potential hazardous waste sites, and remedial activities across the nation, including sites that are on the National Priorities List (NPL) or being considered for the NPL. CERCLIS is used by EPA to track activities conducted under its Superfund program. Specific information is tracked for each individual Superfund site. Sites which come to EPA's attention because of a potential for releasing hazardous substances into the environment are added to the CERCLIS inventory.

Indicator derivation (project, program, organization, report): EPA, Office of Solid Waste and Emergency Response. National Priorities List Site Totals by Status and Milestone. March 26, 2003. (April 3, 2003; *http://www.epa.gov/superfund/sites/query/queryhtm/npltotal.htm*) and Number of NPL Site Actions and Milestones by Fiscal Year. March 26, 2003. (April 3, 2003; *http://www.epa.gov/ superfund/sites/query/queryhtm/nplfy/htm*).

Web site: http://www.epa.gov/superfund/sites/cursites/index.htm

Indicator name: Number and location of RCRA Corrective Action Sites

Indicator type (status or trend): Status and Trend

Indicator Category: 2

Associated question: What is the extent of contaminated land?

Spatial coverage: National

Temporal coverage: 1997-1999

Characterization of supporting data set(s): Corrective Action (CA) is the term the Resource Conservation and Recovery Act (RCRA) program uses to describe the cleanup of sites that manage hazardous wastes. The EPA Office of Solid Waste and Emergency Response (OSWER) CA program keeps information on CA sites in the RCRAInfo database. RCRAInfo is EPA's comprehensive information system, providing access to data supporting the Resource Conservation and Recovery Act (RCRA) of 1976 and the Hazardous and Solid Waste Amendments (HSWA) of 1984. RCRAInfo replaces the data recording and reporting abilities of the Resource Conservation and Recovery Information System (RCRIS) and the Biennial Reporting System (BRS). The RCRAInfo system allows tracking of many types of information about the regulated universe of RCRA hazardous waste handlers. RCRAInfo characterizes facility status, regulated activities, and compliance histories and captures detailed data on the generation of hazardous waste from large quantity generators and on waste management practices from treatment, storage, and disposal facilities. Currently, EPA believes that there are over 6,500 facilities subject to RCRA CA statutory authorities. Of these, approximately 3,700 facilities have CA already underway or will need to implement CA as part of the process to obtain a permit to treat, store, or dispose of hazardous waste. EPA refers to these 3,700 facilities as the "corrective action workload." To help prioritize resources further, EPA established specific short-term goals for 1,714 facilities referred to as the RCRA Cleanup Baseline.

Indicator derivation (project, program, organization, report): U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response. Corrective action background. October 8, 2002. (October 15, 2002; *http://www.epa.gov/epaoswer/hazwaste/ca/backgnd.htm#5*).

Web site: http://www.epa.gov/epaoswer/hazwaste/ca/index.htm

Chapter 4: Human Health

Health Status of the United States: Indicators and Trends of Health and Disease

Indicator name: Life expectancy

Indicator type (status or trend): Trend

Indicator category (1 or 2): 1

Associated question: What are the trends for life expectancy?

Spatial coverage: National. Data are for the 50 states and the District of Columbia, unless otherwise specified.

Temporal coverage: 1933 to present.

Characterization of supporting data set(s): National Center for Health Statistics (NCHS), through the National Vital Statistics Systems (NVSS), has collected and published data on births, deaths, marriages, and divorces in the United States. Virtually all births and deaths are registered. U.S. Standard Live Birth and Death Certificates are revised periodically. Most state certificates conform closely in content and arrangement to the standard certificate recommended by NCHS and all certificates contain a minimum data set specified by NCHS. The mother provides demographic information on the birth certificate, such as race and ethnicity, at the time of birth. Medical and health information is based on hospital records. Demographic information on the death certificate is provided by the funeral director based on information supplied by an informant. A physician, medical examiner, or coroner provides medical certification of cause of death.

Indicator source (project, program, organization, report): NCHS, NVSS

Web site: http://www.cdc.gov/nchs/nvss.htm

Indicator name: Cancer mortality

Indicator type (status or trend): Trend

Indicator category (1 or 2): 1

Associated question: What are the trends for cancer, cardiovascular disease, chronic obstructive pulmonary disease and asthma?

Spatial coverage: National. Data are for the 50 states and the District of Columbia, unless otherwise specified.

Temporal coverage: 1933 to present; 1973-1998 data displayed.

Characterization of supporting data set(s): National Center for Health Statistics (NCHS), through the National Vital Statistics Systems (NVSS), has collected and published data on births, deaths, marriages, and divorces in the United States. Virtually all births and deaths are registered. U.S. Standard Live Birth and Death Certificates are revised periodically. Most state certificates conform closely in content and arrangement to the standard certificate recommended by NCHS and all certificates contain a minimum data set specified by NCHS. The mother provides demographic information on the birth certificate, such as race and ethnicity, at the time of birth. Medical and health information is based on hospital records. Demographic information on the death certificate is provided by the funeral director based on information supplied by an informant. A physician, medical examiner, or coroner provides medical certification of cause of death.

Indicator source (project, program, organization, report): NCHS, National Vital Statistics Systems (NVSS)

Web site: http://www.cdc.gov/nchs/nvss.htm

Indicator name: Cancer incidence

Indicator type (status or trend): Trend

Indicator category (1 or 2): 2

Associated question: What are the trends for cancer, cardiovascular disease, chronic obstructive pulmonary disease and asthma?

Spatial coverage: National

Temporal coverage: 1997-2001

Characterization of supporting data set(s): The purpose of the National Notifiable Disease Surveillance System is primarily to provide weekly provisional information on the occurrence of diseases defined as notifiable by the Council of State and Territorial Epidemiologists (CSTE) and annual summary data. State epidemiologists report cases of notifiable diseases to CDC, and CDC tabulates and publishes these data in the *Morbidity and Mortality Weekly Report (MMWR)* and the *Summary of Notifiable Diseases, United States*. Policies for reporting notifiable disease cases can vary by disease or reporting jurisdiction. CSTE and CDC annually review and recommend additions or deletions to the list or nationally notifiable diseases based on the need to respond to emerging priorities. However, reporting nationally notifiable diseases to CDC is voluntary. Reporting is currently mandated by law or regulation only at the local and state level. Therefore, the list of diseases that are considered notifiable varies slightly by state. Notifiable disease data are useful for analyzing disease trends and determining relative disease burdens. However, these data must be interpreted in light of reporting practices. The degree of completeness of data reporting also is influenced by the diagnostic facilities available, the control measures in effect, public awareness of a specific disease, and the interests, resources, and priorities of state and local officials responsible for disease control and public health surveillance, introduction of new diagnostic tests, or discovery of new disease entities can cause changes in disease reporting that are independent of the true incidence of disease.

Indicator source (project, program, organization, report): Centers for Disease Control and Prevention, Epidemiology Program Office, National Notifiable Disease Surveillance System

Web site: *Morbidity and Mortality Weekly Report* http://www.cdc.gov/mmwr/; *Summary of Notifiable Diseases* http://www.cdc.gov/epo/dphsi/annsum/

Indicator name: Cardiovascular disease mortality

Indicator type (status or trend): Trend

Indicator category (1 or 2): 1

Associated question: What are the trends for cancer, cardiovascular disease, chronic obstructive pulmonary disease and asthma?

Spatial coverage: National. Data are for the 50 states and the District of Columbia, unless otherwise specified.

Temporal coverage: 1933 to present; 1900-1996 data displayed.

Characterization of supporting data set(s): National Center for Health Statistics (NCHS), through the National Vital Statistics Systems (NVSS), has collected and published data on births, deaths, marriages, and divorces in the United States. Virtually all births and deaths are registered. U.S. Standard Live Birth and Death Certificates are revised periodically. Most state certificates conform closely in content and arrangement to the standard certificate recommended by NCHS and all certificates contain a minimum data set specified by NCHS. The mother provides demographic information on the birth certificate, such as race and ethnicity, at the time of birth. Medical and health information is based on hospital records. Demographic information on the death certificate is provided by the funeral director based on information supplied by an informant. A physician, medical examiner, or coroner provides medical certification of cause of death.

Indicator source (project, program, organization, report): NCHS, NVSS

Web site: http://www.cdc.gov/nchs/nvss.htm

Indicator name: Cardiovascular disease prevalence

Indicator type (status or trend): Trend

Indicator category (1 or 2): 1

Associated question: What are the trends for cancer, cardiovascular disease, chronic obstructive pulmonary disease and asthma?

Spatial coverage: National

Temporal coverage: NHANES III, 1998-1994

Characterization of supporting data set(s): The National Health and Nutrition Examination Survey (NHANES) is comprised of a series of surveys conducted by the Centers for Disease Control's (CDC) National Center for Health Statistics (NCHS). The survey is designed to collect data on the health of the United States population, including information about many topics, such as nutrition, heart disease, and exposure to chemicals (CDC, 2001). The NHANES surveys have been performed over a number of years. The first survey, NHANES I, took place from 1971 through 1975; NHANES II occurred from 1976-80; NHANES III was performed in 1988 through 1994; and the current NHANES began in 1999 and is ongoing. As part of the survey, blood and urine samples were collected to measure the amounts of certain chemicals thought to be harmful to people. Because of the extensive work involved with laboratory analyses, some chemicals were measured for all people in the survey, while other chemicals were only measured for a small sample of people in an age group. The current NHANES IV measures exposure for 27 chemicals for people in the U.S. In previous NHANES, exposure had been assessed via laboratory analysis for only three chemicals: lead, cadmium and cotinine.

Indicator source (project, program, organization, report): NHANES III, 1999. *The CDC National Report on Human Exposure to Environmental Chemicals* (often referred to as the "CDC Report Card") summarizes chemical exposure data from the 1999 NHANES.

Web site: http://www.cdc.gov/nchs/nhanes.htm

Indicator name: Chronic obstructive pulmonary disease mortality

Indicator type (status or trend): Trend

Indicator category (1 or 2): 1

Associated question: What are the trends for cancer, cardiovascular disease, chronic obstructive pulmonary disease and asthma?

Spatial coverage: National. Data are for the 50 states and the District of Columbia, unless otherwise specified.

Temporal coverage: 1933 to present; 1980-1998 data displayed.

Characterization of supporting data set(s): National Center for Health Statistics (NCHS), through the National Vital Statistics Systems (NVSS), has collected and published data on births, deaths, marriages, and divorces in the United States. Virtually all births and deaths are registered. U.S. Standard Live Birth and Death Certificates are revised periodically. Most state certificates conform closely in content and arrangement to the standard certificate recommended by NCHS and all certificates contain a minimum data set specified by NCHS. The mother provides demographic information on the birth certificate, such as race and ethnicity, at the time of birth. Medical and health information is based on hospital records. Demographic information on the death certificate is provided by the funeral director based on information supplied by an informant. A physician, medical examiner, or coroner provides medical certification of cause of death.

Indicator source (project, program, organization, report): NCHS, NVSS

Web site: http://www.cdc.gov/nchs/nvss.htm

Indicator name: Asthma mortality

Indicator type (status or trend): Trend

Indicator category (1 or 2): 1

Associated question: What are the trends for cancer, cardiovascular disease, chronic obstructive pulmonary disease and asthma?

Spatial coverage: National. Data are for the 50 states and the District of Columbia, unless otherwise specified.

Temporal coverage: 1933 to present; 1980-1999 data displayed

Characterization of supporting data set(s): National Center for Health Statistics (NCHS), through the National Vital Statistics Systems (NVSS), has collected and published data on births, deaths, marriages, and divorces in the United States. Virtually all births and deaths are registered. U.S. Standard Live Birth and Death Certificates are revised periodically. Most state certificates conform closely in content and arrangement to the standard certificate recommended by NCHS and all certificates contain a minimum data set specified by NCHS. The mother provides demographic information on the birth certificate, such as race and ethnicity, at the time of birth. Medical and health information is based on hospital records. Demographic information on the death certificate is provided by the funeral director based on information supplied by an informant. A physician, medical examiner, or coroner provides medical certification of cause of death.

Indicator source (project, program, organization, report): NCHS, NVSS

Web site: http://www.cdc.gov/nchs/nvss.htm

Indicator name: Asthma prevalence

Indicator type (status or trend): Trend

Indicator category (1 or 2): 1

Associated question: What are the trends for cancer, cardiovascular disease, chronic obstructive pulmonary disease and asthma?

Spatial coverage: National

Temporal coverage: NHIS has been conducted continuously since 1957, the content of the survey has been updated about every 10-15 years. In 1996 a substantially revised NHIS content began field testing. This new questionnaire, described in detail below, began in 1997 and improves the ability of the NHIS to provide important health information. 1980-1996 and 1980-1999 data displayed.

Characterization of supporting data set(s): The National Health Interview Survey (NHIS) is a continuous nationwide survey in which data are collected through personal household interviews. Self-reported information is obtained on personal and demographic characteristics, illnesses, injuries, impairments, chronic conditions, utilization of health resources, and other health topics. The sample scheduled for each week is representative of the target population, and the weekly samples are additive over time. Response rates for special health topics (supplements) have generally been lower. Because of the extensive redesign of the questionnaire in 1997 and introduction of the computer-assisted personal interviewing (CAPI) method of data collection, data from 1997 and later years may not be comparable with earlier years.

Indicator source (project, program, organization, report): National Center for Health Statistics (NCHS), National Health Interview Survey (NHIS)

Web site: http://www.cdc.gov/nchs/nhis.htm

Indicator name: Cholera prevalence

Indicator type (status or trend): Trend

Indicator category (1 or 2): 2

Associated question: What are the trends for gastrointestinal illnesses?

Spatial coverage: National

Temporal coverage: 1997-2001

Characterization of supporting data set(s): The purpose of the National Notifiable Disease Surveillance System is primarily to provide weekly provisional information on the occurrence of diseases defined as notifiable by the Council of State and Territorial Epidemiologists (CSTE) and annual summary data. State epidemiologists report cases of notifiable diseases to CDC, and CDC tabulates and publishes these data in the *Morbidity and Mortality Weekly Report (MMWR)* and the *Summary of Notifiable Diseases, United States*. Policies for reporting notifiable disease cases can vary by disease or reporting jurisdiction. CSTE and CDC annually review and recommend additions or deletions to the list or nationally notifiable diseases based on the need to respond to emerging priorities. However, reporting nationally notifiable diseases to CDC is voluntary. Reporting is currently mandated by law or regulation only at the local and state level. Therefore, the list of diseases that are considered notifiable varies slightly by state. Notifiable disease data are useful for analyzing disease trends and determining relative disease burdens. However, these data must be interpreted in light of reporting practices. The degree of completeness of data reporting also is influenced by the diagnostic facilities available, the control measures in effect, public awareness of a specific disease, and the interests, resources, and priorities of state and local officials responsible for disease control and public health surveillance, introduction of new diagnostic tests, or discovery of new disease entities can cause changes in disease reporting that are independent of the true incidence of disease.

Indicator source (project, program, organization, report): Centers for Disease Control and Prevention, Epidemiology Program Office, National Notifiable Disease Surveillance System

Web site: *Morbidity and Mortality Weekly Report*
http://www.cdc.gov/mmwr/;
Summary of Notifiable Diseases
http://www.cdc.gov/epo/dphsi/annsum/

Indicator name: Cryptosporidiosis prevalence

Indicator type (status or trend): Trend

Indicator category (1 or 2): 2

Associated question: What are the trends for gastrointestinal illnesses?

Spatial coverage: National

Temporal coverage: 1997-2001

Characterization of supporting data set(s): The purpose of the National Notifiable Disease Surveillance System is primarily to provide weekly provisional information on the occurrence of diseases defined as notifiable by the Council of State and Territorial Epidemiologists (CSTE) and annual summary data. State epidemiologists report cases of notifiable diseases to CDC, and CDC tabulates and publishes these data in the *Morbidity and Mortality Weekly Report (MMWR)* and the *Summary of Notifiable Diseases, United States*. Policies for reporting notifiable disease cases can vary by disease or reporting jurisdiction. CSTE and CDC annually review and recommend additions or deletions to the list or nationally notifiable diseases based on the need to respond to emerging priorities. However, reporting nationally notifiable diseases to CDC is voluntary. Reporting is currently mandated by law or regulation only at the local and state level. Therefore, the list of diseases that are considered notifiable varies slightly by state. Notifiable disease data are useful for analyzing disease trends and determining relative disease burdens. However, these data must be interpreted in light of reporting practices. The degree of completeness of data reporting also is influenced by the diagnostic facilities available, the control measures in effect, public awareness of a specific disease, and the interests, resources, and priorities of state and local officials responsible for disease control and public health surveillance, introduction of new diagnostic tests, or discovery of new disease entities can cause changes in disease reporting that are independent of the true incidence of disease.

Indicator source (project, program, organization, report): Centers for Disease Control and Prevention, Epidemiology Program Office, National Notifiable Disease Surveillance System

Web site: *Morbidity and Mortality Weekly Report*
http://www.cdc.gov/mmwr/;
Summary of Notifiable Diseases
http://www.cdc.gov/epo/dphsi/annsum/

Indicator name: *E. coli* 0157:H7 prevalence

Indicator type (status or trend): Trend

Indicator category (1 or 2): 2

Associated question: What are the trends for gastrointestinal illnesses?

Spatial coverage: National

Temporal coverage: 1997-2001

Characterization of supporting data set(s): The purpose of the National Notifiable Disease Surveillance System is primarily to provide weekly provisional information on the occurrence of diseases defined as notifiable by the Council of State and Territorial Epidemiologists (CSTE) and annual summary data. State epidemiologists report cases of notifiable diseases to CDC, and CDC tabulates and publishes these data in the *Morbidity and Mortality Weekly Report (MMWR)* and the *Summary of Notifiable Diseases, United States*. Policies for reporting notifiable disease cases can vary by disease or reporting jurisdiction. CSTE and CDC annually review and recommend additions or deletions to the list or nationally notifiable diseases based on the need to respond to emerging priorities. However, reporting nationally notifiable diseases to CDC is voluntary. Reporting is currently mandated by law or regulation only at the local and state level. Therefore, the list of diseases that are considered notifiable varies slightly by state. Notifiable disease data are useful for analyzing disease trends and determining relative disease burdens. However, these data must be interpreted in light of reporting practices. The degree of completeness of data reporting also is influenced by the diagnostic facilities available, the control measures in effect, public awareness of a specific disease, and the interests, resources, and priorities of state and local officials responsible for disease control and public health surveillance, introduction of new diagnostic tests, or discovery of new disease entities can cause changes in disease reporting that are independent of the true incidence of disease.

Indicator source (project, program, organization, report): Centers for Disease Control and Prevention, Epidemiology Program Office, National Notifiable Disease Surveillance System

Web site: *Morbidity and Mortality Weekly Report*
http://www.cdc.gov/mmwr/;
Summary of Notifiable Diseases
http://www.cdc.gov/epo/dphsi/annsum/

Indicator name: Hepatitis A prevalence

Indicator type (status or trend): Trend

Indicator category (1 or 2): 2

Associated question: What are the trends for gastrointestinal illnesses?

Spatial coverage: National

Temporal coverage: 1997-2001

Characterization of supporting data set(s): The purpose of the National Notifiable Disease Surveillance System is primarily to provide weekly provisional information on the occurrence of diseases defined as notifiable by the Council of State and Territorial Epidemiologists (CSTE) and annual summary data. State epidemiologists report cases of notifiable diseases to CDC, and CDC tabulates and publishes these data in the *Morbidity and Mortality Weekly Report (MMWR)* and the *Summary of Notifiable Diseases, United States*. Policies for reporting notifiable disease cases can vary by disease or reporting jurisdiction. CSTE and CDC annually review and recommend additions or deletions to the list or nationally notifiable diseases based on the need to respond to emerging priorities. However, reporting nationally notifiable diseases to CDC is voluntary. Reporting is currently mandated by law or regulation only at the local and state level. Therefore, the list of diseases that are considered notifiable varies slightly by state. Notifiable disease data are useful for analyzing disease trends and determining relative disease burdens. However, these data must be interpreted in light of reporting practices. The degree of completeness of data reporting also is influenced by the diagnostic facilities available, the control measures in effect, public awareness of a specific disease, and the interests, resources, and priorities of state and local officials responsible for disease control and public health surveillance, introduction of new diagnostic tests, or discovery of new disease entities can cause changes in disease reporting that are independent of the true incidence of disease.

Indicator source (project, program, organization, report): Centers for Disease Control and Prevention, Epidemiology Program Office, National Notifiable Disease Surveillance System

Web site: *Morbidity and Mortality Weekly Report*
http://www.cdc.gov/mmwr/;
Summary of Notifiable Diseases
http://www.cdc.gov/epo/dphsi/annsum/

Indicator name: Salmonellosis prevalence

Indicator type (status or trend): Trend

Indicator category (1 or 2): 2

Associated question: What are the trends for gastrointestinal illnesses?

Spatial coverage: National

Temporal coverage: 1997-2001

Characterization of supporting data set(s): The purpose of the National Notifiable Disease Surveillance System is primarily to provide weekly provisional information on the occurrence of diseases defined as notifiable by the Council of State and Territorial Epidemiologists (CSTE) and annual summary data. State epidemiologists report cases of notifiable diseases to CDC, and CDC tabulates and publishes these data in the *Morbidity and Mortality Weekly Report (MMWR)* and the *Summary of Notifiable Diseases, United States*. Policies for reporting notifiable disease cases can vary by disease or reporting jurisdiction. CSTE and CDC annually review and recommend additions or deletions to the list or nationally notifiable diseases based on the need to respond to emerging priorities. However, reporting nationally notifiable diseases to CDC is voluntary. Reporting is currently mandated by law or regulation only at the local and state level. Therefore, the list of diseases that are considered notifiable varies slightly by state. Notifiable disease data are useful for analyzing disease trends and determining relative disease burdens. However, these data must be interpreted in light of reporting practices. The degree of completeness of data reporting also is influenced by the diagnostic facilities available, the control measures in effect, public awareness of a specific disease, and the interests, resources, and priorities of state and local officials responsible for disease control and public health surveillance, introduction of new diagnostic tests, or discovery of new disease entities can cause changes in disease reporting that are independent of the true incidence of disease.

Indicator source (project, program, organization, report): Centers for Disease Control and Prevention, Epidemiology Program Office, National Notifiable Disease Surveillance System

Web site: *Morbidity and Mortality Weekly Report*
http://www.cdc.gov/mmwr/;
Summary of Notifiable Diseases
http://www.cdc.gov/epo/dphsi/annsum/

Indicator name: Shigellosis prevalence

Indicator type (status or trend): Trend

Indicator category (1 or 2): 2

Associated question: What are the trends for gastrointestinal illnesses?

Spatial coverage: National

Temporal coverage: 1997-2001

Characterization of supporting data set(s): The purpose of the National Notifiable Disease Surveillance System is primarily to provide weekly provisional information on the occurrence of diseases defined as notifiable by the Council of State and Territorial Epidemiologists (CSTE) and annual summary data. State epidemiologists report cases of notifiable diseases to CDC, and CDC tabulates and publishes these data in the *Morbidity and Mortality Weekly Report (MMWR)* and the *Summary of Notifiable Diseases, United States*. Policies for reporting notifiable disease cases can vary by disease or reporting jurisdiction. CSTE and CDC annually review and recommend additions or deletions to the list or nationally notifiable diseases based on the need to respond to emerging priorities. However, reporting nationally notifiable diseases to CDC is voluntary. Reporting is currently mandated by law or regulation only at the local and state level. Therefore, the list of diseases that are considered notifiable varies slightly by state. Notifiable disease data are useful for analyzing disease trends and determining relative disease burdens. However, these data must be interpreted in light of reporting practices. The degree of completeness of data reporting also is influenced by the diagnostic facilities available, the control measures in effect, public awareness of a specific disease, and the interests, resources, and priorities of state and local officials responsible for disease control and public health surveillance, introduction of new diagnostic tests, or discovery of new disease entities can cause changes in disease reporting that are independent of the true incidence of disease.

Indicator source (project, program, organization, report): Centers for Disease Control and Prevention, Epidemiology Program Office, National Notifiable Disease Surveillance System

Web site: *Morbidity and Mortality Weekly Report*
http://www.cdc.gov/mmwr/;
Summary of Notifiable Diseases
http://www.cdc.gov/epo/dphsi/annsum/

Indicator name: Typhoid fever prevalence

Indicator type (status or trend): Trend

Indicator category (1 or 2): 2

Associated question: What are the trends for gastrointestinal illnesses?

Spatial coverage: National

Temporal coverage: 1997-2001

Characterization of supporting data set(s): The purpose of the National Notifiable Disease Surveillance System is primarily to provide weekly provisional information on the occurrence of diseases defined as notifiable by the Council of State and Territorial Epidemiologists (CSTE) and annual summary data. State epidemiologists report cases of notifiable diseases to CDC, and CDC tabulates and publishes these data in the *Morbidity and Mortality Weekly Report (MMWR)* and the *Summary of Notifiable Diseases, United States*. Policies for reporting notifiable disease cases can vary by disease or reporting jurisdiction. CSTE and CDC annually review and recommend additions or deletions to the list or nationally notifiable diseases based on the need to respond to emerging priorities. However, reporting nationally notifiable diseases to CDC is voluntary. Reporting is currently mandated by law or regulation only at the local and state level. Therefore, the list of diseases that are considered notifiable varies slightly by state. Notifiable disease data are useful for analyzing disease trends and determining relative disease burdens. However, these data must be interpreted in light of reporting practices. The degree of completeness of data reporting also is influenced by the diagnostic facilities available, the control measures in effect, public awareness of a specific disease, and the interests, resources, and priorities of state and local officials responsible for disease control and public health surveillance, introduction of new diagnostic tests, or discovery of new disease entities can cause changes in disease reporting that are independent of the true incidence of disease.

Indicator source (project, program, organization, report): Centers for Disease Control and Prevention, Epidemiology Program Office, National Notifiable Disease Surveillance System

Web site: *Morbidity and Mortality Weekly Report*
http://www.cdc.gov/mmwr/;
Summary of Notifiable Diseases
http://www.cdc.gov/epo/dphsi/annsum/

Indicator name: Infant mortality

Indicator type (status or trend): Trend

Indicator category (1 or 2): 1

Associated question: What are the trends for children's environmental health issues?

Spatial coverage: National. Data are for the 50 states and the District of Columbia, unless otherwise specified.

Temporal coverage: 1933 to present; 1999 data displayed

Characterization of supporting data set(s): National Center for Health Statistics (NCHS), through the National Vital Statistics Systems (NVSS), has collected and published data on births, deaths, marriages, and divorces in the United States. Virtually all births and deaths are registered. U.S. Standard Live Birth and Death Certificates are revised periodically. Most state certificates conform closely in content and arrangement to the standard certificate recommended by NCHS and all certificates contain a minimum data set specified by NCHS. The mother provides demographic information on the birth certificate, such as race and ethnicity, at the time of birth. Medical and health information is based on hospital records. Demographic information on the death certificate is provided by the funeral director based on information supplied by an informant. A physician, medical examiner, or coroner provides medical certification of cause of death.

Indicator source (project, program, organization, report): National Center for Health Statistics (NCHS), National Vital Statistics Systems (NVSS)

Web site: http://www.cdc.gov/nchs/nvss.htm

Indicator name: Low birthweight incidence

Indicator type (status or trend): Trend

Indicator category (1 or 2): 1

Associated question: What are the trends for children's environmental health issues?

Spatial coverage: National. Data are for the 50 states and the District of Columbia, unless otherwise specified.

Temporal coverage: 1933 to present; 1991-2000 data displayed.

Characterization of supporting data set(s): National Center for Health Statistics (NCHS), through the National Vital Statistics Systems (NVSS), has collected and published data on births, deaths, marriages, and divorces in the United States. Virtually all births and deaths are registered. U.S. Standard Live Birth and Death Certificates are revised periodically. Most state certificates conform closely in content and arrangement to the standard certificate recommended by NCHS and all certificates contain a minimum data set specified by NCHS. The mother provides demographic information on the birth certificate, such as race and ethnicity, at the time of birth. Medical and health information is based on hospital records. Demographic information on the death certificate is provided by the funeral director based on information supplied by an informant. A physician, medical examiner, or coroner provides medical certification of cause of death.

Indicator source (project, program, organization, report): National Center for Health Statistics (NCHS), National Vital Statistics Systems (NVSS)

Web site: http://www.cdc.gov/nchs/nvss/htm

Indicator name: Childhood cancer mortality

Indicator type (status or trend): Trend

Indicator category (1 or 2): 1

Associated question: What are the trends for children's environmental health issues?

Spatial coverage: National. Data are for the 50 states and the District of Columbia, unless otherwise specified.

Temporal coverage: 1933 to present; 1994-1998 data displayed.

Characterization of supporting data set(s): National Center for Health Statistics (NCHS), through the National Vital Statistics Systems (NVSS), has collected and published data on births, deaths, marriages, and divorces in the United States. Virtually all births and deaths are registered. U.S. Standard Live Birth and Death Certificates are revised periodically. Most state certificates conform closely in content and arrangement to the standard certificate recommended by NCHS and all certificates contain a minimum data set specified by NCHS. The mother provides demographic information on the birth certificate, such as race and ethnicity, at the time of birth. Medical and health information is based on hospital records. Demographic information on the death certificate is provided by the funeral director based on information supplied by an informant. A physician, medical examiner, or coroner provides medical certification of cause of death.

Indicator source (project, program, organization, report): National Center for Health Statistics (NCHS), National Vital Statistics Systems (NVSS)

Web site: http://www.cdc.gov/nchs/nvss.htm

Indicator name: Childhood cancer incidence

Indicator type (status or trend): Trend

Indicator category (1 or 2): 2

Associated question: What are the trends for children's environmental health issues?

Spatial coverage: Eleven Standard Metropolitan Statistical Areas (SMSAs) amounting to fourteen percent of the U.S. population.

Temporal coverage: 1973 to present; 1975-1998 data displayed.

Characterization of supporting data set(s): The Surveillance, Epidemiology, and End Results (SEER) Program of the National Cancer Institute is a source of information on cancer incidence and survival in the United States. The SEER Program began on January 1, 1973. NCI contracts with 11 population-based registries that cover eleven SMSAs (and three supplemental registries) within the United States to provide data on all residents diagnosed with cancer during each year and to provide current followup information on all previously diagnosed patients. The SEER Program covers approximately 14 percent of the U.S. population. The SEER Program is the only comprehensive source of population-based information in the United States that includes stage of cancer at the time of diagnosis and survival rates within each stage.

Indicator source (project, program, organization, report): National Institutes of Health (NIH), NCI, SEER

Web site: http://seer.cancer.gov

Indicator name: Childhood asthma mortality

Indicator type (status or trend): Trend

Indicator category (1 or 2): 1

Associated question: What are the trends for children's environmental health issues?

Spatial coverage: National. Data are for the 50 states and the District of Columbia, unless otherwise specified.

Temporal coverage: 1933 to present

Characterization of supporting data set(s): National Center for Health Statistics (NCHS), through the National Vital Statistics Systems (NVSS), has collected and published data on births, deaths, marriages, and divorces in the United States. Virtually all births and deaths are registered. U.S. Standard Live Birth and Death Certificates are revised periodically. Most state certificates conform closely in content and arrangement to the standard certificate recommended by NCHS and all certificates contain a minimum data set specified by NCHS. The mother provides demographic information on the birth certificate, such as race and ethnicity, at the time of birth. Medical and health information is based on hospital records. Demographic information on the death certificate is provided by the funeral director based on information supplied by an informant. A physician, medical examiner, or coroner provides medical certification of cause of death.

Indicator source (project, program, organization, report): National Center for Health Statistics (NCHS), National Vital Statistics Systems (NVSS)

Web site: http://www.cdc.gov/nchs/nvss.htm

Indicator name: Childhood asthma prevalence

Indicator type (status or trend): Trend

Indicator category (1 or 2): 1

Associated question: What are the trends for children's environmental health issues?

Spatial coverage: National

Temporal coverage: NHIS has been conducted continuously since 1957, the content of the survey has been updated about every 10-15 years. In 1996 a substantially revised NHIS content began field testing. This new questionnaire, described in detail below, began in 1997 and improves the ability of the NHIS to provide important health information. 1980-2001 data displayed.

Characterization of supporting data set(s): The National Health Interview Survey (NHIS) is a continuous nationwide survey in which data are collected through personal household interviews. Self-reported information is obtained on personal and demographic characteristics, illnesses, injuries, impairments, chronic conditions, utilization of health resources, and other health topics. The sample scheduled for each week is representative of the target population, and the weekly samples are additive over time. Response rates for special health topics (supplements) have generally been lower. Because of the extensive redesign of the questionnaire in 1997 and introduction of the computer-assisted personal interviewing (CAPI) method of data collection, data from 1997 and later years may not be comparable with earlier years.

Indicator source (project, program, organization, report): National Center for Health Statistics (NCHS), National Health Interview Survey (NHIS)

Web site: http://www.cdc.gov/nchs/nhis.htm

Indicator name: Deaths due to birth defects

Indicator type (status or trend): Trend

Indicator category (1 or 2): 1

Associated question: What are the trends for children's environmental health issues?

Spatial coverage: National. Data are for the 50 states and the District of Columbia, unless otherwise specified.

Temporal coverage: 1933 to present.

Characterization of supporting data set(s): National Center for Health Statistics (NCHS), through the National Vital Statistics Systems (NVSS), has collected and published data on births, deaths, marriages, and divorces in the United States. Virtually all births and deaths are registered. U.S. Standard Live Birth and Death Certificates are revised periodically. Most state certificates conform closely in content and arrangement to the standard certificate recommended by NCHS and all certificates contain a minimum data set specified by NCHS. The mother provides demographic information on the birth certificate, such as race and ethnicity, at the time of birth. Medical and health information is based on hospital records. Demographic information on the death certificate is provided by the funeral director based on information supplied by an informant. A physician, medical examiner, or coroner provides medical certification of cause of death.

Indicator source (project, program, organization, report): National Center for Health Statistics (NCHS), National Vital Statistics Systems (NVSS)

Web site: http://www.cdc.gov/nchs/nvss.htm

Indicator name: Birth defect incidence

Indicator type (status or trend): Trend

Indicator category (1 or 2): 1

Associated question: What are the trends for children's environmental health issues?

Spatial coverage: National. Data are for the 50 states and the District of Columbia, unless otherwise specified.

Temporal coverage: 1933 to present; 2000 data displayed.

Characterization of supporting data set(s): National Center for Health Statistics (NCHS), through the National Vital Statistics Systems (NVSS), has collected and published data on births, deaths, marriages, and divorces in the United States. Virtually all births and deaths are registered. U.S. Standard Live Birth and Death Certificates are revised periodically. Most state certificates conform closely in content and arrangement to the standard certificate recommended by NCHS and all certificates contain a minimum data set specified by NCHS. The mother provides demographic information on the birth certificate, such as race and ethnicity, at the time of birth. Medical and health information is based on hospital records. Demographic information on the death certificate is provided by the funeral director based on information supplied by an informant. A physician, medical examiner, or coroner provides medical certification of cause of death.

Indicator source (project, program, organization, report): National Center for Health Statistics (NCHS), National Vital Statistics Systems (NVSS)

Web site: http://www.cdc.gov/nchs/nvss.htm

Measuring Exposure to Environmental Pollution: Indicators and Trends

Indicator name: Blood lead level

Indicator type (status or trend): Trend

Indicator category (1 or 2): 1

Associated question: What is the level of exposure to heavy metals?

Spatial coverage: National

Temporal coverage: NHANES 1999-2000

Characterization of supporting data set(s): The National Health and Nutrition Examination Survey (NHANES) is comprised of a series of surveys conducted by the Centers for Disease Control's (CDC) National Center for Health Statistics (NCHS). The survey is designed to collect data on the health of the United States population, including information about many topics, such as nutrition, heart disease, and exposure to chemicals (CDC, 2001). The NHANES surveys have been performed over a number of years. The first survey, NHANES I, took place from 1971 through 1975; NHANES II occurred from 1976-80; NHANES III was performed in 1988 through 1994; and the current NHANES began in 1999 and is ongoing. As part of the survey, blood and urine samples were collected to measure the amounts of certain chemicals thought to be harmful to people. Because of the extensive work involved with laboratory analyses, some chemicals were measured for all people in the survey, while other chemicals were only measured for a small sample of people in an age group. The current NHANES IV measures exposure for 27 chemicals for people in the U.S. In previous NHANES, exposure had been assessed via laboratory analysis for only three chemicals: lead, cadmium and cotinine.

Indicator source (project, program, organization, report): National Health and Nutrition Examination Survey (NHANES), 1999. *The CDC National Report on Human Exposure to Environmental Chemicals* (often referred to as the "CDC Report Card") summarizes chemical exposure data from the 1999 NHANES.

Web site: http://www.cdc.gov/nchs/nhanes.htm

Indicator name: Urine arsenic level

Indicator type (status or trend): Trend

Indicator category (1 or 2): 2

Associated question: What is the level of exposure to heavy metals?

Spatial coverage: NHEXAS-Region 5

Temporal coverage: 1999

Characterization of supporting data set(s): The National Human Exposure Assessment Survey (NHEXAS) was developed by the Office of Research and Development (ORD) of the U.S. Environmental Protection Agency (EPA) early in the 1990s to provide critical information about multipathway, multimedia population exposure distribution to chemical classes. Phase 1 of NHEXAS consisted of demonstration and scoping studies in Maryland, Phoenix, Arizona, and EPA Region 5 using probability- based sampling designs. Although the study was conducted in three different regions of the U.S., it was not designed to be nationally representative. The Region 5 study was conducted in Ohio, Michigan, Illinois, Indiana, Wisconsin, and Minnesota, and measured metals and volatile organic chemicals (VOCs).

Indicator source (project, program, organization, report): 1) NHEXAS-Region 5; 2) National Research Council. Arsenic in Drinking Water. Washington, DC: National Academies Press, 1999.

Web site: *NHEXAS*
http://www.epa.gov/nerl/research/nhexas/nhexas.htm;
NHEXAS data in EPA's Human Exposure Database System
http://www.epa.gov/heds/

Indicator name: Blood mercury level

Indicator type (status or trend): Trend

Indicator category (1 or 2): 1

Associated question: What is the level of exposure to heavy metals?

Spatial coverage: National

Temporal coverage: NHANES, 1999-2000

Characterization of supporting data set(s): The National Health and Nutrition Examination Survey (NHANES) is comprised of a series of surveys conducted by the Centers for Disease Control's (CDC) National Center for Health Statistics (NCHS). The survey is designed to collect data on the health of the United States population, including information about many topics, such as nutrition, heart disease, and exposure to chemicals (CDC, 2001). The NHANES surveys have been performed over a number of years. The first survey, NHANES I, took place from 1971 through 1975; NHANES II occurred from 1976-80; NHANES III was performed in 1988 through 1994; and the current NHANES began in 1999 and is ongoing. As part of the survey, blood and urine samples were collected to measure the amounts of certain chemicals thought to be harmful to people. Because of the extensive work involved with laboratory analyses, some chemicals were measured for all people in the survey, while other chemicals were only measured for a small sample of people in an age group. The current NHANES IV measures exposure for 27 chemicals for people in the U.S. In previous NHANES, exposure had been assessed via laboratory analysis for only three chemicals: lead, cadmium and cotinine.

Indicator source (project, program, organization, report): National Health and Nutrition Examination Survey (NHANES), 1999. *The CDC National Report on Human Exposure to Environmental Chemicals* (often referred to as the "CDC Report Card") summarizes chemical exposure data from the 1999 NHANES.

Web site: http://www.cdc.gov/nchs/nhanes.htm

Indicator name: Blood cadmium level

Indicator type (status or trend): Trend

Indicator category (1 or 2): 1

Associated question: What is the level of exposure to heavy metals?

Spatial coverage: National

Temporal coverage: NHANES, 1999-2000

Characterization of supporting data set(s): The National Health and Nutrition Examination Survey (NHANES) is comprised of a series of surveys conducted by the Centers for Disease Control's (CDC) National Center for Health Statistics (NCHS). The survey is designed to collect data on the health of the United States population, including information about many topics, such as nutrition, heart disease, and exposure to chemicals (CDC, 2001). The NHANES surveys have been performed over a number of years. The first survey, NHANES I, took place from 1971 through 1975; NHANES II occurred from 1976-80; NHANES III was performed in 1988 through 1994; and the current NHANES began in 1999 and is ongoing. As part of the survey, blood and urine samples were collected to measure the amounts of certain chemicals thought to be harmful to people. Because of the extensive work involved with laboratory analyses, some chemicals were measured for all people in the survey, while other chemicals were only measured for a small sample of people in an age group. The current NHANES IV measures exposure for 27 chemicals for people in the U.S. In previous NHANES, exposure had been assessed via laboratory analysis for only three chemicals: lead, cadmium and cotinine.

