Chapter 4

Land

Contents

4.1 Introduction

The land within the boundaries of the U.S., covering nearly 2.3 billion acres, provides food, fiber, and shelter for all Americans, as well as terrestrial habitat for many other species. Land is the source of most extractable resources, such as minerals and petroleum. Land produces renewable resources and commodities such as livestock, vegetables, fruit, grain, and timber; it also supports other uses, such as residential, industrial, commercial, and transportation uses. Additionally, land and the ecosystems that it is part of provide services such as trapping chemicals as they move through soil, storing and breaking down chemicals and wastes, and filtering and storing water. The use of land, what is applied to or released on it, and its condition change constantly: there are changes in the types and amounts of resources that are extracted, the distribution and nature of cover types, the amounts and types of chemicals used and wastes managed, and perceptions of the land's value.

Numerous agencies and individuals have responsibilities for managing and protecting land in the U.S., in terms of resources associated with land (e.g., timber, minerals) and land uses (e.g., wilderness designations, regulatory controls). Between 30 and 40 percent of the nation is owned or managed by public agencies.[1] The other 60 to 70 percent is managed by private owners, under a variety of federal, state, and local laws. Local governments have primary responsibilities for regulating land use, while state and federal agencies regulate chemicals and waste that are frequently used on, stored on, or released to land. EPA is interested in land because human activities on land such as food and fiber production, land development, manufacturing, or resource extraction can involve the creation, use, or release of chemicals and pollutants that can affect the environment and human health.

EPA works with other federal agencies, states, and partners to protect land resources, ecosystems, environmental processes, and uses of land through regulation of chemicals, waste, and pollutants, and through cleanup and restoration of contaminated lands. The complexities of responsibilities underscore the challenges of collecting data and assessing trends on the state of land.

This chapter addresses critical land questions by describing national trends in naturally occurring and human uses of land, stressors that affect land, and associated exposures and effects among humans and ecological systems. ROE indicators are presented to address five fundamental questions about the state of the nation's land:

- **What are the trends in land cover and their effects on human health and the environment?** "Land cover" refers to the actual or physical presence of vegetation or other materials (e.g., rock, snow, buildings) on the surface

EPA's 2008 Report on the Environment (ROE): Essentials

ROE Approach

This 2008 Report on the Environment:

- Asks questions that EPA considers important to its mission to protect human health and the environment.
- Answers these questions, to the extent possible, with available indicators.
- Discusses critical indicator gaps, limitations, and challenges that prevent the questions from being fully answered.

ROE Questions

The air, water, and land chapters (Chapters 2, 3, and 4) ask questions about trends in the condition and/or extent of the environmental medium; trends in stressors to the medium; and resulting trends in the effects of the contaminants in that medium on human exposure, human health, and the condition of ecological systems.

The human exposure and health and ecological condition chapters (Chapters 5 and 6) ask questions about trends in aspects of health and the environment that are influenced by many stressors acting through multiple media and by factors outside EPA's mission.

ROE Indicators

An indicator is derived from actual measurements of a pressure, state or ambient condition, exposure, or human health or ecological condition over a specified geographic domain. This excludes indicators such as administrative, socioeconomic, and efficiency indicators.

Indicators based on one-time studies are included only if they were designed to serve as baselines for future trend monitoring.

All ROE indicators passed an independent peer review against six criteria to ensure that they are useful; objective; transparent; and based on data that are high-quality, comparable, and representative across space and time.

Most ROE indicators are reported at the national level. Some national indicators also report trends by region. EPA Regions were used, where possible, for consistency and because they play an important role in how EPA implements its environmental protection efforts.

Several other ROE indicators describe trends in particular regions as examples of how regional indicators might be included in future versions of the ROE. They are not intended to be representative of trends in other regions or the entire nation.

EPA will periodically update and revise the ROE indicators and add new indicators as supporting data become available. In the future, indicators will include information about the statistical confidence of status and trends. Updates will be posted electronically at http://www.epa.gov/roe.

Additional Information

You can find additional information about the indicators, including the underlying data, metadata, references, and peer review, at http://www.epa.gov/roe.

[1] Lubowski, R.N., M. Vesterby, S. Bucholtz, A. Baez, and M.J. Roberts. 2006. Major uses of land in the United States, 2002. Economic Information Bulletin No. (EIB-14). U.S. Department of Agriculture, Economic Research Service. <http://www.ers.usda.gov/publications/eib14/>

of the land (it differs from land use—see the next question). It is important from the perspective of understanding land as a resource and its ability to support humans and other species. Changes in land cover can affect other media (e.g., air and water).

- **What are the trends in land use and their effects on human health and the environment?** "Land use" refers to the economic and cultural activities practiced by humans on land. Land use can have effects on both human health and the environment, particularly as land is urbanized or used for agricultural purposes.
- **What are the trends in wastes and their effects on human health and the environment?** Numerous types of waste are generated as part of most human activities. Trends in waste include trends in types and quantities of, and mechanisms for, managing wastes. Waste trends reflect the efficiency of use and reuse of materials and resources and potential for land contamination.
- **What are the trends in chemicals used on the land and their effects on human health and the environment?** Various chemicals are produced or used on land for many purposes. The quantity and diversity of chemicals and the potential for interactions among them have created challenges in understanding the full effects of their use. Pesticides, fertilizers, and toxic chemicals are examples of chemicals applied or released on land.
- **What are the trends in contaminated land and their effects on human health and the environment?** Contaminated lands are those lands that have been affected by human activities or natural events such as manufacturing, mining, waste disposal, volcanoes, or floods that pose a concern to human health or the environment. The worst-contaminated lands are tracked and their cleanups overseen by EPA.