Indicator source (project, program, organization, report): National Health and Nutrition Examination Survey (NHANES), 1999. *The CDC National Report on Human Exposure to Environmental Chemicals* (often referred to as the "CDC Report Card") summarizes chemical exposure data from the 1999 NHANES.

Web site: http://www.cdc.gov/nchs/nhanes.htm

Indicator name: Blood cotinine level

Indicator type (status or trend): Trend

Indicator category (1 or 2): 1

Associated question: What is the level of exposure to cotinine?

Spatial coverage: National

Temporal coverage: NHANES, 1999-2000

Characterization of supporting data set(s): The National Health and Nutrition Examination Survey (NHANES) is comprised of a series of surveys conducted by the Centers for Disease Control's (CDC) National Center for Health Statistics (NCHS). The survey is designed to collect data on the health of the United States population, including information about many topics, such as nutrition, heart disease, and exposure to chemicals (CDC, 2001). The NHANES surveys have been performed over a number of years. The first survey, NHANES I, took place from 1971 through 1975; NHANES II occurred from 1976-80; NHANES III was performed in 1988 through 1994; and the current NHANES began in 1999 and is ongoing. As part of the survey, blood and urine samples were collected to measure the amounts of certain chemicals thought to be harmful to people. Because of the extensive work involved with laboratory analyses, some chemicals were measured for all people in the survey, while other chemicals were only measured for a small sample of people in an age group. The current NHANES IV measures exposure for 27 chemicals for people in the U.S. In previous NHANES, exposure had been assessed via laboratory analysis for only three chemicals: lead, cadmium and cotinine.

Indicator source (project, program, organization, report): National Health and Nutrition Examination Survey (NHANES)

Web site: http://www.cdc.gov/nchs/nhanes.htm

Indicator name: Blood volatile organic compound levels

Indicator type (status or trend):

Indicator category (1 or 2): 1

Associated question: What is the level of exposure to volatile organic compounds?

Spatial coverage: National

Temporal coverage: NHANES III (1988-1994)

Characterization of supporting data set(s): The National Health and Nutrition Examination Survey (NHANES) is comprised of a series of surveys conducted by the Centers for Disease Control's (CDC) National Center for Health Statistics (NCHS). The survey is designed to collect data on the health of the United States population, including information about many topics, such as nutrition, heart disease, and exposure to chemicals (CDC, 2001). The NHANES surveys have been performed over a number of years. The first survey, NHANES I, took place from 1971 through 1975; NHANES II occurred from 1976-80; NHANES III was performed in

1988 through 1994; and the current NHANES began in 1999 and is ongoing. As part of the survey, blood and urine samples were collected to measure the amounts of certain chemicals thought to be harmful to people. Because of the extensive work involved with laboratory analyses, some chemicals were measured for all people in the survey, while other chemicals were only measured for a small sample of people in an age group. The current NHANES IV measures exposure for 27 chemicals for people in the U.S. In previous NHANES, exposure had been assessed via laboratory analysis for only three chemicals: lead, cadmium and cotinine.

Indicator source (project, program, organization, report): National Health and Nutrition Examination Survey (NHANES), 1999. *The CDC National Report on Human Exposure to Environmental Chemicals* (often referred to as the "CDC Report Card") summarizes chemical exposure data from the 1999 NHANES.

Web site: http://www.cdc.gov/nchs/nhanes.htm

Indicator name: Urine organophosphate levels to indicate pesticides

Indicator type (status or trend): Trend

Indicator category (1 or 2): 1

Associated question: What is the level of exposure to pesticides?

Spatial coverage: National

Temporal coverage: NHANES, 1999-2000

Characterization of supporting data set(s): The National Health and Nutrition Examination Survey (NHANES) is comprised of a series of surveys conducted by the Centers for Disease Control's (CDC) National Center for Health Statistics (NCHS). The survey is designed to collect data on the health of the United States population, including information about many topics, such as nutrition, heart disease, and exposure to chemicals (CDC, 2001). The NHANES surveys have been performed over a number of years. The first survey, NHANES I, took place from 1971 through 1975; NHANES II occurred from 1976-80; NHANES III was performed in 1988 through 1994; and the current NHANES began in 1999 and is ongoing. As part of the survey, blood and urine samples were collected to measure the amounts of certain chemicals thought to be harmful to people. Because of the extensive work involved with laboratory analyses, some chemicals were measured for all people in the survey, while other chemicals were only measured for a small sample of people in an age group. The current NHANES IV measures exposure for 27 chemicals for people in the U.S. In previous NHANES, exposure had been assessed via laboratory analysis for only three chemicals: lead, cadmium and cotinine.

Indicator source (project, program, organization, report): National Health and Nutrition Examination Survey (NHANES), 1999. *The CDC National Report on Human Exposure to Environmental Chemicals* (often referred to as the "CDC Report Card") summarizes chemical exposure data from the 1999 NHANES.

Web site: http://www.cdc.gov/nchs/nhanes.htm

Indicator name: Blood lead level in children

Indicator type (status or trend): Trend

Indicator category (1 or 2): 1

Associated question: What are the trends in exposure to environmental contaminants for children?

Spatial coverage: National

Temporal coverage: NHANES, 1999-2000

Characterization of supporting data set(s): The National Health and Nutrition Examination Survey (NHANES) is comprised of a series of surveys conducted by the Centers for Disease Control's (CDC) National Center for Health Statistics (NCHS). The survey is designed to collect data on the health of the United States population, including information about many topics, such as nutrition, heart disease, and exposure to chemicals (CDC, 2001). The NHANES surveys have been performed over a number of years. The first survey, NHANES I, took place from 1971 through 1975; NHANES II occurred from 1976-80; NHANES III was performed in 1988 through 1994; and the current NHANES began in 1999 and is ongoing. As part of the survey, blood and urine samples were collected to measure the amounts of certain chemicals thought to be harmful to people. Because of the extensive work involved with laboratory analyses, some chemicals were measured for all people in the survey, while other chemicals were only measured for a small sample of people in an age group. The current NHANES IV measures exposure for 27 chemicals for people in the U.S. In previous NHANES, exposure had been assessed via laboratory analysis for only three chemicals: lead, cadmium and cotinine.

Indicator source (project, program, organization, report): National Health and Nutrition Examination Survey (NHANES), 1999. *The CDC National Report on Human Exposure to Environmental Chemicals* (often referred to as the "CDC Report Card") summarizes chemical exposure data from the 1999 NHANES.

Web site: http://www.cdc.gov/nchs/nhanes.htm

Indicator name: Blood mercury level in children

Indicator type (status or trend): Trend

Indicator category (1 or 2): 1

Associated question: What are the trends in exposure to environmental contaminants for children?

Spatial coverage: National

Temporal coverage: NHANES, 1999-2000

Characterization of supporting data set(s): The National Health and Nutrition Examination Survey (NHANES) is comprised of a series of surveys conducted by the Centers for Disease Control's (CDC) National Center for Health Statistics (NCHS). The survey is designed to collect data on the health of the United States population, including information about many topics, such as nutrition, heart disease, and exposure to chemicals (CDC, 2001). The NHANES surveys have been performed over a number of years. The first survey, NHANES I, took place from 1971 through 1975; NHANES II occurred from 1976-80; NHANES III was performed in 1988 through 1994; and the current NHANES began in 1999 and is ongoing. As part of the survey, blood and urine samples were collected to measure the amounts of certain chemicals thought to be harmful to people. Because of the extensive work involved with laboratory analyses, some chemicals were measured for all people in the survey, while other chemicals were only measured for a small sample of people in an age group. The current NHANES IV measures exposure for 27 chemicals for people in the U.S. In previous NHANES, exposure had been assessed via laboratory analysis for only three chemicals: lead, cadmium and cotinine.

Indicator source (project, program, organization, report): National Health and Nutrition Examination Survey (NHANES), 1999. *The CDC National Report on Human Exposure to Environmental Chemicals* (often referred to as the "CDC Report Card") summarizes chemical exposure data from the 1999 NHANES.

Web site: http://www.cdc.gov/nchs/nhanes.htm

Indicator name: Blood cotinine level in children

Indicator type (status or trend): Trend

Indicator category (1 or 2): 1

Associated question: What are the trends in exposure to environmental contaminants for children?

Spatial coverage: National

Temporal coverage: NHANES, 1999-2000

Characterization of supporting data set(s): 1) The National Health and Nutrition Examination Survey (NHANES) is comprised of a series of surveys conducted by the Centers for Disease Control's (CDC) National Center for Health Statistics (NCHS). The survey is designed to collect data on the health of the United States population, including information about many topics, such as nutrition, heart disease, and exposure to chemicals (CDC, 2001). The NHANES surveys have been performed over a number of years. The first survey, NHANES I, took place from 1971 through 1975; NHANES II occurred from 1976-80; NHANES III was performed in 1988 through 1994; and the current NHANES began in 1999 and is ongoing. As part of the survey, blood and urine samples were collected to measure the amounts of certain chemicals thought to be harmful to people. Because of the extensive work involved with laboratory analyses, some chemicals were measured for all people in the survey, while other chemicals were only measured for a small sample of people in an age group. The current NHANES IV measures exposure for 27 chemicals for people in the U.S. In previous NHANES, exposure had been assessed via laboratory analysis for only three chemicals: lead, cadmium and cotinine.

Indicator source (project, program, organization, report): National Health and Nutrition Examination Survey (NHANES)

Web site: http://www.cdc.gov/nchs/nhanes.htm

Chapter 5: Ecological Condition

Forests

Indicator name: Extent of area by forest type

Indicator type (status or trend): Status

Indicator Category: 1

Associated question: What is the ecological condition of forests?

Spatial coverage: Lower 48 states

Temporal coverage: 1963-1997. Data from late 1940s to present. Data since 1953 provided with a reliability of ± 3-10 percent per 1 million acres (67 percent confidence limit). FIA provides updates of assessment data every five years.

Characterization of supporting data set(s): The USDA Forest Service Forest Inventory and Analysis (FIA) program is a survey-based program that has operated since the late 1940s, collecting information on a variety of forest characteristics. FIA has used a two-phase sample (generally, double sampling for stratification) to collect information on the nation's forests. Phase one establishes a large number of samples (more than 4 million, roughly every 0.6 miles). These are selected using aerial photographs or other remote-sensing images, which are then interpreted for various forest attributes. Phase two establishes a subset of approximately 450,000 phase-one points (roughly every 3 miles) for ground sampling. About 125,000 of these samples are permanently established on forest land. The forest characteristics measured include ownership, protection status, species composition, stand age and structure, tree growth, occurrences of mortality and removals, tree biomass, incidences of pathogens, natural and human-caused disturbances, and soil descriptors (The Heinz Center, 2002).

Indicator derivation (project, program, organization, report): Smith, W.B., J.S. Vissage, D.R. Darr, and R.M. Sheffield. *Forest Statistics of the United States, 1997*, General Technical Report NC-219. St. Paul, MN: U.S. Department of Agriculture Forest Service, North Central Research Station, 2001. Presented in *The State of the Nation's Ecosystems*, pages 118 and 240 (The Heinz Center, 2002).

Web site: http://fia.fs.fed.us

Indicator name: Forest age class

Indicator type (status or trend): Status

Indicator Category: 2

Associated question: What is the ecological condition of forests?

Spatial coverage: National, all 50 states

Temporal coverage: 1997. Data from late 1940s to present. Data since 1953 provided with a reliability of ± 3-10 percent per 1 million acres (67 percent confidence limit). FIA provides updates of assessment data every five years.

Characterization of supporting data set(s): The USDA Forest Service Forest Inventory and Analysis (FIA) program is a survey-based program that has operated since the late 1940s, collecting information on a variety of forest characteristics. FIA has used a two-phase sample (generally, double sampling for stratification) to collect information on the nation's forests. Phase one establishes a large number of samples (more than 4 million, roughly every 0.6 miles). These are selected using aerial photographs or other remote-sensing images, which are then interpreted for various forest attributes. Phase two establishes a subset of approximately 450,000 phase-one points (roughly every 3 miles) for ground sampling. About 125,000 of these samples are permanently established on forest land. The forest characteristics measured include ownership, protection status, species composition, stand age and structure, tree growth, occurrences of mortality and removals, tree biomass, incidences of pathogens, natural and human-caused disturbances, and soil descriptors (The Heinz Center, 2002).

Indicator derivation (project, program, organization, report): Smith, W.B., J. Vissage, D. Darr, and R. Sheffield. *Forest Statistics of the United States, 1997*. U.S. Department of Agriculture, U.S. Forest Service, General Technical Report NC-219. St. Paul, MN: USDA, Forest Service. 2001. Presented in *The State of the Nation's Ecosystems*, pages 126 and 242 (The Heinz Center, 2002).

Web site: http://fia.fs.fed.us

Indicator name: Forest pattern and fragmentation

Indicator type (status or trend): Status

Indicator Category: 2

Associated question: What is the ecological condition of forests?

Spatial coverage: Lower 48 states

Temporal coverage: 1992 satellite imagery and data from late 1940s to present. Data since 1953 provided with a reliability of ± 3-10 percent per 1 million acres (67 percent confidence limit). FIA provides updates of assessment data every five years.

Characterization of supporting data set(s): 1) The Multi-Resolution Land Characterization (MRLC) Consortium's National Land Cover Dataset (NLCD) provides a consistent, uniform, spatially explicit description of general land cover/land use across the continental U.S. at a 30-meter resolution. It does not contain habitat types. 2) The USDA Forest Service Forest Inventory and Analysis (FIA) program is a survey-based program that has operated since the late 1940s, collecting information on a variety of forest characteristics. FIA has used a two-phase sample (generally, double sampling for stratification) to collect information on the nation's forests. Phase one establishes a large number of samples (more than 4 million, roughly every 0.6 miles). These are selected using aerial photographs or other remote-sensing images, which are then interpreted for various forest attributes. Phase two establishes a subset of approximately 450,000 phase-one points (roughly every 3 miles) for ground sampling. About 125,000 of these samples are permanently established on forest land. The forest characteristics measured include ownership, protection status, species composition, stand age and structure, tree growth, occurrences of mortality and removals, tree biomass, incidences of pathogens, natural and human-caused disturbances, and soil descriptors (The Heinz Center, 2002).

Indicator derivation (project, program, organization, report): 1)Multi-Resolution Land Characterization Consortium (MRLC) - National Land Cover Data (NLCD); 2) Conkling, B., J. Coulston, and M. Ambrose (eds.). *Forest Health Monitoring National Technical Report 1991-1999*, Asheville, NC: U.S. Department of Agriculture Forest Service, Southern Research Station, 2002; 3) Riiters, K.H., J.D. Wickham, R.V. O'Neill, K.B. Jones, E.R. Smith, J.W. Coulston, T.G. Wade, and J.H. Smith. Fragmentation of Continental United States Forests. *Ecosystems* 5: 815-822 (2002). Presented in *The State of the Nation's Ecosystems*, pages 120-121 and 240 (The Heinz Center, 2002).

Web sites: *MRLC* http://www.epa.gov/mrlc/;
NLCD http://www.epa.gov/mrlc/nlcd.html;
Riitters, et al. material http://www.srs.fs.usda.gov/4803/landscapes/

Indicator name: At-risk native forest species

Indicator type (status or trend): Status

Indicator Category: 2

Associated question: What is the ecological condition of forests?

Spatial coverage: Natural Heritage programs in all 50 states.

Temporal coverage: 2000. Data managed consistently since 1974.

Characterization of supporting data set(s): NatureServe is an independent nonprofit organization whose research biologists gather, review, integrate, and record available information about species taxonomy, status, and use of different habitats or ecological system types. They are assisted in this work by scientists in the network of Natural Heritage programs as well as by contracted experts for different invertebrate taxa. NatureServe staff and collaborators assign a conservation status by using standard Heritage ranking criteria. The Heritage ranking process considers five major status ranks: critically imperiled (G1), imperiled (G2), vulnerable (G3), apparently secure (G4), and demonstrably widespread, abundant, and secure (G5). In addition, separate ranks are assigned for species regarded as presumed extinct (GX) or possibly extinct (GH).

Indicator derivation (project, program, organization, report): NatureServe and its member programs in the network of Natural Heritage programs develop and maintain information on species at risk. Presented in *The State of the Nation's Ecosystems*, pages 124 and 214 (The Heinz Center, 2002).

Web site: http://www.natureserve.org

Indicator name: Populations of representative forest species

Indicator type (status or trend): Status and Trend

Indicator Category: 2

Associated question: What is the ecological condition of forests?

Spatial coverage: National data for birds, 37 states for trees

Temporal coverage: 1970-2002. FIA data date from late 1940s to present. Data since 1953 provided with a reliability of ± 3-10 percent per 1 million acres (67 percent confidence limit). FIA provides updates of assessment data every five years. BBS was initiated in 1966.

Characterization of supporting data set(s): 1) *The North American Breeding Bird Survey (BBS)* is a long-term, large-scale international avian monitoring program intended to track the status and trends of North American bird populations. Today there are approximately 3700 active BBS routes across the continental U.S. and Canada of which 2900 are surveyed each year (Sauer, et al., 2001). 2) The USDA Forest Service Forest Inventory and Analysis (FIA) program is a survey-based program that has operated since the late 1940s, collecting information on a variety of forest characteristics. FIA has used a two-phase sample (generally, double sampling for stratification) to collect information on the nation's forests. Phase one establishes a large number of samples (more than 4 million, roughly every 0.6 miles). These are selected using aerial photographs or other remote-sensing images, which are then interpreted for various forest attributes. Phase two establishes a subset of approximately 450,000 phase-one points (roughly every 3 miles) for ground sampling. About 125,000 of these samples are permanently established on forest land. The forest characteristics measured include ownership, protection status, species composition, stand age and structure, tree growth, occurrences of mortality and removals, tree biomass, incidences of pathogens, natural and human-caused disturbances, and soil descriptors (The Heinz Center, 2002).

Indicator derivation (project, program, organization, report): Bird data are from the U.S. Geological Survey's *North American Breeding Bird Survey (BBS)*, and tree data are from the U.S. Forest Service, Draft Resource Planning and Assessment Tables, August 2002. Reported in U.S. Department of Agriculture. *National Report on Sustainable Forests - 2003, Final Draft*, Washington, DC: U.S. Department of Agriculture, Forest Service, 2002. This indicator was based on the final review draft of the Sustainable Forests report (USDA, FS, 2002) and the website for corresponding technical support material is provided below. The final version of the report and supporting technical material will be found at http://www.fs.fed.us/research/sustain/.

Web site: *Sustainable Forests Report* http://www.fs.fed.us/research/sustain/data.htm (Indicator 9); *RPA tables* http://www.ncrs.fs.fed.us/4801/FIADB/rpa_tabler/Draft_RPA_2002_Forest_Resource_Tables.pdf; *BBS* http://www.mp2-pwrc.usgs.gov/bbs/

Indicator name: Forest disturbance: fire, insects, and disease

Indicator type (status or trend): Trend

Indicator Category: 1

Associated question: What is the ecological condition of forests?

Spatial coverage: National, all 50 states

Temporal coverage: 1979-2000. FIA data date from late 1940s to present. Data since 1953 provided with a reliability of ± 3-10 percent per 1 million acres (67 percent confidence limit). FIA provides updates of assessment data every five years.

Characterization of supporting data set(s): The USDA Forest Service Forest Inventory and Analysis (FIA) program is a survey-based program that has operated since the late 1940s, collecting information on a variety of forest characteristics. FIA has used a two-phase sample (generally, double sampling for stratification) to collect information on the nation's forests. Phase one establishes a large number of samples (more than 4 million, roughly every 0.6 miles). These are selected using aerial photographs or other remote-sensing images, which are then interpreted for various forest attributes. Phase two establishes a subset of approximately 450,000 phase-one points (roughly every 3 miles) for ground sampling. About 125,000 of these samples are permanently established on forest land. The forest characteristics measured include ownership, protection status, species composition, stand age and structure, tree growth, occurrences of mortality and removals, tree biomass, incidences of pathogens, natural and human-caused disturbances, and soil descriptors (The Heinz Center, 2002). Data on insects and disease are based on a probability sample that represents unbiased estimates of both public and private forests in the U.S.

Indicator derivation (project, program, organization, report): Data on fires are from 1) U.S. General Accounting Office. *Western National Forests: Nearby Communities Are Increasingly Threatened by Catastrophic Wildfires*, GAO/T-RCED-99-79. Washington, DC: U.S. General Accounting Office, 1999 and 2) National Interagency Fire Center. Wildland Fire Statistics. 2002. (May 2003; http://www.nifc.gov/stats/wildlandfirestats.html).; data on insects and disease are from Conkling, B., J. Coulston, and M. Ambrose (eds.). *Forest Health Monitoring National Technical Report 1991-1999*, Asheville, NC: U.S. Department of Agriculture Forest Service, Southern Research Station, 2002. Presented in *The State of the Nation's Ecosystems*, pages 127 and 242 (The Heinz Center, 2002).

Web site: *FHM* http://www.na.fs.fed.us/spfo/fhm/index.htm; *NIFC* http://www.nifc.gov/stats/wildlandfirestats.html

Indicator name: Tree condition

Indicator type (status or trend): Status

Indicator Category: 2

Associated question: What is the ecological condition of forests?

Spatial coverage: 32 states; more than half of the South and Rocky Mountain regions had insufficient or no data.

Temporal coverage: 1990-1999

Characterization of supporting data set(s): Available national data relates almost exclusively to trees, not the entire suite of forest biota. Three metrics are used to determine tree condition: tree mortality, tree crown condition, and fire condition class. National scale data is lacking on many components of forest ecosystems. Available data coverages are incomplete. Fundamental research linking biological components to ecological processes is lacking (USFS, FS, 2002).

Indicator derivation (project, program, organization, report): 1) Conkling, B., J. Coulston and M. Ambrose (eds). *Forest Health Monitoring National Technical Report, 1991-1999*. Asheville, NC: USDA Forest Service, Forest Health Monitoring (FHM) Program, Southern Research Station. 2002; 2) U.S. Department of Agriculture. *National Report on Sustainable Forests - 2003, Final Draft*, Washington, DC: U.S. Department of Agriculture, Forest Service, 2002. This indicator was based on the final review draft of the Sustainable Forests report (USDA, FS, 2002) and the website for corresponding technical support material is provided below. The final version of the report and supporting technical material will be found at http://www.fs.fed.us/research/sustain/.

Web site: *FHM* http://www.na.fs.fed.us/spfo/fhm/index.htm; *Sustainable Forest Report* http://www.fs.fed.us/ research/sustain/data.htm (Indicator 17)

Indicator name: Ozone injury to trees

Indicator type (status or trend): Status

Indicator Category: 2

Associated question: What is the ecological condition of forests?

Spatial coverage: 32 states

Temporal coverage: 1994-2000

Characterization of supporting data set(s): The USDA Forest Service Forest Health Monitoring (FHM) Program collects information about ozone air quality on a network of biomonitoring plots using ozone sensitive bioindicator plants (trees, woody shrubs, and non-woody herb species). In 2000, there were 918 biomonitoring sites in 32 states.

Indicator derivation (project, program, organization, report): 1) Conkling, B., J. Coulston, and M. Ambrose (eds.). *Forest Health Monitoring National Technical Report 1991-1999*, Asheville, NC: U.S. Department of Agriculture Forest Service, Southern Research Station, 2002; 2) U.S. Department of Agriculture. *National Report on Sustainable Forests - 2003, Final Draft*, Washington, DC: U.S. Department of Agriculture, Forest Service, 2002. This indicator was based on the final review draft of the Sustainable Forests report (USDA, FS, 2002) and the website for corresponding technical support material is provided below. The final version of the report and supporting technical material will be found at http://www.fs.fed.us/research/sustain/.

Web site: *Sustainable Forest Report*
http://www.fs.fed.us/research/sustain/data.htm (Indicator 16);
FHM http://www.na.fs.fed.us/spfo/fhm/index.htm

Indicator name: Carbon storage

Indicator type (status or trend): Trend

Indicator Category: 2

Associated question: What is the ecological condition of forests?

Spatial coverage: National. Data for Alaska and Hawaii are not included in this data series.

Temporal coverage: 1953-1996. Volume, area, and other forest characteristics are compiled in Smith, et al., 2001 for the years 1953, 1963, 1977, 1987, and 1997. The inventory years begin on the first calendar day of each year. More detailed data are available in databases for 1997 (USDA, FS, 2002).

Characterization of supporting data set(s): All carbon pools, with the exception of soil carbon, are estimated using USDA Forest Service Forest Inventory and Analysis (FIA) measured data or imputed data, along with inventory-to-carbon relationships, developed with information from ecological studies (USDA, 2003). Carbon storage is estimated by the FIA program using on-the ground measurements of tree trunk size from many forest sites and statistical models that show the relationship between trunk size and the weight of branches, leaves, coarse roots (>0.1 inch in diameter), and forest floor litter. Such data are combined with estimates of forest land area obtained from aerial photographs and satellite imagery. Forest floor litter includes all dead organic matter above the mineral soil horizons, including litter, humus, small twigs, and coarse woody debris (branches and logs greater than 1.0 inches in diameter lying on the forest floor). Note that there are 1.1 English tons per metric ton. In most international discussions, carbon storage is reported in metric tons.

Indicator derivation (project, program, organization, report): 1) Smith, W.B., J.S. Vissage, D.R. Darr, and R.M. Sheffield. *Forest Statistics of the United States, 1997*, General Technical Report NC-219. St. Paul, MN: U.S. Department of Agriculture Forest Service, North Central Research Station, 2001. 2) U.S. Department of Agriculture. *National Report on Sustainable Forests - 2003, Final Draft*, Washington, DC: U.S. Department of Agriculture, Forest Service, 2002. This indicator was based on the final review draft of the Sustainable Forests report (USDA, FS, 2002) and the website for corresponding technical support material is provided below. The final version of the report and supporting technical material will be found at http://www.fs.fed.us/research/sustain/.

Web site: *FIA* http://fia.fs.fed.us;
Sustainable Forests Report
http://www.fs.fed.us/research/sustain/data.htm (primarily Indicator 27 with reference to Indicators 26 and 28)

Indicator name: Soil compaction

Indicator type (status or trend): Status

Indicator Category: 2

Associated question: What is the ecological condition of forests?

Spatial coverage: 37 states (mostly east of the Mississippi, Rocky Mountains and Pacific Coast); STATSGO data are available for the conterminous U.S., Alaska, Hawaii, and Puerto Rico.

Temporal coverage: 1998-2000

Characterization of supporting data set(s):
1) Forest Health Monitoring (FHM) Program data collected on a representative sample of 2006 plots, a subset of the Forest Inventory Analysis (FIA) plot network (USDA, FS, 2003). The FIA soil indicator program is in the implementation phase and plots have not yet been established in all states. Analysis from the program is limited in scope. Data used for this indicator are based on visual inspection and state soil maps. No measurements were made regarding the intensity of compaction and physical disturbances that are not readily visible from the surface may be underreported. Compaction data from FIA/FHM are intended only to provide a "presence/absence" index of the occurrence of disturbed soils across the landscape (USDA, FS, 2003). 2) State Soil Geographic Database (STATSGO) consists of state general soil maps made by generalizing the detailed soil survey data. The level of mapping is designed to be used for broad planning and management uses covering state, regional, and multi-state areas. STATSGO data are designed for use in a Geographic Information System (GIS). The mapping scale for STATSGO map is 1:250,000 (with the exception of Alaska, which is 1:1,000,000). Each STATSGO map is linked to the Soil Interpretations Record (SIR) attribute data base. The attribute data base gives the proportionate extent of the component soils and their properties for each map unit. The STATSGO map units consist of 1 to 21 components each. The Soil Interpretations Record data base includes over 25 physical and chemical soil properties, interpretations, and productivity. Examples of information that can be queried from the data base are available water capacity, soil reaction, salinity, flooding, water table, bedrock, and interpretations for engineering uses, cropland, woodland, rangeland, pastureland, wildlife, and recreation development.

Indicator derivation (project, program, organization, report): 1) U.S. Department of Agriculture. *National Report on Sustainable Forests - 2003*, Washington, DC: U.S. Department of Agriculture, Forest Service, Forthcoming, 2003. This indicator was based on finalized portions of the forthcoming report referenced above that were provided to EPA for this report. The report, including technical support material for this indicator can be found at the website listed below. 2) STATSGO.

Web site: *Sustainable Forests Report* http://www.fs.fed.us/research/sustain/; *STATSGO* http://www.ftw.nrcs.usda.gov/stat_data.html

Indicator name: Soil erosion

Indicator type (status or trend): Status

Indicator Category: 2

Associated question: What is the ecological condition of forests?

Spatial coverage: 37 states (mostly east of the Mississippi, Rocky Mountains and Pacific Coast); STATSGO data are available for the conterminous U.S., Alaska, Hawaii, and Puerto Rico.

Temporal coverage: 1998-2000

Characterization of supporting data set(s): 1) Forest Health Monitoring (FHM) Program measured erosion rates on plots and modeled the data using the Water Erosion Prediction Project (WEPP). Erosion estimates are limited by model assumptions and aggregate estimates of soil erosion often have little meaning in and of themselves due to natural variability in soil erosion (USDA, FS, 2003). 2) State Soil Geographic Database (STATSGO) consists of state general soil maps made by generalizing the detailed soil survey data. The level of mapping is designed to be used for broad planning and management uses covering state, regional, and multi-state areas. STATSGO data are designed for use in a Geographic Information System (GIS). The mapping scale for STATSGO map is 1:250,000 (with the exception of Alaska, which is 1:1,000,000). Each STATSGO map is linked to the Soil Interpretations Record (SIR) attribute data base. The attribute data base gives the proportionate extent of the component soils and their properties for each map unit. The STATSGO map units consist of 1 to 21 components each. The Soil Interpretations Record data base includes over 25 physical and chemical soil properties, interpretations, and productivity. Examples of information that can be queried from the data base are available water capacity, soil reaction, salinity, flooding, water table, bedrock, and interpretations for engineering uses, cropland, woodland, rangeland, pastureland, wildlife, and recreation development.

Indicator derivation (project, program, organization, report): U.S. Department of Agriculture. *National Report on Sustainable Forests - 2003*, Washington, DC: U.S. Department of Agriculture, Forest Service, Forthcoming, 2003. This indicator was based on finalized portions of the forthcoming report referenced above that were provided to EPA for this report. The report, including technical support material for this indicator can be found at the website listed below. 2) STATSGO.

Web site: Sustainable Forests Report—http://www.fs.fed.us/research/sustain/; STATSGO—http://www.ftw.nrcs.usda.gov/stat_data.html

Indicator name: Processes beyond the range of historic variation

Indicator type (status or trend): Trend

Indicator category (1 or 2): 2

Associated question: What is the ecological condition of forests?

Spatial coverage: National

Temporal coverage: Effects during 1800-1850 (historic or baseline time period) were compared with the 1996-2000 (current time period) and beyond the range of recent variation (using data from the past 20-80 years) the effects of the recent past, e.g. 1979-1995, were compared with those during the current time period (USDA, FS, 2002).

Characterization of supporting data set(s): Primarily anecdotal data.

Indicator source (project, program, organization, report): U.S. Department of Agriculture. *National Report on Sustainable Forests - 2003, Final Draft*, Washington, DC: U.S. Department of Agriculture, Forest Service, 2002. This indicator was based on the final review draft of the Sustainable Forests report (USDA, FS, 2002) and the website for corresponding technical support material is provided below. The final version of the report and supporting technical material will be found at http://www.fs.fed.us/research/sustain/.

Web site: Sustainable Forests Report—http://www.fs.fed.us/research/sustain/data.htm (Indicator 15)

Farmlands

Indicator name: Pesticide leaching potential

Indicator type (status or trend): Status

Indicator category (1 or 2): 2

Associated question: What is the ecological condition of farmlands?

Spatial coverage: Agricultural lands covering 5.5 million hectares in six mid-Atlantic states

Temporal coverage: 1994 and 1995

Characterization of supporting data set(s): EPA's Environmental Monitoring and Assessment Program (EMAP) used the National Agricultural Statistics Service (NASS) probability area sampling frame in the Mid-Atlantic region to select 122 sites in 1994 and 152 sites in 1995. The sites were sampled during the NASS Fall Survey. Soil samples and questionnaire data were collected from a random sample of 293 sites. Indicators addressed productivity, management at the agroecosystem scale, and management for the landscape scale on annual crop land. Crop yields were almost 30% higher than those of the 1980s, with a mean observed to expected yield index of 1.27. The mean soil quality index showed moderate quality for supporting plant growth. Non-tilled sites, which were mostly hay, had greater microbial biomass than tilled sites. Just over half of the annual crop land was covered by rotation plans; hay fields accounted for most of the land where one crop was grown continuously. Hay showed a lower use of applied nitrogen than seed crops. Integrated pest management was practiced on less than 20% of annual crop land. Twenty-seven different annual crops were grown in the region, with hay (all types) the dominant crop. Less than 20% of the land where pesticides were applied had high to moderately high potential for pesticides leaching into groundwater. This information provides a baseline for long-term monitoring of agricultural lands in the region (Hellkamp, et al. 2000).

Indicator source (project, program, organization, report): Hellkamp, A.S., J.M. Bay, C.L. Campbell, K.N. Easterling, D.A. Fiscus, G.R. Hess, B.F. McQuaid, M.J. Munster, G.L. Olson, S.L. Peck, S.R. Shafer, K. Sidik, and M.B. Tooley. Assessment of the condition of agricultural lands in six mid-Atlantic states. *Journal of Environmental Quality* 29: 79-804 (2000).

Web site: Paper abstract—
http://oaspub.epa.gov/emap/bib.print_abstract?pub_id_in=1284

Indicator name: Soil quality index

Indicator type (status or trend): Status

Indicator category (1 or 2): 2

Associated question: What is the ecological condition of farmlands?

Spatial coverage: Mid-Atlantic states

Temporal coverage: 1994-1995

Characterization of supporting data set(s): EPA's Environmental Monitoring and Assessment Program (EMAP) used the National Agricultural Statistics Service (NASS) probability area sampling frame in the Mid-Atlantic region to select 122 sites in 1994 and 152 sites in 1995. The sites were sampled during the NASS Fall Survey. Soil samples and questionnaire data were collected from a random sample of 293 sites. Indicators addressed productivity, management at the agroecosystem scale, and management for the landscape scale on annual crop land. Crop yields were almost 30% higher than those of the 1980s, with a mean observed to expected yield index of 1.27. The mean soil quality index showed moderate quality for supporting plant growth. Non-tilled sites, which were mostly hay, had greater microbial biomass than tilled sites. Just over half of the annual crop land was covered by rotation plans; hay fields accounted for most of the land where one crop was grown continuously. Hay showed a lower use of applied nitrogen than seed crops. Integrated pest management was practiced on less than 20% of annual crop land. Twenty-seven different annual crops were grown in the region, with hay (all types) the dominant crop. Less than 20% of the land where pesticides were applied had high to moderately high potential for pesticides leaching into groundwater. This information provides a baseline for long-term monitoring of agricultural lands in the region (Hellkamp, et al. 2000).

Indicator source (project, program, organization, report): Data are available from the EPA Mid- Atlantic Integrated Assessment (MAIA) initiative and the index is described in Hellkamp, A.S., J.M. Bay, C.L. Campbell, K.N. Easterling, D.A. Fiscus, G.R. Hess, B.F. McQuaid, M.J. Munster, G.L. Olson, S.L. Peck, S.R. Shafer, K. Sidik, and M.B. Tooley. Assessment of the condition of agricultural lands in six mid-Atlantic states. *Journal of Environmental Quality* 29: 79-804 (2000).

Web site: *Paper abstract*
http://oaspub.epa.gov/emap/bib.print_abstract?pub_id_in=1284

Indicator name: Soil erosion

Indicator type (status or trend): Status

Indicator category: 2

Associated question: What is the ecological condition of farmlands?

Spatial coverage: National

Temporal coverage: At each Natural Resources Inventory (NRI) sample point, information is available for 1982, 1987, 1992, and 1997 so that trends and changes in land use and resource characteristics over 15 years can be examined and analyzed.

Characterization of supporting data set(s): 1) The NRI is a statistical sampling of over 800,000 locations to collect data on land cover and use, soil erosion, prime farmland soils, wetlands, habitat diversity, conservation practices, and related resource attributes on non-federal land in the U.S. 2) Soil erosion estimates were calculated using the USGS watersheds, NRI soils data, and the Universal Soil Loss Equation (Renard et al., 1997) and the Wind Erosion Equation (Bondy et al., 1980; Skidmore and Woodruff, 1968). 3) Soil parameters were obtained from the USDA Natural Resources Conservation Service (NRCS) soils database. The State Soil Geographic Database (STATSGO) consists of state general soil maps made by generalizing the detailed soil survey data. The level of mapping is designed to be used for broad planning and management uses covering state, regional, and multi-state areas. STATSGO data are designed for use in a Geographic Information System (GIS). The mapping scale for STATSGO map is 1:250,000 (with the exception of Alaska, which is 1:1,000,000). Each STATSGO map is linked to the Soil Interpretations Record (SIR) attribute data base. The attribute data base gives the proportionate extent of the component soils and their properties for each map unit. The STATSGO map units consist of 1 to 21 components each. The Soil Interpretations Record data base includes over 25 physical and chemical soil properties, interpretations, and productivity. Examples of information that can be queried from the data base are available water capacity, soil reaction, salinity, flooding, water table, bedrock, and interpretations for engineering uses, cropland, woodland, rangeland, pastureland, wildlife, and recreation development.

Indicator derivation (project, program, organization, report): Data are from 1) USDA, NRCS STATSGO soils data and 2) USDA, NRCS NRI 1997 data (adjusted in 2000). Presented in *The State of the Nation's Ecosystems*, pages 100 and 235 (The Heinz Center, 2002).

Web site: *NRI* http://www.nrcs.usda.gov/technical/NRI/; *STATSGO* http://www.ftw.nrcs.usda.gov/stat_data.html

Grasslands and Shrublands

Indicator name: At-risk native grasslands and shrublands species

Indicator type (status or trend): Status

Indicator category: 2

Associated question: What is the ecological condition of grasslands and shrublands?

Spatial coverage: National

Spatial coverage: Natural Heritage programs in all 50 states.

Temporal coverage: 2000. Data managed consistently since 1974.

Characterization of supporting data set(s): NatureServe is an independent nonprofit organization whose research biologists gather, review, integrate, and record available information about species taxonomy, status, and use of different habitats or ecological system types. They are assisted in this work by scientists in the network of Natural Heritage programs as well as by contracted experts for different invertebrate taxa. NatureServe staff and collaborators assign a conservation status by using standard Heritage ranking criteria. The Heritage ranking process considers five major status ranks: critically imperiled (G1), imperiled (G2), vulnerable (G3), apparently secure (G4), and demonstrably widespread, abundant, and secure (G5). In addition, separate ranks are assigned for species regarded as presumed extinct (GX) or possibly extinct (GH).

Indicator derivation (project, program, organization, report): NatureServe and its member programs in the network of Natural Heritage programs develop and maintain information on species at risk. Presented in *The State of the Nation's Ecosystems*, pages 168 and 214 (The Heinz Center, 2002).

Web site: http://www.natureserve.org

Indicator name: Population trends in invasive and native non-invasive bird species

Indicator type (status or trend): Trend

Indicator category: 1

Associated question: What is the ecological condition of grasslands and shrublands?

Spatial coverage: National

Temporal coverage: Data were analyzed in seven 5-year intervals from 1966 to 2000.

Characterization of supporting data set(s): The North American Breeding Bird Survey (BBS) is a long- term, large-scale international avian monitoring program intended to track the status and trends of North American bird populations. Today there are approximately 3700 active BBS routes across the continental U.S. and Canada of which 2900 are surveyed each year (Sauer, et al., 2001).

Indicator derivation (project, program, organization, report): U.S. Geological Survey's Biological Resources Division, Breeding Bird Survey. Presented in *The State of the Nation's Ecosystems*, pages 170 and 262 (The Heinz Center, 2002).