These ROE questions are posed without regard to whether indicators are available to answer them. This chapter presents the indicators available to answer these questions, and also points out important gaps where nationally representative data are lacking.

4.1.1 Overview of the Data

Data are collected by many agencies with varying responsibilities for managing and protecting land and its resources. Several different sources and types of data are used to develop the indicators that address the questions in this chapter. They include:

- **Satellite imagery.** Data used in the land cover question are derived from analysis of satellite data.[2] A set of data on U.S. land cover called the National Land Cover Database is currently available for the period around 2001. Analyses are currently underway to compare these data with earlier land cover data, to provide a better understanding of trends. Multiple agencies, including EPA, have jointly funded satellite data processing efforts and are working together to derive a common classification approach for the data.
- **National surveys.** The data used in the land use question are primarily derived from two national surveys: the National Resources Inventory (NRI)[3] conducted by the U.S. Department of Agriculture (USDA) Natural Resource Conservation Service and the Forest Inventory and Analysis (FIA)[4] conducted by the USDA Forest Service. These surveys are collected over specific areas for specific USDA purposes; the NRI data are collected only on non-federal lands, and FIA data address only forest and timberlands. These limitations contribute to the need to rely on multiple data sets for national estimates.
- **Regulatory data.** The data used for most of the chemical, waste, and contaminated land questions are derived from self-reporting or government-collected measurements to address regulatory requirements. For example, the chemical release information reported under the chemical question is derived from the Toxics Release Inventory based on industry reporting. These data, in general, represent only a small sample of the total picture of waste, chemicals, and land contamination. State and local governments collect additional data, but the lack of consistency in approaches makes compilation of national data difficult.

This chapter presents only data that meet the ROE indicator definition and criteria (see Box 1-1, p. 1-3). Note that non-scientific indicators, such as administrative and economic indicators, are not included in this definition. Thorough documentation of the indicator data sources and metadata can be found online at http://www.epa.gov/roe. All indicators were peer-reviewed during an independent peer review process (again, see http://www.epa.gov/roe for more information). Readers should not infer that the ROE indicators included reflect the complete state of knowledge on the nation's land. Many other data sources, publications, and site-specific research projects have contributed to the current understanding of land trends, but are not used in this report because they did not meet some aspect of the ROE indicator criteria.

4.1.2 Organization of This Chapter

The remainder of this chapter is organized into five sections corresponding to the five questions that EPA seeks to answer about land. Each section introduces a question and its importance, presents the ROE indicators to help answer the question, and discusses what the ROE indicators, taken together,

[2] Multi-Resolution Land Characteristics Consortium. 2007. National Land Cover Database 2001 (NLCD 2001). Accessed November 28, 2007. <http://www.mrlc.gov/mrlc2k_nlcd.asp>

[3] U.S. Department of Agriculture, Natural Resources Conservation Service. 2007. National Resources Inventory, 2003 annual NRI: Land use. <http://www.nrcs.usda.gov/technical/nri/2003/nri03landuse-mrb.html>

[4] Smith, W.B., P.D. Miles, J.S. Vissage, and S.A. Pugh. 2004. Forest resources of the United States, 2002. USDA Forest Service. <http://ncrs.fs.fed.us/pubs/gtr/gtr_nc241.pdf>

say about the question. Several of the National Indicators also provide information organized by EPA Regions, and one Regional Indicator addresses specific issues at a sub-EPA Region scale. Each section concludes by highlighting the major challenges to answering the question and identifying important information gaps.

Table 4-1 lists the indicators used to answer the five questions in this chapter and shows where the indicators are presented.

4.2 What Are the Trends in Land Cover and Their Effects on Human Health and the Environment?

4.2.1 Introduction

Land cover—the surface components of land that are physically present and visible—provides a means to examine landscape patterns and characteristics. Patterns and landscape characteristics are important in understanding the extent, availability, and condition of lands; ecological system extent, structure, and condition; and the potential for dispersion and effects of chemicals and other pollutants in and on the environment. Land cover represents a starting point from which a variety of monitoring activities can be performed. EPA considers land cover information to be critically important for a number of reasons, including the ability to assess nonpoint sources of pollution, understanding landscape variables for ecological analyses, assessing the behavior of chemicals, and analyzing the effects of air pollution.

Land cover, in its naturally occurring condition, integrates and reflects a given site's climate, geology and soils, and available biota over a time span of decades or longer. Land cover can be affected on shorter time scales by naturally occurring disturbances (e.g., storms, floods, fires, volcanic eruptions, insects, landslides) and human activities. Land cover represents the results of both naturally occurring conditions and disturbances and human activities such as population change, industrial and urban development, deforestation or reforestation, water diversion, and road-building. Depending on one's perspective, the changes wrought by natural processes and human activities can be perceived as improvements or degradations of the state of land cover.

Table 4-1. Land—ROE Questions and Indicators

Question	Indicator Name	Section	Page
What are the trends in land cover and their effects on human health and the environment?	Land Cover (N/R)	4.2.2	4-7
	Forest Extent and Type (N/R)	6.2.2	6-8
	Land Cover in the Puget Sound/Georgia Basin (R)	4.2.2	4-10
What are the trends in land use and their effects on human health and the environment?	Land Use (N/R)	4.3.2	4-14
	Urbanization and Population Change (N/R)	4.3.2	4-19
What are the trends in wastes and their effects on human health and the environment?	Quantity of Municipal Solid Waste Generated and Managed (N)	4.4.2	4-24
	Quantity of RCRA Hazardous Waste Generated and Managed (N)	4.4.2	4-26
What are the trends in chemicals used on the land and their effects on human health and the environment?	Fertilizer Applied for Agricultural Purposes (N/R)	4.5.2	4-30
	Toxic Chemicals in Production-Related Wastes Combusted for Energy Recovery, Released, Treated, or Recycled (N)	4.5.2	4-33
	Pesticide Residues in Food (N)	4.5.2	4-37
	Reported Pesticide Incidents (N)	4.5.2	4-39
What are the trends in contaminated land and their effects on human health and the environment?	Current Human Exposures Under Control at High-Priority Cleanup Sites (N)	4.6.2	4-44
	Migration of Contaminated Ground Water Under Control at High-Priority Cleanup Sites (N)	4.6.2	4-47