Web site: *BBS*
http://www.mbr-pwrc.usgs.gov/bbs/introbbs.html and
http://www.mp2- pwrc.usgs.gov/bbs/;
Sauer, et al. http://www.mbr-pwrc.usgs.gov/bbs/trend/tfmb.html

Urban and Suburban Lands

Indicator name: Patches of forest, grassland, shrubland, and wetland in urban/suburban areas

Indicator type (status or trend): Status

Indicator category: 2

Associated question: What is the ecological condition of urban and suburban areas?

Spatial coverage: Lower 48 states

Temporal coverage: 1992 satellite imagery

Characterization of supporting data set(s): NLCD provides a consistent, uniform, spatially explicit description of general land cover/land use across the continental U.S. at a 30-meter resolution. It does not contain habitat types. Eight of the 21 NLCD classifications were defined as "natural" for this analysis, including three classes of forest, three types considered grasslands/shrublands, and two wetlands types (The Heinz Center, 2002).

Indicator derivation (project, program, organization, report): Multi-Resolution Land Characterization Consortium (MRLC) - National Land Characterization Data (NLCD). Data analyses were undertaken by the U.S. Geological Survey's Earth Resources Observations Systems (EROS) Data Center. Presented in *The State of the Nation's Ecosystems*, pages 183 and 266 (The Heinz Center, 2002).

Web sites: *MRLC* http://www.epa.gov/mrlc/;
EROS Data Center "raw" data (requiring "considerable computing power" (The Heinz Center, 2002) http://edcwww.cr.usgs.gov/program/lccp/mrlcreg.html

Fresh Waters

Indicator name: Extent of ponds, lakes, and reservoirs

Indicator type (status or trend): Trend

Indicator category (1 or 2): 1

Associated question: What is the ecological condition of fresh waters?

Spatial coverage: Lower 48 states. Lake area does not include the Great Lakes, which cover about 60.2 million acres within the United States.

Temporal coverage: 1950s-1990s

Characterization of supporting data set(s): The U.S. Fish and Wildlife Service's National Wetlands Inventory (NWI) counts all lakes, reservoirs, and ponds regardless of land ownership. A permanent study design is used, based initially on stratification of the 48 conterminous states by state boundaries and 35 physiographic subdivisions. Within these subdivisions are 4375 randomly selected sample plots that are examined with the use of aerial imagery of varying scale and type. Ponds include the category of open- water ponds and non-vegetated palustrine wetlands (mud flats and shorelines of ponds) generally less than six feet deep and less than 20 acres in size. Lakes and reservoirs are generally larger than 20 acres and deeper than six feet (The Heinz Center, 2002).

Indicator source (project, program, organization, report): Data for lakes, reservoirs, and ponds come from 1) Dahl, T.E. *Status and Trends of Wetlands in the Conterminous United States 1986 to 1997*, Washington, DC: U.S. Department of the Interior, U.S. Fish and Wildlife Service, 2000; 2) Dahl, T.E., and C.E. Johnson. *Status and Trends of Wetlands in the Conterminous United States, Mid-1970's to Mid-1980's*, Washington, DC: U.S. Department of the Interior, U.S. Fish and Wildlife Service, 1991; 3) Frayer, W.E., T.J. Monahan, D.C. Bowden, and F.A. Graybill. *Status and Trends of Wetlands and Deepwater Habitats in the Conterminous United States, 1950's to 1970's*, Fort Collins, CO: Colorado State University, Department of Forest and Wood Sciences, 1983; and 4) unpublished data from the U.S. Fish and Wildlife Service (The Heinz Center, 2002). Presented in *The State of the Nation's Ecosystems*, pages 139 and 246 (The Heinz Center, 2002).

Web site: *Dahl, 2000*
http://wetlands.fws.gov/bha/SandT/ SandTReport.html

Indicator name: At-risk native fresh water species

Indicator type (status or trend): Status

Indicator category: 2

Associated question: What is the ecological condition of fresh waters?

Spatial coverage: Natural Heritage programs in all 50 states.

Temporal coverage: 2000. Data managed consistently since 1974.

Characterization of supporting data set(s): NatureServe is an independent nonprofit organization whose research biologists gather, review, integrate, and record available information about species taxonomy, status, and use of different habitats or ecological system types. They are assisted in this work by scientists in the network of Natural Heritage programs as well as by contracted experts for different invertebrate taxa. NatureServe staff and collaborators assign a conservation status by using standard Heritage ranking criteria. The Heritage ranking process considers five major status ranks: critically imperiled (G1), imperiled (G2), vulnerable (G3), apparently secure (G4), and demonstrably widespread, abundant, and secure (G5). In addition, separate ranks are assigned for species regarded as presumed extinct (GX) or possibly extinct (GH).

Indicator derivation (project, program, organization, report): NatureServe and its member programs in the network of Natural Heritage programs develop and maintain information on species at risk. Presented in *The State of the Nation's Ecosystems*, pages 144 and 214 (The Heinz Center, 2002).

Web site: http://www.natureserve.org/explorer

Indicator name: Non-native fresh water species

Indicator type (status or trend): Status

Indicator category: 2

Associated question: What is the condition of fresh waters?

Spatial coverage: Lower 48 states

Temporal coverage: 2000. An expansive spatial database underlies the Nonindigenous Aquatic Species (NAS) program, which was created in 1978 and continues to be updated and revised.

Characterization of supporting data set(s): Roughly 90 percent of the data in the U.S. Geological Survey's NAS database are derived from the published literature. Data are collected for the most part by federal and state biologists, although the public does contribute by reporting sightings (The Heinz Center, 2002). NAS is a repository for accurate and spatially referenced biogeographic accounts of nonindigenous aquatic species. Provided are scientific reports, online/realtime queries, spatial data sets, regional contact lists, and general information. The data is made available for use by biologists, interagency groups, and the general public.

Indicator derivation (project, program, organization, report): U.S. Geological Survey, Biological Resources Division (BRD), NAS Database. Presented in *The State of the Nation's Ecosystems*, pages 145 and 251 (The Heinz Center, 2002).

Web site: http://nas.er.usgs.gov/

Indicator name: Animal deaths and deformities

Indicator type (status or trend): Status

Indicator category: 2

Associated question: What is the ecological condition of fresh waters?

Spatial coverage: National. Database covers all 50 states, Puerto Rico, and the U.S. Virgin Islands

Temporal coverage: 1985-1999

Characterization of supporting data set(s): The National Wildlife Health Center (NWHC) maintains a database that contains wildlife disease and mortality events information on avian, mammalian, and amphibian mortality events. Information in the database is provided by various sources, such as state and federal personnel, diagnostic laboratories, wildlife refuges, and published reports (The Heinz Center, 2002).

Indicator derivation (project, program, organization, report): U.S. Geological Survey, Biological Resource Division (BRD), NWHC. Presented in *The State of the Nation's Ecosystems*, pages 146 and 252 (The Heinz Center, 2002).

Web site: http://www/mwhc.usgs.gov/pub_metadata/ qrt_mortality_report.html

Indicator name: At-risk fresh water plant communities

Indicator type (status or trend): Status

Indicator category: 2

Associated question: What is the ecological condition of fresh waters?

Spatial coverage: Natural Heritage programs in all 50 states, but this coverage excludes Alaska

Temporal coverage: 2000. Data managed consistently since 1974.

Characterization of supporting data set(s): NatureServe is an independent nonprofit organization whose research biologists gather, review, integrate, and record available information about species taxonomy, status, and use of different habitats or ecological system types. They are assisted in this work by scientists in the network of Natural Heritage programs as well as by contracted experts for different invertebrate taxa. NatureServe staff and collaborators assign a conservation status by using standard Heritage ranking criteria. The Heritage ranking process considers five major status ranks: critically imperiled (G1), imperiled (G2), vulnerable (G3), apparently secure (G4), and demonstrably widespread, abundant, and secure (G5). In addition, separate ranks are assigned for species regarded as presumed extinct (GX) or possibly extinct (GH).

Indicator derivation (project, program, organization, report): NatureServe and its member programs in the network of Natural Heritage programs develop and maintain information on species at risk. Presented in *The State of the Nation's Ecosystems*, 148 and 253 (The Heinz Center, 2002).

Web site: http://www.natureserve.org

Indicator name: Fish Index of Biotic Integrity (IBI) in streams

Indicator type (status or trend): Status

Indicator category: 2

Associated question: What is the ecological condition of fresh waters?

Spatial coverage: Statistically selected stream sites in the Mid-Atlantic Highlands (parts of Virginia, Maryland, Pennsylvania, and New York and all of West Virginia)

Temporal coverage: 1993-1994 sampling years

Characterization of supporting data set(s): About 450 stream reaches were sampled in the Mid-Atlantic Highlands. To describe the condition of all streams within the Highlands without sampling all of them EMAP worked with EPA Region 3 and the states to develop a regional statistical survey of streams. Examples of fish metrics measured were: the number of fish species present in the stream who cannot tolerate pollution; the proportion of individuals present that require clean gravel for spawning; and the number of bottom versus water column species present. Each metric was scored against the researchers expectations of what value was possible for each stream based on reference conditions.

Indicator derivation (project, program, organization, report): 1)Mid-Atlantic Integrated Assessment (MAIA), Environmental Monitoring and Assessment Program (EMAP), U.S. Environmental Protection Agency, *Mid-Atlantic Highlands Streams Assessment*, EPA/903/R-00/015, August 2000. 2) McCormick, F.H., R.M. Hughes, P.R. Kaufmann, D.V. Peck, J.L. Stoddard, and A.T. Herlihy. Development of an index of biotic integrity for the Mid-Atlantic Highlands Region. *Transactions of the American Fisheries Society* 130: 857-877 (2001).

Web site: *MAIA Report* http://www.epa.gov/maia/html/maha.html

Indicator name: Macroinvertebrate Biotic Integrity Index (MBII) for streams

Indicator type (status or trend): Status

Indicator category: 2

Associated question: What is the condition of fresh waters?

Spatial coverage: Statistically selected stream sites in the Mid-Atlantic Highlands (parts of Virginia, Maryland, Pennsylvania, and New York and all of West Virginia)

Temporal coverage: 1993-1994 sampling years

Characterization of supporting data set(s): About 450 stream reaches were sampled in the Mid-Atlantic Highlands. To describe the condition of all streams within the Highlands without sampling all of them EMAP worked with EPA Region 3 and the states to develop a regional statistical survey of streams. One aquatic insect index, EPT, has been used extensively to evaluate stream condition throughout the United States and was used in the Highlands. It is calculated from the number of species that are found in three orders of aquatic insects–mayflies (*Ephemeoptera*), stoneflies (*Plecoptera*), and caddisflies (*Trichoptera*) and gets its name from the first initials of these three orders (**EPT**). Many of the species in these three orders are sensitive to pollution and other stream disturbances, and the total number of species is a good gauge of how disturbed any given stream may be. EPT scores from least-disturbed Highland streams were used to set expectations. Expectations were set separately for streams with fast-moving sections or "riffles" (the vast majority of Highland streams) and slow-moving streams where "pools" dominate, because fewer EPT species naturally occur in pools.

Indicator derivation (project, program, organization, report): 1) Klemm, D.J., K.A. Blocksom, F.A. Fulk, A.T. Herlihy, R.M. Hughes, P.R. Kaufmann, D.V. Peck, J.L. Stoddard, W.T. Thoeny, M.B. Griffith, and W.S. Davis. Development and Evaluation of a Macroinvertebrate Biotic Integrity Index (MBII) for Regionally Assessing Mid-Atlantic Highlands Streams. *Environmental Management* 31 (5): 656-669 (2003). 2) Mid-Atlantic Integrated Assessment (MAIA), Environmental Monitoring and Assessment Program (EMAP), U.S. Environmental Protection Agency, *Mid-Atlantic Highlands Streams Assessment*, EPA/903/R-00/015, August 2000.

Web site: *MAIA Report* http://www.epa.gov/maia/html/maha.html

Coasts and Oceans

Indicator name: Extent of estuaries and coastline

Indicator type (status or trend): Status

Indicator category (1 or 2): 1

Associated question: What is the ecological condition of coasts and oceans?

Spatial coverage: National, all 50 states and territories

Temporal coverage: 1996-1998

Characterization of supporting data set(s): Data were submitted by the states and territories to EPA's Office of Water which compiled a national report. Data were collected using different methodologies, definitions, and assumptions, so the data is unlikely to be consistent.

Indicator source (project, program, organization, report): U.S. Environmental Protection Agency, Office of Water, *2000 National Water Quality Inventory*, EPA 841-R-02-001, August 2002, Table C-1 Total Estuarine and Ocean Shoreline Waters in the Nation.

Web site: http://www.epa.gov/305b/2000report/appendixc.pdf

Indicator name: Coastal living habitats

Indicator type (status or trend): Trend

Indicator category: 2

Associated question: What is the ecological condition of coasts and oceans?

Spatial coverage: National

Temporal coverage: 1950s to 1990s

Characterization of supporting data set(s): While data gaps are reported for the coral reef, seagrasses, and shellfish beds components of the indicator (The Heinz Center, 2002), the wetlands component is supported by U.S. Fish and Wildlife Service's (USFWS) recent report, *The Status and Trend of Wetlands in the Conterminous United States 1986-1997*. The report utilizes National Wetlands Inventory (NWI) and other wetland data. NWI counts all wetlands, regardless of land ownership, but recognizes only wetlands that are at least three acres. To ensure adequate coverage of coastal wetlands, supplemental sampling along the Atlantic and Gulf coast fringes was added (The Heinz Center, 2002).

Indicator source (project, program, organization, report): Dahl, T.E. *Status and Trends of Wetlands in the Conterminous United States 1986 to 1997*, Washington, DC: U.S. Department of the Interior, U.S. Fish and Wildlife Service, 2000. Presented in *The State of the Nation's Ecosystems*, pages 69 and 218 (The Heinz Center, 2002).

Web site: http://wetlands.fws.gov/bha/SandT/SandTReport.html

Indicator name: Shoreline types

Indicator type (status or trend): Status

Indicator category: 2

Associated question: What is the ecological condition of coasts and oceans?

Spatial coverage: National in scope; Pacific Northwest, Southern California, and South Atlantic regions only

Temporal coverage: 1984-2001

Characterization of supporting data set(s): Data were extracted from Environmental Sensitivity Index (ESI) atlases, a product of the National Oceanic and Atmospheric Administration's (NOAA), Office of Response and Restoration (ORR). The ESI method provides a standardized mapping approach for coastal geomorphology as well as biological and human use elements. Data from multiple atlases were aggregated into the regions used. Some of the data atlases utilized were more than 15 years old (The Heinz Center, 2002).

Indicator derivation (project, program, organization, report): NOAA, ORR, Hazardous Materials Response Division, ESI atlases. Presented in *The State of the Nation's Ecosystems*, pages 70 and 219 (The Heinz Center, 2002).

Web site: *Some NOAA ESI data are available at* http://response.restoration.noaa.gov/esi/esiintro.html

Indicator name: Benthic Community Index

Indicator type (status or trend): Status

Indicator category: 2

Associated question: What is the ecological condition of coasts and oceans?

Spatial coverage: National in scope, 24 coastal states

Temporal coverage: Stations on the west coast were sampled in 1999. The entire U.S. coast, including the Gulf of Maine, was sampled in 2000.

Characterization of supporting data set(s): In 2000, EPA, NOAA, and USGS, in cooperation with all 24 U.S. coastal states, initiated the National Coastal Assessment. Using a compatible, probabilistic design and a common set of survey indicators, each state conducted the survey and independently assessed the condition of their coastal resources. While the complete assessment of national coastal waters is scheduled for publication in 2003, a preliminary assessment of selected estuaries was published by EPA in 2001. The EPA Environmental Monitoring and Assessment Program (EMAP) National Coastal Database contains estuarine and coastal data that EMAP and Regional-EMAP have collected since 1990 from hundreds of stations between Cape Cod and the Mexican border. These include water column data, sediment chemistry and toxicity data, demersal fish and invertebrate community and contaminant data and benthic invertebrate community data.

Indicator derivation (project, program, organization, report): 1) EMAP National Coastal Database; 2) U.S. Environmental Protection Agency. *National Coastal Condition Report*, EPA 620-R-01-005. Washington DC: U.S. Environmental Protection Agency, Office of Research and Development and Office of Water, September 2001.

Web site: *NCCR* http://epa.gov/owow/oceans/nccr/downloads.html; *National Coastal Database* http://www.epa.gov/emap/nca/html/data/index.html

Indicator name: Fish diversity

Indicator type (status or trend): Status

Indicator category: 2

Associated question: What is the ecological condition of coasts and oceans?

Spatial coverage: Mid-Atlantic estuaries

Temporal coverage: 1997-1998

Characterization of supporting data set(s): The EPA Mid-Atlantic Integrated Assessment (MAIA) Estuaries Summary Database contains water quality, sediment, benthic community, and fish data collected by several partners in MAIA Region estuaries in 1997 and 1998. The MAIA program conducted regular fish surveys during the summer of 1998 to characterize the structure and health of the fish communities. The stations sampled were selected according to a probabilistic design. These stations were not identical with the stations sampled for water and sediment quality analyses conducted primarily in 1997; therefore, it is not possible to directly compare these different analyses station by station. However, it is statistically valid to compare results among classes of estuaries, (e.g., large versus small estuaries, Delaware Estuary versus Chesapeake Estuary).

Indicator source (project, program, organization, report): U.S. Environmental Protection Agency. *Mid- Atlantic Integrated Assessment, MAIA - Estuaries 1997-98, Summary Report*, EPA 620-R-02-003. Narragansett, RI: U.S. Environmental Protection Agency, Office of Research and Development, Atlantic Ecology Division, May 2003.

Web site: *MAIA data* http://www.epa.gov/emap/maia/html/data/estuary/9798/xport.html

Indicator name: Submerged aquatic vegetation

Indicator type (status or trend): Status

Indicator category: 2

Associated question: What is the ecological condition of coasts and oceans?

Spatial coverage: Mid-Atlantic estuaries, Chesapeake Bay

Temporal coverage: 1985-1998

Characterization of supporting data set(s): The Chesapeake Bay Program's second submerged aquatic vegetation (SAV) Technical Synthesis revises and updates the first synthesis published in 1992, by providing new light requirements for SAV through the water column and at the leaf surface, providing diagnostic tools for their application and interpretation, and identifying preliminary sets of physical, chemical, and other biological habitat requirements. An algorithm was applied to analyze SAV habitat suitability for some 50 sites in Chesapeake Bay and its tidal tributaries using data collected over 14 years (1985-1998) of environmental monitoring (EPA, CBP, 2000). 2) Mid-Atlantic Integrated Assessment (MAIA) field crews noted the presence or absence of SAV at their sampling stations as an ancillary measurement. No attempt was made to estimate the extent of SAV the MAIA region. The MAIA database contains water quality, sediment, benthic community, and fish data collected by several partners in MAIA Region estuaries in 1997 and 1998. The MAIA program conducted regular fish surveys during the summer of 1998 to characterize the structure and health of the fish communities. The stations sampled were selected according to a probabilistic design. These stations were not identical with the stations sampled for water and sediment quality analyses conducted primarily in 1997; therefore, it is not possible to directly compare these different analyses station by station. However, it is statistically valid to compare results among classes of estuaries, (e.g., large versus small estuaries, Delaware Estuary versus Chesapeake Estuary).

Indicator source (project, program, organization, report): 1) Batiuk, R.A., P. Bergstrom, M. Kemp, E. Koch, L. Murray, J.C. Stevenson, R. Bartleson, V. Carter, N.B. Rybicki, J.M. Landwehr, C. Gallegos, L. Karrh, M. Naylor, D. Wilcox, K.A. Moore, S. Ailstock, and M. Teichberg. *Chesapeake Bay Submerged Aquatic Vegetation Water Quality and Habitat-Based Requirements and Restoration Targets: A Second Technical Synthesis*, CBP-TRS 245-00, EPA 903-R-00-014. Annapolis, MD: U.S. Environmental Protection Agency, Chesapeake Bay Program, 2000; 2) U.S. Environmental Protection Agency. *Mid-Atlantic Integrated Assessment, MAIA - Estuaries 1997-98, Summary Report*, EPA 620-R-02-003. Narragansett, RI: U.S. Environmental Protection Agency, Office of Research and Development, Atlantic Ecology Division, May 2003.

Web site: *CBP report*
http://www.chesapeakebay.net/pubs/ sav/index.html

Indicator name: Fish abnormalities

Indicator type (status or trend): Status

Indicator category: 2

Associated question: What is the ecological condition of coasts and oceans?

Spatial coverage: National assessment, data presented for Gulf of Mexico to Cape Cod, Great Lakes excluded

Temporal coverage: Data collected in 2000, available in 2002 for Pacific Coast

Characterization of supporting data set(s): U.S. Environmental Protection Agency Environmental Monitoring and Assessment Program (EMAP) data on fish pathologies by estuarine province.

Indicator source (project, program, organization, report): U.S. Environmental Protection Agency. *National Coastal Condition Report*, EPA 620-R-01-005. Washington DC: U.S. Environmental Protection Agency, Office of Research and Development and Office of Water, September 2001.

Web site: *NCCR* http://epa.gov/owow/oceans/nccr/downloads.html

Indicator name: Unusual marine mortalities

Indicator type (status or trend): Status

Indicator category: 2

Associated question: What is the ecological condition of coasts and oceans?

Spatial coverage: National in scope for marine mammals

Temporal coverage: 1992-2001

Characterization of supporting data set(s): Data is available for whales, dolphins, porpoises, seals, sea lions, sea otters, and manatees. Data is not available for turtle, seabird, fish, and shellfish mortality. The 2001 data for two unusual mortality events and the total number of gray whales lost in the 1999-2001 unusual mortality event were obtained directly from National Marine Fisheries Service (NMFS). All other unusual mortality event data were obtained from Dierauf and Gulland, (2001) (The Heinz Center, 2002).

Indicator derivation (project, program, organization, report): 1) U.S. Department of Commerce, NOAA, NMFS, Office of Protected Resources, Marine Mammal Health and Stranding Response Program; 2) Dierauf, L.A., and F.M.D. Gulland (eds.) *CRC Handbook of Marine Mammal Medicine: Health, Disease, and Rehabilitation, 2nd Edition*, Boca Raton, FL: CRC Press, Inc., 2001. Presented in *The State of the Nation's Ecosystems*, pages 77 and 223 (The Heinz Center, 2002).

Web site: *NMFS data*
http://www.nmfs.noaa.gov/prot_res/PR2/Health_and_Stranding_Response_Program/WGUMMME.html

The Entire Nation

Indicator name: Ecosystem extent

Indicator type (status or trend): Status and Trend

Indicator category (1 or 2): 2

Associated question: What is the ecological condition of the entire nation?

Spatial coverage: National in all cases

Temporal coverage: 1950s-1990s.

Characterization of supporting data set(s): 1) For cropland, the data source is the USDA Economic Research Service (ERS) relying on data from the National Agricultural Statistics Service and a variety of other sources to provide an estimate of extent. 2) For forests, the data source is the USDA Forest Service Forest Inventory and Analysis (FIA) program, a survey-based program that has operated since the late 1940s, collecting information on a variety of forest characteristics. 3) For fresh water wetlands, the data source is the U.S. Fish and Wildlife Service's National Wetlands Inventory as reported in the most recent wetlands status and trends report (Dahl, 2000). 4) For grasslands and shrublands, the data source is the National Land Cover Dataset (NLCD). In the 1990s, a federal interagency consortium (the Multi- Resolution Land Characterization (MRLC) Consortium) was created to coordinate access to and use of land cover data from the Landsat 5 Thematic Mapper. Using Landsat data and a variety of ancillary data, the consortium processed data from a series of 1992 Landsat images, to create the NLCD on a square grid covering the lower 48 states. The MRLC NLCD with 21 land cover classes, was used to estimate the area coverage for the U.S. 5) For urban/suburban, the data source is the NLCD.

Indicator derivation (project, program, organization, report): 1) ERS; 2) FIA; 3) Dahl, T.E. *Status and Trends of Wetlands in the Conterminous United States 1986 to 1997*, Washington, DC: U.S. Department of the Interior, U.S. Fish and Wildlife Service, 2000; 4) NLCD; 5) NLCD. Presented in *The State of the Nation's Ecosystems*, pages 41-43 and 207 (The Heinz Center, 2002).

Web site: *ERS* http://www.ers.usda.gov/Emphases/Harmony/issues/arei2000/; *FIA* http://fia.fs.fed.us; *Dahl, 2000* http://wetlands.fws.gov/bha/SandT/SandTReport.html; *NLCD* http://www.usgs.gov/mrlcreg.html

Indicator name: At-risk native species

Indicator type (status or trend): Status

Indicator Category: 2

Associated question: What is the ecological condition of the entire nation?

Spatial coverage: Natural Heritage programs in all 50 states.

Temporal coverage: 2000. Data managed consistently since 1974.

Characterization of supporting data set(s): NatureServe is an independent nonprofit organization whose research biologists gather, review, integrate, and record available information about species taxonomy, status, and use of different habitats or ecological system types. They are assisted in this work by scientists in the network of Natural Heritage programs as well as by contracted experts for different invertebrate taxa. NatureServe staff and collaborators assign a conservation status by using standard Heritage ranking criteria. The Heritage ranking process considers five major status ranks: critically imperiled (G1), imperiled (G2), vulnerable (G3), apparently secure (G4), and demonstrably widespread, abundant, and secure (G5). In addition, separate ranks are assigned for species regarded as presumed extinct (GX) or possibly extinct (GH).

Indicator derivation (project, program, organization, report): NatureServe and its member programs in the network of Natural Heritage programs develop and maintain information on species at risk. Presented in *The State of the Nation's Ecosystems*, pages 52-53 and 214 (The Heinz Center, 2002).

Web site: http://www.natureserve.org

Indicator name: Bird Community Index

Indicator type (status or trend): Status

Indicator Category: 2

Associated question: What is the ecological condition of the entire nation?

Spatial coverage: Mid-Atlantic Highlands (parts of Virginia, Maryland, Pennsylvania, and New York and all of West Virginia)

Temporal coverage: 1995-1996 data

Characterization of supporting data set(s): Birds and vegetation were surveyed across the entire Mid-Atlantic highlands within sites sufficiently large (200 acres) to represent most of the habitat elements that are required by breeding birds. Use of EPA's Environmental Monitoring and Assessment Program (EMAP) survey design guaranteed that data from the 126 sample sites were representative of the entire highlands area. Sixteen specific groups of bird species, such as omnivores, bark probers, residents, migrants, shrub nesters, etc., were ultimately selected as representative of the mostly forested Mid-Atlantic Highlands area. Of the 16 groups, nine were "specialists" and seven were "generalists"; for example, insectivores are specialists and omnivores are generalists. Placement of specific bird species within each group was based on a review of scientific publications. Species may be assigned to several groups as well as to both specialist and generalist groups simultaneously. In general, a high proportion of birds with specialized requirements indicates healthy natural habitat that provides ecological benefits at local and larger scales (EPA, 2000).

Indicator derivation (project, program, organization, report): 1) O'Connell, T.J., L.E. Jackson, and R.P. Brooks. Bird guilds as indicators of ecological condition in the central Appalachians. *Ecological Applications* 10: 1706-1721 (2000). 2) U.S. Environmental Protection Agency. *MAIA Project Summary: Birds Indicate Ecological Condition of the Mid-Atlantic Highlands*. EPA 620-R-000-003. Washington, DC: EPA, Office of Research and Development, June 2000.

Web site: *MAIA summary* http://www.epa.gov/maia/html/bird.htm; *Full research report* http://www.wetlands.cas.psu.edu

Indicator name: Terrestrial Plant Growth Index

Indicator type (status or trend): Status and Trend

Indicator Category: 1

Associated question: What is the ecological condition of the entire nation?

Spatial coverage: Lower 48 states

Temporal coverage: 1989-2000, except for 1994 when the satellite failed. The Normalized Difference Vegetation Index (NDVI) is calculated at two-week intervals and summed throughout the growing season; only values that exceed non-growing-season, background NDVI are included. Growing season dates, end dates, and background NDVI were calculated for each land cover type and region (The Heinz Center, 2002).

Characterization of supporting data set(s): The plant growth index is based on data collected by the Advanced Very High Radiation Radiometer (AVHRR) aboard NOAA's polar orbiting satellites. Because the relationship between NDVI and absorbed photosynthetically active radiation varies by cover type, the growing season accumulated NDVI was calculated separately for the forest, farmland, and grassland/shrubland areas in each county of the conterminous 48 states. The 11-year average growing- season accumulated NDVI was also calculated for each of the three land cover types in each county. The values in each county segment for each year were then normalized by using the corresponding 11-year average for that county segment to produce a plant growth index where a value of 1.0 equals the long-term average. Areas with plant growth indices greater than 1.0 have higher-than-average accumulated NDVI; within the same cover type and in an area as small as a county, this implies higher-than-average plant growth for that year. The regional and system specific plant growth indices are the area-weighted averages of the segments contained within the region and system (The Heinz Center, 2002).

Indicator derivation (project, program, organization, report): Data on accumulated NDVI and analysis of those data are from the USGS's Earth Resources Observations Systems (EROS) Data Center, Sioux Falls, South Dakota. Presented in *The State of the Nation's Ecosystems*, pages 56-57 and 216 (The Heinz Center, 2002).

Web site: http://edcwww.cr.usgs.gov/

Indicator name: Movement of nitrogen

Indicator type (status or trend): Status

Indicator Category: 1

Associated question: What is the ecological condition of the entire nation?

Spatial coverage: Lower 48 states

Temporal coverage: 1996-1999

Characterization of supporting data set(s): Riverine loads of total nitrogen were estimated using streamflow and water-quality data collected by the U.S. Geological Survey as part of its National Stream Water Accounting Network (NASQAN), its 1996-1999 National Water Quality Assessment (NAWQA), and its Federal State Cooperative Program. At the sites for which data are included in this indicator, samples were collected at least quarterly over the four-year period and at most sites, approximately 15 samples were collected each year. A regression model relating nitrogen concentration to discharge, day- of-year (to capture seasonal effects), and time (to capture any trend over the period) was developed. Another model was developed for nitrate plus nitrite concentrations (note that nitrite is usually much less abundant than nitrate, so it is normal to discuss the sum of nitrate plus nitrite simply as nitrate) and a third model was developed for whole-water organic nitrogen plus ammonia for each station. These models were then used to make daily estimates of concentration, which were multiplied by the daily average discharge to yield the daily load. The daily load of total nitrogen was the sum of predictions of the latter two models (The Heinz Center, 2002).

Indicator derivation (project, program, organization, report): USGS, NASQAN and NAWQA programs, and the USGS Federal-State Cooperative Program. Presented in *The State of the Nation's Ecosystems*, pages 46-47 and 210 (The Heinz Center, 2002).

Web site: *NASQAN* http://water.usgs.gov/nasqan; *NAWQA* http://water.usgs.gov/nawqa

Indicator name: Chemical contamination

Indicator type (status or trend): Trend

Indicator Category: 2

Associated question: What is the ecological condition of the entire nation?

Spatial coverage: Lower 48 states

Temporal coverage: 1990-1997 (EMAP) and 1992-1998 (USGS)

Characterization of supporting data set(s): 1) The data for fresh-water streams and ground water were collected and analyzed by the U.S. Geological Survey's (USGS), National Water Quality Assessment (NAWQA) in 36 major river basins and aquifers across the U.S. 2) The data for sediments and fish contamination in coastal waters were collected and analyzed by the U.S. Environmental Protection Agency's, Environmental Monitoring and Assessment Program (EMAP) in a manner that allows conclusions to be drawn concerning the majority (approximately 76 percent) of the areas of estuaries in the U.S. 3) Data on sediment contamination in the Great Lakes are collected by a number of agencies and were provided by EPA's Great Lakes National Program Office (The Heinz Center, 2002).

Indicator derivation (project, program, organization, report): 1) USGS, NAWQA; 2) EPA, EMAP; and 3) Great Lakes National Program Office. Presented in *The State of the Nation's Ecosystems*, pages 48-51 and 210 (The Heinz Center, 2002).

Web site: *NAWQA* http://water.usgs.gov/nawqa; *EMAP* http://www.epa.gov/emap/

Appendix C: Acronyms and Abbreviations

A

1NAP: 1-napthol

AFO: animal feeding operation

AHA: American Heart Association

AHEF: Atmospheric and Health Effects Framework

AIRS: Aerometric Information Retrieval System

AM: atrazine mercapturate

ANC: acid-neutralizing capacity

APCs: areas of probable concern

AQI: Air Quality Index

AQS: Air Quality System

AREAL: Atmospheric Research and Exposure Assessment Laboratory

ARS: Agricultural Research Center

ATSDR: Agency for Toxic Substances and Disease Registry

A**VHRR:** advanced very high resolution radiometer

AVS: acid volatile sulfide

B

BASE: Building Assessment Survey and Evaluation

BBS: Breeding Bird Survey

BCI: Bird Community Index

BEACH: Beaches Environmental Assessment and Coastal Health Program

BEIR VI: Biological Effects of Ionizing Radiation

BLM: Bureau of Land Management

BRAC: base realignment and closure facilities

BRD: Biological Resources Division

C

C&I: criteria and indicators

CAA: Clean Air Act

CAFOs: confined animal feeding operations

CAPI: computer-assisted personal interviewing

CASTNet: Clean Air Status and Trends Network

CBP: Chespeake Bay Program

CCA: chromate copper arsenate

C-CAP: Coastal Change Analysis Program

CDC: Centers for Disease Control and Prevention

CDDS: California Department of Developmental Services

CEMS: continuous emissions monitors

CENR: Council on the Environment and Natural Resources

CERCLA: Comprehensive Environmental Response, Compensation, and Liability Act

CERCLIS: Comprehensive Environmental Response, Compensation, and Liability Information System

CESQGs: conditionally exempt small quantity generators

CFCs: chloroflourocarbons

CHD: coronary heart disease

cm: centimeter

CMSAs: consolidated metropolitan statistical areas

CO: carbon monoxide

COHb: carboxyhemoglobin

COPD: chronic obstructive pulmonary disease

COS: carbonyl sulfide

CPI: Consumer Price Index

CPSC: Consumer Product Safety Commission

CRA: comparative risk assessment

CRP: Conservation Reserve Program

CSO: combined sewer overflow

CSTE: Council of State and Territorial Epidemiologists

CVD: cardiovascular disease

CWA: Clean Water Act

CWS: community water system

D

DBPs: disinfection byproducts

DDE: dichlorodiphenyldichloroethylene

DDT: dichlorodiphenltrichloroethane

DO: dissolved oxygen

DOC: dissolved organic carbon

DOE: U.S. Department of Energy

DOI: U.S. Department of the Interior

DSS: decision support systems

DU: Dobson Units

E

EBD: environmental burden of disease

ECAO: Environmental Criteria and Assessment Office

ECI: Employee Cost Index

EDC: endocrine-disrupting compounds

EEA: essential ecological attribute

EECL: equivalent effective chlorine

EEZ: U.S. Exclusive Economic Zone

EMAP: Environmental Monitoring and Assessment Program

ENSO: El Niño-Southern Oscillation

EPA: U.S. Environmental Protection Agency

STAR: Science to Achieve Results

EPCRA: Emergency Planning and Community Right-to-Know Act

EPHI: environmental public health indicators

EPO: Epidemiology Program Office

EPT: Ephemeoptera, Plecoptera, and Trichoptera Index

ERL: effects range low

ERM: effects range medium

EROS: Earth's Resources Observation System

ESG: Equilibrium Partitioning Sediment Guidelines

ESI: Environmental Sensitivity Index

ESRD: end stage renal disease

ETS: environmental tobacco smoke

F

FDA: Food and Drug Administration

FHM: Forest Health Monitoring Program

FIA: Forest Inventory and Analysis

FQPA: Food Quality Protection Act

FS: Forest Service

FY: fiscal year

G

GAO: General Accounting Office

GBD: global burden of disease

GDP: gross domestic product

GI: gastrointestinal illness

GIS: geographic information systems

GLEAMS: groundwater loading effects of agricultural management

GPRA: Government Performance Results Act

H

HABs: harmful algal blooms

HCB: hexachlorobenzene

HCFCs: hydrochlorofluorocarbons

HFCs: hydrofluorocarbons

HHS: Department of Health and Human Services

HHW: household hazardous waste

HUC: hydrologic unit code

HUMUS: hydrologic unit modeling of the United States

I-J

IAQ: indoor air quality

IBI: index of biotic integrity

ICCC: international classification of childhood cancer

ICTDRN: International Center for Tropical Disease Research Network

IDEM: Indiana Department of Environmental Management

IMP: integrated pest management

IMPROVE: Interagency Monitoring of Protected Visual Environments

IPCS: International Programme on Chemical Safety

IQ: intelligence quotient

IRIS: Integrated Risk Information System

IWI: Index of Watershed Indicators

K-L

lbs: pounds

LDC: least distributed condition

LQGs: large quantity generators

LTER: long-term ecological research

LUST: leaking underground storage tanks

km: kilometers

M

MA: metropolitan area

MAD: malathion dicarboxylic acid

MAIA: Mid-Atlantic Integrated Assessment

MBII: Macroinvertebrate Biotic Integrity Index

MCL: maximum contaminant levels

MDC: minimally distributed condition

MDN: Mercury Deposition Network

μ/m3: micrograms per cubic meter

μ/dl: micrograms per deciliter

μ/L: micrograms per liter

MRLC: Multi-Resolution Land Characteristics

MSAs: metropolitan statistical areas

N

N_2: nitrogen

NAAQS: National Ambient Air Quality Standards

NADP: National Atmospheric Deposition Program

NAE: National Academy of Engineering

NAMS: national air monitoring stations

NAO: North Atlantic Oscillation

NAPAP: National Acid Precipitation Assessment Program

NAS: Nonindigenous Aquatic Species

NASA: National Aeronautics and Space Administration

NASQAN: National Stream Quality Accounting Network

NASS: National Agricultural Statistics Service

NAWQA: National Water Quality Assessment Program

NCEA: National Center for Environmental Assessment

NCES: National Center for Education Strategies

NCEH: National Center for Environmental Health

NCFAP: National Center for Food and Agricultural Policy

NCHS: National Center for Health Statistics

NCI: National Cancer Institute

NCS: National Children's Study

NDVI: Normalized Difference Vegetation Index

NEI: National Emissions Inventory

NEP: National Estuary Program

NEPA: National Environmental Policy Act

NERRS: National Estuarine Research Reserve System

ng/mL: nanograms per milliliter

NHANES: National Health and Nutrition Examination Survey

NHATS: National Human Adipose Tissue Survey

NH_3: ammonia

NHD: National Hydrography Dataset

NHEXAS: National Human Exposure Assessment Survey

NHIS: National Health Interview Survey

NHLBI: National Heart, Lung, and Blood Institute

NIH: National Institutes of Health

NINDS: National Institute of Neurological Disorders and Stroke

NLCD: National Land Cover Data

N**LFWA:** National Listing of Fish and Wildlife Advisories

NLV: Norwalk-like virus

nm: nanometers

NMI: Nematode Maturity Index

MMWR: Morbidity and Mortality Weekly Report

NMVOCs: non-methane volatile organic compounds

NO_2: nitrogen dioxide

NO_x: nitrogen oxides

NOAA: National Oceanic and Atmospheric Administration

NOPES: Nonoccupational Pesticide Exposure Study

NPL: National Priorities List

NPP: Net Primary Production

NRC: National Research Council

NRCS: Natural Resources Conservation Service

NRI: National Resources Inventory

NSF: National Science Foundation

NSI: National Sediment Inventory

N**SSP:** National Sanitary Survey Program

NS&T: National Status and Trends Program

NTN: National Trends Network

NVSS: National Vital Statistics System

NWHC: National Wildlife Health Center

N**WI:** National Wetlands Inventory

O

O_3: ozone

OAQPS: Office of Air Quality Planning and Standards

OAR: Office of Air and Radiation

OCFO: Office of the Chief Financial Officer

OCHP: Office of Children's Health Protection

OCIR: Office of Congressional and Intergovernmental Relations

OECA: Office of Enforcement and Compliance Assurance

OEI: Office of Environmental Information

ODP: ozone-depleting potential

ODS: ozone-depleting substance

OE: Office of Enforcement

OECD: Organization for Economic Cooperation and Development

OPEI: Office of Policy, Economics, and Innovation

OPs: organophosphate pesticides

OPP: Office of Pesticide Programs

OPPE: Office of Policy, Planning, and Evaluation

OPPT: Office of Pollution Prevention and Toxics

OPPTS: Office of Prevention, Pesticides, and Toxic Substances

ORD: Office of Research and Development

OSWER: Office of Solid Waste and Emergency Response

OW: Office of Water

P

P: phosphorus

PAH: polycyclic aromatic hydrocarbons

Pb: lead

PBTs: persistent bioaccumulative toxics

PCBs: polychlorinated biphenyls

PCC: poison control centers

PCDD: polychlorinated dibenzo-dioxin

PCDF: polychlorinated dibenzo-furan

pCi/L: picocuries per liter

PDO: Pacific Decadal Oscillation

PDP: Pesticides Data Program

PECDF: pentachlorodibenzofuran

PERC: chloroform tetrachloroethylene

PFCs: perflourinated carbons

PIBI: Periphyton Index of Biotic Integrity

PM: particulate matter

PM_{10}, $PM_{2.5}$: particulate matter 10, 2.5 micrometers (coarse, fine)

PMSAs: primary metropolitan statistical areas

POPs: persistent organic pollutants

POTW: publicly owned treatment works

PPI: Producer Price Index

PSR: pressure-state-response framework

PSR/E: pressure-state-response-effects framework

PWS: public water system

Q-R

QA/QC: quality assurance/quality control

RB meter: Robertson-Berger meter

RCRA: Resource Conservation and Recovery Act

RCRAInfo: Resource Conservation and Recovery Act Information System

ReVA: Regional Vulnerability Assessment Program

RMSF: rocky mountain spotted fever

ROE: EPA's Report on the Environment

RPA: Resource Planning Act

RUSLE: revised universal soil loss equation

S

SAB: Science Advisory Board

SARA: Superfund Amendment and Reauthorization Act

SAV: submerged aquatic vegetation

SDWA: Safe Drinking Water Act

SDWIS: Safe Drinking Water Information System

SDWIS/FED: Safe Drinking Water Information System/Federal version

SeaWiFS: sea viewing wide field-of-view sonar

SEER: Surveillance, Epidemiology, and End Results Program

SEM: simultaneously extracted metals

SF6: sulfur hexafluoride

SIC: standard industrial classification

SIDS: sudden infant death syndrome

SLAMS: state/local air monitoring stations

SMSA: Standard Metropolitan Statistical Area

SO2: sulfur dioxide

SOLEC: State of the Great Lakes Ecosystem Conference

SQI: Soil Quality Index

SPARROW: SPAtially-Referenced Regression On Watershed Attributes

SQGs: small quantity generators

SSO: sanitary sewer overflow

SST: sea surface temperature

STATSGO: State Soil Geographic Database

STORET: STORage and RETrieval Database

SWAT: Soil and Water Assessment Tool

T

TBP: theoretical bioaccumulation potential

TCE: trichloroethylene

TDCF: tetrachlorodibenzofuran

TESS: Toxic Exposure Surveillance System

THMs: trihalomethanes

TIME: temporally integrated monitoring of ecosystems

TMDL: total maximum daily load

TN: total nitrogen

TOC: total organic carbon

TOMS: total ozone mapping spectrometer

TP: total phosphorus

TRI: Toxics Release Inventory

TD: Technical Document for EPA's Report on the Environment

TSDs: treatment, storage, and disposal facilities

TYPY: 3,5,6-trichloro-2-pyridinol

U-Z

UAs: urbanized areas

UCs: urban clusters

UN: United Nations

UNEP: United Nations Environment Programme

USDA: U.S. Department of Agriculture

USFWS: U.S. Fish and Wildlife Service

USGS: U.S. Geological Survey

UST: underground storage tanks

UV: ultraviolet

UV-A: ultraviolet A

UV-B: ultraviolet B

VMT: vehicle miles traveled

VOCs: volatile organic compounds

WBDO: Waterborne disease outbreak

WHO: World Health Organization

WMO: World Meteorological Organization

WMPC: waste minimization priority chemicals

Appendix D: Glossary of Terms

A

accretion: The gradual build-up of sediment along the bank or shore of a river or stream.

acid deposition: A complex chemical and atmospheric phenomenon that occurs when emissions of sulfur and nitrogen compounds are transformed by chemical processes in the atmosphere and then deposited on earth in either wet or dry form. The wet forms, often called "acid rain," can fall to earth as rain, snow, or fog. The dry forms are acidic gases or particulate matter.

adipose tissue: Fatty tissue.

advisory: A nonregulatory document that communicates risk information to those who may have to make risk management decisions. (EPA, December 1997)

aerosol: 1. Small droplets or particles suspended in the atmosphere, typically containing sulfur. They are emitted naturally (e.g., in volcanic eruptions) and as a result of human activities (e.g. burning fossil fuels). 2. The pressurized gas used to propel substances out of a container. (EPA, December 1997)

agricultural waste: Byproducts generated by the rearing of animals and the production and harvest of crops or trees. Animal waste, a large component of agricultural waste, includes waste (e.g., feed waste, bedding and litter, and feedlot and paddock runoff) from livestock, dairy, and other animal-related agricultural and farming practices.

air pollutant: Any substance in air that could, in high enough concentration, harm man, other animals, vegetation, or material. Pollutants may include almost any natural or artificial composition of airborne matter capable of being airborne. They may be in the form of solid particles, liquid droplets, gases, or in combination thereof. Generally, they fall into two main groups: (1) those emitted directly from identifiable sources and (2) those produced in the air by interaction between two or more primary pollutants, or by reaction with normal atmospheric constituents, with or without photoactivation. Exclusive of pollen, fog, and dust, which are of natural origin, about 100 contaminants have been identified. Air pollutants are often grouped in categories for ease in classification; some of he categories are: solids, sulfur compounds, volatile organic compounds, particulate matter, nitrogen compounds, oxygen compounds, halogen compounds, radioactive compounds, and odors. (EPA, December 1997)

air pollution: The presence of contaminants or pollutant substances in the air that interfere with human health or welfare or produce other harmful environmental effects. (EPA, December 1997)

air quality criteria: The levels of pollution and lengths of exposure above which harmful health and welfare effects may occur. (EPA, December 1997)

air quality standards: The level of pollutants prescribed by regulations that are not to be exceeded during a given time in a defined area. (EPA, December 1997)

air toxics: Air pollutants that cause or may cause cancer or other serious health effects, such as reproductive effects or birth defects, or adverse environmental and ecological effects. Examples of toxic air pollutants include benzene, found in gasoline; perchloroethylene, emitted from some dry cleaning facilities; and methylene chloride, used as a solvent by a number of industries.

algal blooms: Sudden spurts of algal growth, which can degrade water quality and indicate potentially hazardous changes in local water chemistry. (EPA, December 1997)

ambient air: Any unconfined portion of the atmosphere; open air, surrounding air. (EPA, December 1997)

ambient air quality standards: See *criteria pollutants* and *National Ambient Air Quality Standards*.

animal waste: Byproducts that result from livestock, diary, and other animal-related agricultural practices.

anthropogenic: Originating from humans, not naturally occurring. (EPA, MAIA, August 2002)

aquatic ecosystems: Salt water or fresh water ecosystems, includes rivers, streams, lakes, wetlands, estuaries and coral reefs.

aquifer: An underground geological formation, or group of formations, containing water; source of ground water for wells and springs. (USGS, 1996)

arsenic: A silvery, nonmetallic element that occurs naturally in rocks and soil, water, air, and plants and animals. It can be released into the environment through natural activities such as volcanic action, erosion of rocks, and forest fires or through human actions. Approximately 90 percent of industrial arsenic in the U.S. is used as a wood preservative, but arsenic is also used in paints, dyes, metals, drugs, soaps, and semiconductors. Agricultural applications (used in rodent poisons and some herbicides), mining, and smelting also contribute to arsenic releases in the environment. It is a known human carcinogen.

arteriosclerosis: Hardening of the arteries.

asbestos: Naturally occurring strong, flexible fibers that can be separated into thin threads and woven. These fibers resist heat and chemicals and do not conduct electricity. Asbestos is used for insulation, making automobile brake and clutch parts, and many other products. These fibers break easily and form a dust composed of tiny particles that are light and sticky. When inhaled or swallowed they can cause health problems. (NCI, 2001)

assemblage: The association of interacting populations of organisms in a selected habitat.

B

basal cell carcinoma: A type of skin cancer, usually curable if treated in time.

beach day: A day that a beach would normally be open to the public.

benthic: Occurring at or near the bottom of a body of water.

benthic organisms: The worms, clams, crustaceans, and other organisms that live at the bottom of the estuaries and the sea.

benthos: In fresh water and marine ecosystems, organisms attached to, resting on, or burrowed into bottom sediments.

bioaccumulation: A process whereby chemicals (e.g., DDT, PCBs) are retained by plants and animals and increase in concentration over time. Uptake can occur through feeding or direct absorption from water or sediments. (EPA, MAIA, August 2002)

biodiversity: The variety and variability among living organisms and the ecological complexes in which they occur. Diversity can be defined as the number of different items and their relative frequencies. The term encompasses three basic levels of biodiversity: ecosystems, species, and genes.

biological diversity: See *biodiversity*.

biomarker: 1. A parameter that can be used to identify a toxic effect in an individual organism and can be used in extrapolation between species. 2. An indicator signaling an event or condition in a biological system or sample and giving a measure of exposure, effect, or susceptibility. (International Union of Pure and Applied Chemistry, 1993)

biomass: All of the living material in a given area; often refers to vegetation. (EPA, December 1997)

biomonitoring: Use of a living organism or biological entity as a detector and its response as a measure to determine environmental conditions. Ambient biological surveys and toxicity tests are common biological monitoring methods.

biotic: Refers to living organisms.

biotic condition: The state of living things.

biotic integrity: The ability to support and maintain balanced, integrated functionality in the natural habitat of a given region.

body burden: The amount of various contaminants retained in a person's tissues.

bog: A type of wetland that accumulates appreciable peat deposits. Bogs depend primarily on precipitation for their water source and are usually acidic and rich in plant residue, with a conspicuous mat of living green moss. (EPA, December 1997)

brownfield: Real property, the expansion, redevelopment or reuse of which may be complicated by the presence or potential presence of a hazardous substance, pollutant, or contaminant.

C

cadmium: A metal found in natural deposits as ores containing other elements. The greatest use of cadmium is primarily for metal plating and coating operations, including transportation equipment, machinery and baking enamels, photography, and television phosphors. It is also used in nickel-cadmium and solar batteries and in pigments. (EPA, OGWDW, September 2002)

carcinogen: An agent that causes cancer.

cerebrovascular disease: A category of diseases, including stroke, related to blood vessels supplying the brain.

chlorination: The application of chlorine to drinking water, sewage, or industrial waste to disinfect or to oxidize undesirable compounds. (EPA, December 1997)

chlorine: A greenish-yellow gas that is slightly soluble in water. Chlorine is often used in disinfection of water and treatment of sewage effluent as well as in the manufacture of products such as antifreeze, rubber, and cleaning agents.

chromium: A heavy metal that occurs naturally in rocks, plants, soil, and volcanic dust and gases. It is tasteless and odorless. It can damage living things at low concentrations and tends to accumulate in the food chain.

chronic exposure: Multiple exposures occurring over an extended period of time or over a significant fraction of an animal's or human's lifetime (usually seven years to a lifetime). (EPA, December 1997)

Class I area: Under the Clean Air Act, a Class I area is one in which visibility is protected more stringently than under the national ambient air quality standards; includes national parks, wilderness areas, monuments, and other areas of special national and cultural significance. (EPA, December 1997)

cleanup: Action taken to deal with a release or threat of release of a hazardous substance that could affect humans, the environment, or both. The term "cleanup" is sometimes used interchangeably with the terms "remedial action," "removal action," "response action," or "corrective action."

coastal and ocean ecosystem: An ecosystem that consists primarily of estuaries and ocean waters under U.S. jurisdiction. U.S. waters extend to the boundaries of the U.S. Exclusive Economic Zone, 200 miles from the U.S. coast. (The Heinz Center, 2002) (This report focuses on waters within 25 miles of the coast.)

coastal wetland: Ecosystem generally found along the Atlantic, Pacific, Alaskan, and Gulf coasts and closely linked to the nation's estuaries, where sea water mixes with fresh water to form an environment of varying salinities. The plants in coastal wetlands have adapted to changing fluctuating water levels and salinities to create tidal salt marshes, mangrove swamps, and tidal fresh water wetlands, which form beyond the upper edges of tidal salt marshes where the influence of salt water ends. Fresh water coastal wetlands can also be found adjacent to the Great Lakes.

community water system: A public water system that serves at least 15 service connections used by year-round residents or regularly serves at least 25 year-round residents. (EPA, December 1997)

composting: The controlled biological decomposition of organic material in the presence of air to form a humus-like material. Controlled methods of composting include mechanical mixing and aerating, ventilating the materials by dropping them through a vertical series of aerated chambers, and placing the them in piles out in the open air and mixing it or turning it periodically.

congenital anomalies: Birth defects.

construction and demolition debris: Waste generated during building, renovation, and wrecking projects. This type of waste generally consists of materials such as wood, concrete, steel, brick, and gypsum.

contaminant: Any physical, chemical, biological, or radiological substance or matter that has an adverse effect on air, water, or soil. (EPA, December 1997)

contaminated land: Ground that has been polluted with hazardous materials and requires cleanup or remediation. Contaminated sites may contain both polluted objects (e.g., buildings, machinery) and land (e.g. soil, sediments, and plants).

contaminated media: Materials such as soil, sediment, water, and sludge that are polluted at levels requiring cleanup or further assessment.

contamination: Introduction into water, air, or soil of microorganisms, chemicals, toxic substances, wastes, or waste water in a concentration that makes the medium unfit for its next intended use. Also applies to surfaces of objects, buildings, and various household and agricultural use products. (EPA, December 1997)

conterminous: Enclosed within one common boundary (e.g., the 48 *conterminous* states).

cotinine: A breakdown product (*metabolite*) of nicotine that can be measured in urine.

criteria air pollutants: A group of six widespread and common air pollutants regulated by the EPA on the basis of standards set to protect public health or environmental effects of pollution. These six criteria pollutants are carbon monoxide, lead, nitrogen dioxide, ozone, particulate matter, and sulfur dioxide.

cropland: A National Resources Inventory land cover/use category that includes areas used for the production of adapted crops for harvest. Two subcategories of cropland are recognized: cultivated and noncultivated. Cultivated cropland comprises land in row crops or close-grown crops and also other cultivated cropland, for example, hayland or pastureland that is in a rotation with row or close-grown crops. Noncultivated cropland includes permanent hayland and horticultural cropland. (USDA, NRCS, 2000)

D

depuration: The process of reducing the number of pathogenic organisms that may be present in shellfish by using a controlled aquatic environment as the treatment process. (FDA, 2000)

dermal absorption: The process by which a chemical penetrates the skin and enters the body as an internal dose. (EPA, December 1997)

designated uses: Those water uses identified in state water quality standards that must be achieved and maintained as required under the Clean Water Act. Uses can include fishing, shellfish harvesting, public water supply, swimming, boating, and irrigation. (EPA, December 1997)

developed land: A combination of National Resource Inventory land cover/use categories: large urban and built-up areas, small built-up areas, and rural transportation land. (USDA, NRCS, 2000)

dioxin: A group of chemically similar compounds, known chemically as dibenzo-p-dioxins, that are created inadvertently during combustion, chlorine bleaching of pulp and paper, and some types of chemical manufacturing. Tests on laboratory animals indicate that it is one of the more toxic anthropogenic (manmade) compounds.

disinfection byproduct: A compound formed by the reaction of a disinfectant such as chlorine with organic material in the water supply; a chemical byproduct of the disinfection process. (EPA, December 1997)

Dobson unit (DU): A measurement of ozone in the atmosphere. If, for example, 100 DU of ozone were brought to earth's surface, they would form a layer one millimeter thick. (EPA, December 1997)

dose: 1. The actual quantity of a chemical administered to an organism or to which it is exposed. 2. The amount of a substance that reaches a specific tissue (e.g., the liver). 3. The amount of a substance available for interaction with metabolic processes after crossing the outer boundary of an organism. (EPA, December 1997)

dry deposition: The settling of gases and particles out of the atmosphere. Dry deposition is a type of acid deposition, more commonly referred to as "acid rain." (EPA, Clean Air Markets Division, October 2002).

E

ecological indicators: Measurable characteristics related to the structure, composition, or functioning of ecological systems (EPA, SAB, 2002); a measure, an index of measures, or a model that characterizes an ecosystem or one of its critical components (Jackson et.al, 2000); any expression of the environment that quantitatively estimates the condition of ecological resources, the magnitude of stress, the exposure of biological components to stress, or the amount of change in condition. (Barber, 1994)

ecological processes: The metabolic functions of ecosystems—energy flow, elemental cycling, and the production, consumption, and decomposition of organic matter, (EPA, SAB, 2002)

ecology: The study of the structure and function of nature; the totality of relations between organisms and their environment. (Odum, 1971)

ecoregions: Areas within which ecosystems with similar characteristics are likely to occur with predictable patterns; variables include such things as landform, vegetation, soils, and fauna.

ecosystem: 1. The interacting system of a biological community and its nonliving environmental surroundings. 2. A geographic area including all living organisms (people, plants, animals, and microorganisms), their physical surroundings (such as soil, water and air), and the natural cycles that sustain them.

ecotone: A habitat created by the juxtaposition of distinctly different habitats; an edge habitat; or an ecological zone or boundary where two or more ecosystems meet. (EPA, December 1997)

emissions standard: The maximum amount of air-polluting discharge legally allowed from a single source, mobile or stationary. (EPA, December 1997)

endangered species: Animals, birds, fish, plants, or other living organisms threatened with extinction by anthropogenic (human-caused) or natural changes in their environment. Requirements for declaring a species "endangered" are contained in the Endangered Species Act. (EPA, December 1997)

endocrine disruptors: Chemicals that interfere with the endocrine systems, leading to adverse effects. Some chemicals do this by binding to receptors, such as the estrogen and androgen receptors.

endocrine system: The components of the body that produce hormones that regulate reproductive and developmental functions. Major endocrine glands include the pituitary, thyroid, adrenal glands, testes, and ovaries.

enrichment: The addition of nutrients (e.g. nitrogen, phosphorus, carbon compounds) from sewage effluent, agricultural or urban runoff, or other sources to surface water. Enrichment greatly increases the growth potential for algae and other aquatic plants. (EPA, December 1997)

environmental burden of disease: The proportion of diseases, disability, and injury caused by factors in the environment: chemical pollutants, infectious microorganisms, and radiation.

environmental exposure: Human exposure to pollutants in their surroundings. Low-level chronic exposure to pollutants is one of the most common forms of environmental exposure (see threshold level). (EPA, December 1997)

environmental indicators: Scientific measurements that help measure over time the state of air, water, and land resources, pressures on those resources, and resulting effects on ecological and human health. Indicators show progress in making the air cleaner and the water purer and in protecting land.

environmental risk: The potential for adverse effects on living organisms associated with pollution of the environment by effluents, emissions, wastes, or accidental chemical releases; energy use, or the depletion of natural resources. (EPA, December 1997)

environmental risk factor: An exposure to something in the environment that, based on evidence, is known to be associated with health-related conditions and considered important to prevent. (Green, 1999)

environmental tobacco smoke: A mixture of smoke exhaled by a smoker and the smoke from the burning end of a smoker's cigarette, pipe, or cigar. Also known as second hand smoke.

epidemiology: The study of how diseases occur in a population or area.

epiphyte: A plant, fungus, or microbe sustained entirely by nutrients and water received, by means other than a parasite, from within the canopy in which it resides. (Moffett, 2000)

erosion: The wearing away of land surface by wind or water, intensified by land-clearing practices related to farming, residential or industrial development, road building, or logging. (EPA, December 1997)

estuaries: Partially enclosed bodies of water (this term includes bays, sounds, lagoons, and fjords); they are generally considered to begin at the upper end of tidal or saltwater influence and end where they meet the ocean. (The Heinz Center, 2002)

eutrophic: Pertaining to a lake or other body of water characterized by large nutrient concentrations, resulting in high productivity of algae.

eutrophication: The slow aging process during which a lake, estuary, or bay evolves into a bog or marsh and eventually disappears. During the later stages of this process, the water body is choked by abundant plant life that result from higher levels of nutritive compounds such as nitrogen and phosphorus. Human activities can accelerate the process. (EPA, December 1997)

exotic species: A species that is not indigenous to a region. (EPA, December 1997)

exposure: The amount of radiation or pollutant present in a given environment that represents a potential health threat to living organisms. (EPA, December 1997)

exposure pathway: The path from sources of pollutants via, soil, water, or food to humans and other species. (EPA, December 1997)

exposure route: The way a chemical or pollutant enters an organism after contact; i.e. by ingestion, inhalation, or dermal absorption. (EPA, December 1997)

extraction waste: Byproducts produced as a result of mining practices.

F

farmlands: Include both croplands-lands used for production of annual and perennial crops and livestock-and surrounding landscape, such as field borders and windbreaks, small woodlots, grassland or shrubland areas, wetlands, farmsteads, small villages and other built-up areas, and similar areas within and adjacent to croplands. (The Heinz Center, 2002)

fauna: Animal life.

fertilizers: Supplements to improve plant growth that are commonly used on agricultural lands, as well as in urban, industrial, and residential settings.

fish kill: A large-scale die-off of fish caused by factors such as pollution, noxious algae, harmful bacteria, and hypoxic conditions.

floodplain: Any land area susceptible to being inundated by water from any source.

flora: Plant or bacterial life.

forage: Food for animals especially when taken by browsing or grazing.

forests: Lands at least 10 percent covered by trees of any size, at least one acre in extent. This includes areas in which trees are intermingled with other cover, such as chaparral and pinyon, juniper areas in the Southwest, and both naturally regenerating forests and areas planted for future harvest (plantations or "tree farms"). (The Heinz Center, 2002)

forest fragmentation: The division of a formerly healthy forest into patches, usually as a result of conversion to agricultural or residential land. (EPA, August 2002)

forest land: Land that is at least 10 percent stocked by forest trees of any size, including land that formerly had tree cover and that will be naturally or artificially regenerated. The minimum area for classification of forest land is one acre. (USDA, Forest Service, April 2001)

fresh water systems: Include:

- Rivers and streams, including those that flow only part of the year
- Lakes, ponds, and reservoirs, from small farm ponds to the Great Lakes
- Ground water, which is often directly connected to rivers, streams, lakes, and wetlands
- Fresh water wetlands, including forested, shrub, and emergent wetlands (marshes), and open water ponds
- Riparian areas–they usually vegetated margins of streams and rivers (although this term can also apply to lake margins). (The Heinz Center, 2002)

G

geomorphology: The scientific study of the nature and origin of the landforms on the surface of earth and other planets.

giardiasis: The illness resulting from infection of the gastrointestinal tract with Giardia lamblia. The symptoms of giardiasis include gastric pain, fatigue, extreme diarrhea, fever, chills, and nausea. The most acute symptoms typically last only a few days (Garcia, 1999).

global burden of disease: The overall impact of disease related to all causes. It takes into account the burden represented by years of life lived with illness or disability.

grasslands and shrublands: Lands in which the dominant vegetation is grasses and other nonwoody vegetation, or where shrubs (with or without scattered trees) are the norm (also called rangelands); includes bare-rock deserts, alpine meadows, arctic tundra, pastures, and haylands (an overlap with the farmland system). Less-managed pastures and haylands fit well within the grassland/shrubland system; more heavily managed ones fit well as part of the farmlands system. (The Heinz Center, 2002)

gross primary production: Total energy captured in units of carbon gain.

ground-level ozone: See ozone.

ground water: Subsurface water that occurs beneath the water table in soils and geologic formations that are fully saturated.

H

habitat: The place where a population (e.g., human, animal, plant, microorganism) lives and its surroundings, both living and nonliving. (EPA, December 1997)

habitat fragmentation: The division of large areas of natural habitat into smaller sections through conversion of the natural habitat to other uses (e.g., roads, development), resulting in populations of plants and animals becoming isolated from each other and potentially threatening their survival.

habitat loss: The destruction of habitat by natural disasters (hurricanes, fires, flooding, etc.) and human activity (clearing land for agricultural, industrial, and residential development; clear-cut harvesting of timber; oil spills; and war).

halogens: Compounds that contain atoms of chlorine, bromine, or fluorine.

hardwood: The wood of an angiospermous tree as distinguished from that of a coniferous tree; a tree that yields hardwood.

hazardous waste: Byproducts of society that can pose a substantial or potential threat to human health or the environment when improperly managed. Hazardous waste possesses at least one of four characteristics: ignitability, corrosivity, reactivity, or toxicity.

health outcomes: An outcome measured by the quality of life, likelihood of disease, life expectancy, and overall health of individuals or communities. (HIC, 2000-2001)

heavy metals: Metallic elements with high atomic weights (e.g., mercury, chromium, cadmium, arsenic, lead); can damage living things at low concentrations and tend to accumulate in the food chain. (EPA, December 1997)

herbicide: A form of pesticide used to control weeds that limit or inhibit the growth of the desired crop.

high-level radioactive waste: Highly radioactive waste material from the chemical processing of spent fuel. It includes spent fuel, liquid waste, and highly radioactive solid waste from the liquid. High-level radioactive waste contains elements that decay very slowly and remain radioactive for thousands of years. (DOE, 1997)

household hazardous waste: Hazardous products used and disposed of by residential rather than industrial consumers. It includes paints, stains, varnishes, solvents, pesticides, and other materials or products containing volatile chemicals that can catch fire, react, or explode, or are corrosive or toxic.

human exposure to contaminants: The contact of a chemical contacting and the outer boundary of a human. (EPA, ORD, March 1998)

hydrologic cycle: Movement or exchange of water between the atmosphere and earth. (EPA, December 1997)

hydrologic unit code (HUC): An eight-digit code that is used to classify watersheds in the U.S. This code uniquely identifies each of four levels of watershed classification within four two-digit fields. The first two digits of the code identify the water-resources region; the first four digits identify the sub-region; the first six digits identify the accounting unit; and the final two digits identify the cataloging unit. For example, in hydrologic unit code (HUC) 01080204, 01 identifies the region; 0108 identifies the sub-region; 010802 identifies the accounting unit; and 01080204 identifies the cataloging unit.

hydrology: The geology of ground water, with particular emphasis on the chemistry and movement of water. (EPA, December 1997)

hypertrophic: Pertaining to a lake or other body of water characterized by excessive nutrient concentrations, resulting high productivity.

hypoxia/hypoxic waters: Waters with low levels of dissolved oxygen concentrations, typically less than two ppm, the level generally accepted as the minimum required for most marine life to survive and reproduce. (EPA, December 1997).

I

impervious surface: A hard surface area that either prevents or retards the entry of water into the soil mantle or causes water to run off the surface in greater quantities or at an increased rate of flow. Common impervious surfaces include, but are not limited to, rooftops, walkways, patios, driveways, parking lots, storage areas, concrete or asphalt paving, and gravel roads. (Washington Department of Ecology, 1992).

impounded: Refers to a body of water such as a pond, lake, or river that has been confined by a dam, dike, floodgate, or other barrier. (Texas Environmental Center, 1991)

incidence rate of disease: The number of new cases of a disease or condition in a given period of time in a specified population.

indoor air: The breathable air inside a habitable structure or conveyance. (EPA, December 1997)

indoor air pollution: Chemical, physical, or biological contaminants in indoor air. (EPA, December 1997)

industrial waste: Process waste associated with manufacturing. This waste usually is not classified as either municipal waste or RCRA hazardous waste by federal or state laws. (EPA, OSWER, October 1988)

industrial non-hazardous waste: Process waste associated with generation of electric power and manufacture of materials such as pulp and paper, iron and steel, glass, and concrete. This waste usually is not classified as either municipal waste or hazardous waste by federal or state laws.

infant mortality: The death of children in the first year of life.

inland wetlands: Wetlands that include marshes, wet meadows, and swamps. These areas are often dry one or more seasons every year. In the arid West of the U.S., they may be wet only periodically.

integrated pest management: The coordinated use of available pest-control methods to prevent unacceptable levels of pest damage by the most economical means and with the least possible hazard to people, property, and the environment.

invasive species/invasive nuisance species: See nonnative species.

inversion: The condition that occurs when warm air is trapped near the ground and normal temperature gradients don't permit air to flow into the atmosphere. (Nadakavukaren, 2000).

J

Julian day (JD): A Julian day is a continuous count of days beginning with January 1, 4713 BC. Julian days are often used by astronomers and sometimes used by historians to provide a precise date for an event, independent of all calendar systems. The date 4713 BC was chosen for the start of the count because this was earlier than all known historical records and happened to be a convenient starting point for several chronological and astronomical cycles. The length of the year in the Julian calendar is exactly 365.25 Julian days.

K

keystone species: A species that interacts with a large number of other species in a community. Because of the interactions, the removal of this species can cause widespread changes to community structure. (Pidwirny, 2000-2001)

L

lagoons (for waste treatment): Water impoundments in which organic wastes are stored, stabilized, or both. A shallow, artificial treatment pond where sunlight, bacterial action, and oxygen work to purify wastewater; a stabilization pond. An aerated lagoon is a treatment pond that uses oxygen to speed up the natural process of biological decomposition of organic wastes. (EPA, August 2002)

land cover: The ecological status and physical structure of the vegetation on the land surface. (NRC, 2000)

land use: Describes how a piece of land is managed or used by humans. The degree to which the land reflects human activities (e.g., residential and industrial development, roads, mining, timber harvesting, agriculture, grazing, etc.).

landfills: 1. Sanitary landfills: Disposal sites for nonhazardous solid wastes spread in layers, compacted to the smallest practical volume, and covered by material applied at the end of each operating day. 2. Secure chemical landfills: Disposal sites for hazardous waste, selected and designed to minimize the chance of release of hazardous substances into the environment.

landscape: The traits, patterns, and structure of a specific geographic area, including its biological composition, its physical environment, and its anthropogenic or social patterns. An area where interacting ecosystems are grouped and repeated in similar form. (EPA, December 1997)

landscape condition: The extent, composition, and patterns of habitats in a landscape.

landscape pattern: The spatial distribution of the land use/land cover types, the arrangement of patches, connectivity among patches, and corridors for movement.

large urban and built-up areas: A National Resources Inventory land cover/use category composed of developed tracts of at least 10 acres, meeting the definition of *urban and built-up areas*. (USDA, NRCS, 2000)

large-quantity generators: Businesses that generate substantial "RCRA hazardous waste" as a part of their regular activities.

leaching: The process by which soluble materials in the soil, such as nutrients, pesticide chemicals, or contaminants, are washed into a lower layer of soil or are dissolved and carried away by water. (Texas Environmental Center, 1991)

lead: A heavy metal used in many materials and products. It is a natural element and does not break down in the environment. When absorbed into the body, it can be highly toxic to many organs and systems.

levee: A natural or manmade earthen barrier along the edge of a stream, lake, or river. Land alongside rivers can be protected from flooding by levees.

lichen: Any of numerous complex thallophytic plants made up of an alga and a fungus growing in symbiotic association on a solid surface (e.g., a rock).

life expectancy: The probable number of years (or other time period) that members of a particular age class of a population are expected to live, based on statistical studies of similar populations in similar environments.

life expectancy (at birth): The average number of years that a group or cohort of infants born in the same year are expected to live.

low birthweight: Refers to children born weighing less than 2,500 grams (5.5 pounds).

low-level waste: Radioactive waste, including accelerator-produced waste, that is not high-level radioactive waste, spent nuclear fuel, transuranic waste, byproduct material (as defined in the Atomic Energy Act of 1954), or naturally occurring radioactive material.

M

macroinvertebrate: An organism that lacks a backbone and can be seen with the naked eye. (EPA, OW, November 2002).

malignant melanoma: A type of skin cancer, more often fatal than other types of skin cancer.

media: Specific environments—air, water, soil—that are the subject of regulatory concern and activities. (EPA, December 1997)

medical waste: Any solid waste generated during the diagnosis, treatment, or immunization of human beings or animals, in research, production, or testing.

mercury: Mercury is a metallic element that occurs in many forms and in combination with other elements. When combined with carbon, which readily occurs in water, it forms more-bioavailable organic mercury compounds (e.g., methylmercury).

mesotrophic: Pertaining to a lake or other body of water characterized by moderate nutrient concentrations and moderate productivity in terms of aquatic animal and plant life.

metabolic rate: The rate at which the body can turn food into energy.

metabolites: Compound that result from human digestion (metabolism) of contaminants and that serve as a biomarkers of exposure.

metadata: Information about data. It describes the content, quality, condition, and other characteristics of data.

methemoglobinemia: A rare but potentially fatal condition in infants that results from interferences in the blood's ability to carry oxygen. Nitrates in drinking water are associated with methemoglobinemia (also known as "blue baby syndrome").

metropolitan area: A Metropolitan Area (MA) is a U.S. Census Bureau construct that consists of an area comprising a core with a large population nucleus, together with adjacent communities that have a high degree of economic and social integration with that core. Each MA must contain either a place with a minimum population of 50,000 or a Census Bureau-defined urbanized area and a total MA population of at least 100,000 (75,000 in New England). The area is defined by county boundaries. (U.S. Census Bureau, 2001)

microorganisms: Tiny life forms that can be seen only with the aid of a microscope. Some microorganisms can cause acute health problems when consumed; also known as microbes. (EPA, OGWDW, November 2002)

Mid-Atlantic Highlands: A region that encompass 79,000 square miles and extends east to west from the Blue Ridge Mountains in Virginia to the Ohio River, and north to south from the Catskill Mountains to the North Carolina-Tennessee-Virginia border

mixed low-level waste: Low-level radioactive waste that also contains hazardous constituents. (DOE, December 1999)

mobile sources: Moving objects that release pollution from combustion of fossil fuels, such as cars, trucks, buses, planes, trains, lawn mowers, construction equipment, and snowmobiles. Some mobile sources, such as some construction equipment or movable diesel generators, are called nonroad sources, because they are usually operated off road.

Monte Carlo analysis: A computer-based statistical tool—drawing on various probabilistic techniques—that is used to help quantify variability and uncertainty inherent to risk assessment.

morbidity: Sickness, illness, or disease that does not result in death.

mortality: Death; death rate, the proportion of the population who die of a disease, often expressed as a number per 100,000.

municipal solid waste: Waste discarded by households, hotels/motels, and commercial, institutional, and industrial sources. It typically consists of everyday items such as product packaging, grass clippings, furniture, clothing, bottles, food scraps, newspapers, appliances, paint, and batteries. It does not include waste water.

N

National Ambient Air Quality Standards: Standards established by EPA under the Clean Air Act that apply to outdoor air throughout the country (see *criteria pollutants*). (EPA, December 1997)

nematodes: Simple worms consisting of an elongate stomach and reproduction system inside a resistant outer cuticle (outer skin). (USDA, 2001)

net primary production: Gross primary production minus all sources of plant respiration. Represents the carbon or biomass that is available to other organisms, providing the base of the food web.

nitrate: The primary chemical form of nitrogen in most aquatic systems; occurs naturally; a plant nutrient and fertilizer; can be harmful to humans and aninmals.

nitric oxide (NO): A gas formed by combustion under high temperature and high pressure in an internal combustion engine; it is converted by sunlight and photochemical processes in ambient air to nitrogen oxide. NO is a precursor of ground-level ozone pollution, or smog. (EPA, December 1997)

nitrogen dioxide (NO_2): The result of nitric oxide combining with oxygen in the atmosphere; major component of photochemical smog. (EPA, December 1997)

nitrogen export: The annual quantity of total nitrogen produced by nitrogen sources in a watershed that leaves the watershed through a river or stream that connects to other watersheds downstream

nitrogen oxide (NO_X): The result of photochemical reactions of nitric oxide in ambient air; major component of photochemical smog. Product of combustion from transportation and stationary sources and a major contributor to the formation of ozone in the troposphere and to acid deposition. (EPA, December, 1997)

noncommunity water system: A public water system that is not a community water system. Nontransient noncommunity water systems are those that regularly supply water to at least 25 of the same people at least six months per year but not year-round (e.g., schools, factories, office buildings, and hospitals that have their own water systems). Transient noncommunity water systems provide water in a place where people do not remain for long periods of time (e.g., a gas station or campground).

nonhazardous waste: See *solid waste*.

nonisolated intermediaries: An intermediate compound in a chemical manufacturing process that can be a by-product or can be released as a result of the process.

nonnative species: A species that has been introduced by human action, either intentionally or by accident, into areas outside its natural geographical range. Other names for these species include alien, exotic, introduced, and nonindigenous.

nonpoint source pollution: Pollution that occurs when rainfall, snowmelt, or irrigation water runs over land or through the ground, picks up pollutants, and deposits them into rivers, lakes, coastal waters, or ground water. Types of pollution include sediments, nutrients, pesticides, pathogens (bacteria and viruses), toxic chemicals, heavy metals that runoff from agricultural land, urban development, and roads.

noxious algae: Toxic algae commonly associated with harmful algae blooms such as red tides.

nutrient: Any substance assimilated by living things that promotes growth. The term is generally applied to nitrogen and phosphorus, but is also applied to other essential and trace elements.

nutrient enrichment: See *eutrophication*.

O

oil and gas production wastes: Drilling fluids, produced waters, and other wastes associated with the exploration, development, and production of crude oil or natural gas that are conditionally exempted from regulation as hazardous wastes.

oligotrophic: Pertaining to a lake or other body of water characterized by extremely low nutrient concentrations, often with very limited plant growth but with high dissolved-oxygen levels.

organic matter: Plant and animal material that is in the process of decomposing. When it has fully decomposed, it is called "humus." This humus is important for soil structure because it holds individual mineral particles together in clusters. (USDA, NRCS, 2000)

organophosphate: Pesticides that contain phosphorus; short-lived, but some can be toxic when first applied. (EPA, December, 1997)

outer boundary: In reference to the body, includes skin and body openings.

ozone (O_3): A very reactive form of oxygen that is a bluish irritating gas of pungent odor. It is formed naturally in the atmosphere by a photochemical reaction and is a beneficial component of the upper atmosphere. It is also a major air pollutant in the lower atmosphere, where it can form by photochemical reactions when there are conditions of air pollutants, bright sunlight, and stagnant weather.

ozone depletion: Destruction of the stratospheric ozone layer, which shields earth from ultraviolet radiation harmful to life. This destruction of ozone is caused by the breakdown of certain compounds that contain chlorine, bromine, or both (chlorofluorocarbons or halons), which occurs when they reach the stratosphere and then catalytically destroy ozone molecules. (EPA, December 1997)

ozone hole: A well-defined, large-scale area of significant thinning of the ozone layer. It occurs over Antarctica each spring.

ozone layer: The protective stratum in the atmosphere, about 15 miles above the ground, that absorbs some of the sun's ultraviolet rays, thereby reducing the amount of potentially harmful radiation that reaches earth's surface. (EPA, December 1997)

ozone precursors: Chemicals that contribute to the formation of ozone.