N = National Indicator

R = Regional Indicator

N/R = National Indicator displayed at EPA Regional scale

Land cover is also important because it affects other environmental variables including water quality, watershed hydrology, habitat and species composition, climate, and carbon storage. Land cover influences the mass and energy exchanges between the surface and the atmosphere and thus influences weather and climate.[5] Land cover is also a primary ingredient of ecological structure and function, with changes affecting species habitat and distribution. Land cover changes in watersheds can alter hydrologic regimes, runoff patterns, and flood buffering.[6]

4.2.2 ROE Indicators

The question of trends in and effects of land cover is addressed by two National Indicators and one Regional Indicator (Table 4-2). Nationwide land cover information is derived from two data collection programs: the National Land Cover Database (NLCD) and the Forest Inventory and Analysis (FIA). The NLCD is described in more detail in the Land Cover indicator summary (p. 4-7), and the FIA is described in the Forest Extent and Type indicator summary (p. 6-8).

The classification approach used in the Land Cover indicator is primarily based on the use of satellite data processing. Where satellite data were not available or processed, survey data have been included to develop the national statistics. The classification approach used in the Land Cover in Puget Sound/Georgia Basin indicator (p. 4-10), while also based on satellite data, is different from the Land Cover National Indicator, and is described in the Regional Indicator discussion. More detailed definitions of land cover types are included in the box within the text of the Land Cover indicator (p. 4-7).

Data for the Land Cover in Puget Sound/Georgia Basin indicator are derived from the NOAA Coastal Change Analysis Program and Landsat satellite data of both the U.S. and Canadian portions of the Puget Sound/Georgia Basin. This indicator depicts two cover classes: forest and urban.

The data presented in the Forest Extent and Type indicator are derived from national surveys of forest land and timberland in the U.S. These data reflect total extent of forest land both nationally and by EPA Region, as well as trends in many species types on timberland.

Table 4-2. ROE Indicators of Trends in Land Cover and Their Effects on Human Health and the Environment

National Indicators	Section	Page
Land Cover (N/R)	4.2.2	4-7
Forest Extent and Type (N/R)	6.2.2	6-8
Regional Indicators	**Section**	**Page**
Land Cover in the Puget Sound/Georgia Basin	4.2.2	4-10

N/R = National Indicator displayed at EPA Regional scale

[5] Marland, G., R.A. Pielke, Sr., M. Apps, R. Avissar, R.A. Betts, K.J. Davis, et al. 2003. The climatic impacts of land surface change and carbon management, and the implications for climate-change policy. Clim. Pol. 3:149-157.

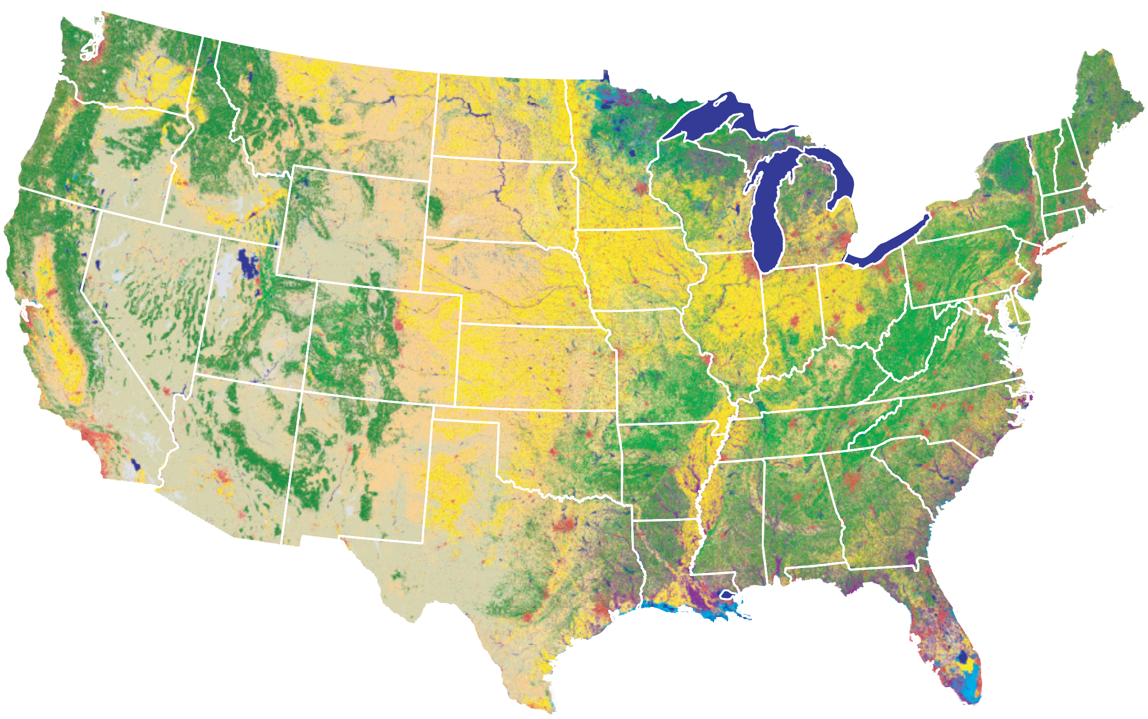
[6] de Sherbinin, A. 2002. Land-use and land-cover change: A CIESIN thematic guide. Palisades, NY: Center for International Earth Science Information Network of Columbia University. <http://sedac.ciesin.columbia.edu/tg/guide_main.jsp>

INDICATOR | Land Cover

Land cover represents the actual or physical presence of vegetation (or other materials where vegetation is nonexistent) on the land surface. Land cover is also often described as what can be seen on land when viewed from above. Land cover is one means to categorize landscape patterns and characteristics, and is critical in understanding the condition of the environment, including the availability of habitat, changes in habitat, and dispersion and effects of chemicals and other pollutants in and on the environment. For the purposes of this indicator, land cover is described in terms of six major classes: forest, grass, shrub, developed, agriculture, and other (includes ice/snow, barren areas, and wetlands). A seventh category, water, is not discussed as a land cover type in this chapter. See Chapter 3 for more information on trends related to water. More information about forest land can be found in the Forest Extent and Type indicator (p. 6-8), and wetland acreage is discussed in greater detail in the Wetlands indicator (p. 3-32).

In 1992, several federal agencies agreed to operate as a consortium, known as the Multi-Resolution Land Characteristics (MRLC) Consortium, to acquire and analyze satellite-based remotely sensed data for environmental monitoring programs (MRLC Consortium, 2006). The initial result of the MRLC effort was development of the 1992 National Land Cover Dataset (NLCD), which, until recently, was the only comprehensive recent classification of land cover in the contiguous U.S. (USGS, 2007). In 2007, the MRLC Consortium published the 2001 National Land Cover Database, an updated and improved version of the 1992 NLCD (Homer et al., 2007). The database provides information about 16 land cover classes at a 30-meter

Exhibit 4-1. Land cover of the contiguous U.S., based on 2001 NLCD [a]



Agriculture
- Cultivated crops
- Pasture/hay

Developed
- High-density (impervious ≥80%)
- Medium-density (impervious 50-79%)
- Low-density (impervious 20-49%)
- Open space (impervious <20%)

Forest cover
- Deciduous forest
- Evergreen forest
- Mixed forest

Grass cover
- Grassland

Shrub cover
- Shrubland

Other
- Perennial ice/snow
- Barren
- Woody wetland
- Emergent herbaceous wetland

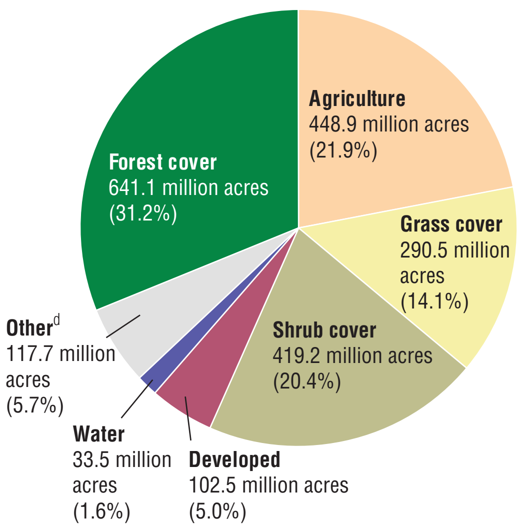
Water
- Open water

[a]See box on p. 4-9 for definitions of land cover categories.

Data source: *U.S. EPA, 2007b*

INDICATOR | Land Cover *(continued)*

Exhibit 4-2. Land cover types in the U.S., based on 2001 NLCD and FIA[a,b,c]



[a]**Coverage:** All surface area of the contiguous 48 states, plus forest land in Alaska and Hawaii.

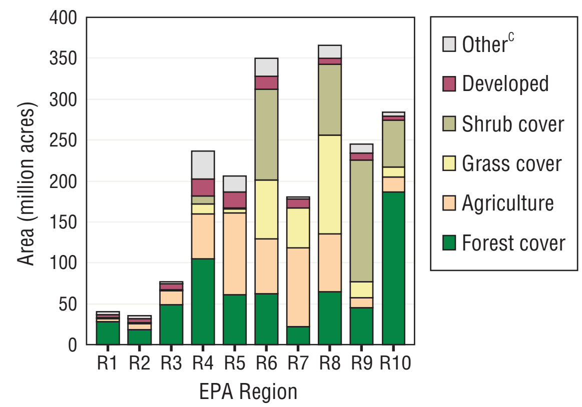
[b]See box on p. 4-9 for definitions of land cover categories.

[c]Totals may not add to 100% due to rounding.

[d]"Other" includes ice/snow, barren areas, and wetlands.

Data source: *Smith et al., 2004; U.S. EPA, 2007b*

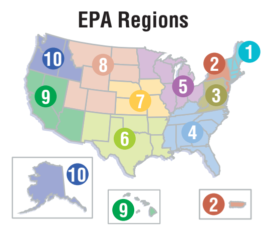
Exhibit 4-3. Land cover types in the U.S. by EPA Region, based on 2001 NLCD and FIA[a,b]



[a]**Coverage:** All land area of the contiguous 48 states (excluding water), plus forest land in Alaska and Hawaii.

[b]See box on p. 4-9 for definitions of land cover categories.

[c]"Other" includes ice/snow, barren areas, and wetlands.



Data source: *Smith et al., 2004; U.S. EPA, 2007b*

resolution, comprising approximately 27 billion cells covering the contiguous U.S., based on Landsat images from 1999 to 2002. Due to differences in methodology, direct comparison of the 1992 and 2001 NLCD data sets does not currently provide valid trend data. Efforts are underway to develop an algorithm that will allow such comparisons in the near future.