P

particulate matter: Solid particles or liquid droplets suspended or carried in the air (e.g., soot, dust, fumes, mist). (EPA, OAR, October 2002)

passive smoking: Exposure to tobacco smoke, or the chemicals in tobacco smoke, without actually smoking. It usually refers to a situation where a nonsmoker inhales smoke emitted into the environment by other people smoking. This smoke is known as "environmental tobacco smoke" (ETS). (National Public Health Partnership, 2000)

pastureland: A National Resources Inventory land cover/use category of land managed primarily for the production of introduced forage plants for livestock grazing. Pastureland cover may consist of a single species in a pure stand, a grass mixture, or a grass-legume mixture. For the NRI, it includes land that has a vegetative cover of grasses, legumes, and/or forbs, regardless of whether or not it is being grazed by livestock. (USDA, NRCS, 2000).

pathogen: Microorganism (e.g., bacteria, viruses, or parasites) that can cause disease in humans, animals, and plants. (EPA, December 1997)

periphyton: Microscopic underwater plants and animals that are firmly attached to solid surfaces such as rocks, logs, and pilings. (EPA, December 1997)

persistent organic pollutants: Chemicals that endure in the environment and bioaccumulate as they move up trough the food chain. They include organochlorine pesticides, polychlorinated biphenyls (PCBs), dioxins, and furans.

pesticides: Any substance or mixture of substances intended to prevent, destroy, repel, or mitigate any pest. Pests can be insects, mice and other animals, unwanted plants (weeds), fungi, or microorganisms such as bacteria and viruses. Though often misunderstood to refer only to insecticides, the term "pesticide" also applies to herbicides, fungicides, and various other substances used to control pests. Under U.S. law, a pesticide is also any substance or mixture of substances intended for use as a plant regulator, defoliant, or desiccant.

phosphorus: An essential chemical food element that can contribute to the eutrophication of lakes and other water bodies. Increased phosphorus levels result from discharge of phosphorus-containing materials into surface waters. (EPA, December 1997)

photosynthesis: The manufacture by plants of carbohydrates and oxygen from carbon dioxide mediated by chlorophyll in the presence of sunlight. (EPA, December 1997)

phytoplankton: That portion of the plankton community composed of tiny plants (e.g. algae, diatoms). (EPA, December 1997)

playas: Areas at the bottom of undrained desert basins that are sometimes covered with water. (EPA, OWOW, July 2002)

$PM_{2.5}$: Fine particles that are less than or equal to 2.5 micrometers in diameter.

PM_{10}: Particles less than or equal to 10 micrometers in diameter.

point source pollution: Effluent or discharges directly from a pipe into a waterway (e.g., from many industries and sewage treatment plants).

pollutant: Generally, any substance introduced into the environment that adversely affects the usefulness of a resource or the health of humans, animals, or ecosystems. (EPA, December 1997)

pollution: Generally, the presence of a substance in the environment that, because of its chemical composition or quantity, prevents the functioning of natural processes and produces undesirable environmental and health effects. Under the Clean Water Act, for example, the term has been defined as the manmade or man-induced alteration of the physical, biological, chemical, and radiological integrity of water and other media. (EPA, December 1997)

polychlorinated biphenyls (PCBs): A group of synthetic chemicals that can exist as oily liquids and waxy solids. Due to their non-flammability, chemical stability, high boiling point and electrical insulating properties, PCBs were used in hundreds of industrial and commercial applications including electrical, heat transfer, and hydraulic equipment; as plasticizers in paints, plastics and rubber products; in pigments, dyes and carbonless copy paper, and many other applications. PCBs can produce toxic effects and are probable carcinogen. (EPA, OPPT, February 2003)

pressure: See *stressor*.

prevalence of disease: That part of the total population affected by a condition or disease.

prevalence rate: The total number of persons with a given disease or condition in a specified population at a specified period of time.

production capacity: Chlorophyll per unit area for terrestrial ecosystems (including wetlands and riparian areas) and per unit volume for aquatic ecosystems.

productivity: The rate at which ecosystems use energy (principally solar energy) to fix atmospheric carbon dioxide. (NRC, 2000)

R

radioactive waste: Garbage, refuse, sludge, and other discarded material, including solid, liquid, semisolid, or contained gaseous material that must be managed for its radioactive content (DOE, July 1999). Types of radioactive waste include high-level waste, spent nuclear fuel, transuranic waste, low-level waste, mixed low-level waste, and contaminated media.

radon (Rn-222): A naturally occurring radioactive gas that has no color, odor, or taste and is chemically inert. Radon comes from the radioactive decay of uranium in soil, rock, and ground water and is found all over the U.S. It has a half-life of 3.8 days, emitting ionizing radiation (alpha particles) during its radioactive decay to several radioactive isotopes known as "radon decay products." It gets into indoor air primarily from soil under homes and other buildings. Radon is a known human lung carcinogen and represents the largest fraction of the public's exposure to natural radiation.

rangelands: A National Resources Inventory land cover/use category on which the climax or potential plant cover is composed principally of native grasses, grasslike plants, forbs or shrubs suitable for grazing and browsing, and introduced forage species that are managed like rangeland. This would include areas where introduced hardy and persistent grasses, such as crested wheatgrass, are planted and such practices as deferred grazing, burning, chaining, and rotational grazing are used, with little or no chemicals or fertilizer being applied. Grasslands, savannas, many wetlands, some deserts, and tundra are considered to be rangeland. Certain communities of low forbs and shrubs, such as mesquite, chaparral, mountain shrub, and pinyon-juniper, are also included as rangeland. (USDA, NRCS, 2000).

rare and at-risk species: Rare species are those that are particularly vulnerable to both human-induced threats and natural fluctuations and hazards. At-risk species are those classified by the Association for Biodiversity Information as vulnerable or more rare.

RCRA hazardous waste: Applies to certain types of hazardous wastes that appear on EPA's regulatory listing (RCRA) or that exhibit specific characteristics of ignitability, corrosiveness, reactivity, or excessive toxicity.

red tide: A common name for the phenomenon where certain phytoplankton species contain reddish pigments and "bloom" such that the water appears to be colored red.

regional and continental areas: Heterogeneous areas at regional (e.g, Southeast) and continental scales composed of a cluster or mosaic of interacting ecosystems. Regional and continental ecosystems are not characterized primarily by a dominant land cover type such as forests, farmlands, grasslands or urban areas, but rather include many or all these ecosystems at these larger spatial scales. Regional and continental ecosystems reflect the underlying landscape patterns at these larger scales.

relative risk: A measurement of the chance of contracting a disease in those who have been exposed to a risk factor compared with the risk for those who have not been exposed.

remediation: Cleanup or other methods used to remove or contain a toxic spill or hazardous materials from a contaminated site.

reserved forest land: Forested land withdrawn from timber utilization through statute, administrative regulation, or designation. (USDA, Forest Service, April 2001)

richness: A measure of species diversity, which usually decreases with impairment. It is based on the number of distinct taxa (at a level selected to identify, e.g., order, family, species); can be the total number of taxa, or the number in an identified group (e.g., number of mayfly taxa).

rill: A small channel eroded into the soil by surface runoff; can be easily smoothed out or obliterated by normal tillage. (EPA, December 1997)

riparian area: The area adjacent to streams and rivers, important as buffers to runoff. Many riparian areas include wetlands.

riparian wetland: A wetland along a stream or river.

riparian zone: A 30-meter buffer on each side of a stream or river.

risk: The probability that a health problem, injury, or disease will occur.

risk factor: A characteristic (e.g., race, sex, age, obesity) or variable (e.g., smoking, occupational exposure level) associated with increased probability of an adverse effect. (EPA, December 1997)

runoff: That part of precipitation, snowmelt, or irrigation water that runs off the land into streams or other surface water. It can carry pollutants from the air and land into receiving waters. (EPA, December 1997)

rural transportation land: A National Resources Inventory land cover/use category that consists of all highways, roads, railroads, and associated right-of-ways outside urban and built-up areas; including private roads to farmsteads or ranch headquarters, logging roads, and other private roads, except field lanes. (USDA, NRCS, 2000)

S

secondhand smoke: See *environmental tobacco smoke*.

sediment transport: The movement of sediment in rivers and streams.

sedimentation: the process of forming or depositing sediment; letting solids settle out of wastewater by gravity during treatment.

self-supplied water: Water not drawn from the public water supply.

silica: An inorganic compound mined from the earth; has been found to be associated with lung cancer (Steenland, 1997). Silica is used in foundries, pottery making, brick making, and sand blasting.

silviculture: The science of producing and tending a forest; the theory and practice of controlling forest establishment, composition, and growth. (Matthews, 1989)

sludge: Solid, semisolid, or liquid waste generated from a municipal, commercial, or industrial waste water facility.

small built-up areas: A National Resources Inventory land cover/use category consisting of developed land units of 0.25 to 10 acres, which meet the definition of *urban and built-up areas*. (USDA, NRCS, 2000)

smart growth: The management of "urbanization" that seeks to serve the economy, the community, and the environment. Smart growth seeks to foster healthy communities, a clean environment, economic development and jobs, and strong neighborhoods with a range of housing options.

softwood: Coniferous trees, usually evergreen, that have needles or scale-like leaves. (USDA, Forest Service, November 2002)

solid waste: Nonliquid, nonsoluble materials ranging from municipal garbage to industrial wastes that contain complex and sometimes hazardous substances. Solid wastes also include sewage sludge, agricultural refuse, demolition wastes, mining residues, and liquids and gases in containers. (EPA, December 1997)

species richness: The absolute number of species in an assemblage or community.

spent nuclear fuel: Nuclear reactor fuel that has been used to the extent that it can no longer effectively sustain a chain reaction. (EPA, December 2002)

spray drift: The physical movement of a pesticide through air at the time of application, or soon thereafter, to any site other than that intended for application.

sprawl: See *urban sprawl*.

squamous cell carcinoma: A type of skin cancer, usually curable if treated in time.

stationary source: A place or object from which pollutants are released and that stays in one place. These sources include many types of facilities, including power plants, gas stations, dry cleaners, incinerators, factories, and houses.

stressor: A physical, chemical, or biological entity that can induce adverse effects on ecosystems or human health. (EPA, December 1997)

submerged aquatic vegetation (SAV): Rooted vegetation that grows under water in shallow zones where light penetrates. (EPA, CBP, October 2002)

Superfund: The program operated under the legislative authority of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) and the Superfund Amendments and Reauthorization Act (SARA) that funds and carries out EPA solid waste emergency and long-term removal and remedial activities. These activities include establishing the National Priorities List, investigating sites for inclusion on the list, determining their priority, and conducting and/or supervising cleanup and other remedial actions. (EPA, December 1997)

Superfund site: Any land in the U.S. that has been contaminated by hazardous waste and identified by EPA as a candidate for cleanup because it poses a risk to human health, the environment, or both.

surface eythemal: Sun-burning UV radiation at earth=s surface.

surface water: Water in rivers, streams, lakes, ponds, reservoirs, estuaries, and wetlands (found at the surface, in contrast to ground water).

sustainability: Long-term management of ecosystems to meet the needs of present human populations without interruption, weakening, or loss of the resource base for future generations. (Environment Canada, 1997)

T

thermoelectric water use: Use of water for cooling in the generation of electric power.

threatened and endangered species: Those species that are in danger of extinction throughout all or a significant portion of their range or are likely to become endangered in the future. (Grondahl, et al, July 1997)

threshold: 1.The lowest dose of a chemical at which a specified measurable effect is observed and below which it is not observed. 2.The dose or exposure level below which a significant adverse effect is not expected. (EPA, December 1997)

timber land: Forest land that is capable of producing crops of industrial wood (at least 20 cubic feet per acre per year in natural stands) and not withdrawn from timber use by statute or administrative regulation. (USDA, Forest Service, April 2001)

total off-site releases: The total annual amount (in pounds) of a toxic chemical transferred from a facility to publicly owned treatment works (POTW) or to an off-site location (non-POTW). (EPA, TRI, November 2002)

total on-site releases: The total annual release quantities (in pounds) of a chemical to air, water, on-site land, and underground injection wells. (EPA, TRI, November 2002)

Toxics Release Inventory (TRI): A publicly available EPA database that contains information on toxic chemical releases and other waste management activities reported annually by certain covered industries and federal facilities. TRI was established under the Emergency Planning and Community Right-to-Know Act of 1986 (EPCRA) and expanded by the Pollution Prevention Act of 1990. (EPA, TRI, December 2002)

t**oxic substance:** Any substance that presents a significant risk of injury to health or the environment through exposure.

toxic waste: A waste that can produce injury if inhaled, swallowed, or absorbed through the skin. (EPA, December 1997)

transuranic waste: A category of radioactive waste. It contains elements that have atomic numbers higher than uranium (92), such as plutonium; results primarily from past nuclear weapons production and cleanup of nuclear weapons facilities.

trophic status: Classification of a lake or water body as eutrophic, oligotrophic, mesotrophic, or hypertrophic.

troposphere: The layer of the atmosphere closest to the earth's surface. (EPA, December 1997)

U

ultraviolet (UV) radiation Radiation from the sun that can be useful or potentially harmful. UV radiation from one part of the spectrum (UV-A) enhance plant life. UV radiation from other parts of the spectrum (UV-B) can cause skin cancer or other tissue damage. The ozone layer in the atmosphere partly shields earth from UV radiation reaching the surface. (EPA, December 1997)

underground storage tanks: Tanks and their underground piping that have at least 10 percent of their combined volume underground.

urban and built-up areas: A National Resources Inventory land cover/use category consisting of residential, industrial, commercial, and institutional land construction sites; public administrative sites; railroad yards; cemeteries; airports; golf courses; sanitary structures and spillways; small parks (less than 10 acres) within urban and built-up areas; and highways, railroads, and other transportation facilities if they are surrounded by urban areas. Also included are tracts of less than 10 acres that do not meet the above definition but are completely surrounded by urban and built-up land. (USDA, NRCS, 2000)

urbanized areas (UAs) and urban clusters (UCs): Densely settled areas consisting of core census block groups that have a population density of at least 1,000 people per square mile and other surrounding census blocks that have an overall density of at least 500 people per square mile. UAs contain 50,000 or more people; UCs contain at least 2,500 people but fewer than 50,000. (U.S. Census Bureau, 2001)

urban and suburban areas: Places where the land is primarily devoted to buildings, houses, roads, concrete, grassy lawns, and other elements of human use and construction. Urban and suburban areas, in which about three-fourths of all Americans live, span a range of density, from the city center–characterized by high-rise buildings and little green space–to the suburban fringe–where development thins to a rural landscape. This definition does not include all developed lands, for example, small residential zones, the area of rural interstate highways, farmsteads, and the like, which are "developed but are not sufficiently built up to be considered "urban or suburban." (The Heinz Center, 2002)

urbanization: The concentration of development in relatively small areas (cities and suburbs). The U.S. Census Bureau defines "urban" as areas with densities of people above 1.5 people per acre.

V-Z

vehicle miles traveled: A measure of the extent of motor vehicle operation; the total number of vehicle miles traveled by all vehicles within a specific geographic area over a given period of time. Vehicle miles traveled and other variables are used to estimate air pollutant emissions.

vernal pools: Seasonal wetlands that occur under the Mediterranean climate conditions of the West Coast. They are covered by shallow water for variable periods from winter to spring but may be completely dry for most of the summer and fall. These wetlands range in size from small puddles to shallow lakes and are usually found in a gently sloping plain of grassland. Beneath vernal pools lies either bedrock or a hard clay layer in the soil that helps keep water in the pool.

volatile organic compounds: Chemicals, such as gasoline and perchloroethylene (a dry cleaning solvent) that contain carbon and vaporize readily.

waste minimization priority chemicals: A group of 30 chemicals—3 metals (lead, mercury, and cadmium) and 27 organic compounds—identified as the highest priority for reduction in industrial and hazardous waste.

water clarity: A measure of how clear a body of water is; measured in the distance light penetrates into the water.

water quality criteria: Levels of water quality expected to render a body of water suitable for its designated use. Criteria are based on specific levels of pollutants that would make the water harmful if used for drinking, swimming, irrigation, fish production, or industrial processes. (EPA, December 1997)

water quality standards: State-adopted and EPA-approved ambient standards for water bodies. The standards define the water quality goals of a water body by designating the uses of the water and setting criteria to protect those uses. The standards protect public health and welfare, enhance the quality of the water, and provide the baseline for surface water protection under the Clean Water Act.

waterborne disease outbreak: is defined as an event in which (1) more than two persons have experienced an illness after either the ingestion of drinking water or exposure to water encountered in recreational or occupational settings, and (2) epidemiologic evidence implicates water as the probable source of illness.

watershed: An area of land from which all water that drains from it flows to a single water body.

wetland ecosystems: Areas that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands generally include swamps, marshes, bogs and similar areas.

Appendix E: References

Chapter 1: Cleaner Air

CNN.com. "Asian Brown Cloud" poses global threat. August 12, 2002 (August 12, 2002; *http://www.cnn.com/2002/WORLD/asiapcf/south/08/12/asia.haze.glb/index.html*).

Centers for Disease Control. Blood lead levels in young children – United States and selected states, 1996-1999. *Morbidity and Mortality Weekly Report* 49 (50): 1133 (2000).

Centers for Disease Control, National Center for Health Statistics. Asthma prevalence, health care use and mortality, 2000-2001. January 28, 2003. (February 14, 2003; *http://www.cdc.gov/nchs/products/pubs/pubd/hestats/asthma/asthma.htm)*.

DeMora, S., S. Demers, and M. Vernet. *The Effects of UV Radiation in the Marine Environment*, Cambridge, UK: Cambridge University Press, 2000.

Friedman, Michael S., K.E. Powell, L. Hutwagner, L.M. Graham, and W.G. Teague. Impacts of changes in transportation and commuting behaviors during the 1996 Summer Olympics Games in Atlanta on air quality and childhood asthma. *The Journal of the American Medical Association* 285 (7): 897-905 (2001).

Hackshaw, A.K. Lung cancer and passive smoking. *Statistical Methods in Medical Research* 7 (2): 119- 136 (1998).

Mannino, D.M., J.E. Moorman, B. Ingsley, D. Rose, and J. Repace. Health effects related to environmental tobacco smoke exposure in children in the United States: data from the third National Health and Nutritional Examination Survey. *Archives of Pediatric and Adolescent Medicine* 155 (1): 36- 41 (2001).

McConnell, R.K. Berhane, F. Gilliland, S.J. London, T. Islam, W. Gauderman, A. James, M. Edward, H.G. Margolis, and J.M. Peters. Asthma in exercising children exposed to ozone: a cohort study. *The Lancet* 359: 386-391 (2002).

Montzka, S.A., J.H. Butler, J.W. Elkins, T.M. Thompson, A.D. Clarke, and L.T. Lock. Present and future trends in the atmospheric burden of ozone-depleting halogens. *Nature* 398: 690-694 (1999).

National Acid Precipitation Assessment Program. Acid Deposition: *State of Science and Technology. Volume II. Aquatic Processes and Effects*, Washington, DC: National Acid Precipitation Assessment Program, 1991.

National Aeronautics and Space Administration. Ozone Levels Over North America - NIMBUS- 7/TOMS. March 1979 and March 1994. (January 24, 2003; *http://epa.gov/ozone/science/glob_dep.html*).

National Aeronautics and Space Administration, Advanced Supercomputing Division. August 14, 2002. (August 14, 2002; *http://www.nas.nasa.gov/About/Education/Ozone.html*).

National Research Council. *Health Effects of Exposure to Radon: BEIR VI; Sixth Committee on Biological Effects of Ionizing Radiation*, Washington, DC: National Academies Press, 1998.

Northeast States for Coordinated Air Use Management (NESCAUM). Why clean air? 2003. (August, 2002; *http://www.nescaum.org/cleanair.html*).

Pope, C.A., III, R.T. Burnett, M.J. Thun, E.E. Calle, D. Krewski, K. Ito, and G.D. Thurston. Lung cancer, cardiopulmonary mortality, and long-term exposure to fine particulate air pollution. *Journal of American Medical Association* 287: 1132-1141 (2002).

Scientific Assessment Panel of the Montreal Protocol on Substances that Deplete the Ozone Layer. *Scientific Assessment of Ozone Depletion: 2002, Executive Summary*, Report No. 47. Geneva, Switzerland: World Meteorological Organization, Global Ozone Research and Monitoring Project, 2003.

The H. John Heinz III Center for Science, Economics, and the Environment. *The State of the Nation's Ecosystems: Measuring the Lands, Waters, and Living Resources of the United States*, New York, NY: Cambridge University Press, September 2002.

National Oceanic and Atmospheric administration, Climate Monitoring & Diagnostics Laboratory. Haolcarbons and other Atmospheric Trace Species (HATS). 2002. March 18, 2003; *http://www.emdl.noaa.gov/hats/graphs/graphs.html*).

United Nations Environment Programme. *Environmental Effects of Ozone Depletion*: 1994 Assessment, Nairobi, Kenya: United Nations Environment Programme, Secretariat for The Vienna Convention for the Protection of the Ozone Layer and The Montreal Protocol on Substances that Deplete the Ozone Layer, November 1994.

United Nations Environment Programme. *Production and Consumption of Ozone Depleting Substances under the Montreal Protocol 1986-2000*, Nairobi, Kenya: United Nations Environment Programme, Secretariat for The Vienna Convention for the Protection of the Ozone Layer and The Montreal Protocol on Substances that Deplete the Ozone Layer, April 2002.

United States-Canada Air Quality Committee. *Ground-Level Ozone: Occurrence and Transport in Eastern North America; A Report by the United States-Canada Air Quality Committee; Subcommittee 1: Program*

Monitoring and Reporting, Washington, DC and Ottawa, Ontario: International Joint Commission, March 1999.

United States Code. Clean Air Act, as amended in 1990, Title 1: Air Pollution Prevention and Control. 42 U.S.C. 7408 and 7409.

U.S. Department of Agriculture. *National Report on Sustainable Forests - 2003, Final Draft*, Washington, DC: U.S. Department of Agriculture, Forest Service, 2002.

U.S. Department of Education, National Center for Education Statistics. *Condition of America's Public School Facilities: 1999*, NCES 2000-032. June 2000.

U.S. Department of Health and Human Services, National Center for Health Statistics. *Healthy People 2000 Final Review,* DHHS Publication No. 01-0256. Hyattsville, MD: Public Health Service, October 2001.

U.S. Environmental Protection Agency. *Air Quality Criteria for Particulate Matter and Sulfur Oxides*, EPA 600-P-82-020a-c. Research Triangle Park, NC: U.S. Environmental Protection Agency, Office of Research and Development, Environmental Criteria and Assessment Office, 1982.

U.S. Environmental Protection Agency. *Second Addendum to the Air Quality Criteria for Particulate Matter and Sulfur Oxides (1982): Assessment of Newly Available Health Effects Information*, EPA-450- 5-86-012. Research Triangle Park, NC: U.S. Environmental Protection Agency, Office of Research and Development, Environmental Criteria and Assessment Office, 1986.

U.S. Environmental Protection Agency. *Regulatory Impact Analysis: Protection of Stratospheric Ozone*, Washington, DC: U.S. Environmental Protection Agency, Stratospheric Protection Program, Office of Program Development, Office of Air and Radiation, August 1988.

U.S. Environmental Protection Agency. *Non-occupational Pesticide Exposure Study,* EPA-600-3-90-003. Research Triangle Park, NC: U.S. Environmental Protection Agency, Atmospheric Research and Exposure Assessment Laboratory, January 1990.

U.S. Environmental Protection Agency. *National Residential Radon Survey: Summary Report*, EPA-402- R-92-011. Washington, DC: U.S. Environmental Protection Agency, Office of Air and Radiation, October 1992.

U.S. Environmental Protection Agency. *Respiratory Health Effects of Passive Smoking: Lung Cancer and Other Disorders*, EPA 600-6-90-006F. Washington, DC: U.S. Environmental Protection Agency, Office of Research and Development, Office of Health and Environmental Assessment, December 1992.

U.S. Environmental Protection Agency. *Air Quality Criteria for Oxides of Nitrogen*, EPA 600-8-91- 049aF-cF. Research Triangle Park, NC: U.S. Environmental Protection Agency, Office of Research and Development, Environmental Criteria and Assessment Office, August 1993.

U.S. Environmental Protection Agency. Map of radon zones. EPA 402-F-93-013. September 1993. *http://www.epa.gov/iaq/radon/zonemap.html*).

U.S. Environmental Protection Agency. *A Standardized EPA Protocol for Characterizing Indoor Air Quality in Large Office Buildings*, Washington, DC: U.S. Environmental Protection Agency, Office of Research and Development and Office of Air and Radiation, June 1994.

U.S. Environmental Protection Agency. *Supplement to the Second Addendum (1986) to the Air Quality Criteria for Particulate Matter and Sulfur Oxides (1982): Assessment of New Findings on Sulfur Dioxide Acute Exposure Health Effects in Asthmatic Individuals*, EPA 600-FP-93-002. Research Triangle Park, NC: U.S. Environmental Protection Agency, Office of Research and Development, Office of Health and Environmental Assessment, Environmental Criteria and Assessment Office, August 1994.

U.S. Environmental Protection Agency. *Regulatory Impact Analysis for the Petroleum Refinery NESHAP*, EPA 452-R-95-004. Research Triangle Park, NC: U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards, July 1995.

U.S. Environmental Protection Agency. *Air Quality Criteria for Particulate Matter*, EPA 600-P-95- 001aF-cF.3v. Research Triangle Park, NC: U.S. Environmental Protection Agency, Office of Research and Development, National Center for Environmental Assessment, April 1996.

U.S. Environmental Protection Agency. *Air Quality Criteria for Ozone and Related Photochemical Oxidants*, EPA 600-P-93-004aF-cF. Research Triangle Park, NC: U.S. Environmental Protection Agency, Office of Research and Development, National Center for Environmental Assessment. July 1996.

U.S. Environmental Protection Agency. *Regulatory Impact Analysis for the Particulate Matter and Ozone National Ambient Air Quality Standards and Proposed Regional Haze Rule*, Research Triangle Park, NC: U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards, July 1997.

U.S. Environmental Protection Agency. *Mercury Study Report to Congress*, EPA-452-R-97-003. Research Triangle Park, NC: U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards and Office of Research and Development, December 1997.

U.S. Environmental Protection Agency. 40 CFR Part 50: National ambient air quality standards for particulate matter; final rule. *Federal Register* 62 (138): 2-102 (1997).

U.S. Environmental Protection Agency. *National Air Quality and Emissions Trends Reports, 1997*, EPA 454-R-98-016. Research Triangle Park, NC: U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards, December 1998.

U.S. Environmental Protection Agency. *The Benefits and Costs of the Clean Air Act: 1990 to 2010. Final Report to Congress,* EPA 410-R-99-001. Washington, DC: U.S. Environmental Protection Agency, Office of Air and Radiation, Office of Policy, November 1999.

U.S. Environmental Protection Agency. *Air Quality Criteria for Carbon Monoxide*, EPA 600-P-99-001F. Research Triangle Park, NC: U.S. Environmental Protection Agency, Office Research and Development, National Center for Environmental Assessment. June 2000.

U.S. Environmental Protection Agency. *National Air Quality and Emissions Trends Report, 1999*, EPA 454-R-01-004. Research Triangle Park, NC: U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards, March 2001.

U.S. Environmental Protection Agency. *Latest Findings on National Air Quality: 2000 Status and Trends*, EPA 454-K-01-002. Research Triangle Park, NC: U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards, September 2001.

U.S. Environmental Protection Agency. Air Trends: Metropolitan area trends, Table A-17. 2001. (February 25, 2003; *http://www.epa.gov/airtrends/metro.html*).

U.S. Environmental Protection Agency. *Air Quality Criteria for Particulate Matter, Third External Review Draft, Volume II*, EPA 600-P-99-002bC. Research Triangle Park, NC: U.S. Environmental Protection Agency, Office of Research and Development, National Center for Environmental Assessment, April 2002.

U.S. Environmental Protection Agency. *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990- 2000*, EPA 430-R-02-003. Washington, DC: U.S. Environmental Protection Agency, Office of Atmospheric Programs, April 2002.

U.S. Environmental Protection Agency, Office of Air and Radiation, Technology Transfer Network. National air toxic assessment: summary of results. September 18, 2002 (January 27, 2003; *http://www.epa.gov/ttn/atw/nata/risksum.html*).

U.S. Environmental Protection Agency. *Latest Findings on National Air Quality: 2001 Status and Trends*, EPA 454-K-02-001. Research Triangle Park, NC: U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards, September 2002.

U.S. Environmental Protection Agency. *EPA Acid Rain Program: 2001 Progress Report*, EPA 430-R-02- 009. Washington, DC: U.S. Environmental Protection Agency, Office of Air and Radiation, November 2002.

U.S. Environmental Protection Agency. 40 CFR Part 50: National ambient air quality standards for ozone: final response to remand; final rule. *Federal Register* 68 (3): 614-645 (2003).

U.S. Environmental Protection *Agency. Response of Surface Water Chemistry to the Clean Air Act Amendments of 1990*, EPA 620-R-03-001. Research Triangle Park, NC: U.S. Environmental Protection Agency, Office of Research and Development, National Health and Environmental Effects Research Laboratory, January 2003.

U.S. General Accounting Office. Pesticides: *Use, Effects, and Alternatives to Pesticides in Schools*, GAO/RCED-00-17. Washington, DC: U.S. General Accounting Office, Resources, Community, and Economic Development Division, 1999.

U.S. Institute of Medicine, Committee on the Health Effects of Indoor Allergens. *Indoor Allergens: Assessing and Controlling Adverse Health Effects*, Washington, DC: National Academy Press, 1993.

U.S. Institute of Medicine, Committee on the Assessment of Asthma and Indoor Air. *Clearing the Air: Asthma and Indoor Air Exposures, Executive Summary*, Washington, DC: National Academy Press, 2000.

U.S. International Trade Commission. *1993. Synthetic Organic chemicals; U.S. Production and Sales*, Washington DC: Government Printing Office, 1994.

Wingo, Phyllis A., Ries, Lynn A.G., Giovino, Gary A., et al. Annual report to the nation on the status of cancer, 1973-1996, with a special section on lung cancer and tobacco smoking. *Journal of the National Cancer Institute* 91 (8): 675-690 (1999).

Chapter 2: Purer Water

Alley, W.M., T.E. Reilly, and O.L. Franke. *Sustainability of Ground-water Resources*, U.S. Geological Survey Circular 1186. Denver, CO: U.S. Geological Survey, 1999.

Baker, L.A., A. Herlihy, P. Kaufmann, and J. Eilers. Acid lakes and streams in the United States: the role of acid deposition. *Science* 252: 1151-1154 (1991).

Batiuk, R.A., P. Bergstrom, M. Kemp, E. Koch, L. Murray, J.C. Stevenson, R. Bartleson, V. Carter, N.B. Rybicki, J.M. Landwehr, C. Gallegos, L. Karrh, M. Naylor, D. Wilcox, K.A. Moore, S. Ailstock, and M. Teichberg. *Chesapeake Bay Submerged Aquatic Vegetation Water Quality and Habitat- Based Requirements and Restoration Targets: A Second Technical Synthesis*, CBP-TRS 245-00, EPA 903-R-00-014. Annapolis, MD: U.S. Environmental Protection Agency, Chesapeake Bay Program, 2000.

Boesch, D.F., R.B. Brinsfield, and R.E. Magnien. Chesapeake Bay eutrophication: scientific understanding, ecosystem restoration, and challenges for agriculture. *Journal of Environmental Quality* 30: 303-320 (2001).

Bricker, S.B., C.G. Clement, D.E. Pirhalla, S.P. Orlando, and D.R.G. Farrow. *National Estuarine Eutrophication Assessment: Effects of Nutrient Enrichment in the Nation's Estuaries*, Silver Spring, MD: National Oceanic and Atmospheric Administration, National Ocean Service, Special Projects Office and the National Centers for Coastal Ocean Science, 1999.

Chapman, P.M., R.N. Dexter, and E.R. Long. Synoptic measures of sediment contamination, toxicity, and infaunal community composition (the sediment quality triad) in San Francisco Bay. *Marine Ecology Progress Series* 37: 75-96 (1987).

Committee on Environment and Natural Resources of the National Science and Technology Council. *Integrated Assessment of Hypoxia in the Northern Gulf of Mexico*, Washington, DC: National Science and Technology Council Committee on Environment and Natural Resources, 2000.

Council for Agricultural Science and Technology. *Gulf of Mexico Hypoxia: Land and Sea Interactions*, Report 134. Ames, IA: Council for Agricultural Science and Technology, June 1999.

Cowardin, L.M., V. Carter, F.C. Golet, and E.T. LaRoe. *Classification of Wetlands and Deepwater Habitats of the United States*, FW/OBS-79/31. Washington, DC: U.S. Fish and Wildlife Service, 1979.

Dahl, T.E. *Status and Trends of Wetlands in the Conterminous United States* 1986 to 1997, Washington, DC: U.S. Department of the Interior, U.S. Fish and Wildlife Service, 2000.

Dahl, T.E. *Wetland Losses in the United States 1780's to 1980's*. Washington, DC: U.S. Department of the Interior, Fish and Wildlife Service, 1990.

Dahl, T.E., and C.E. Johnson. Status and *Trends of Wetlands in the Conterminous United States, Mid-1970s to Mid-1980*, Washington, DC: U.S. Department of the Interior, U.S. Fish and Wildlife Service, 1991.

Danielson, T. J. *Wetland Bioassessment Fact Sheets,* EPA 843-F-98-001a-j. Washington, DC: U.S. Environmental Protection Agency, Office of Wetlands, Oceans, and Watersheds, Wetlands Division, July 1998.

Davis, D.G. North American Birds - A Rough Assessment of Wetland Dependency., unpublished. Preparation for a presentation given at the Wetlands, Migratory Birds, and Ecotourism Workshop in Newburyport, Massachusetts, October 24, 2000.

Day Boylan, K. and D.R. MacLean. Linking species loss with wetland loss. *National Wetlands Newsletter* 19 (6), (Nov/Dec 1997).

Diaz, R.J. and R. Rosenberg. Marine benthic hypoxia: a review of its ecological effects and the behavioural responses of benthic macrofauna. *Oceanography and Marine Biology Annual Review* 33: 245-303 (1995).

Duda, A.M. Municipal point source and agricultural nonpoint source contributions to coastal eutrophication. *Water Resources Bulletin* 18: 397-407 (1982).

Environment Canada and U.S. Environmental Protection Agency. *The Great Lakes, An Environmental Atlas and Resource Book*, Toronto, Ont: Government of Canada and Chicago, IL: United States Environmental Protection Agency, Great Lakes National Program Office, 1995.

Fisher, S.G. Stream ecosystems of the western United States. In C.E. Cushing, K.W. Cummings, G.W. Minshall (eds.), *River and Stream Ecosystems, Ecosystems of the World 22*, New York, NY: Elsevier Press, 1995.

Frayer, W.E., T.J. Monahan, D.C. Bowden, and F.A. Graybill. *Status and Trends of Wetlands and Deepwater Habitats in the Conterminous United States, 1950's to 1970's*, Fort Collins, CO: Colorado State University, Department of Forest and Wood Sciences, 1983.

Gilliom, R.J., D.K. Mueller, J.S. Zogorski, and S.J. Ryker. A national look at water quality. *Water Resources Impact* 4: 12-16 (2002).

Houser, L.S. and F.J. Silva. *National Register of Shellfish Production Areas*, PHS Publication No. 1500. Washington, DC: U.S. Department of Health, Education, and Welfare, Public Health Service, Division of Environmental Engineering and Food Protection, Shellfish Sanitation Branch, 1966.

Hoxie, N.J., J.P. Davis, J.M. Vergeront, R.D. Nashold, and K.A. Blair. Cryptosporidiosis - associated mortality following a massive waterborne outbreak in Milwaukee, WI. *American Journal of Public Health* 87 (12): 2032-2035 (1997).

Kaufmann, P.R., P. Levine, E.G. Robison, C. Seeliger, and D.V. Peck. *Surface waters: Quantifying Physical Habitat in Wadeable Streams*, EPA 620-R-99-003. Washington, DC: U.S. Environmental Protection Agency, Office of Research and Development, July 1999.

National Atmospheric Deposition Program, Mercury Deposition Network. Total Mercury Wet Deposition, 2001. 2001. (March 25, 2003; *http://nadp.sws.uiuc.edu/mdn/maps/2001/01MDNdepo.pdf*)

National Atmopheric Deposition Program, National Trends Network. Nitrate ion wet deposition, 2001. 2001. (March 25, 2003; *http://nadp.sws.uiuc.edu/isopleths/maps2001/no3dep.pdf*)

National Atmopheric Deposition Program, National Trends Network. Ammonium ion wet deposition, 2001. 2001. (March 25, 2003; *http://nadp.sws.uiuc.edu/isopleths/maps2001/nh4dep.pdf*)

National Oceanic and Atmospheric Administration. *The 1990 National Shellfish Register of Classified Estuarine Waters*, Rockville, MD: ORCA Strategic Environmental Assessments Division, 1991.

National Oceanic and Atmospheric Administration. T*he 1995 National Shellfish Register of Classified Growing Waters*, Silver Spring, MD: ORCA, Office of Ocean Resources Conservation and Assessment, Strategic Environmental Assessments Division, 1997.

National Oceanic and Atmospheric Administration. *Population: distribution, density and growth, NOAA's State of the Coast Report*. Silver Spring, MD. 1998. (February 2003; *http://state-of-coast.noaa.gov/bulletins/html/pop_01/pop.html*).

National Research Council. *Clean Coastal Waters: Understanding and Reducing the Effects of Nutrient Pollution*, Washington, DC: National Academies Press, 2000.

Nixon, S.W. Coastal marine eutrophication: a definition, social causes, and future concerns. *Ophelia* 41: 199-219 (1995).

Paul, J.F., J.H. Gentile, K.J. Scott, S.C. Schimmel, D.E. Campbell, and R.W. Latimer. EMAP - *Virginian Province Four-year Assessment Report (1990-1993)*, EPA 620-R-99-004. Narragansett, RI: U.S. Environmental Protection Agency, Office of Research and Development, Atlantic Ecology Division. October 1999.

Peierls, B.L., N.F. Caraco, M.L. Pace, and J.J. Cole. Human influence on river nitrogen. Nature 350: 386-387 (1991).

Peterson, S.A., N.S. Urquhart, and E.B. Welch. Sample representativeness: a must for reliable regional lake condition estimates. *Environmental Science and Technology* 33 (10): 1559-1565 (1999).

Rippey, S.R. Infectious diseases associated with molluscan shellfish consumption. *Clinical Microbiology Review* 7 (4): 419-425 (1994).

Schindler, D.W. Evolution of phosphorus limitation in lakes. *Science* 179: 260-262 (1977).

Schlesinger, W.H. *Biogeochemistry: An Analysis of Global Change*, San Diego, CA: Academic Press, 1997.

Solley, W.B., R.R. Pierce, and H.A. Perlman. *Estimated Use of Water in the United States in 1995*, U.S. Geological Survey Circular 1200. Denver, CO: U.S. Geological Survey, 1998.

Smith, R.A., G.E. Schwarz, and R.B. Alexander. Regional interpretation of water-quality monitoring data. *Water Resources Research* 33: 2781-2798 (1997).

Stoddard, J. L., A. D. Newell, N. S. Urquhart, and D. Kugler. The TIME project design: II. Detection of regional acidification trends. *Water Resources Research* 32: 2529-2538 (1996).

Stoddard, J. L., C. T. Driscoll, S. Kahl, and J. Kellogg. Can site-specific trends be extrapolated to a region? An acidification example for the Northeast. *Ecological Applications* 8: 288-299 (1998).

The H. John Heinz III Center for Science, Economics, and the Environment. *The State of the Nation's Ecosystems: Measuring the Lands, Waters, and Living Resources of the United States*, New York, NY: Cambridge University Press, September 2002.

Thrush, W.J., S.M. McBain, and L.B. Leopold. Attributes of an alluvial river and their relation to water policy and management. *Proceedings of the National Academy of Sciences* 97 (22): 11858-11863 (2000)

Turner, R.E. and N.N. Rabalais. Changes in Mississippi River water quality this century, implications for coastal food webs. *BioScience* 41: 140-147 (1991).

U.S. Department of Agriculture, Natural Resources Conservation Service. *Summary Report: 1997 National Resources Inventory (Revised December 2000)*, Washington, DC: Natural Resources Conservation Service and Ames, IA: Iowa State University, Statistical Laboratory, December 1999, revised December 2000.

U.S. Department of Commerce and U.S. Department of Health and Human Services. *1985 National Shellfish Register of Classified Estuarine Waters*, Rockville, MD: National Oceanic and Atmospheric Administration, Ocean Assessments Division and Kingstown, RI: Food and Drug Administration, Shellfish Sanitation Branch, 1985.

U.S. Environmental Protection Agency. *National Shellfish Register of Classified Estuarine Waters, 1974*, Denver, CO: U.S. Environmental Protection Agency, Office of Enforcement, National Enforcement Investigations Center, 1975.

U.S. Environmental Protection Agency. *Quality Criteria for Water - 1986*, EPA 440-5-86-001. Washington, DC: U.S. Environmental Protection Agency, Office of Water, November 1986.

U.S. Environmental Protection Agency. *America's Wetlands: Our Vital Link Between Land and Water*, EPA 843-K-95-001. Washington, DC: U.S. Environmental Protection Agency, Office of Wetlands, Oceans and Watersheds, December 1995.