This indicator represents data from the 2001 NLCD and the U.S. Department of Agriculture Forest Service's Forest Inventory and Analysis (FIA), which uses a statistical survey design and comparable methods to assess the extent, type, age, and health of forests on private and public land in all states. The 2001 NLCD provides a synoptic classification of land cover, but does not include Alaska and Hawaii, thereby classifying only 1.92 billion acres out of approximately 2.3 billion acres of land in the U.S. To supplement the NLCD, data from the 2001 FIA were used to provide forest cover estimates in Alaska and Hawaii (128.6 million acres). For this indicator, the 16 land cover classes created in the NLCD were aggregated into the six major land cover types described above, along with water (Heinz Center, 2005).

What the Data Show

The combination of the NLCD for the contiguous 48 states and the FIA for forest cover estimates in Alaska and Hawaii shows approximately 641 million acres of forest, 449 million acres of agriculture, 419 million acres of shrub, 291 million acres of grass, and 103 million acres of developed cover types (Exhibits 4-1 and 4-2).

NLCD and FIA data show variation in cover types by EPA Region, with forest dominating in Regions 1, 2, 3, 4, and 10; agriculture in Regions 5 and 7; grass in Region 8; and shrub in Region 6 and 9 (Exhibit 4-3). Two-thirds of the grass acreage in the nation is located in Regions 6 and 8, nearly two-thirds of shrub acreage is in Regions 6 and 9, and nearly half the forest acreage is in Regions 4 and 10 (including Alaska).

Indicator Limitations

- Trend data are not available for this indicator. Land cover data for the entire nation at adequate resolution to support this indicator are currently available for two points in time (1992 and 2001). However, due to differences in methodology in creation of the data sets, they are not directly comparable. The MRLC Consortium is developing a change product intended to enable valid

Definitions of Land Cover Categories for Exhibits 4-1, 4-2, and 4-3

Agricultural (NLCD 2001 definition): Areas characterized by herbaceous vegetation that has been planted; is intensively managed for the production of food, feed, or fiber; or is maintained in developed settings for specific purposes. Herbaceous vegetation must account for 75 to 100 percent of the cover. Includes the "orchards/vineyards/other" subcategory, which covers areas planted or maintained for the production of fruits, nuts, berries, or ornamentals. Includes two subcategories: "pasture/hay" and "cultivated crops."

Developed (NLCD 2001 definition): Areas characterized by a high percentage (30 percent or greater) of constructed materials (e.g., asphalt, concrete, buildings). Includes four subcategories: "Developed, open space" (less than 20 percent impervious surface), "Developed, low intensity" (20-49 percent impervious surface), "Developed, medium intensity" (50-79 percent impervious surface), and "Developed, high intensity" (80 percent or more impervious surface).

Shrubland (NLCD 2001 definition): Areas characterized by natural or semi-natural woody vegetation with aerial stems, generally less than 6 meters tall, with individuals or clumps not touching or interlocking. Both evergreen and deciduous species of true shrubs, young trees, and trees or shrubs that are small or stunted because of environmental conditions are included.

Grassland (NLCD 2001 definition): Upland areas dominated by grammanoid or herbaceous vegetation, generally greater than 80 percent of the total vegetation. These areas are not subject to intensive management, such as tilling, but can be utilized for grazing.

Forest (NLCD 2001 definition): Areas characterized by tree cover (natural or semi-natural woody vegetation, generally greater than 6 meters tall); tree canopy accounts for 25 to 100 percent of the cover.

Forest (FIA definition): Land at least 10 percent stocked by forest trees of any size, including land that formerly had such tree cover and that will be naturally or artificially regenerated. Forest land includes transition zones, such as areas between heavily forested and nonforested lands that are at least 10 percent stocked with forest trees and forest areas adjacent to urban and built-up lands. Also included are pinyon-juniper and chaparral areas in the West and afforested areas. The minimum area for classification of forest land is 1 acre. Roadside, streamside, and shelterbelt strips of trees must have a crown width of at least 120 feet to qualify as forest land. Unimproved roads and trails, streams, and clearings in forest areas are classified as forest if less than 120 feet wide. (FIA data are used in Alaska and Hawaii, due to lack of NLCD availability.)

Other: Includes NLCD 2001 snow, ice, wetlands, and barren. Barren areas are defined as areas of bedrock, desert pavement, scarps, talus, slides, volcanic material, glacial debris, sand dunes, strip mines, gravel pits, and other accumulations of earthen material. Generally, vegetation accounts for less than 15 percent of total cover. <http://www.epa.gov/mrlc/definitions.html>

Sources: U.S. EPA, 2007a; Smith et al., 2004.

comparisons of the two data sets (MRLC Consortium, 2007a,b). The product is scheduled to be available in 2008. Until this project is completed, there are no consistent, comprehensive, nationwide data to describe trends in land cover at the national or EPA Regional levels.

- FIA data for forest land in Alaska and Hawaii were used to complement the NLCD because NLCD data do not currently exist for these states, although they are planned for late 2007. Ongoing data collection under both the FIA and the NLCD is needed to assess land cover trends.
- National estimates of land cover vary, depending on the survey approach, data sources, classification, timing, etc. The interaction of these variables will result in different estimates of the extent of any given land cover category depending on the data set used. Techniques relying on satellite data to generate land cover estimates classify what is visible from above, meaning they may underestimate developed cover in heavily treed urban areas and underestimate forest cover where trees have been harvested. For example, National Resources Inventory (USDA NRCS, 2007) estimates for developed land are 6 percent above the NLCD estimates and FIA estimates of forestland in 2002 are nearly 17 percent above the NLCD.
- No standardized land cover classification system is currently used among federal agencies. As a result of this limitation, there is no consistency in the assessment of land cover trends across agencies.