U.S. Environmental Protection Agency. *Guidelines for Preparation of the Comprehensive State Water Quality Assessments (305(b) Reports) and Electronic Updates, Report Contents and Supplement*, EPA 841-B-97-002A and EPA 841-B-97-002B. Washington, DC: U.S. Environmental Protection Agency, Office of Water, September 1997.

U.S. Environmental Protection Agency. *Mercury Report to Congress, Volume I,* Washington, DC: U.S. Environmental Protection Agency, Office of Water, December 1997.

U.S. Environmental Protection Agency. *National Strategy for the Development of Regional Nutrient Criteria,* EPA 822-R-98-002. Washington, DC: U.S. Environmental Protection Agency, Office of Water, June 1998.

U.S. Environmental Protection Agency. *Action Plan for Beaches and Recreational Waters*, EPA 600- R-98-079. Washington, DC: U.S. Environmental Protection Agency, Office of Research and Development and Office of Water, March 1999.

U.S. Environmental Protection Agency. *25 Years of the Safe Drinking Water Act: History and Trends*, EPA 816-R-99-007. Washington, DC: U.S. Environmental Protection Agency, Office of Water, December 1999.

U.S. Environmental Protection Agency. *Deposition of Air Pollutants to the Great Waters. Third Report to Congress*, EPA 453-R-00-005.

Research Triangle Park, NC: U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards, June 2000.

U.S. Environmental Protection Agency. *Mid-Atlantic Highlands Streams Assessment*, EPA 903-R-00- 015. Philadelphia, PA: U.S. Environmental Protection Agency, Office of Research and Development, Region 3, August 2000.

U.S. Environmental Protection Agency. *Ambient Water Quality Criteria for Dissolved Oxygen (Saltwater): Cape Cod to Cape Hatteras*, EPA 822-R-00-012. Washington, DC: U.S. Environmental Protection Agency, Office of Water, October 2000.

U.S. Environmental Protection Agency. *National Listing of Fish and Wildlife Advisories (NLFWA)*. June 2001.

U.S. Environmental Protection Agency, Office of Water. *National Listing of Fish and Wildlife Advisories (NLFWA) Mercury Fish Tissue Database*. June 2001.

U.S. Environmental Protection Agency. *National Coastal Condition Report*, EPA 620-R-01-005. Washington DC: U.S. Environmental Protection Agency, Office of Research and Development and Office of Water, September 2001.

U.S. Environmental Protection Agency. *Mercury Maps: Linking Air Deposition and Fish Contamination on a National Scale,* EPA 823-F-01-026. Washington, DC: U.S. Environmental Protection Agency, Office of Water, November 2001.

U.S. Environmental Protection Agency. *The Incidence and Severity of Sediment Contamination in Surface Waters of the United States, National Sediment Quality Survey: Second Edition*, DRAFT, EPA 823-R-01-01. Washington, DC: U.S. Environmental Protection Agency, Office of Water, December 2001.

U.S. Environmental Protection Agency. *Function and Values of Wetlands Fact Sheet*, EPA 843-F-01-002c. Washington, DC: U.S. Environmental Protection Agency, Office of Water, Office of Wetlands, Oceans, and Watersheds, March 2002.

U.S. Environmental Protection Agency. *2001 National Listing of Fish and Wildlife Advisories*, EPA 823-F-02-010. Washington, DC: U.S. Environmental Protection Agency, Office of Water, May 2002. 2002b

U.S. Environmental Protection Agency. *Update: National Listing of Fish and Wildlife Advisories*, EPA 823-F-02-007. Washington, DC: U.S. Environmental Protection Agency, Office of Water, May 2002. 2002a

U.S. Environmental Protection Agency. *2000 Toxics Release Inventory Public Data Release Report*, EPA 260-S-02-001. Washington, DC: U.S. Environmental Protection Agency, Office of Environmental Information, May 2002.

U.S. Environmental Protection Agency. *EPA's Beach Watch Program: 2001 Swimming Season*, EPA 823-F-02-006. Washington, DC: U.S. Environmental Protection Agency, Office of Water, May 2002.

U.S. Environmental Protection Agency. *Consolidated Assessment and Listing Methodology–Toward a Compendium of Best Practices, First Edition*, Washington, DC: U.S. Environmental Protection Agency, Office of Water, July 2002.

U.S. Environmental Protection Agency. *Response of Surface Water Chemistry to the Clean Air Act Amendments of 1990*, EPA 620-R-03-001. Research Triangle Park, NC: U.S. Environmental Protection Agency, Office of Research and Development, National Health and Environmental Effects Research Laboratory, January 2003.

U.S. Environmental Protection Agency, Office of Water. National Section 303(d) List Fact Sheet. March 10, 2003. (February 14, 2003; *http://oaspub.epa.gov/waters/national_rept.control*).

U.S. Environmental Protection Agency. *Mid-Atlantic Integrated Assessment, MAIA - Estuaries 1997- 98, Summary Report*, EPA 620-R-02-003. Narragansett, RI: U.S. Environmental Protection Agency, Office of Research and Development, Atlantic Ecology Division, May 2003.

U.S. Environmental Protection Agency, Office of Water. *Safe Drinking Water Information System/Federal Version* (SDWIS/FED). 2003.

U.S. Fish and Wildlife Service. *2001 National Survey of Fishing, Hunting, and Wildlife-Associated Recreation, National Overview*, Washington, DC: U.S. Department of the Interior, U.S. Fish and Wildlife Service and U.S. Department of Commerce, October 2002.

U.S. Food and Drug Administration. *1971 National Shellfish Register of Classified Estuarine Waters*, Davisville, RI: Public Health Service, Shellfish Sanitation Branch, Northeast Technical Services Unit, 1971.

U.S. Food and Drug Administration. *National Shellfish Sanitation Program Manual of Operations: Part I, Sanitation of Shellfish Growing Areas, 1993 Revision*, Washington, DC: Center for Food Safety and Applied Nutrition, 1993.

U.S. Geological Survey. *Strategic Directions for the U.S. Geological Survey Ground-Water Resources Program: A Report to Congress*. Reston, VA: U.S. Geological Survey, November 30, 1998.

U.S. Geological Survey. *The Quality of Our Nation's Water*, U.S. Geological Survey Fact Sheet 116-99. Reston, VA: U.S. Geological Survey, 1999.

U.S. Geological Survey. *Report to Congress, Concepts for National Assessment of Water Availability and Use*, U.S. Geological Survey Circular 1223. Reston, VA: U.S. Geological Survey, 2002.

Chapter 3: Better Protected Land:

Agency of Toxic Substances and Disease Registry. CERCLA priority list of hazardous substances. 2001. (September 2002; *http://www.atsdr.cdc.gov/clist.html*).

Alaska Department of Natural Resources. Fact Sheet: Land Ownership in Alaska. March, 2000. (September 2002; *http://www.dnr.state.ak.us/mlw/factsht/land_own.pdf*).

Amdur, M.O., J. Doull and C.D. Klassen (Eds.). *Toxicology: the Basic Science of Poisons.* NY: Pergamon Press, 1996, 1033

Battaglin W. A., and D.A. Goolsby. *Spatial Data in Geographic Information System Format on Agricultural Chemical Use, Land Use, and Cropping Practices in the United States,* Water Resources Investigations Report 94-4176. Lakewood, CO: U.S. Geological Survey, 1994.

Beaulac, M.N. and K.H. Reckhow. An examination of land use-nutrient relationships. *Water Resources Bulletin* 18 (6): 1013-1024 (1982).

Blondell, J.M. *Updated Review of Rodenticide Incident Reports Primarily Concerning Children*, Memorandum to Dennis Deziel and Michael McDavit, June 3, 1999.

Brewer, Cynthia A. and Trudy A. Suchan. *Mapping Census 2000: The Geography of U.S. Diversity*. U.S. Census Bureau, Census Special Reports, Series CENSR/01-1. Washington, DC: U.S. Government Printing Office. June 2001.

California Department of Pesticide Regulation. *Pesticide Use Reporting: An Overview of California's Unique Full Reporting System,* Sacramento, California: California Department of Pesticide Regulation, May, 2000. (March 12, 2003; *http://www.cdpr.ca.gov/docs/pur/purovrvw/tabofcon.htm*)

Calvert, G.M., Barnett, M., Blondell, J.M., Mehler, L.N. and Sanderson, W.T. "Surveillance of pesticide- related illness and injury in humans." In Krieger, R. (ed.), *Handbook of Pesticide Toxicology. 2nd edition*. San Diego, CA: Academic Press, 1999.

Council on Environmental Quality. The 24th Annual Report of the Council on Environmental Quality, 1993. (May 21, 2003; http://ceq.eh.doe/gov/nepa/reports/1993/toc.htm)

Daberkow, S., H. Taylor, and W. Huang. "Agricultural Resources and Environmental Indicators: Nutrient Use and Management." September, 2000. *In Agricultural Resources and Environmental Indicators,* Agricultural Handbook No. AH722. U.S. Department of Agriculture, Economic Research Service, Washington, DC, February 2003, 4.4.1-4.4.49.

Flemming, M.D. *A Statewide Vegetation Map of Alaska Using a Phenological Classification of AVHRR Data*, Anchorage, AK: 1996 Alaska Surveying and Mapping Conference, February 1996.

General Accounting Office. *Superfund: Extent of Nation's Potential Hazardous Waste Problem Still Unknown*, GAO/RCED-88-44. Washington, DC: General Accounting Office, December 1, 1987.

General Services Administration. "Summary report on real property owned by the United States throughout the world." 1999. In *Statistical Abstract of the United States 2001: The National Data Book*, Washington, DC: U.S. Census Bureau, 2001.

Gianessi, L.P., and J.E. Anderson. *Pesticide Use in US Crop Production: National Data Report*, Washington, DC: National Center for Food and Agricultural Policy, February 1995.

Gianessi, L.P., and M.B. Marcelli. *Pesticide Use in U.S. Crop Production: 1997, National Summary Report*, Washington, DC: National Center for Food and Agricultural Policy, November 2000.

Goebel, J.J. "The National Resources Inventory and its role in U.S. agriculture." In *Proceedings of the Conference on Agricultural Statistics Organized by the National Agricultural Statistics Service of the U.S. Department of Agriculture, Under the Auspices of the International Statistical Institute,* 1998.

Goldstein, N. 12th annual Biocycle nationwide survey: the state of garbage in America. *Biocycle Journal of Composting and Organics Recycling* 41 (4): 30-40 (April 2000).

Goss, D.W. Pesticide Runoff Potential,1990-1995. Pesticide Loss Database. Temple, TX: Texas Agricultural Experiment Station. August 24, 1999. (September 2002; *http://www.epa.gov/iwi/1999sept/iv12a_usmap.html*).

Hellkamp, A.S., S.R. Shafer, C.L. Campbell, J.M. Bay, D.A. Fiscus, G.R. Hess, B.F. McQuaid, M.J. Munster, G.L. Olson, S.L. Peck, K.N. Easterling, K. Sidik, and M.B. Tooley. Assessment of the condition of agricultural lands in five mid-Atlantic states. *Environmental Monitoring and Assessment* 51: 317-324 (1998).

Klopatek, J.M., R.J. Olson, C.J. Emerson, and J.L. Jones. Land-use conflicts with natural vegetation in the United States. *Environmental Conservation* 6: 191–199 (1979).

Knisel, W.G. (ed.). GLEAMS: *Groundwater Loading Effects of Agricultural Management. Systems, Version 2.10*, Publication No. 5. Tifton, GA: Biological and Agricultural Engineering Department, 1993.

Smith, W.B., J.S. Vissage, D.R. Darr, and R.M. Sheffield. *Forest Statistics of the United States, 1997*, General Technical Report NC-219. St. Paul, MN: U.S. Department of Agriculture Forest Service, North Central Research Station, 2001, 191.

The H. John Heinz III Center for Science, Economics and the Environment. *The State of the Nation's Ecosystems: Measuring the Lands, Waters, and Living Resources of the United States*, New York, NY: Cambridge University Press, September 2002.

U.S. Census Bureau. *Statistical Abstract of the United States 2001: The National Data Book*, Washington, DC: U.S. Census Bureau, 2001.

U.S. Census Bureau. Census 2000: redistricting data (PL 94-171) summary file. March 1, 2001. (February 26, 2003; *http://www.census.gov/clo/www/redistricting.html*).

U.S. Census Bureau. Corrected Lists of Urbanized Areas and Urban Clusters. November 25, 2002. (March 2003; *http://www.census.gov/geo/www/ua/ua_state_corr.txt* and *http://www.census.gov/geo/www/ua/uc_state_corr.txt*)

U.S. Congress. *Small Business Liability Relief and Brownfields Revitalization Act*, Public Law 107- 118 (H.R. 2869),Washington, DC: January, 2002.

U.S. Department of Agriculture, Natural Resources Conservation Service. *National Resources Inventory*, Washington, DC: Natural Resources Conservation Service and Ames, Iowa: Iowa State University, Statistical Laboratory. 1992.

U.S. Department of Agriculture, Natural Resources Conservation Service. *America's Private Land: A Geography of Hope*, Washington, DC: U.S. Department of Agriculture, June 1997.

U.S. Department of Agriculture, Natural Resources Conservation Service. *Summary Report: 1997 National Resources Inventory (Revised December 2000)*, Washington, DC: Natural Resources Conservation Service and Ames, IA: Iowa State University, Statistical Laboratory, December 1999, revised December 2000. 2000a

U.S. Department of Agriculture, Natural Resources Conservation Service. National Resources Inventory 1997, revised December 2000: Change in Average Annual Soil Erosion by Water on Cropland and CRP Land, 1982-1997. 2000 (January 2003; *http://www.nrcs.usda.gov/technical/land/meta/m5060.html*). 2000f.

U.S. Department of Agriculture, Natural Resources Conservation Service. National Resources Inventory 1997, revised December 2000: Total Wind and Water Erosion, 1997. 2000 (January 2003; *http://www.nrcs.usda.gov/technical/land/meta/m5083.html*). 2000g.

U.S. Department of Agriculture, Natural Resources Conservation Service. Natural Resources Inventory, 1997, revised December 2000: Percent Change in Cropland Area, 1982-1997. December 2000b. (January 2003; *http://www.nrcs.usda.gov/land/meta/m5874.html*).2000e

U.S. Department of Agriculture, Natural Resources Conservation Service. National Resources Inventory, 1997, revised December 2000: Acres of Non-Federal Developed Land, 1997. December 2000c. (January 2003; *http://www.nrcs.usda.gov/technical/land/meta/m4974.html*). 2000b

U.S. Department of Agriculture, National Resources Conservation Service. Natural Resources Inventory, 1997, revised December 2000: Acres of Cropland. December 2000d. (January 2003; *http://www.nrcs.usda.gov/ technical/land/meta/m4964.html*).2000d

U.S. Department of Agriculture, Natural Resources Conservation Service. National Resources Inventory, 1997, revised December 2000: Land Development, 1982-1997. December 2000e. (January 2003; http://www.nrcs.usda.gov/technical/land/meta/m5009.html).2000c

U.S. Department of Agriculture, Natural Resources Conservation Service. 1997 National Resources Inventory Highlights. January 2001. (February 2003; *http://www.nrcs.usda.gov/technical/land/pubs/97highlights.pdf*).

U.S. Department of Agriculture, Forest Service. *U.S. Forest Facts and Historical Trends*, Brochure #FS-696. Washington, DC: U.S. Department of Agriculture, April 2001.

U.S. Department of Agriculture, Agricultural Marketing Service. *Pesticide Data Program: Annual Summary Calendar Year 2000*, Washington, DC: U.S. Department of Agriculture, February 2002.

U.S. Department of Agriculture, Forest Service. Draft Resource Planning and Assessment Tables. August 12, 2002. (September 2002; *http://www.ncrs.fs.fed.us/4801/FIADB/rpa_tabler/Draft_RPA_2002_Forest_Resource_Tables.pdf*).

U.S. Department of Commerce, Bureau of Economic Analysis. GDP and Other Major NIPA Series, 1929-2002. 2002. (February 2003; *http://www.bea.doc.gov/bea/ARTICLES/2002/08August/0802GDP_& Other_Major_NIPAs..pdf*)

U.S. Department of Defense. Fiscal Year 2001 Defense Environmental Restoration Program Annual Report to Congress. 2001. (November 2002; *http://63.88.245.60/derparc_fy01/ derp/indexTen.htm*).

U.S. Department of Energy. *Status Report on Paths to Closure*, DOE EM-0526. U.S. Department of Energy, Office of Environmental Management, March 2000.

U.S. Department of Energy, Office of Environmental Management and Office of Long-Term Stewardship. *A Report to Congress on Long-term Stewardship Volume I - Summary Report,* DOE EM-0563. January 2001.

U.S. Department of Energy, Office of Environmental Management. *Summary Data on the Radioactive Waste, Spent Nuclear Fuel, and Contaminated Media Managed by the U.S. Department of Energy*, April 2001.

U.S. Department of Energy, Energy Information Administration. United States country analysis brief. November 2002. (January 2003; *http://www.eia.doe.gov/emeu/cabs/usa.html*).

U.S. Department of Energy, Office of Environmental Management. Central Internet Database. 2002. (January 2003; *http://cid.em.doe.gov*).

U.S. Department of the Interior. *Rangeland Reform '94, Draft Environmental Impact Statement*, Washington, DC: Bureau of Land Management, 1994.

U.S. Department of the Interior, Bureau of Land Management. Frequently asked questions on the Abandoned Mine Lands Cleanup Program. August 9, 2002. (January, 2003; *http://www.blm.gov/aml/ faqs.htm*).

U.S. Environmental Protection Agency. *EPA Report to Congress, Solid Waste Disposal in the United States, Volumes I-II*, EPA 530-SW-88-011 (B). Washington, DC: U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response, October 1988.

U.S. Environmental Protection Agency, Office of Research and Development. Multi-Resolution Land Characteristics Consortium - National Land Cover Data. 1992. (February 19, 2003; *http://www.epa.gov/mrlc/nlcd.html*)

U.S. Environmental Protection Agency. *National Water Quality 1994 Inventory Report to Congress: Ground Water and Drinking Water Chapters*, EPA 813-R-96-001. Washington, DC: U.S. Environmental Protection Agency, Office of Water, June 1996.

U.S. Environmental Protection Agency. *National Water Quality Inventory: 1996 Report to Congress (305(b))*, EPA 841-R-97-008. Washington DC: U.S. Environmental Protection Agency, Office of Water, December 1997.

U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response. Number of NPL Site Actions and Milestones by Fiscal Year. March 26, 2003 (April 3, 2003; *http://www.epa.gov/superfund/sites/query/queryhtm/nplfy/htm*)

U.S. Environmental Protection Agency, Office of Wetlands, Oceans, and Watersheds. Pesticide Runoff Potential - 1990-1995. August 24, 1999. (September 2002; *http://www.epa.gov/iwi/1999sept/iv12a_usamap.html*)

U.S. Environmental Protection Agency, Office of Water. Sediment runoff potential–1990-1995. August 24, 1999. (September, 2002; *http://www.epa.gov/iwi/1999sept/iv12c_usmap.html*)

U.S. Environmental Protection Agency. Persistent bioaccumulative toxic (PBT) chemicals; final rule. 40 CFR Part 372: *Federal Register* 64 (209), October 29, 1999.

U.S. Environmental Protection Agency. *RCRA Orientation Manual,* EPA 530-R-0-006. U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response, June 2000.

U.S. Environmental Protection Agency. *National Water Quality 1998 Inventory Report to Congress: Ground Water and Drinking Water Chapters*, EPA 816-R-00-013. Washington, DC: U.S. Environmental Protection Agency, Office of Water, August 2000.

U.S. Environmental Protection Agency. *Industrial Surface Impoundments in the United States,* EPA 530-R-01-005. Washington, DC: U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response, March 2001.

U.S. Environmental Protection Agency. *The National Biennial RCRA Hazardous Waste Report*, EPA 530-R-01-009. Washington DC: U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response, June 2001.

U.S. Environmental Protection Agency. *Pesticide Industry Sales and Usage 1998 and 1999 Market Estimates*, Washington, DC: U.S. Environmental Protection Agency, Office of Prevention, Pesticides, and Toxic Substances, August 2002.

U.S. Environmental Protection Agency, Office of Pesticide Programs. Biopesticides registration action document: *Bacillus thuringiensis* plant-incorporated protectants. October 16, 2001. (January 2003; *http://www.epa.gov/pesticides/biopesticides/pips/bt_brad.htm*).

U.S. Environmental Protection Agency. *Municipal Solid Waste in the United States: 2000 Facts and Figures*, EPA 530-S-02-001. U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response, June 2002.

U.S. Environmental Protection Agency. *Current Drinking Water Standards*, EPA 816-F-02-013. Washington, DC: U.S. Environmental Protection Agency, Office of Water, July 2002.

U.S. Environmental Protection Agency. *National Water Quality Inventory - 2000 Report*, EPA 841-R- 02-001. Washington DC: U.S. Environmental Protection Agency, Office of Water, August 2002.

U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response. Household hazardous waste. No date available. (August 2002; www.epa.gov/epaoswer/non-hw/muncpl/hhw.htm)

U.S. Environmental Protection Agency. *Waste Minimization Trends Report (1991-1998)*, EPA 530-R- 02-007. Washington, DC: U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response, September 2002.

U.S. Environmental Protection Agency, Superfund Emergency Response Program. Sources of Common Contaminants and Their Health Effects. September 20, 2002. (February 25, 2003; http://www.epa.gov/superfund/programs/er/hazsubs/sources.htm).

U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response. Corrective action background. October 8, 2002. (October 15, 2002; *http://www.epa.gov/epaoswer/hazwaste/ca/backgnd.htm#5*).

U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response. Brownfields assessment demonstration pilots. October 17, 2002. (January 2003; *http://www.epa.gov/brownfields/jlocat.htm*).

U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response. End-of-year activity report memorandum to UST regional division directors. December 23, 2002. (February 25, 2003; *http://www.epa.gov/swerust1/cat/eoy02memo.pdf*).

U.S. Environmental Protection Agency, Superfund Emergency Response Program. National Priorities List Site Totals by Status and Milestone. February 6, 2003. (February 25, 2003; *http://epa.gov/superfund/sites/query/queryhtm/npltotal.htm*). –

U.S. Fish and Wildlife Service. Invasive species encroachment is one of the biggest threats to native ecosystems that resource managers face today. No date available. (August 2002; *http://invasives.fws.gov/Index7.html*).

U.S. Geological Survey. Kramer, D.A., J.F. Papp, N.M. LaTurno, J. Gambogi. Mine and Mineral Processing Plant Locations: Supplemental Information for USGS Map 1-2654. 2000a. (May 9, 2003; *http://minerals.usgs.gov/minerals/pubs/mapdata/*) 2000a

U.S. Geological Survey. Ewell, M.E. Mining and Quarrying Trends 2000. 2000b. (February 25, 2003; *http://minerals.usgs.gov/minerals/pubs/commodity/m&q/873400.pdf*) 2000b

U.S. Geological Survey, National Land Cover Dataset. NLCD Land Cover Statistics. 2001. (March 2003; *http://landcover.usgs.gov/nlcd.html*).

Vesterby, M., "Agricultural resources and environmental indicators: land use." In *Agricultural Resources and Environmental Indicators Report*, Ag Handbook No. AH722. Washington, DC: U.S. Department of Agriculture, Economic Research Service, February 2003, 1-33.

Walker, C. Sediment Runoff Potential, 1990-1995. Hydrologic Unit Modeling of the United States (HUMUS) Project. Temple, TX: Texas Agricultural Experiment Station. August 24, 1999. (September, 2002; *http://www.epa.gov/iwi/1999sept/iv12c_usmap.html*).

Westbrooks, R. *Invasive Plants, Changing the Landscape of America: Fact Book*, Washington, DC: Federal Interagency Committee for the Management of Noxious and Exotic Weeds, 1998.

Wickham, J.D., K.H. Riitters, R.V. O'Neill, K.H. Reckhow, T.G. Wade, and K.B. Jones. Land cover as a framework for assessing risk of water pollution. *Journal of the American Water Resources Association* 36 (6): 1-6 (2000).

Wilderness Information Network. National wilderness preservation system database. August 2002. (February 10, 2003; *http://www.wilderness.net/nwps*).

World Resources Institute. *World Resources 2000-2001 People and Ecosystems: the Fraying Web of Life*, Washington, DC: World Resources Institute, 2000.

Chapter 4: Human Health

Adams, P., G.E. Hendershot, and M. Marano. Current estimates from the National Health Interview Survey. 1996. *Vital and Health Statistics* 10: 82, 92, 94 (1999).

Agency for Toxic Substances and Disease Registry. Public health statement for chromium. 2000. (February 27, 2003; *http://www.atsdr.cdc.gov/interactionsprofiles/ps7.html*).

Agency for Toxic Substances and Disease Registry, Centers for Disease Control. ToxFAQ's: chromium. 2001. (April 21, 2003; ; *http://www.atsdr.cdc.gov/tfacts7.html*).

Akinbami, L.J. and K.C. Schoendorf. Trends in Childhood Asthma: Prevalence, Health Care Utilization and Mortality. *Pediatrics* 110: 315-332 (2002).

American Conference of Governmental Industrial Hygienists. *Documentation of the Threshold Limit Values and Biological Exposure Indices, 6th Edition*, Cincinnati, OH: ACGIH. 1991.

American Heart Association. *2001 Heart and Stroke Statistical Update*, Dallas, TX: American Heart Association, 2001, 5-9, 13-16.

American Lung Association. Breathless in America: background on COPD. 2001. (April 5, 2002; *http://www.lungusa.org/press/lung_dis/asn_copdback.html*).

American Lung Association, U.S. Environmental Protection Agency, Consumer Product Safety Commission, and The American Medical Association. *Indoor Air Pollution: An Introduction for Health Professionals*, Publication No. 1994-523-217/81. Washington, DC: U.S. Government Printing Office, 1994.

Anderson, R.N. Deaths: Leading causes for 1999. *National Vital Statistics Report* 49 (11): 8 (2001).

California Department of Developmental Services. Changes in the population of persons with autism and pervasive developmental disorders in California's developmental services system: 1987 through 1988: a report to the legislature. 1999. (April 13, 2002; *http://www.cahwnet.gov/autism/pdf/autism_report_1999.pdf*).

Caraballo, R.S., G.A. Giovino, T.F. Pechacek, P.D. Mowery, P.A. Richter, W.J. Strauss, et al. Racial and ethnic differences in serum cotinine levels of cigarette smokers: third national health and nutrition examination survey. 1988-1991. *Journal of the American Medical Association* 280: 135-139 (1998).

Centers for Disease Control and Prevention. Preventing lead poisoning in young children. 1991. (April 12, 2002; *http://aepo-xdv-www.epo.cdc.gov/wonder/prevguid/p0000029/p0000029.asp*).

Centers for Disease Control and Prevention. Current trends in autopsy frequency—United States, 1980- 1985. *Morbidity and Mortality Weekly Report* 37 (12): 191-194 (1998). 1998a.

Centers for Disease Control and Prevention. Gastrointestinal infections. 1998. (March 27, 2002; *http://www.cdc.gov/ncidod/hip/INFECT/gi_excerpt.htm*). 1998b.

Centers for Disease Control and Prevention. Notice to readers: final 1997 reports of notifiable diseases. *Morbidity and Mortality Weekly Report* 47 (34): 717-718 (1998). 1998c.

Centers for Disease Control and Prevention. *Decline in Deaths from Heart Disease and Stroke, United States, 1990-1999*, Washington, DC: Centers for Disease Control, 1999. 1999a.

Centers for Disease Control and Prevention. Notice to readers: final 1998 reports of notifiable diseases. *Morbidity and Mortality Weekly Report* 48 (36): 804-805, 815-822 (1999). 1999b.

Centers for Disease Control and Prevention. *Chronic diseases and their risk factors: the nation's leading causes of death (1999)*, Atlanta, GA: NCCDHP, 2000. 2000a.

Centers for Disease Control and Prevention. Consequences of delayed diagnosis of Rocky Mountain spotted fever in children-West Virginia, Michigan, Tennessee, and Oklahoma, May-July 2000. *Morbidity and Mortality Weekly Report* 49 (39): 885-888 (2000). 2000b.

Centers for Disease Control and Prevention. Notice to readers: final 1999 reports of notifiable diseases. *Morbidity and Mortality Weekly Report* 49 (37): 841 (2000). 2000c.

Centers for Disease Control and Prevention. Update: West Nile virus activity—Eastern United States, 2000. *Morbidity and Mortality Weekly Report* 49 (46): 1044-1047 (2000). 2000d.

Centers for Disease Control and Prevention. Cholera. 2001. (November 19, 2002; *http://www.cdc.gov/ncidod/dbmd/diseaseinfo/cholera_g.htm*). 2001a.

Centers for Disease Control and Prevention. Escherichia coli O157:H7. 2001. (November 19, 2002; *http://www.cdc.gov/ncidod/dbmd/diseaseinfo/escherichiacoli_g.htm*). 2001b.

Centers for Disease Control and Prevention. National Report on Human Exposure to Environmental Chemicals. 2001. (May 21, 2002; *http://www.cdc.gov/nceh/dls/report/PDF/CompleteReport.pdf*). 2001c.

Centers for Disease Control and Prevention. Notice to readers: final 2000 reports of notifiable diseases. *Morbidity and Mortality Weekly Report* 50 (33): 712 (2001). 2001d.

Centers for Disease Control and Prevention. Prevalence of disabilities and associated health conditions among adults—United States, 1999. *Morbidity and Mortality Weekly Report* 50: 120-125 (2001). 2001e.

Centers for Disease Control and Prevention. Salmonellosis. 2001. (November 19, 2002; *http://www.cdc.gov/ncidod/dbmd/diseaseinfo/salmonellosis_g.htm*). 2001f.

Centers for Disease Control and Prevention. Shigellosis. 2001. (November 19, 2002; *http://www.cdc.gov/ncidod/dbmd/diseaseinfo/shigellosis_g.htm*). 2001g.

Centers for Disease Control and Prevention. Typhoid fever. 2001. (November 19, 2002; *http://www.cdc.gov/ncidod/dbmd/diseaseinfo/typhoidfever_g.htm*). 2001h.

Centers for Disease Control and Prevention. National diabetes fact sheet. 2002. (February 26 2002; *http://www.cdc.gov/diabetes/pubs/estimates.htm*). 2002a.

Centers for Disease Control and Prevention. Notice to readers: final 2001 reports of notifiable diseases. *Morbidity and Mortality Weekly Report* 51 (32): 710 (2002). 2002b.

Centers for Disease Control and Prevention. Rocky Mountain spotted fever: epidemiology. 2002 (June 6, 2002; *http://www.cdc.gov/ncidod/dvrd/rmsf/epidemiology.htm*). 2002c.

Centers for Disease Control and Prevention. Viral hepatitis. 2002. (November 19, 2002; *http://www.cdc.gov/ncedod/diseases/hepatitis/index.htm*). 2002d.

Centers for Disease Control and Prevention. Viral hepatitis surveillance: disease burden from hepatitis A, B, and C in the United States. 2002. (November 19, 2002: *http://www.cdc.gov/ncidod/diseases/hepatitis/resource/dz_burden02.htm*) 2002e.

Centers for Disease Control and Prevention. West Nile virus update: current case count, 2002. 2002. (November 14, 2002: *http://www.cdc.gov/od/oc/media/wncount.htm*). 2002f.

Centers for Disease Control and Prevention. Asthma's impact on children and adolescents. 2002. (March 25, 2002; *http://www.cdc.gov/nceh/airpollution/asthma/children.htm*). 2002g.

Centers for Disease Control and Prevention. *Second National Report on Human Exposure to Environmental Chemicals*, NCEH Publication No. 03-0022. Atlanta, GA: Centers for Disease Control and Prevention, January 2003. 2003a.

Centers for Disease Control and Prevention. Asthma prevalence, health care use and mortality, 2000- 2001. 2003. (April 21, 2003; *http://www.cdc.gov/nchs/products/pubs/pubd/hestats/asthma/asthma.htm*). 2003b.

Centers for Disease Control and Prevention. Birth defects. Undated. (April 21, 2003; *http://www.cdc.gov/ncbddd/bd*). 2003c.

Centers for Disease Control. Radiation facts. (May 17, 2003; *http://www.bt.cdc.gov/radiation/facts.asp*). 2003d.

Checkoway, H. and Nelson, L. Epidemiologic approaches to the study of Parkinson's disease etiology. *Epidemiology* 10: 327-336 (1999).

Churchill, J., and W. Kaye. Recent chemical exposures and blood volatile organic compound levels in a large population-based sample. *Archives of Environmental Health* 56 (2): 157-166 (2001).

Clayton, C.A., E.D. Pellizzari, R.W. Whitmore, R.L. Perritt, and J.J. Quackenboss. National Human Exposure Assessment Survey (NHEXAS): distributions and associations of lead, arsenic and volatile organic compounds in EPA region 5. *Journal of Exposure Analysis and Environmental Epidemiology* 9: 381-392 (1999).

Craun, G.F. "Chapter 5: Statistics of Waterborne Outbreaks in the U.S. (1920-1980)" In G.F. Craun, (ed.) *Waterborne Diseases in the United States*, Boca Raton: FL, CRC Press, Inc., 1986, 74-155.

Craun, G.F. and R.L. Calderon. "Waterborne Outbreaks in the United States, 1971-2000." In Frederick W. Pontius (ed.), *Drinking Water Regulation and Health*, New York, NY: John Wiley & Sons, 2003, 40- 56.

Crinnion, W.J. Environmental medicine, part one: the human burden of environmental toxins and their common health effects. *Alternative Medicine Review* 5 (1): 52-63 (2000).

Dockery D.W. and Pope, C.A. "Outdoor Air I: Particulates." In K. Steenland and D.A. Savitz (eds.), *Topics in Environmental Epidemiology*, New York, NY: Oxford University Press, 1997.

Doll, R., and R. Peto. *The Causes of Cancer: Quantitative Estimates of Avoidable Risks of Cancer in the United States Today*, New York: Oxford University Press, 1981.

Eberhardt, M.S., D.D. Ingram, D.M. Makuc, et al. *Health, United States, 2001: With Urban and Rural Health Chartbook*, Hyattsville, MD: National Center for Health Statistics, 2001, 161-163.

Eiseman, E., and S. Haga. *A National Resource of Human Tissue Samples*, ISBN 0-8330-2766-2. Arlington, VA: RAND, 1999.

Fombonne, E. Is there an epidemic of autism? *Pediatrics* 107: 411-412 (2001).

Fox, K. National Risk Management Research Laboratory, personal communication, 2003.

Franzen, C., and A. Muller. Cryptosporidia and microsporidia—waterborne diseases in the immunocompromised host. *Diagnostic Microbiology and Infectious Disease* 34: 245-262 (1999).

Friis, R.H. and T.A. Sellers, E*pidemiology for Public Health Practice, Second Edition.* Gaithersburg, MD: Aspen Publishers, Inc., 1999.

Gayle, A. and E. Ringdahl. Tick-borne diseases. *American Family Physician* 64: 461-466 (2001).

GLOBOCAN 2000. *Cancer Incidence, Mortality and Prevalence Worldwide, Version 1.0., IARC CancerBase No. 5*. [Computer software.] Lyon: IARC Press, 2001.

Guerrant, R.L. Cryptosporidiosis: an emerging, highly infectious threat. *Emerging Infectious Diseases* 3 (1): 51-57 (1997).

Hanzlick, R. National autopsy data dropped from the National Center for Health Statistics Database. *Journal of the American Medical Association* 280 (10): 886 (1998).

Holman, R.C., C.D. Paddock, A.T. Curns, J.W. Krebs, J.H. McQuiston, and J.E. Childs. Analysis of risk factors for fatal Rocky Mountain Spotted Fever: evidence for superiority of tetracyclines for therapy. *Journal of Infectious Diseases* 184: 1437-1444 (2001).

Horga, M. A. and A. Fine. West Nile virus. *Pediatric Infectious Diseases Journal* 20: 801-802 (2001).

Hoyert, D.L. and H.M. Rosenberg. Mortality from Alzheimer's disease: an update. *National Vital Statistics Report* 47: 5 (1999).

Hoyert, D.L., E. Arias, B.L. Smith, S.L. Murphy, and K.D. Kochanek. Deaths: Final Data for 1999. *National Vital Statistics Report* 49: 6-9 (2001).

International Center for Tropical Disease Research Network. 10th Anniversary: tropical diseases. 2002. (November 19, 2002; *http://www.niaid.nih.gov/dmid/pdf/factsheet.pdf*).

International Programme on Chemical Safety. G*lobal Assessment of the State-of-the-Science of Endocrine Disruptors*, WHO/PCS/EDC/02.2. Geneva: World Health Organization, International Programme on Chemical Safety, 2002.

Iversen, P. Autism: what does the future hold for, what can we learn from the past, and what can we do right now? *California Pediatrician* Fall: 1-3 (2000).

Kay, D., A. Pruss, and C. Corvalan. Methodology for assessment of environmental burden of disease; report on the ISEE session on environmental burden of disease, Buffalo, August 22, 2000. (May 19, 2002; *http://www.who.int/peh/burden/methodologyhtm.htm*).

Kramarow, E., H. Lentzner, R. Rooks, J. Weeks, S. Saydah. *Health, United States, 1999: With Health and Aging Chartbook*, Hyattsville, MD: National Center for Health Statistics, 1999.

MacIntosh, D.L., L.L. Needham, K.A. Hammerstrom, and P.B. Ryan. A longitudinal investigation of selected pesticide metabolites in urine. *Journal of Exposure Analysis and Environmental Epidemiology* 9: 494-501 (1999).

Mannino, A.M., and B.L. Smith. Deaths: preliminary data for 2000. *National Vital Statistics Report* 53 (49): 3 (2001).

Mannino, D.M, D.M. Huma, L.J. Akinbami, et al. Surveillance for asthma - United States, 1980-1999. *Morbidity and Mortality Weekly Report Surveillance Summaries* 51 (SS-1): 8, 9, 13 (2002).

Martin, J.A., B.E. Hamilton, S.J. Ventura, F. Menacker, and M.M. Park. Births: Final data for 2000. *National Vital Statistics Report* 50 (5): 16, 79 (2002).

Moore, G.W., J.J. Berman, R.L. Hanzlick, J.J. Buchino, and G.M. Hutchins. A prototype internet autopsy database: 1625 consecutive fetal and neonatal autopsy facesheets spanning twenty years. 1996. (March 1, 2002; *http://www.autopsydb.org/protoiad.htm*).

Nadakavukaren, A. *Our Global Environment: a Health Perspective, Fifth Edition*, Prospect Heights, IL: Waveland Press, Inc, 2000.

National Academy of Engineering. Greatest engineering achievements of the 20th century. 2000. (February 28, 2003; *http://greatachievements.org*).

National Research Council. *Risk Assessment in the Federal Government: Managing the Process*, Washington, DC: National Academies Press, 1983.

National Research Council. *Measuring Lead Exposure in Infants, Children, and Other Sensitive Populations*, Washington DC: National Academies Press, 1993.

National Research Council. *Arsenic in Drinking Water.* Washington, DC: National Academies Press, 1999.

National Research Council. *Toxicological Effects of Methylmercury*, Washington, DC: National Academy of Sciences, 2000.

National Cancer Institute. Health disparities. 2002. (January 30, 2003; *http://surveillance.cancer.gov/disparities*).

National Cancer Institute. Dictionary. Undated. (April 18, 2003; *http://cancer.gov/dictionary*).

National Center for Educational Statistics. Digest of education statistics. 2001. (February, 18, 2003; *http://nces.ed.gov/pubs2002/digest2001/tables/dt052.asp*).

National Center for Environmental Health. CDC's lead poisoning prevention program. 1998. (April 12, 2002; *http://www.cdc.gov/nceh/Lead/factsheets/leadfacts.pdf*).

National Center for Health Statistics. *Healthy People 2000 Final Review*, PHS 2001-0256 ed. Hyattsville, MD: Department of Health and Human Services, Centers for Disease Control and Prevention, National Center for Health Statistics, 2001.

National Heart, Lung and Blood Institute. Particulate air pollution and cardiovascular morbidity. 2000. (April 3, 2002; *http://www.arb.ca.gov/research/cardio/cardio.htm*).

National Institute of Diabetes and Digestive and Kidney Diseases. Kidney and urologic diseases statistics for the United States. 2001. (April 5, 2002; *http://www.niddk.nih.gov/health/kidney/pubs/kustats/kustats.htm*).