Data Sources

Land cover data for the contiguous 48 states were obtained from the NLCD (U.S. EPA, 2007b). These data were

INDICATOR | Land Cover *(continued)*

grouped into the major land cover categories as described by the Heinz Center (2005) (see technical note for the Heinz Center's "Ecosystem Extent" indicator). Forest cover estimates for 2002 in Alaska and Hawaii were obtained from a report published by the FIA program (Smith et al., 2004). FIA data in this report have a nominal date of 2002 but represent the best data available at the end of the 2001 field season for each state.

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U.S. EPA. 2007b. NLCD 2001 data provided to ERG (an EPA contractor) by James Wickham, Office of Research and Development. November 29, 2007. <http://www.mrlc.gov/nlcd.php>

USGS (United States Geological Survey). 2007. National Land Cover Dataset 1992 (NLCD 1992). Accessed November 2007. <http://landcover.usgs.gov/natllandcover.php>

INDICATOR | Land Cover in the Puget Sound/Georgia Basin

Changes in land use and corresponding changes in land cover can alter the basic functioning and resilience of ecological systems. Watersheds, for example, experience a cascade of effects among critical physical, chemical, and biological processes when land cover changes (NWP, 1995; Thom and Borde, 1998). For instance, removal of vegetation can increase erosion, leading to impacts on soil and water quality, and increases in developed land typically result in a corresponding increase in impervious surfaces with consequences for runoff, among other issues. While individual impacts to a landscape may appear as small changes, the combined impacts of particular land uses or land management practices on watersheds can have substantial effects on water quality, species composition, and flooding patterns (PSAT, 2002, 2004). Such combined impacts are often referred to as "cumulative effects." As a result of their potential to broadly and substantially influence environmental condition, land cover and use are important factors to monitor.

This indicator compares changes in two land cover metrics for the Puget Sound and Georgia Basin in Washington state and part of British Columbia, Canada. The metrics include percent change of urban and forest land cover. Data cover the period from 1995 to 2000 for the U.S. portion of the basin and from 1992 to 1999 for the Canadian side of the basin. The metrics represent the change in total urban or forested land area divided by total land area in the watershed. Forest and urban land cover are two of the most important factors affecting the condition of watersheds in the Puget Sound Basin (Alberti and Marzluff, 2004; Alberti, 2005). In contrast to the nationwide land cover indicator, which is based on NLCD data, this indicator relies on data derived from four assembled USGS Landsat scenes covering the U.S. portion of the Puget Sound Basin

and from a combined scene covering the Canadian land area. The land cover data for all USGS 6th field watersheds in the basin were produced from NOAA Coastal Change Analysis Program (C-CAP) data and from Canadian Baseline Thematic Mapping (BTM) data. The USGS Hydrologic Unit Codes and Canadian watershed groupings provide topographically delineated watersheds, which are aggregated, or "nested," into larger sub-basin and basin units.

What the Data Show

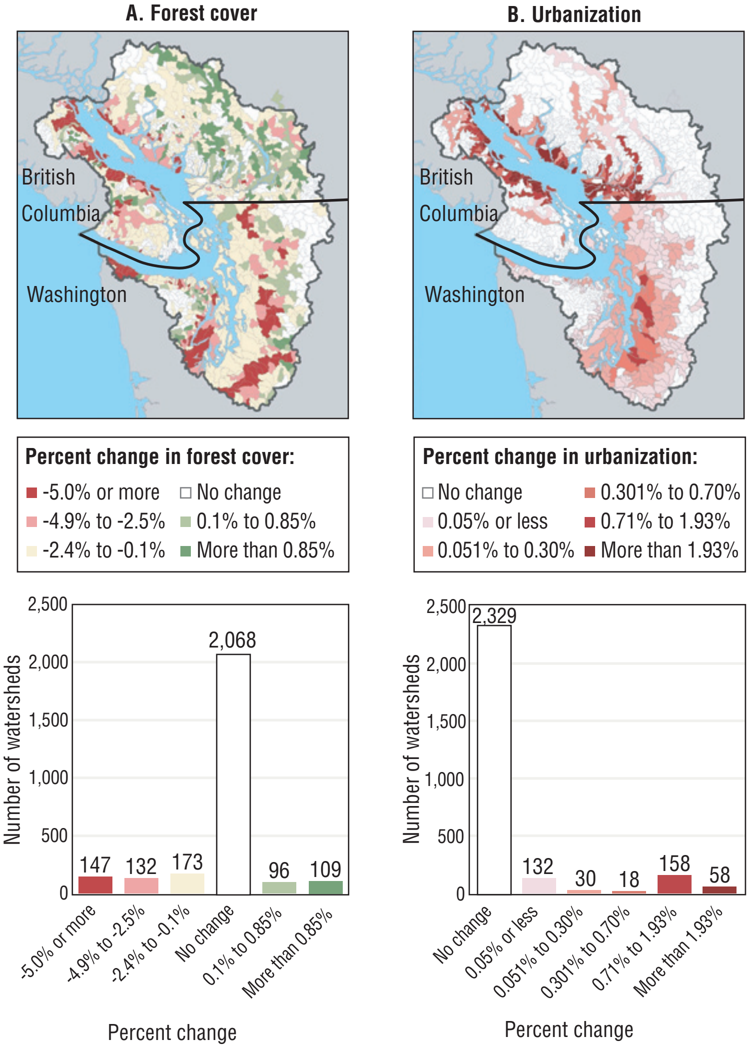
Forest Cover

Little or no change in forest cover was observed in 2,068 watersheds (76 percent) of the 2,725 watersheds assessed (Exhibit 4-4, panel A). However, 279 watersheds (10 percent) saw at least 2.5 percent of their mature forest cover converted to some other land cover, often bare ground, immature vegetation, or industrial/urban uses. At the same time, another group of 205 watersheds (8 percent), generally those at higher elevations, indicated a net increase in forest cover as young stands or cleared areas have re-grown into more mature forest cover classes.