National Institute of Neurological Disorders and Stroke. Parkinson's disease backgrounder. 2002. (May 13, 2002; *http://www.ninds.nih.gov/health_and_medical/pubs/parkinson's_disease_backgrounder.htm*).

Orban, J.E., J.S. Stanley, J.G. Schwemberger, and J.C. Remmers. Dioxins and dibenzofurans in adipose tissue of the general U.S. population and selected subpopulations. *American Journal of Public Health* 84: 439-445 (1994).

Orloski, K.A., E.B. Hayes, G.L. Campbell, and D.T. Dennis. Surveillance for Lyme disease-United States, 1992-1998. *Morbidity and Mortality Weekly Report Surveillance Summaries* 49 (SS-1): 4 (2002).

Paddock, C. D., P.W. Greer, T.L. Ferebee, J. Jr. Singleton, D.B. McKechnie, T.A. Treadwell, et al. Hidden mortality attributable to Rocky Mountain spotted fever: immunohistochemical detection of fatal, serologically unconfirmed disease. *Journal of Infectious Diseases* 179: 1469-1476 (1999).

Pastor, P.N., D.M. Makuc, C. Reuben, and H. Xia, et al. *Chartbook on Trends in the Health of Americans. Health, United States, 2002*, Hyattsville, MD: National Center for Health Statistics, 2002.

Pellizzari, E.D., R. Fernando, G.M. Cramer, G.M. Meaburn, and K. Bangerter. Analysis of mercury in hair of EPA region V population. *Journal of Exposure Analysis and Environmental Epidemiology* 9: 393-401 (1999).

Peterson, C.A. and R.L. Calderon. Trends in enteric disease as a cause of death in the United States, 1989-1996. *American Journal of Epidemiology* 57: 58-65 (2003).

Pirkle, J.L., K.M. Flegal, J.T. Bernert, D.J. Brody, R.A. Etzel, and K.R. Maurer. Exposure of the U.S. population to environmental tobacco smoke: The Third National Health and Nutrition Examination Survey, 1988 to 1991. *Journal of the American Medical Association* 275: 1233-1240 (1996).

Pirkle, J.L., R.B. Kaufmann, D.J. Brody, T. Hickman, E.W. Gunter, and D.C. Pashal. Exposure of the U.S. population to lead: 1991-1994. *Environmental Health Perspectives* 106: 745-50 (1998).

Prüss, A., C.F. Corvalan, H. Pastides, and A.E. De Hollander. Methodologic considerations in estimating burden of disease from environmental risk factors at national and global levels. *International Journal of Occupational Medicine and Environmental Health* 7: 58-67 (2001).

Rappole, J. H., S.R. Derrickson, and Z. Hubalek. Migratory birds and spread of West Nile virus in the Western Hemisphere. *Emerging Infectious Diseases* 6: 319-328 (2000).

Ries, L.A.G., M.P. Eisner, C.L. Kosary, et al., eds. *SEER Cancer Statistics Review*, 1973-1998. Bethesda, MD: National Cancer Institute, 2001.

Rom, W.N. *Environmental and Occupational Medicine, 2nd Edition*, Boston, MA: Little, Brown and Company. 1992

Schmidt, C. W. Poisoning young minds. *Environmental Health Perspectives* 107: A302-A307 (1999).

Shapiro, E. D. and M.A. Gerber. Lyme disease. *Clinical Infectious Diseases* 31: 533-542 (2000).

Smith, K.R., Corvalan, C.F., and Kfellstrom, T. How much global ill health is attributable to environmental factors? *Epidemiology* 10: 573-584 (1999).

The Pew Environmental Health Commission, The Johns Hopkins University School of Public Health. Transition report to the new administration: Strengthening our public health defense against environmental threats. 2001. (May 27, 2002; http://pewenvirohealth.jhsph.edu/html/reports/5 Pager.pdf).

United Nations. *Demographic Yearbook 1999*, New York: United Nations, 2001, 479-506.

U.S. Department of Housing and Urban Development. Eliminating childhood lead poisoning: a federal strategy targeting lead paint hazards. 2000. (February 20, 2003; *http://www.hud.gov/offices/lead/reports/fedstrategy2000.pdf*).

U.S. Environmental Protection Agency. Regulation of fuels and fuel additives: control of lead additives in gasoline. *Federal Register* 38 (234): 33733-33741 (December, 6 1973).

U.S. Environmental Protection Agency. *Air Quality Criteria for Lead*. EPA 600-8-83-028aF. Research Triangle Park, NC: U.S. Environmental Protection Agency, Office of Research and Development, Environmental Criteria and Assessment Office, 1986.

U.S. Environmental Protection Agency. *Respiratory Health Effects of Passive Smoking: Lung Cancer and Other Disorders,* EPA 600-6-90-006F. Washington, DC: U.S. Environmental Protection Agency, Office of Research and Development, Office of Health and Environmental Assessment, December 1992.

U.S. Environmental Protection Agency. EPA's report on environmental health threats to children. 1996. (May 23, 2002; *http://www.epa.gov/epadocs/child.htm*).

U.S. Environmental Protection Agency. *Research Plan for Microbial Pathogens and Disinfection Byproducts in Drinking Water*, EPA 600-R-97-122. Washington, DC: U.S. Environmental Protection Agency, Office of Research and Development, November 1997.

U.S. Environmental Protection Agency. *EPA's Children's Environmental Health Yearbook*, Washington, DC: U.S. Environmental Protection Agency, Office of Children's Health Protection. June 1998.

U.S. Environmental Protection Agency. February 10-12, 1999, M/DBP (microbial/disinfection byproducts) stage 2 FACA: health effects workshop meeting summary. 1999. (November 21, 2002; *http://www.epa.gov/safewater/mdbp/st2feb99.html*).

U.S. Environmental Protection Agency. Radiation: risks & realities - what is radiation? 2000. (June 2, 2002; *http://www.epa.gov/radiation/docs/risksandrealities/rrpage2.html*). 2000a.

U.S. Environmental Protection Agency. *Air Quality Criteria for Carbon Monoxide*, EPA 600-P-99-001F. Research Triangle Park, NC: U.S. Environmental Protection Agency, Office Research and Development, National Center for Environmental Assessment. June 2000. 2000b.

U.S. Environmental Protection Agency, *America's Children and the Environment – a First View of Available Measures*, EPA 240-R-00-006. Washington, DC: Environmental Protection Agency, Office of Children's Health Protection, December 2000. 2000c.

U.S. Environmental Protection Agency. *Handbook of Groundwater Policies for RCRA Corrective Action* (updated 4/20/2000), EPA 530-D-00-001. Washington, DC: U.S. Environmental Protection Agency, April 2000d.

U.S. Environmental Protection Agency. Fact sheet: drinking water standard for arsenic, EPA 815-F-00- 015. 2001. (November 24, 2002; *http://www.epa.gov/safewater/ars/ars_rule_factsheet.html*). *2001a.*

U.S. Environmental Protection Agency. Pesticides: regulating pesticides—Persistent organic pollutants (POPs). 2001. (May 21, 2002; *http://www.epa.gov/oppfead1/international/pops.htm*). 2001b.

U.S. Environmental Protection Agency. *Drinking Water Priority Rulemaking: Microbial and Disinfection Byproduct Rules*, EPA 816-F-01-012. Washington, DC: U.S. Environmental Protection Agency, Office of Water, June 2001a.

U.S. Environmental Protection Agency. *National Air Quality and Emissions Trends Report, 1999*, EPA 454-R-01-004. Research Triangle Park, NC: U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards, March 2001.

U.S. Environmental Protection Agency. Ionizing radiation. 2002. (February 18, 2003; *http://www.epa.gov/earth1r6/6pd/radon/radon.htm*). 2002a.

U.S. Environmental Protection Agency, Region 6. Radon. 2002. (June 6, 2002; *http://www.epa.gov/earth1r6/6pd/radon/radon.htm*). 2002b.

U.S. Environmental Protection Agency. Drinking water contaminants: disinfection by-products. 2002. (November 21, 2002; *http://www.epa.gov/safewater/hfacts.html*). 2002c.

U.S. Environmental Protection Agency. *Air Quality Criteria for Particulate Matter, Third External Review Draft, Volume II,* EPA 600-P-99-002bC. Research Triangle Park, NC: U.S. Environmental Protection Agency, Office of Research and Development, National Center for Environmental Assessment, April 2002. 2002d.

U.S. Environmental Protection Agency. *Current Drinking Water Standards*, EPA 816-F-02-013. Washington, DC: U.S. Environmental Protection Agency, July 2002. 2002e.

U.S. Environmental Protection Agency. *National Recommended Water Quality Criteria: 2002*, EPA 822- R-02-047. Washington, DC: U.S. Environmental Protection Agency, November 2002f.

U.S. Environmental Protection Agency. Consumer factsheet on hexachlorobenzene. 2002. (May 8, 2003; *http://www.epa.gov/safewater/dwh/c-soc/hexachlo.html*). 2002g.

U.S. Environmental Protection Agency. Radiation information: common questions, clear answers. (May 17, 2003; *http://www.epa.gov/radiation/faqs.htm*). 2002h.

U.S. Environmental Protection Agency. Understanding radiation: ionizing and non-ionizing radiation. (May 17, 2003; *http://www.epa.gov/radiation/understand/ionize_nonionize.htm*). 2002i.

U.S. Environmental Protection Agency. Understanding radiation: health effects. (May 17, 2003; *http://www.epa.gov/radiation/understand/health_effects.htm*). 2002j.

U.S. Environmental Protection Agency. Understanding radiation: exposure pathways. (May 17, 2003; *http://www.epa.gov/radiation/understand/pathways.htm*). 2002k.

U.S. Environmental Protection Agency, *America's Children and the Environment – Measures of Contaminants, Body Burdens, and Illnesses, Second Edition*, EPA 240-R-03-001. Washington, DC: Environmental Protection Agency, Office of Children's Health Protection, National Center for Environmental Economics, Office of Policy, Economics and Innovation, February 2003. 2003a.

U.S. Environmental Protection Agency. Hexachlorobenzene. 2003. (May 8, 2003; *http://www.epa.gov/ttn/atw/hlthef/hexa-ben.html*). 2003b.

U.S. Environmental Protection Agency. Hexachlorobenzene. 2003. (May 8, 2003; *http://www.epa.gov/opptintr/pbt/hexa.htm*). 2003c.

U.S. Environmental Protection Agency. EPA map of radon zones. 2003. (February 27, 2003; *http://www.epa.gov/iaq/radon/zonemap.html*). 2003d.

U.S. Environmental Protection Agency. *Framework for Cumulative Risk Assessment*, EPA-630-P-02- 001F. Washington, DC: Risk Assessment Forum, 2003. (Available online at http://cfpub.epa.gov/ncea/raf/recordisplay.cfm?deid=54944) 2003e.

Walker, D. H. Tick-transmitted infectious diseases in the United States. *Annual Review of Public Health* 19: 237-269 (1998).

Whipple G.C. *Influence of Public Water-Supplies on the Typhoid Fever Death-Rates of Cities. In Typhoid Fever - Its Causation, Transmission and Prevention*, John Wiley and Sons, Inc., 1908, 228-270.

World Health Organization. Typhoid fever, 1997. Fact sheet N149. (February 1, 2003; *http://www.who.int/inf-fs/en/fact149.html*)

World Health Organization. Environmental burden of disease. 2002. (April 11, 2002; *http://www.who.int/peh/burden/burdenindex.htm*).

World Resources Institute, United Nations Environment Programme, United Nations Development Programme, and World Bank. *World Resources* 1998-99, London: Oxford University Press, 1998, 10.

Yazbak, F.E. Autism 99: a national emergency. 1999. (April 13, 2002; *http://www.garynull.com/Documents/autism_99.htm*).

Chapter 5: Ecological Condition

American Forests. *Urban Ecosystem Analysis - Atlanta Metro Area: Calculating the Value of Nature*, Washington, DC: American Forests, 2001.

American Forests. *Urban Ecosystem Analysis for the Washington DC Metropolitan Area: An Assessment of Existing Conditions and a Resource for Local Action*, Washington, DC: American Forests, 2002.

Anderson, D., and D. Garrison (eds.). The ecology and oceanography of harmful algal blooms. *Limnology and Oceanography* 42: 1009-130 (2000).

Arnold, D.L., and C.J. Gibbons. Impervious surface coverage: The emergence of a key environmental indicator. *Journal of the American Planning Association* 62 (2): 243-258 (1996).

Baker, L.A., A. Herlihy, P. Kaufmann, and J. Eilers. Acid lakes and streams in the United States: the role of acid deposition. *Science* 252: 1151-1154 (1991).

Barker, J., and D. Tingey. *Air Pollution Effects on Biodiversity*, New York: Van Nostrand Reinhold, 1992.

Batiuk, R.A., P. Bergstrom, M. Kemp, E. Koch, L. Murray, J.C. Stevenson, R. Bartleson, V. Carter, N.B. Rybicki, J.M. Landwehr, C. Gallegos, L. Karrh, M. Naylor, D. Wilcox, K.A. Moore, S. Ailstock, and M. Teichberg. *Chesapeake Bay Submerged Aquatic Vegetation Water Quality and Habitat- Based Requirements and Restoration Targets: A Second Technical Synthesis*, CBP-TRS 245-00, EPA 903-R-00-014. Annapolis, MD: U.S. Environmental Protection Agency, Chesapeake Bay Program, 2000.

Bennett, J.P., R.L. Anderson, M.L. Mielke, and J.J. Ebersole. Foliar injury air pollution surveys of eastern white pine (*Pinus strobus L.*): a review™. *Environmental Monitoring and Assessment* 30: 247-274 (1994).

Boesch, D.F., and Rosenberg, R. "Response to stress in marine benthic communities." In G.W. Barret and R. Rosenberg (eds.), *Stress Effects on Natural Ecosystems*, New York, NY: John Wiley and Sons, 1981, 179-200.

Bondy, E., L. Lyles, and W.A. Hayes. Computing soil erosion by periods using wind energy distribution. *Journal of Soil and Water Conservation* 35 (4): 173-176 (1980).

Booth, D.B., and C.R. Jackson. Urbanization of aquatic systems: Degradation thresholds, stormwater detection, and the limits of mitigation. *Journal of the American Water Resources Association* 35 (5): 1077-1090 (1997).

Carlson, R.E. A trophic state index for lakes. *Limnology and Oceanography* 22 (2): 361-369 (1977).

Committee on Environment and Natural Resources of the National Science and Technology Council. *Integrated Assessment of Hypoxia in the Northern Gulf of Mexico*, Washington, DC: National Science and Technology Council Committee on Environment and Natural Resources, 2000.

Council for Agricultural Science and Technology. *Gulf of Mexico Hypoxia: Land and Sea Interactions*, Report 134. Ames, IA: Council for Agricultural Science and Technology, June 1999.

Conkling, B., J. Coulston, and M. Ambrose (eds.). *Forest Health Monitoring National Technical Report 1991-1999*, Asheville, NC: U.S. Department of Agriculture Forest Service, Southern Research Station, 2002.

Cunningham, C., and K. Walker. Enhancing public access to the coast through the CZMA. *Current: The Journal of Marine Education* 14 (1): 8-12 (1996).

Dahl, T.E. *Status and Trends of Wetlands in the Conterminous United States 1986 to 1997*, Washington, DC: U.S. Department of the Interior, U.S. Fish and Wildlife Service, 2000.

Daily, G.S. *Nature's Services: Societal Dependence on Natural Ecosystems 1997*, Washington, DC: Island Press, 1997.

Dierauf, L.A., and F.M.D. Gulland (eds.) *CRC Handbook of Marine Mammal Medicine: Health, Disease, and Rehabilitation, 2nd Edition*, Boca Raton, FL: CRC Press, Inc., 2001.

Ehrenfeld, D.H. "Ecosystem health and ecological theories." In Costanza, R., et al. (eds.), *Ecosystem Health: New Goals for Environmental Management*, Washington, DC: Island Press, 1992, 135-143.

Engle, V.D., J.K. Summers, and G.R. Gaston. Benthic index of environmental condition of Gulf of Mexico estuaries. *Estuaries* 17 (2): 372-384 (1994).

Engle, V.D., and J.K. Summers. Refinement, validation, and application of a benthic condition index for northern Gulf of Mexico estuaries. *Estuaries* 22 (3A): 624-635 (1999).

Fisher, R.F., and D. Binkley. *Ecology and Management of Forest Soils, 3rd Edition*, New York: John Wiley and Sons, 2000.

Forman, T.T. and M. Godron. *Landscape Ecology*, New York: Wiley, 1986.

Frayer, W.E., T.J. Monahan, D.C. Bowden, and F.A. Graybill. *Status and Trends of Wetlands and Deepwater Habitats in the Conterminous United States, 1950's to 1970's*, Fort Collins, CO: Colorado State University, Department of Forest and Wood Sciences, 1983.

Gallagher, E., and K. Keay. "Organism sediment contaminant in Boston Harbor." In K. Stolzenbach and E. Adams (eds.). *Contaminated Sediment in Boston Harbor*, Boston, MA: MIT Sea Grant Press, 1998.

Galloway, J., and E. Cowling. Reactive nitrogen and the world: 200 years of change. *Ambio* 31: 64-71 (2002).

Grime, J.P. Biodiversity and ecosystem function: the debate deepens. *Science* 277: 1260-1261 (1997).

Grimm, N.B., L. Baker, and D. Hope. "An ecosystem approach to understanding cities: familiar foundations and uncharted frontiers." In A.R. Berkowitz, K.S. Hollweg, and C.H. Nilon (eds.). *Understanding Urban Ecosystems: A New Frontier for Science and Education*, Springer-Verlag: New York, 2002, 95-114.

Hadidian, J., J. Sauer, C. Swarth, P. Handly, S. Droege, C. Williams, J. Huff, and G. Didden. A citywide breeding bird survey for Washington, DC. *Urban Ecosystems* 1: 87-102 (1997).

Hellkamp, A.S., J.M. Bay, C.L. Campbell, K.N. Easterling, D.A. Fiscus, G.R. Hess, B.F. McQuaid, M.J. Munster, G.L. Olson, S.L. Peck, S.R. Shafer, K. Sidik, and M.B. Tooley. Assessment of the condition of agricultural lands in six mid-Atlantic states. *Journal of Environmental Quality* 29: 79-804 (2000).

Herlihy, A.T., D. Larsen, S. Paulsen, N. Urquhart, and B. Rosenbaum. Designing a spatially balanced, randomized site selection process for regional stream surveys: the EMAP mid-Atlantic pilot study. *Environmental Monitoring Assessment* 63: 95-113 (2000).

Hess, G.R., A.S. Hellkamp, S.R. Shafer, B.F. McQuaid, M.J. Munster, S.L. Peck, and C.L. Campbell. A conceptual model and indicators for assessing the ecological condition of agricultural lands. *Journal of Environmental Quality* 29 (3): 728-737 (2000).

Hodgson, J.G., K. Thompson, P.J. Wilson, and A. Bogaard. Does biodiversity determine ecosystem function? The Ecotron experiment reconsidered. *Functional Ecology* 12: 843-848 (1998).

Holland, A.F., A. Shaughnessey, and M.H. Heigel. Long-term variation in mesohaline Chesapeake Bay benthos: spatial and temporal patterns. *Estuaries* 10: 227-245 (1987).

Holland, A.F., A.T. Shaughnessey, L.C. Scott, V.A. Dickens, J.A. Ranasinghe, and J.K. Summers. *Progress Report: Long-term Benthic Monitoring and Assessment Program for the Maryland Portion of the Chesapeake Bay (July 1986-October1987)*, Maryland Power Plant Research Program and Maryland Department of the Environment, Office of Environmental Programs PPRP-LTB/EST-88-1. Columbia, MD: Versar Inc., ESM Operations, 1988.

International Programme on Chemical Safety. *Global Assessment of the State-of-the-Science of Endocrine Disruptors*, WHO/PCS/EDC/02.2. Geneva: World Health Organization, International Programme on Chemical Safety, 2002.

Judy, R.D., Jr., P. Seeley, T. Murray, S. Svirsky, M. Whitworth, and L. Ischiger. *1982 National Fisheries Survey*, FWS/OBS-84/06. Washington, DC: U.S. Fish and Wildlife Service, 1984.

Kaiser, J. Great Smokies species census underway. *Science* 284 (5421): 1747-1748 (1999).

Karr, J.R., K.D. Fausch, P.L. Angermeier, P.R. Yant, and I.J. Schlosser. *Assessing Biological Integrity in Running Waters, A Method and Its Rationale,* Special Publication No. 5. Champaign, IL: Illinois Natural History Survey, 1986.

Karr, J.R., L.S. Fore, and E.W. Chu. *Making Biological Monitoring More Effective: Integrating Biological Sampling with Analysis and Interpretation*, Washington DC: U.S. Environmental Protection Agency, Office of Policy Planning and Evaluation, 1997.

Kaufmann, P.R., A.T. Herlihy, M.E. Mitch, and W.S. Overton. Chemical characteristics of streams in the Eastern United States: I: Synoptic survey design, acid-base status and regional chemical patterns. *Water Resources Research* 27: 611-627 (1991).

Kaufmann, P.R., P. Levine, E.G. Robison, C. Seeliger, and D.V. Peck. *Surface Waters: Quantifying Physical Habitat in Wadeable Streams*, EPA 620-R-99-003. Washington, DC: U.S. Environmental Protection Agency, Office of Research and Development, July 1999.

Kinzig, A.P. and J.M. Grove. "Urban-suburban ecology." In S. Levin (ed.). *The Encyclopedia of Biodiversity*, New York, NY: Academic Press, 2001, 733-746.

Klemm, D.J., K.A. Blocksom, W.T. Thoeny, F.A. Fulk, A.T. Herlihy, P.R. Kaufmann, S.M. Cormier. Methods development and use of macroinvertebrates as indicators of ecological conditions for streams in the mid-Atlantic Highlands region. *Environmental Monitoring and Assessment* 78 (2): 169-212 (2002).

Klemm, D.J., K.A. Blocksom, F.A. Fulk, A.T. Herlihy, R.M. Hughes, P.R. Kaufmann, D.V. Peck, J.L. Stoddard, W.T. Thoeny, M.B. Griffith, and W.S. Davis. Development and evaluation of a Macroinvertebrate

Biotic Integrity Index (MBII) for regionally assessing Mid-Atlantic Highlands streams. *Environmental Management* 31 (5): 656-669 (2003).

Klopatek, J.M., R.J. Olson, C.J. Emerson, and J.L. Joness. Land-use conflicts with natural vegetation in the United States. *Environmental Conservation* 6: 191-199 (1979).

Knight, R. and P. Landres. (eds.). *Stewardship Across Boundaries*, Washington, DC: Island Press. 1998.

Landers, D.H., W. S. Overon, R. Linthurst, and D. Brakke. Eastern lake survey - regional estimates of lake chemistry. *Environmental Science Technology* 22: 128-135 (1988).

Lindenmeyer, D.B., C. Margules, and D. Botkin. Indicators of biodiversity for ecologically sustainable forest management. *Conservation Biology* 10: 941-950 (2000).

Linthurst, R.A., D.H. Landers, J.M. Eilers, P.E. Kellar, D.F. Brakke, W.S. Overton, R. Crowe, E.P. Meier, P. Kanciruk, and D.S. Jefferies. Region chemical characteristics of lakes in North America - II: eastern United States. *Water, Air, and Soil Pollution* 31: 123-129 (1986).

Liu, B.Y., M.A. Nearing, C. Baffaut, and J.C. Ascough II. The WEPP watershed model: III. Comparisons to measured data from small watersheds. *Transactions of the American Society of Agricultural Engineers*, 40(4):945-951 (1997),

Matson, P.A., W.J. Parton, A.G., Power, and M.J. Swift. Agricultural intensification and ecosystem properties. *Science* 277: 504-509 (1997).

McCormick, F.H., R.M. Hughes, P.R. Kaufmann, D.V. Peck, J.L. Stoddard, and A.T. Herlihy. Development of an index of biotic integrity for the mid-Atlantic Highlands region. *Transactions of the American Fisheries Society* 130: 857-877 (2001).

McQuaid, B.F., and Olson, G.L. "Indices of Piedmont soils under different management systems." In R. Lal et al. (eds.), *Advances in Soil Science - Soil Processes and the Carbon Cycle*, Boca Raton, FL: CRC Press, 1998, 427-434.

Messer, J.J. "Indicators in regional ecological monitoring and risk assessment." In D. H. McKenzie et al. (eds.), *Ecological Indicators, Volume 1*, Essex, England: Elsevier Science, 1992, 135-146.

Messer, J.J., D.H. Landers, R.A. Linthurst, and W.S. Overton. Critical design and interpretive aspects of the National Surface Water Survey. *Journal of Lake Reservoir Management* 3: 463-469 (1986).

Messer, J.J., C.W. Ariss, J.R. Baker, S.K. Drouse, K.N. Eshlemann, A.J. Kinney, W.S. Overton, J.J. Sale, and R.D. Schonbrod. Stream chemistry in the southern Blue Ridge: feasibility of a regional synoptic stream sampling approach. *Water Resource Bulletin* 24: 821-829 (1988).

Moore, K.A., D.J. Wilcox, and R.J. Orth. Analysis of the abundance of submersed aquatic vegetation communities in the Chesapeake Bay. *Estuaries* 23 (1): 115-127 (2000).

Naeem, S., D. Byers, S.F. Tjossem, C. Bristow, and S. Li. Plant neighborhood diversity and production. *Ecoscience* 6: 355-365 (1999).

Naiman, R.J. and M.G. Turner. A future perspective on North America's fresh water ecosystems. *Ecological Applications* 10: 958-970 (2000).

National Acid Precipitation Assessment Program. *Acid Deposition: State of Science and Technology. Volume II. Aquatic Processes and Effects*, Washington, DC: National Acid Precipitation Assessment Program, 1991.

National Research Council. *Striking a Balance: Improving Stewardship of Marine Areas*, Washington, DC: National Academies Press, 1997.

National Research Council. *Our Common Journey: A Transition Toward Sustainability*, Washington DC: National Academies Press, 1999.

National Research Council. *Ecological Indicators for the Nation*, Washington, DC: National Academies Press, 2000.

NatureServe. NatureServe Explorer, an online encyclopedia of life. 2002. (February 2003; *http://www.natureserve.org/explorer/*).

Nixon, S.W., Hunt, C.D., and Nowicki, B.L. "The retention of nutrients (C, N, P), heavy metals (Mn, Cd, Pb, Cu), and petroleum hydrocarbons by Narragansett Bay." In P. Lasserre and J.M. Martin (eds.), *Biogeochemical Processes at the Land-Sea Boundary*, New York, NY: Elsevier, 1986, 99-122.

Noss, R.F., and A.Y. Cooperrider. *Saving Nature's Legacy: Protecting and Restoring Biodiversity*, Washington, DC: Island Press, 1994.

Nowak, D., K. Civerelo, S.T. Rao, G. Sistla, C. Luley, and D. Crane. A modeling study of the impact of urban trees on ozone. *Atmospheric Environment* 34: 1601-1613 (2000).

O'Connell, T.J., L.E. Jackson, and R.P. Brooks. A bird community index of biotic integrity for the mid- Atlantic Highlands. *Environmental Monitoring and Assessment* 51: 145-156 (1998).

O'Connell, T.J., L.E. Jackson, and R.P. Brooks. Bird guilds as indicators of ecological condition in the central Appalachians. *Ecological Applications* 10: 1706-1721 (2000).

O'Connell, T.J., J.A. Bishop, and R.P. Brooks. *The North American Breeding Bird Survey as Source Data for Assessments of Ecological Condition with the Bird Community Index*, Final Report to the U.S. Geological Survey – Patuxent Wildlife Research Center Report No. 2002-03. University Park, PA: Penn State Cooperative Wetlands Center, 2002.

Odum, E.P. *Fundamentals of Ecology, Third Edition*, Philadelphia, PA: W.B. Saunders Company, 1971.

Olsen, A.R., J. Sedransk, D. Edwards, C.A. Gotway, W. Liggett, S. Rathbun, K.H. Reckhow, and L.J. Young. Statistical issues for monitoring ecological and natural resources in the United States. *Environmental Monitoring and Assessment* 54: 1-45 (1999).

O'Neill, R.V., T.F. Allen, and D.L. Deangelis. *A Hierarchical Concept of Ecosystems*, Princeton, NJ: Princeton Press. 1986.

Paul, J.F., J.H. Gentile, K.J. Scott, S.C. Schimmel, D.E. Campbell, and R.W. Latimer. *EMAP - Virginian Province Four-year Assessment Report (1990-1993)*, EPA 620-R-99-004. Narragansett, RI: U.S. Environmental Protection Agency, Office of Research and Development, Atlantic Ecology Division, October 1999.

Pearson, T.H., and R. Rosenberg. Macrobenthic succession in relation to organic enrichment and pollution of the marine environment. *Oceanography and Marine Biology Annual Review* 16: 229-311 (1978).

Peterson, S.A., D.P. Larsen, S.G. Paulsen, and N.S. Urquhart. Regional lake trophic patterns in the northeastern United States: three approaches. *Environmental Management* 22 (5): 789-801 (1998).

Pickett, S.T.A., M.L. Cadenasso, J.M. Grove, C.H. Nilon, R.V. Pouyat, W.C. Zipperer, and R. Costanza. Urban ecological systems: linking terrestrial ecology, physical, and socioeconomic components of metropolitan areas. *Annual Review of Ecology and Systematics* 32: 127-157 (2001).

Rabalais, N.N., and R.E. Turner, (eds). *Coastal Hypoxia: Consequences for Living Resources and Ecosystems*, Coastal and Estuarine Studies 58. Washington DC: American Geophysical Union, 2001.

Reed, R.C. and L. Young. Seasonal vegetation characteristics of the United States. *Geocarto International* 12: 65-71 (1997).

Renard, K.G., G.R. Foster, G.A. Weesies, D.K. McCool, and D.C. Yoder. *Predicting Soil Erosion by Water: A Guide to Conservation Planning with the Revised Universal Soil Loss Equation (RUSLE)*, Agriculture Handbook No. 703. Washington DC: U.S. Department of Agriculture, 1997.

Rhoads, D.C., P.L. McCall, and J.Y. Yingst. Disturbance and production on the estuarine sea floor. *American Scientist* 66: 577-586 (1978).

Riiters, K.H., J.D. Wickham, R.V. O'Neill, K.B. Jones, E.R. Smith, J.W. Coulston, T.G. Wade, and J.H. Smith. Fragmentation of Continental United States Forests. *Ecosystems* 5: 815-822 (2002).

Rosswall, T., R. Woodmansee, and P. Risser. *Scales and Global Change: Spatial and Temporal Variability in Biospheric and Geospheric Processes*, Scope 35. New York City, NY: John Wiley, 1988.

Sanders, H.L., J.F. Grassle, G.R. Hampson, L.S. Morse, S. Garner-Price, and C.C. Jones. Anatomy of an oil spill: long-term effects from the grounding of the barge Florida off West Falmouth, Massachusetts. *Journal of Marine Research* 38: 265-380 (1980).

Skelly, J.M., D.D. Davis, W. Merrill, E.A. Cameron, H.D. Brown, D.B. Drummond, and L.S. Dochinger. *Diagnosing Injury to Eastern Forest Trees™*, University Park, PA: U.S. Department of Agriculture Forest Service and Penn State University, 1987.

Skidmore, E.L., and N.P. Woodruff. *Wind Erosion Forces in the United States and Their Use in Predicting Soil Loss*, Agriculture Handbook No. 346. Washington DC: U.S. Department of Agriculture, 1968, 42.

Smith, W.B., J.S. Vissage, D.R. Darr, and R.M. Sheffield. *Forest Statistics of the United States, 1997*, General Technical Report NC-219. St. Paul, MN: U.S. Department of Agriculture Forest Service, North Central Research Station, 2001, 191.

Stein, B.A. *States of the Union: Ranking America's Biodiversity*, Arlington, VA: NatureServe, 2002.

Stoddard, J. L., A. D. Newell, N. S. Urquhart, and D. Kugler. The TIME project design: II. Detection of regional acidification trends. *Water Resources Research* 32: 2529-2538 (1996).

Stoddard, J. L., C. T. Driscoll, S. Kahl, and J. Kellogg. Can site-specific trends be extrapolated to a region? An acidification example for the Northeast. *Ecological Applications* 8: 288-299 (1998).

Stoddard, J.L., D.S. Jeffries, A. Lukewille, T.A. Clair, P.J. Dillon, C.T. Driscoll, M. Forsius, M. Johannessen, J.S. Kahl, J.H. Kellogg, A. Kemp, J. Mannio, D. Monteith, P.S. Murdoch, S. Patrick, A. Rebsdorf, B.L. Skjelkvale, M. Stainton, T.S. Traaen, H. van Dam, K.E. Webster, J. Wieting, and A. Wilander. Regional trends in aquatic recovery from acidification in North America and Europe. *Nature* 401 (6753): 575-8 (1999).

Stoddard J.L., T.S. Traaen, B.L. Skjelkvale, and M. Johannessen. Assessment of nitrogen leaching at UN/ECE ICP-Waters sites (Europe and North America). *Water, Air, and Soil Pollution* 130: 781-86 (2001).

Stolte, K., B. Conkling, S. Campbell, and A. Gillespie. *Forest Health Indicators - Forest Inventory and Analysis Program*, FS-746. Research Triangle Park, NC: U.S. Department of Agriculture, Forest Service. October 2002.

Suter, G.W. *Ecological Risk Assessment*, Chelsea, MI: Lewis Publishers, 1993.

Sutton, R.F. *Soil Properties and Root Development in Forest Trees: A Review*, Information Report O- X-413. Sault Ste. Marie, Ont: Forestry Canada, Great Lakes Forestry Centre, 1991.

The H. John Heinz III Center for Science, Economics, and the Environment. *The State of the Nation's Ecosystems: Measuring the Lands, Waters, and Living Resources of the United States*, New York, NY: Cambridge University Press, September 2002.

Tilman, D. and J.A. Downing. Biodiversity and stability in grasslands. *Nature* 367: 363-365 (1994).

Turner, M.G. Landscape Ecology: The effect of pattern on process. *Annual Review of Ecology and Systematics* 20: 171-197 (1989).

U.S. Census Bureau. *2000 Census of Population and Housing Characteristics*, PCH-1-1. Washington DC: U.S. Census Bureau, 2002.

U.S. Department of Agriculture, Natural Resources Conservation Service. *Summary Report: 1997 National Resources Inventory (Revised December 2000)*, Washington, DC: Natural Resources Conservation Service and Ames, IA: Iowa State University, Statistical Laboratory, December 1999, revised December 2000.

U.S. Department of Agriculture. *National Resources Inventory: Highlights*, Washington, DC: U.S. Department of Agriculture, Natural Resources Conservation Service, January 2001.

U.S. Department of Agriculture, Forest Service. *U.S. Forest Facts and Historical Trends*, Brochure #FS-696. Washington, DC: U.S. Department of Agriculture, April 2001.

U.S. Department of Agriculture, Forest Service. Draft Resource Planning and Assessment Tables. August 12, 2002. (September 2002; *http://www.ncrs.fs.fed.us/4801/FIADB/rpa_tabler/Draft_RPA_2002_Forest_Resource_Tables.pdf*).

U.S. Department of Agriculture. *National Report on Sustainable Forests - 2003*, Final Draft, Washington, DC: U.S. Department of Agriculture, Forest Service, November 2002.

U.S. Department of Agriculture. *National Report on Sustainable Forests - 2003*, Washington, DC: U.S. Department of Agriculture, Forest Service, Forthcoming, 2003.

U.S. Environmental Protection Agency. *The Quality of our Nation's Waters, A Summary of the National Water Quality Inventory: 1998 Report to Congress*, EPA 841-S-00-001. Washington, DC: U.S. Environmental Protection Agency, Office of Water, June 2000.

U.S. Environmental Protection Agency. *Quality Criteria for Water - 1986*, EPA 440-5-86-001. Washington DC: U.S. Environmental Protection Agency, Office of Water, November 1986.

U.S. Environmental Protection Agency. *Air Quality Criteria for Ozone and Related Photochemical Oxidants*, EPA 600-P-93-004aF-cF. Research Triangle Park, NC: U.S. Environmental Protection Agency, Office of Research and Development, National Center for Environmental Assessment. July 1996.

U.S. Environmental Protection Agency. *Special Report on Environmental Endocrine Disruption: An Effects Assessment and Analysis*, EPA 630-R-96-012. Washington, DC: U.S. Environmental Protection Agency, Risk Assessment Forum, December 1997.

U.S. Environmental Protection Agency. *Condition of the Mid-Atlantic Estuaries*, EPA 600-R-98-147. Washington DC: U.S. Environmental Protection Agency, Office of Research and Development, September 1998.

U.S. Environmental Protection Agency. *Birds Indicate Ecological Condition of the Mid-Atlantic Highlands*, EPA 620-R-00-003. Washington, DC: U.S. Environmental Protection Agency, Office of Research and Development, June 2000.

U.S. Environmental Protection Agency. *Mid-Atlantic Highlands Streams* Assessment, EPA 903-R-00- 015. Philadelphia, PA: U.S. Environmental Protection Agency Region 3, Office of Research and Development, August 2000.

U.S. Environmental Protection Agency. *National Coastal Condition Report*, EPA 620-R-01-005. Washington DC: U.S. Environmental Protection Agency, Office of Research and Development and Office of Water, September 2001.

U.S. Environmental Protection Agency. *A Framework for Assessing and Reporting on Ecological Condition*, EPA-SAB-EPEC-02-009. Washington, DC: U.S. Environmental Protection Agency, Science Advisory Board, June 2002.

U.S. Environmental Protection Agency. *National Water Quality Inventory - 2000 Report*, EPA 841-R- 02-001. Washington DC: U.S. Environmental Protection Agency, Office of Water, August 2002.

U.S. Environmental Protection Agency. *Response of Surface Water Chemistry to the Clean Air Act Amendments of 1990*, EPA 620-R-03-001. Research Triangle Park, NC: U.S. Environmental Protection Agency, Office of Research and Development, National Health and Environmental Effects Research Laboratory, January 2003.

U.S. Environmental Protection Agency. *Mid-Atlantic Integrated Assessment, MAIA - Estuaries 1997- 98, Summary Report*, EPA 620-R-02-003. Narragansett, RI: U.S. Environmental Protection Agency, Office of Research and Development, Atlantic Ecology Division, May 2003.

U.S. General Accounting Office. *Western National Forests: Nearby Communities Are Increasingly Threatened by Catastrophic Wildfires*, GAO/T-RCED-99-79. Washington, DC: U.S. General Accounting Office, 1999.

U.S. General Accounting Office. *Water Quality: Key EPA and State Decisions Limited by Inconsistent and Incomplete Data*, GAO/RCED-00-54. Washington, DC: U.S. General Accounting Office, 2000.

U.S. Geological Survey. National Water-Quality Assessment (NAWQA) Program, national synthesis. 2002. (February 2003; *http://water.usgs.gov/nawqa/natsyn.html*).

Valigura R., R. Alexander, M. Castro, T. Meyers, H. Paerl, P. Stacey, and R. Turner (eds.) *Nitrogen Loading in Coastal Water Bodies - An Atmospheric Perspective*, Washington, DC: American Geophysical Union, 2000.

Van Dolah, R.F., J.L. Hyland, A.F. Holland, J.S. Rosen, and T.R. Snoots. A benthic index of biological integrity for assessing habitat quality in estuaries of the southeastern United States. *Marine Environmental Research* 48: 269-283 (1999).

Vitousek, P., H. Mooney, J. Lubchenco, and J. Melillo. Human domination of Earth's ecosystems. *Science* 277: 494-499 (1997).

Vitousek, P., S. Hattenschwiller, L. Olander, and S. Allison. Nitrogen and nature. *Ambio* 31: 97-101 (2002).

Vogelmann, J., S.M. Howard, L. Yang, C.R. Larson, B.K. Wylie, and N.V. Driel. Completion of the 1990s national land cover data set for the conterminous United States from Landsat Thematic Mapper data and ancillary data sources. *Photogrammetric Engineering and Remote Sensing* 67 (6): 650-662 (2001).