Urbanization

During the same period, little or no change in urban land cover was observed in approximately 90 percent of the 2,725 assessed watersheds within the basin (Exhibit 4-4, panel B). However, urbanization increased across many low-elevation watersheds and shoreline areas, with 158 watersheds (6 percent) expanding the urban portion of the watershed by between 0.7 and 1.93 percent, and another 58 watersheds (2 percent) showing increases of more than 1.93 percent. Research has shown that as a watershed's drainage area becomes paved or otherwise impervious, there is a high potential for physical, chemical, and biological impairments to both water quality conditions and other aquatic resources (NWP, 1995; Alberti and Marzluff, 2004).

Exhibit 4-4. Land cover change in watersheds of the Puget Sound/Georgia Basin, 1992-2000[a,b]



[a]**Coverage:** 2,725 watersheds within the Puget Sound/Georgia Basin, located in the state of Washington and the Canadian province of British Columbia. U.S. watersheds are 12-digit Hydrologic Unit Code (HUC12) watersheds.

[b]U.S. data reflect changes from 1995 to 2000, while Canadian data reflect changes from 1992 to 1999.

Data source: *British Columbia Integrated Land Management Bureau, 2001; CommEn Space, 2005; NOAA, 2006*

Indicator Limitations

- While the U.S. C-CAP data and the Canadian BTM data have similar and overlapping time periods, as currently presented, the U.S. data reflect change from 1995 to 2000 and the Canadian data reflect change from 1992 to 1999.
- The size of the data pixels and the minimum mapping unit size affect the classification of certain features such as narrow riparian corridors, and can affect the percentages in the indicators.

INDICATOR | Land Cover in the Puget Sound/Georgia Basin *(continued)*

Data Sources

The full analysis has not been published as a data set, but it is based on publicly available data sets compiled by CommEn Space (http://www.commenspace.org). Raw data for the U.S. portion of this indicator are available from C-CAP (NOAA, 2006), and Canadian data are available from the British Columbia Integrated Land Management Bureau (2001). Additional technical background is provided by U.S. EPA (2006).

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4.2.3 Discussion

What These Indicators Say About Trends in Land Cover and Their Effects on Human Health and the Environment

The most recently available 2001 data are presented for the Land Cover indicator (p. 4-7). As of the writing of the ROE, the data are available for two points in time, 1992 and 2001, but cannot be compared. Work is ongoing to develop a comparison database. The data show that the largest extent of a cover type nationwide is forest land, followed by agriculture, shrubland, grassland, and developed land.

The Land Cover in Puget Sound/Georgia Basin indicator (p. 4-10) shows that land cover in the majority of the approximately 2,700 sub-watersheds that constitute the Puget Sound and Georgia Basin did not change appreciably during the time periods covered by the indicator. The data in this Regional Indicator allow for discrimination of patterns of watersheds where land cover has changed even in the relatively short interval of 5 years. For example, forest cover tended to decrease in coastal and mid-elevation watersheds, while showing a net increase at higher elevations. Developed land cover increased somewhat in approximately 8 percent of the sub-watersheds, mainly in watersheds at low elevations and along the shore. These and related trends may have consequences for human health and ecologic conditions in the areas where land cover is changing. For example, increases in developed land cover may be associated with increases in impervious surface area, which can cause changes in surface water runoff quantity and quality to the point where detrimental effects on aquatic resources may occur.[7]

The Forest Extent and Type indicator (p. 6-8) provides trend data for forest land cover, and shows that the total amount of forest land in the U.S. has remained relatively constant over recent years. On a regional basis, however, there have been shifts, including increases in forest cover over the last century in EPA Regions 1, 2, 3, and 5 and decreases in Regions 6 and 9. The species composition of forest cover has also shifted.[8]

Limitations, Gaps, and Challenges

The current lack of trend data is a key limitation of the Land Cover indicator (p. 4-7) as well as a gap in the data. The changing availability of technology since the 1970s, such as satellites and computing capacity to process large volumes of data, has provided new tools in the effort to track trends in

[7] U.S. Environmental Protection Agency. 2005. Estimating and projecting impervious cover in the southeastern United States. EPA/600/R-05/061. Athens, GA. <http://www.epa.gov/athens/publications/reports/Exum600R05061EstimatingandProjectingImpervious.pdf>

[8] These changes and their effects on the environment are described in Chapter 6.

land cover. The use of these tools continues to be constrained due to complexities in land cover and costs of processing. This is one reason that trend data for national land cover using satellite data are not currently available.

Another gap is the lack of indicators for human health effects related to trends in land cover. While land cover extent may represent a measure of ambient conditions and is a critical input to many other analyses (e.g., models of the water cycle, carbon cycle, ecological system function), it provides limited insight in answering the question of effects on human health.

There are several challenges related to addressing the question of trends in land cover. Two critical challenges are (1) that land cover characteristics can vary depending on the scale of mapping or measurement and (2) that the classification systems used to describe land cover vary by agency and by the agencies' needs. The variability of species and structure within land cover types can be important in how land cover is affected by pollutants or the type of habitat that is provided. While mapping or measuring the details of species and structure of forest or shrubland is possible on a local basis, it is very difficult to do consistently on a national scale. There are many different types or categories of land cover that can be defined at very different levels of detail, and different classification schema often make comparability among data sets and across time frames difficult. The major sources of data used to track land cover are based on national surveys using unique classifications that have been maintained over time to allow valid comparisons of important characteristics to be made. At the same time, technology is changing what can be measured, mapped, and classified. Data that can be collected from ground surveys or in some cases inferred from aerial photos—such as understory species—are seen differently in automated satellite data processing. Coordinating, integrating, and using data collected at a variety of scales and based on diverse data sources and classifications are challenges in tracking trends in and effects of land cover.