Wardle, D.A., M.A. Huston, J.P. Grime, F. Berendse, E. Garnier, W.K. Lauenroth, H. Setala, and S.D. Wilson. Biodiversity and ecosystem function: an issue in ecology. *Bulletin of the Ecological Society of America*. 81: 235-239 (2000).

Weathers, K.C., M.L. Cadenasso, and S.T.A. Pickett. Forest edges as nutrient and pollutant concentrators: potential synergisms between fragmentation, forest canopies, and the atmosphere. Conservation *Biology* 15: 1506-1514 (2001).

Weisberg, S.B., J.A. Ranasinghe, D.M. Dauer, L.C. Schaffner, R.J. Diaz, and J.B. Frithsen. An estuarine benthic index of biotic integrity (B-IBI) for Chesapeake Bay. *Estuaries* 20: 149-158 (1997).

Wickham, J.D., R.V. O'Neill, K.H. Riitters, E.R. Smith, T.G. Wade, and K.B. Jones. Geographic targeting of increases in nutrient export due to future urbanization. *Ecological Applications* 12 (l): 93-106 (2002).

Winter, T.C. The concept of hydrologic landscapes. *Journal American Water Resources Association* 37: 335-349 (2001).

World Resources Institute. *World Resources 2000-2001 People and Ecosystems: the Fraying Web of Life*, Washington, DC: World Resources Institute, 2000.

Yoccoz, N.G., J.D. Nichols, and T. Bouliner. Monitoring biological diversity in space and time. *Trends in Ecology and Evolution* 16: 446-453 (2001).

References for Appendix D: Glossary of Terms

Atomic Energy Act of 1954, Public Law 83-703.

Barber, M.C., (ed.). *The Environmental Monitoring and Assessment Program: Indicator Development Strategy,* EPA 620-R-94-022. Athens, GA: U.S. Environmental Protection Agency, Office of Research and Development, Environmental Research Laboratory, March 1994.

chained dollars - A measure used to adjust for the effects of inflation in the U.S. currency from year to year, such that a consistent monetary value can be understood over time. A chained dollar is based on the average weights of the cost of goods and services in successive pairs of years. It is "chained" because the second year in each pair, with its weights, becomes the first year of the next pair. (DOE, 2001) Ref: U.S. Department of Energy, Energy Information Administration. Annual Energy Review 1999 - Chained Dollars. February 8, 2001. (June 2, 2003; *http://www.eia.doe.gov/emeu/consumptionbriefs/recs/natgas/chained.html*).

Environment Canada and U.S. Environmental Protection Agency. State of the Great Lakes 1997. October 27, 1998. (August 13, 2002; *http://www.epa.gov/docs/grtlakes/solec/96/stofgl/index.htm*).

Garcia, L.S. Flagellates and ciliates. *Clinics in Laboratory Medicine* 19: vii, 621-638 (1999).

Green, L. W. and Kreuter, M. S. *Health promotion planning: An educational and ecological approach. (3rd edition)*, Mountain View, CA: Mayfield Publishing Co, 1999.

Grondahl, C. and Martin, K. North Dakota's endangered and threatened species. North Dakota State Game and Fish Department's Nongame Program, Version 16JUL97. July 1997. (February 3, 2003; *http://www.npwrc.usgs.gov/resource/distr/others/endanger/endanger.htm*).

Health Insurance Commission. HIC annual report 2000-1 glossary. 2000-2001. (February 24, 2003; *http://www.hic.gov.au/annualreport/glossary.htm*).

Intergovernmental Panel on Climate Change. *Climate Change 2001: The Scientific Basis A Contribution of Working Group I to the Third Assessment Report of the IPCC*, Cambridge, UK and New York, NY: Cambridge University Press, 2001.

International Union of Pure and Applied Chemistry, Clinical Chemistry Division Commission on Toxicology. Glossary for Chemists of Terms Used In Toxicology. 1993. (March 6, 2003; *http://www.sis.nlm.nih.gov/Glossary/main.html*).

Jackson, Laura E., J.C. Kurtz, and W.S. Fisher. *Evaluation Guidelines for Ecological Indicators*, EPA 620-R-99-005. Washington, DC: U.S. Environmental Protection Agency, Office of Research and Development, May 2000.

Matthews, John D., *Silvicultural Systems*, Oxford, UK: Oxford University Press, 1989.

Moffett, M. W. What's "up"? A critical look at the basic terms of canopy biology. *Biotropica* 32:569-596 (2000).

Nadakavukaren, A. Our Global Environment: *A Health Perspective, Fifth Edition*, Prospect Heights, IL: Waveland Press, Inc., 2000.

National Cancer Institute. Asbestos exposure: questions and answers. 2001. (April 5, 2002; *http://cis.nci.nih.gov/fact/3_21.htm*).

National Public Health Partnership. National response to passive smoking in enclosed public places and workplaces: a background paper (Commonwealth of Australia). 2000. (November 1, 2002; *http://www.dhs.vic.gov.au/nphp/legtools/smoking/passive/section2.htm*).

National Research Council. *Ecological Indicators for the Nation*, Washington, DC: National Academies Press, 2000.

Odum, E.P. *Fundamentals of Ecology, Third Edition*, Philadelphia, PA: W.B. Saunders Company, 1971.

Pidwirny, Michael. Fundamentals of physical geography, online glossary of terms. 1999-2001. (August 13, 2002; *http://www.geog.ouc.bc.ca/physgeog/physgeoglos/glossary.html*).

Schneider, D. and N. Freeman. Children's environmental health risks: a state-of-the-art conference. *Archives of Environmental Health* 56: 103-110 (2001).

Steenland, K. and L. Stayner. Silica, asbestos, man-made mineral fibers, and cancer. *Cancer Causes Control* 8: 491-503 (1997).

Texas Environmental Center. Encyclopedia of water terms. 1991. (November 25, 2002; *http://www.tec.org/tec/terms2.html*).

The H. John Heinz III Center for Science, Economics and the Environment. *The State of the Nation's Ecosystems: Measuring the Lands, Waters, and Living Resources of the United States*, New York, NY: Cambridge University Press, September 2002.

U.S. Census Bureau. *Statistical Abstract of the United States 2001: The National Data Book*, Washington, DC: U.S. Census Bureau, 2001.

U.S. Census Bureau, Geography Division. Cartographic boundary files: geographic area description. July 2001. (August 13, 2002; *http://www.census.gov/geo/www/cob/ma_metadata.html#ma*).

U.S. Department of Agriculture, Natural Resources Conservation Service. *Summary Report: 1997 National Resources Inventory (Revised December 2000)*, Washington, DC: Natural Resources Conservation Service and Ames, IA: Iowa State University, Statistical Laboratory, December 1999, revised December 2000.

U.S. Department of Agriculture, Forest Service. *U.S. Forest Facts and Historical Trends*, Brochure #FS-696. Washington, DC: U.S. Department of Agriculture, April 2001.

U.S. Department of Agriculture, Nematology Lab. Nematode basics. June 5, 2001. (August 13, 2002; *http://www.barc.usda.gov/psi/nem/what-nem.htm*).

U.S. Department of Agriculture, Forest Service, Southern Research Station, Forest Inventory and Analysis. Forest inventory - definition of terms. November 12, 2002. (December 3, 2002; *http://www.srsfia.usfs.msstate.edu/fidef2.htm*).

U.S. Department of Energy, Office of Environmental Management. Environmental Management manages four types of radioactive waste. November 10, 1997. (March, 7 2003: *http://www.em.doe.gov/emprimer/emws2.html*).

U.S. Department of Energy (DOE). Radioactive Waste Management. Order 435.1. July, 1999.

U.S. Department of Energy, Office of Environmental Management. Fact Sheet: Department of Energy Announces Its Preferred Alternatives for Disposal of Low-Level and Mixed Low-Level Radioactive Waste. December 10, 1999. (March, 7 2003; *http://www.em.doe.gov/emprimer/emws2.html*).

U.S. Environmental Protection Agency. *Terms of Environment: Glossary, Abbreviations, and Acronyms*, EPA 175-B-97-001. Washington, DC: U.S. Environmental Protection Agency, Office of Communications, Education, and Public Affairs, Revised December 1997.

U.S. Environmental Protection Agency. *Exposure Factors Handbook*, Washington, DC: U.S. Environmental Protection Agency, Office of Research and Development, National Center for Environmental Assessment. March 1998.

U.S. Environmental Protection Agency. *EPA Report to Congress, Solid Waste Disposal in the United States, Volumes I-II*, EPA 530-SW-88-011 (B). Washington, DC: U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response, October 1988.

U.S. Environmental Protection Agency, Science Advisory Board. *A Framework for Assessing and Reporting on Ecological Condition*, EPA SAB-EPEC-02-009. Washington, DC: U.S. Environmental Protection Agency, Science Advisory Board, June 2002.

U.S. Environmental Protection Agency, Office of Wetlands, Oceans and Watersheds. Wetlands: Section 404 of the Clean Water Act: Now wetlands are defined and identified. July 2, 2002. (August 13, 2002; *http://www.epa.gov/owow/wetlands/facts/fact11.html*).

U.S. Environmental Protection Agency. Mid-Atlantic Integrated Assessment: glossary. August 8, 2002. (August 13, 2002; *http://www.epa.gov/maia/html/glossary.html*).

U.S. Environmental Protection Agency. National primary drinking water regulations; consumer fact sheet on: Cadmium. September 23, 2002. (August 13, 2002; *http://www.epa.gov/OGWDW/dwh/c-ioc/cadmium.html*).

U.S. Environmental Protection Agency, Office of Air and Radiation. Global warming site: glossary of climate change terms. October 8, 2002. (November 25, 2002; *http://yosemite.epa.gov/oar/globalwarming.nsf/content/glossary.html*).

U.S. Environmental Protection Agency, Chesapeake Bay Program Office. Glossary of terms. October 25, 2002. (February 24, 2003; *http://chesapeakebay.net/glossary.htm*).

U.S. Environmental Protection Agency, Clean Air Markets Division. Glossary. October 29, 2002. (August 13, 2002; *http://www.epa.gov/airmarkets/glossary.html*).

U.S. Environmental Protection Agency. TRI Explorer: releases reports metadata. November 12, 2002. (December 9, 2002; *http://yosemite1.epa.gov/oiaa/explorers_fe.nsf/7c77bcd2e66feb048525677b006ae6cf/871c6234f2 bd8ab385256950005231df?OpenDocument*).

U.S. Environmental Protection Agency, Office of Water. What is up with our nation's waters? Technically speaking - glossary of terms. November 20, 2002. (December 3, 2002; *http://www.epa.gov/owow/monitoring/nationswaters/glossary.html*).

U.S. Environmental Protection Agency, Office of Groundwater Drinking Water. Groundwater and drinking water: drinking water glossary. November 26, 2002. (December 3, 2002; *http://www.epa.gov/safewater/glossary.htm*).

U.S. Environmental Protection Agency. Radiation information: radiation terms. December 3, 2002. (December 3, 2002; *http://www.epa.gov/radiation/terms/index.html*).

U.S. Environmental Protection Agency. Toxic Release Inventory (TRI) Program. What is TRI? December 9, 2002. (December 9, 2002; *http://www.epa.gov/tri/*).

U.S. Environmental Protection Agency, Office of Pollution Prevention and Toxics. PCBs Home Page. February 3, 2003. (March 7, 2003; *http://www.epa.gov/opptintr/pcb/*).

U.S. Environmental Protection Agency. Mid-Atlantic Integrated Assessment: habitat loss. 2003. (August 13, 2002; *http://www.epa.gov/maia/html/habitat.html*).

U. S. Food and Drug Administration, Center for Food Safety and Applied Nutrition, Office of Seafood. National Shellfish Sanitation Program Model Ordinance, 1999 revision. November 3, 2000. (August 13, 2002; *http://vm.cfsan.fda.gov/flear/nssporpd.html*).

U.S. Geological Survey. Estimated use of water in the United States in 1990, glossary of water - use terminology. April 10, 1996. (November 25, 2002; *http://water.usgs.gov/watuse/wuglossary.html*).

Appendix F: Background and Chronology

On November 13, 2001, Administrator Christine Todd Whitman directed the U.S. Environmental Protection Agency (EPA) to undertake an Environmental Indicators Initiative (EII), bringing together national, regional, and program office indicator efforts to produce a Draft Report on the Environment (ROE)and a Draft Report on the Environment Technical Document (ROE TD). This report is the first step in a multi-year process to identify indicators indicators to measure progress toward environmental and human health goals, to identify data gaps and discuss challenges in filling those gaps, and to ensure the Agency's accountability to the public. The ROE TD contains the scientific and technical information from which the ROE was developed.

Report Leadership/Partnerships

Administrator Whitman's chief of staff assembled and chaired a steering committee, comprising senior career officials from EPA program, support, and regional offices, to guide the report development. The Offices of Environmental Information (OEI) and Research and Development (ORD) were charged with leading an integrated process to produce the ROE and the ROE TD. Key staff representatives acted as "theme" or chapter leads, serving as liaisons with subject matter experts throughout EPA. Other federal agencies and tribal and state governments also assisted in reviewing the report and draft development.

Report Foundation-The Questions

The process began with a concerted effort across EPA to identify significant environmental questions both of interest to the public and fundamental to EPA's mission to protect the environment and human health. A series of six workshops was held in early 2002 across EPA program and regional offices for six themes: human health, ecological condition, air, water, land, and global issues. The workshops identified key questions and proposed indicators (both those supported by existing data and potential future indicators), and noted challenges to implementation and limitations of the indicators.

The questions focused on "outcomes" – actual environmental results such as the quality of outdoor air – rather than on more process-oriented "outputs" such as numbers of permits written. The questions included in this report represent a first set that can be refined and expanded. For some questions, one to several indicators were identified; for other questions, there were no indicators available or recommended.

Indicator Selection

By May 2002, the process had identified key questions and associated indicators to address them. The questions were organized into five report chapters: Cleaner Air, Purer Water, Better Protected Land, Human Health, and Ecological Condition. Indicators to respond to the questions were recommended from across EPA, states, tribes, and other federal agencies. The indicators and their supporting data sets were documented in accordance with a standard format, which is allowed for technical review of data quality, sampling design, coverage, data analysis, and data accessibility. An example of the quality review form is presented in Appendix G. For the national indicators that were identified, there was a wide variation in the availability of data, as the lack of data was a major challenge and limitation in writing the chapters.

An expert review was held to review and assess the potential indicators. External EPA experts were invited to participate in a two-day workshop in mid-June 2002 in the Washington, D.C. area, to discuss and record their assessments of the indicators. The reviewers were asked to evaluate the quality review forms for the proposed indicators in advance of the workshop and then to discuss their assessments in small groups of other reviewers at the workshop (an expert review evaluation form is presented in Appendix H).

Guidance was given to the expert reviewers asking that they review the proposed indicators to evaluate:

- Quality of the data set supporting the indicator;
- Scientific basis for the use of the indicator as a measure of the quality of the environment;
- Utility of the indicator in measuring the quality of the environment; and
- Limitations in using the indicator to measure the quality of the environment.

Draft Report Development and Review

After determining a set of indicators, EPA developed and refined several drafts of the report. In November 2002, EPA shared a draft with federal and state agencies and the Environmental Council of States (ECOS) and took their comments into consideration in developing the content of the ROE technical document. That draft was the basis for final review and comment by the Council on Environmental Quality (CEQ) and the Office of Management and Budget (OMB).

This current draft report is now available to the public.

Chronology of Significant Events for Document Development

A chronology of significant milestones in the development of the draft Report on the Environment Technical Document is presented below.

November 2001	Administrator's Memo Launching the Environmental Indicators Initiative
January-February 2002	Theme Workshop Meetings – Initial Identification of Questions and Potential Indicators
March-April 2002	Development of Report Outlines
April 2002	ECOS-Sponsored Meeting with Interested States
May 2002	Quality Review Process
June 2002	External Expert Review Workshop
July 2002-May 2003	Drafting of ROE and ROE Technical Document
Nov. 2002-May 2003	State/Federal Interagency/OMB/CEQ Review Meetings
June 2003	Release of Draft ROE and ROE Technical Document

Appendix G: Indicator Quality Review Form

A. General Background

1. What is the theme this indicator is part of (e.g., land, water, air, global change, human health, ecological health)?

2. What is the name of the Indicator/data set?

3. What is the question the indicator set is being proposed to address?

4. How does this indicator address the questions? (conceptual relevance)

5. Does this indicator/data set require additional processing to optimally address this question and if so, what?

6. Has this indicator previously been peer reviewed? If so, please provide details. This question has been moved from Data Processing and Analysis section.

B. Data Quality

1. What is the known quality of the entire data set?

2. Has any standard data documentation, such as FGDC metadata, been developed to support these data? (If yes, please provide reference or source.)

3. Why were the data originally collected (e.g., what is being measured or monitored)?

4. Were data collected under a single program or were data from multiple programs combined? If multiple data sets were combined please address the quality for each data set independently.

5. What was (were) the program or programs under which the data were collected?

6. Did these programs have quality assurance plans to verify, corroborate, ground truth or otherwise assess the accuracy of the data?

7. If yes, are the quality assurance program plans available (and where)?

8. Were the quality assurance plans followed?

9. Were the analytical methods used consistent throughout the data set?

10. If not what effects could the different analytical methods have on the indicator results?

11. Are you aware of any sources of error that may affect the findings developed from these data? Error types could include errors of omission, commission, mis-classification, incorrect georeferencing, mis-documentation or mistakes in the processing of data. This question is revised from "What are some of the uncertainties of the data and on the findings."

C. Sample Design

1. Generally describe how the data are/were collected (Research, general monitoring, compliance monitoring, regulatory requirement)? If collected under a regulatory requirement, please specify the regulation and links to the regulation and associated guidance.

2. What was the sample design or the monitoring plan?

3. Were any specific strata omitted from the sampling plan (e.g., small systems not in the sampling plan, roads less than 2 miles long, habitat types less than 20 acres)?

4. Which of the processes below was used to select the sites where information is/was collected?

a) Sites selected using a statistical design that enables generalization to entire resource (e.g., probability survey design to select sample of lakes or streams for the United States. such as NRI, NASS, FHM, FIA)

b) Sites determined to meet administrative or regulatory requirements such as sources of or water supply systems.

c) Sites chosen to address suspected or known problems (e.g., Hot spots).

d) Randomly selected sites.

e) Sites selected in unknown way.

5. When did the monitoring begin?

6. When did the monitoring end?

7. What was the periodicity of the sample (yearly, seasonally, quarterly, monthly, weekly, daily, etc.)?

8. Were there any major gaps in the data either spatially or temporally (please explain)

D. Coverage

1. Is there uniform national coverage of information for this indicator?

2. Were data collected in some areas but not others?

3. Was the data collected using remote sensing? If yes please specify the sensor, date and the resolution of the data.

4. If the data are derived from mapped information, what was the original map scale or resolution?

E. Data Processing and Analyses

1. What kinds of analyses have been performed on the data? Please explain.

2. Are the values used in the indicator raw data? Aggregated data? Calculated data? Inferred data? Last sentence deleted, redundant with 1.

3. Are these analyses standard methods? Please reference.

4. Were these results published? If yes please give reference or link.

5. Were these results peer reviewed? If yes by whom? Give references.

6. How were the values calculated or determined?

7 .Please describe the basis of the classification scheme? Why was this scheme chosen?

8. How are the values interpreted?

9. Are there established ranges that indicate the state of the environment? If yes how were these values established? Are the values consistent across the spatial extent of the data set?

10. Is the Indicator developed based on a model? If so, what is this model?

11. Has the model been published?

12. Has the model been peer reviewed?

13. How are data gaps handled when the model is applied?

14. What is the scientific inference process used to generalize from site-specific information to the national coverage?

15. Which of the following was used to generalize or portray data beyond the specific sampling points?

a) Defensible statistical survey analysis inference procedures used to generalize to entire United States. (e.g., current OW National Lake Fish tissue contaminant survey, FIA, FHM, NRI)

b) Defensible statistical model inference procedures used to generalize to entire United States (e.g., generation of wet deposition maps for US or generation of air quality information using kriging).

c) Semi-empirical environmental/ecological model predictions. (e.g., USGS use of SPARROW model to predict nutrients in rivers based on statistical relationships and simple hydrologic flow models)

d) Generalization is restricted to sites visited and it is possible to give a well- defined, meaningful definition of the portion of the ecological resource covered.

e) No generalization possible and no meaningful way to identify the subset of the ecological resource represented by the collection of sites.

F. Data Accessibility

1. Are the data readily available? If yes, please give reference, link or contact.

2. Are the summary reports available? If yes, please give reference, link or contact.

3. Have these results been published? If yes, please give reference.

G. Message or Interpretation

1. Are the messages or answers to the questions appropriate, sound, and understandable?

Appendix H: EPA Draft Report on the Environment Expert Review Workshop Evaluation Form

EPA Draft Report on the Environment Expert Review Workshop Evaluation Form

Name of Theme:

Name of Indicator:

Associated Question:

Reviewer Name:

Please provide brief answers of one to three paragraphs for each question in the following sections. Under the "Primary Questions" section, please provide a summary evaluation of the indicator's data quality and coverage, suitability, and fit. Evaluations shall be based on a scale from 1 to 5 (Excellent = 5; Adequate = 3; Poor = 1).

Primary Questions

Data Quality and Coverage

1. Do the indicator and the supporting data provide adequate geographic coverage for national reporting?

2. What is the quality of the data set supporting the indicator? What is known about the quality? (In your response, please address the adequacy of the data to support the indicator; whether there is uniform national coverage, quality assurance/quality control issues, documentation, consistent analytical methods, and sample design issues.)

*Summary Evaluation of Data Quality and Coverage (Excellent = 5; Adequate = 3; Poor = 1):

Suitability of Indicator

3. Is there a credible scientific basis for this indicator?

4. What are the limitations of this indicator? (e.g., guidance relevant to using the data supporting the indicator, including challenges and gaps)

*Summary Evaluation of Suitability of Indicator (Excellent = 5; Adequate = 3; Poor = 1):

Question and Indicator Fit

5. How well does the indicator answer or fit the associated questions?

*Summary Evaluation of Question and Indicator Fit (Excellent=5; Adequate=3; Poor=1):

Recommendations

6. Considering your overall evaluation, how can the indicator be improved? (e.g., more precise language, alternative data source, different scale)

Secondary Questions

Please address questions # 7 and # 8 primarily in the context of helping to improve indicator use and development in future years.

Other Considerations

7. Are there additional or alternative indicators that would help address the question?

8. Are there other questions and associated indicators that better address the issue? (Please use draft document outline as the basis for developing a short answer.)

Appendix I: Summary Tables of Questions and Indicators

Chapter I: Cleaner Air – Questions and Indicators

Outdoor Air Quality

Question	Indicator Name	Category	Section
What is the quality of outdoor air in the United States? (See also following four questions)	Number and percentage of days that metropolitan statistical areas (MSAs) have Air Quality Index (AQI) values greater than 100	2	1.1.1
– How many people are living in areas with particulate matter and ozone levels above the National Ambient Air Quality Standards (NAAQS)?	Number of people living in areas with air quality levels above the NAAQS for particulate matter (PM) and ozone	1	1.1.1.a
– What are the concentrations of some criteria air pollutants: $PM_{2.5}$, PM_{10}, ozone, and lead?	Ambient concentrations of particulate matter: $PM_{2.5}$ and PM_{10}	1	1.1.1.b
	Ambient concentrations of ozone: 8-hour and 1-hour	1	1.1.1.b
	Ambient concentrations of lead	1	1.1.1.b
– What are the impacts of air pollution on visibility in national parks and other protected lands?	Visibility	1	1.1.1.c
– What are the concentrations of toxic air pollutants in ambient air?	Ambient concentrations of selected air toxics	2	1.1.1.d
What contributes to outdoor air pollution? (See also following three questions)	See emissions indicators		1.1.2
– What are contributors to particulate matter, ozone, and lead in ambient air?	Emissions: particulate matter ($PM_{2.5}$ and PM_{10}) sulfur dioxide, nitrogen oxides, and volatile organic compounds	2	1.1.2.a
	Lead emissions	2	1.1.2.a
– What are contributors to toxic air pollutants in ambient air?	Air toxics emissions	2	1.1.2.b
– To what extent is U.S. air quality the result of pollution from other countries, and to what extent does U.S. air pollution affect other countries?	No Category 1 or 2 indicators identified		1.1.2.c
What human health effects are associated with outdoor air pollution?	No Category 1 or 2 indicators identified Also see Human Health chapter		1.1.3
What ecological effects are associated with outdoor air pollution?	No Category 1 or 2 indicators identified Also see Ecological Condition chapter		1.1.4

Acid Deposition

Question	Indicator Name	Category	Section
What are the deposition rates of pollutants that cause acid rain?	Deposition: wet sulfate and wet nitrogen	2	1.2.1
What are the emissions of pollutants that form acid rain?	Emissions (utility): sulfur dioxide and nitrogen oxides	2	1.2.2
What ecological effects are associated with acid deposition?	No Category 1 or 2 indicators identified Also see Ecological Condition chapter		1.2.3

Chapter 1: Cleaner Air – Questions and Indicators (continued)

Indoor Air Quality

Question	Indicator Name	Category	Section
What is the quality of the air in buildings in the United States?	U.S. homes above EPA's radon action levels	2	1.3.1
	Percentage of homes where young children are exposed to environmental tobacco smoke	2	1.3.1
What contributes to indoor air pollution?	No Category 1 or 2 indicators identified Also see Human Health chapter		1.3.2
What human health effects are associated with indoor air pollution?	No Category 1 or 2 indicators identified Also see Human Health chapter		1.3.3

Stratospheric Ozone

Question	Indicator Name	Category	Section
What are the trends in the Earth's ozone layer?	Ozone levels over North America	1	1.4.1
What is causing changes to the ozone layer?	Worldwide and U.S. production of ozone-depleting substances (ODSs)	2	1.4.2
	Concentrations of ozone-depleting substances (effective equivalent chlorine)	2	1.4.2
What human health effects are associated with stratospheric ozone depletion?	No Category 1 or 2 indicators identified		1.4.3
What ecological effects are associated with stratospheric ozone depletion?	No Category 1 or 2 indicators identified		1.4.4

Chapter 2: Purer Water - Questions and Indicators

Waters and Watersheds

Question	Indicator Name	Category	Section
What is the condition of fresh surface waters and watersheds in the U.S.?	Altered fresh water ecosystems	2	2.2.1
	Lake Trophic State Index	2	2.2.1
What are the extent and condition of wetlands?	Wetland extent and change	1	2.2.2
	Sources of wetland change/loss	2	2.2.2
What is the condition of coastal waters?	Water clarity in coastal waters	2	2.2.3
	Dissolved oxygen in coastal waters	2	2.2.3
	Total organic carbon in sediments	2	2.2.3
	Chlorophyll concentrations	2	2.2.3
What are pressures to water quality?	General pressures		
	Percent urban land cover in riparian areas	2	2.2.4.a
	Agricultural lands in riparian areas	2	2.2.4.a
	Population density in coastal areas	2	2.2.4.a
	Changing stream flows	1	2.2.4.a
	Number/duration of dry stream flow periods in grassland/shrublands	2	2.2.4.a
	Sedimentation index	2	2.2.4.a
	Nutrient pressures		
	Atmospheric deposition of nitrogen	2	2.2.4.b
	Nitrate in farmland, forested, and urban streams and ground water	2	2.2.4.b
	Total nitrogen in coastal waters	2	2.2.4.b
	Phosphorus in farmland, forested, and urban streams	2	2.2.4.b
	Phosphorus in large rivers	2	2.2.4.b
	Total phosphorus in coastal waters	2	2.2.4.b
	Chemical Pressures		
	Atmospheric deposition of mercury	2	2.2.4.c
	Chemical contamination in streams and ground water	2	2.2.4.c
	Pesticides in farmland streams and ground water	2	2.2.4.c
	Acid sensitivity in lakes and streams	2	2.2.4.c
	Toxic releases to water of mercury, dioxin, lead, PCBs, and PBTs	2	2.2.4.c
	Sediment contamination of inland waters	2	2.2.4.c
	Sediment contamination of coastal waters	2	2.2.4.c
	Sediment toxicity in estuaries	2	2.2.4.c
What ecological effects are associated with impaired waters?	Fish Index of Biotic Integrity in streams Also see Ecological Condition chapter	2	2.2.5
	Macroinvertebrate Biotic Integrity index for streams Also see Ecological Condition chapter	2	2.2.5
	Benthic Community Index for coastal waters Also see Ecological Condition chapter	2	2.2.5

Chapter 2: Purer Water - Questions and Indicators (continued)

Drinking Water

Question	Indicator Name	Category	Section
What is the quality of drinking water?	Population served by community water systems that meets all health-based standards	1	2.3.1
What are sources of drinking water contamination?	No Category 1 or 2 indicators identified		2.3.2
What human health effects are associated with drinking contaminated water?	No Category 1 or 2 indicators identified Also see Human Health chapter		2.3.3

Recreation in and on the Water

Question	Indicator Name	Category	Section
What is the condition of waters supporting recreational use?	Number of beach days that beaches are closed or under advisory	2	2.4.1
What are sources of recreational water pollution?	No Category 1 or 2 indicators identified		2.4.2
What human health effects are associated with recreation in contaminated waters?	No Category 1 or 2 indicators identified Also see Human Health chapter		2.4.3

Consumption of Fish and Shellfish

Question	Indicator Name	Category	Section
What is the condition of waters that support consumption of fish and shellfish?	Percent of river miles and lake acres under fish consumption advisories	2	2.5.1
	Contaminants in fresh water fish	2	2.5.1
	Number of watersheds exceeding health-based national water quality criteria for mercury and PCBs in fish tissue	2	2.5.1
What are contaminants in fish and shellfish, and where do they originate?	No Category 1 or 2 indicators identified		2.5.2
What human health effects are associated with consuming contaminated fish and shellfish?	No Category 1 or 2 indicators identified Also see Human Health chapter		2.5.3

Chapter 3: Better Protected Land – Questions and Indicators

Land Use

Question	Indicator Name	Category	Section
What is the extent of developed lands?	Extent of developed lands	1	3.1.1
	Extent of urban and suburban lands	2	3.1.1
What is the extent of farmlands?	Extent of agricultural land uses	1	3.1.2
	The farmland landscape	2	3.1.2
What is the extent of grasslands and shrublands?	Extent of grasslands and shrublands	2	3.1.3
What is the extent of forest lands?	Extent of forest area, ownership, and management	1	3.1.4
What human health effects are associated with land use?	No Category 1 or 2 indicator identified		3.1.5
What ecological effects are associated with land use?	Sediment runoff potential from croplands and pasturelands	2	3.1.6

Chemicals in the Landscape

Question	Indicator Name	Category	Section
How much and what types of toxic substances are released into the environment?	Quantity and type of toxic chemicals released and managed	2	3.2.1
What is the volume, distribution, and extent of pesticide use?	Agricultural pesticide use	2	3.2.2
What is the volume, distribution, and extent of fertilizer use?	Fertilizer use	2	3.2.3
What is the potential disposition of chemicals from land?	Pesticide residues in food	1	3.2.4
	Potential pesticide runoff from farm fields	1	3.2.4
	Risk of nitrogen export	2	3.2.4
	Risk of phosphorus export	2	3.2.4
What human health effects are associated with pesticides, fertilizers, and toxic substances?	No Category 1 or 2 indicator identified		3.2.5
What ecological effects are associated with pesticides, fertilizers, and toxic substances?	No Category 1 or 2 indicator identified		3.2.6

Chapter 3: Better Protected Land – Questions and Indicators (continued)

Waste and Contaminated Lands

Question	Indicator Name	Category	Section
How much and what types of waste are generated and managed ?	Quantity of municipal solid waste (MSW) generated and managed	2	3.3.1
	Quantity of RCRA hazardous waste generated and managed	2	3.3.1
	Quantity of radioactive waste generated and in inventory	2	3.3.1
What is the extent of land used for waste management?	Number and location of municipal solid waste (MSW) landfills	2	3.3.2
	Number and location of RCRA hazardous waste management facilities	2	3.3.2
What is the extent of contaminated lands?	Number and location of Superfund National Priorities List (NPL) sites	2	3.3.3
	Number and location of RCRA Corrective Action sites	2	3.3.3
What human health effects are associated with waste management and contaminated lands?	No Category 1 or 2 indicator identified		3.3.4
What ecological effects are associated with waste management and contaminated lands?	No Category 1 or 2 indicator identified		3.3.5

Chapter 4: Human Health - Questions and Indicators

Health Status of the U.S. : Indicators and Trends of Health and Disease

Question	Indicator Name	Category	Section
What are the trends for life expectancy?	Life expectancy	1	4.3.1
What are the trends for cancer, cardiovascular disease, chronic obstructive pulmonary disease and asthma?	Cancer mortality	1	4.3.2
	Cancer incidence	2	4.3.2
	Cardiovascular disease mortality	1	4.3.2
	Cardiovascular disease prevalence	1	4.3.2
	Chronic obstructive pulmonary disease mortality	1	4.3.2
	Asthma mortality	1	4.3.2
	Asthma prevalence	1	4.3.2
What are the trends for gastrointestinal illness?	Cholera prevalence	2	4.3.3
	Cryptosporidiosis prevalence	2	4.3.3
	E. coli O157:H7 prevalence	2	4.3.3
	Hepatitis A prevalence	2	4.3.3
	Salmonellosis prevalence	2	4.3.3
	Shigellosis prevalence	2	4.3.3
	Typhoid fever prevalence	2	4.3.3
What are the trends for children's environmental health issues?	Infant mortality	1	4.3.4
	Low birthweight incidence	1	4.3.4
	Childhood cancer mortality	1	4.3.4
	Childhood cancer incidence	2	4.3.4
	Childhood asthma mortality	1	4.3.4
	Childhood asthma prevalence	1	4.3.4
	Deaths due to birth defects	1	4.3.4
	Birth defect incidence	1	4.3.4

Measuring Exposure to Environmental Pollution: Indicators and Trends

Question	Indicator Name	Category	Section
What is the level of exposure to heavy metals?	Blood lead level	1	4.4.3
	Urine arsenic level	2	4.4.3
	Blood mercury level	1	4.4.3
	Blood cadmium level	1	4.4.3
What is the level of exposure to cotinine?	Blood cotinine level	1	4.4.4
What is the level of exposure to volatile organic compounds?	Blood volatile organic compound levels	1	4.4.5
What is the level of exposure to pesticides?	Urine organophosphate levels to indicate pesticides	1	4.4.6
What is the level of exposure to persistent organic pollutants?	No Category 1 or 2 indicators identified		4.4.7
What are the trends in exposure to environmental pollutants for children?	Blood lead level in children	1	4.4.8
	Blood mercury level in children	1	4.4.8
	Blood cotinine level in children	1	4.4.8
What is the level of exposure to radiation?	No Category 1 or 2 indicators identified		4.4.9
What is the level of exposure to air pollutants?	No Category 1 or 2 indicators identified Also see Cleaner Air chapter		4.4.9
What is the level of exposure to biological pollutants?	No Category 1 or 2 indicators identified		4.4.9
What is the level of exposure to disinfection by-products?	No Category 1 or 2 indicators identified		4.4.9

Chapter 5: Ecological Condition - Questions and Indicators

Forests

Question	Indicator Name	Category	Section
What is the ecological condition of forests?	*Extent of forest area, ownership, and management*	*1*	*3.1.4*
	Nitrate in farmland, forested, and urban streams and ground water	*2*	*2.2.4.b*
	Deposition: wet sulfate and wet nitrogen	*2*	*1.2.2*
	Changing stream flows	*1*	*2.2.4.a*
	Extent of area by forest type	1	5.2
	Forest age class	2	5.2
	Forest pattern and fragmentation	2	5.2
	At-risk native forest species	2	5.2
	Populations of representative forest species	2	5.2
	Forest disturbance: fire, insects, and disease	1	5.2
	Tree condition	2	5.2
	Ozone injury to trees	2	5.2
	Carbon storage	2	5.2
	Soil compaction	2	5.2
	Soil erosion	2	5.2
	Processes beyond the range of historic variation	2	5.2

Farmlands

Question	Indicator Name	Category	Section
What is the ecological condition of farmlands?	*Extent of agricultural land uses*	*1*	*3.1.2*
	The farmland landscape	*1*	*3.1.2*
	Nitrate in farmland, forested, and urban streams and ground water	*2*	*2.2.4.b*
	Phosphorus in farmland, forested and urban streams	*2*	*2.2.4.b*
	Pesticides in farmland streams and ground water	*2*	*2.2.4.c*
	Potential pesticide runoff from farm fields	*2*	*3.2.4*
	Sediment runoff potential from croplands and pasturelands	*2*	*3.1.6*
	Pesticide leaching potential	2	5.3
	Soil quality index	2	5.3
	Soil erosion	2	5.3

Grasslands and Shrublands

Question	Indicator Name	Category	Section
What is the ecological condition of grasslands and shrublands?	*Extent of grasslands and shrublands*	*1*	*3.1.3*
	Number/duration of dry stream flow periods in grasslands and shrublands	*2*	*2.2.4.a*
	At-risk native grassland and shrubland species	2	5.4
	Population trends of invasive and native non-invasive bird species	1	5.4

Note: Italicized indicators are presented in other chapters.

Chapter 5: Ecological Condition - Questions and Indicators (continued)

Urban and Suburban Lands

Question	Indicator Name	Category	Section
What is the ecological condition of urban and suburban areas?	*Extent of urban and suburban lands*	*1*	*3.1.1*
	Ambient concentrations of ozone: 8-hour and 1-hour	*2*	*1.1.1.b*
	Nitrate in farmland, forested and urban streams, and ground water	*2*	*2.2.4.b*
	Phosphorus in farmland, forested, and urban streams	*2*	*2.2.4.b*
	Chemical contamination in urban streams and ground water	*2*	*2.2.4.c*
	Patches of forest, grassland, shrubland, and wetland in urban/suburban areas	2	5.5

Fresh Waters

Question	Indicator Name	Category	Section
What is the ecological condition of fresh waters?	*Wetland extent and change*	*1*	*2.2.2*
	Altered fresh water ecosystems	*2*	*2.2.1*
	Contaminants in fresh water fish	*2*	*2.5.1*
	Phosphorus in large rivers	*2*	*2.2.4.b*
	Lake Trophic State Index	*2*	*2.2.1*
	Chemical contamination in streams and ground water	*2*	*2.2.4.c*
	Acid sensitivity in lakes and streams	*2*	*2.2.4.c*
	Changing stream flows	*1*	*2.2.4.a*
	Sedimentation index	*2*	*2.2.4.a*
	Extent of ponds, lakes, and reservoirs	1	5.6
	At-risk native fresh water species	2	5.6
	Non-native fresh water species	2	5.6
	Animal deaths and deformities	2	5.6
	At-risk fresh water plant communities	2	5.6
	Fish Index of Biotic Integrity in streams	2	5.6
	Macroinvertebrate Biotic Integrity Index for streams	2	5.6

Coasts and Oceans

Question	Indicator Name	Category	Section
What is the ecological condition of coasts and oceans?	*Chlorophyll concentrations*	*2*	*2.2.3*
	Water clarity in coastal waters	*2*	*2.2.3*
	Total nitrogen in coastal waters	*2*	*2.2.4.b*
	Total phosphorus in coastal waters	*2*	*2.2.4.b*
	Dissolved oxygen in coastal waters	*2*	*2.2.3*
	Total organic carbon in sediments	*2*	*2.2.3*
	Sediment contamination of coastal waters	*2*	*2.2.4.c*
	Sediment toxicity in estuaries	*2*	*2.2.4.c*
	Extent of estuaries and coastline	1	5.7
	Coastal living habitats	2	5.7
	Shoreline types	2	5.7
	Benthic Community Index	2	5.7
	Fish diversity	2	5.7
	Submerged aquatic vegetation	2	5.7
	Fish abnormalities	2	5.7
	Unusual marine mortalities	2	5.7

Note: Italicized indicators are presented in other chapters.

Chapter 5: Ecological Condition - Questions and Indicators (continued)

The Entire Nation

Question	Indicator Name	Category	Section
What is the ecological condition of the entire nation?	Ecosystem extent	2	5.8
	At-risk native species	2	5.8
	Bird Community Index	2	5.8
	Terrestrial Plant Growth Index	1	5.8
	Movement of nitrogen	1	5.8
	Chemical contamination	2	5.8

Note: Italicized indicators are presented in other chapters.