4.3 What Are the Trends in Land Use and Their Effects on Human Health and the Environment?

4.3.1 Introduction

Land use represents the economic and cultural activities that are practiced at a place, such as agricultural, residential, industrial, mining, and recreational uses. Land use changes occur constantly and at many scales, and can have specific and cumulative effects on air and water quality, watershed function, generation of waste, extent and quality of wildlife habitat, climate, and human health. Land use differs from land cover in that some uses are not always physically obvious (e.g., land used for producing timber but not harvested for many years or land used for grazing but without animals will not be visible). Public and private lands frequently represent very different uses. Urban development seldom occurs on public lands, while private lands are infrequently protected for wilderness uses.

EPA is concerned about the use of land because of the potential effects of land use and its byproducts on the environment. For example, land development creates impervious surfaces through construction of roads, parking lots, and other structures. Impervious surfaces contribute to nonpoint 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. Increased storm water runoff from impervious surfaces can deliver more pollutants to water bodies that residents may rely on for drinking and recreation.[9] 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. Impervious surfaces also affect ground water aquifer recharge.

Some land development patterns, in particular dispersed growth such as "suburbanization," can contribute to a variety of environmental concerns. For example, increased air pollution due to increased vehicle use can result in increased concentrations of certain air pollutants in developed areas that may exacerbate human health problems such as asthma.[10] Another potential effect of land development is the formation of "heat islands," or domes of warmer air over urban and suburban areas, 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.[11]

Agricultural land uses can affect the quality of water and watersheds. The types of crops planted, tillage practices, and various irrigation practices can limit the amount of water available for other uses. Livestock grazing in riparian zones 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. Additionally, agricultural land uses may result in loss of native habitats or increased wind erosion and dust, exposing humans to particulate matter and various chemicals.[12]

Some land uses can accelerate or exacerbate the spread of invasive species. Certain land use practices, such as overgrazing, land conversion, fertilization, and the use of agricultural chemicals,

[9] U.S. Environmental Protection Agency. 2005. Estimating and projecting impervious cover in the southeastern United States. EPA/600/R-05/061. Athens, GA. <http://www.epa.gov/athens/publications/reports/Exum600R05061EstimatingandProjectingImpervious.pdf>

[10] Schwartz J. 2004. Air pollution and children's health. Pediatrics 113:1037-1043.

[11] U.S. Environmental Protection Agency. 2003. Cooling summertime temperatures: Strategies to reduce urban heat islands. EPA/430/F-03/014. Washington, DC. <http://www.epa.gov/heatisland/resources/pdf/HIRIbrochure.pdf>

[12] Schenker, M. 2000. Exposures and health effects from inorganic agricultural dusts. Environ. Health Persp. 108(Suppl 4):661-664. <http://ehp.niehs.nih.gov/members/2000/suppl-4/661-664schenker/schenker-full.html>

can enhance the growth of invasive plants.[13] These plants 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 can reduce water quality and water availability for native fish and wildlife species.

Research is beginning to elucidate the connections between land use changes and infectious disease. For example, fragmentation of forest habitat into smaller patches separated by agricultural activities or developed land increases the "edge effect" and promotes the interaction among pathogens, vectors, and hosts.[14]

In some cases, changes in land use may have positive effects, such as increasing habitat as a result of deliberate habitat restoration measures; and reclamation of lands for urban/suburban development as a result of cleanup of previously contaminated land.

4.3.2 ROE Indicators

The question of trends in land use is addressed by two ROE indicators: Land Use and Urbanization and Population Change (Table 4-3). The primary information sources for these indicators are the National Resources Inventory prepared by the U.S. Department of Agriculture's Natural Resources Conservation Service, the Forest Inventory and Analysis conducted by the Forest Service, the Census of Agriculture from the National Agricultural Statistics Service, and population data collected by the U.S. Census Bureau. The box on pages 4-16 and 4-17 provides definitions of the categories used in the indicators.

Table 4-3. ROE Indicators of Trends in Land Use and Their Effects on Human Health and the Environment

National Indicators	Section	Page
Land Use (N/R)	4.3.2	4-14
Urbanization and Population Change (N/R)	4.3.2	4-19

N/R = National Indicator displayed at EPA Regional scale

INDICATOR | Land Use

Land use is the purpose of human activity on the land. Unlike land cover, land use may not always be visible. For example, a unit of land designated for use as timberland may appear identical to an adjacent unit of protected forestland or, if recently harvested, may appear not to be in forest land cover at all. Land use is generally designated through zoning or regulation and is one of the most obvious effects of human inhabitation of the planet. It can affect both human health and ecological systems, for example by changing the hydrologic characteristics of a watershed, the potential of land to erode, the condition or contiguity of plant and animal habitat, or the spread of vector-borne diseases.

This indicator tracks trends in acreages of major land uses over the 1977–2003 period using several data sources. These sources do not always cover the same time period, sample the same resource or geography, or use the same definitions, but each of them provides an important piece of the land use picture over time. Definitions for the various land use categories in this indicator can be found on page 4-16.

The National Resources Inventory (NRI) conducted by the U.S. Department of Agriculture (USDA) Natural Resources Conservation Service was used to track trends in "crop and pasture" land (row crop, orchard, and pasture uses) and "developed" land (residential, commercial, industrial, and transportation uses). The NRI developed estimates every 5 years on non-federal lands in the contiguous U.S. between 1977 and 1997, and annual estimates based on a smaller sample size beginning in 2001.

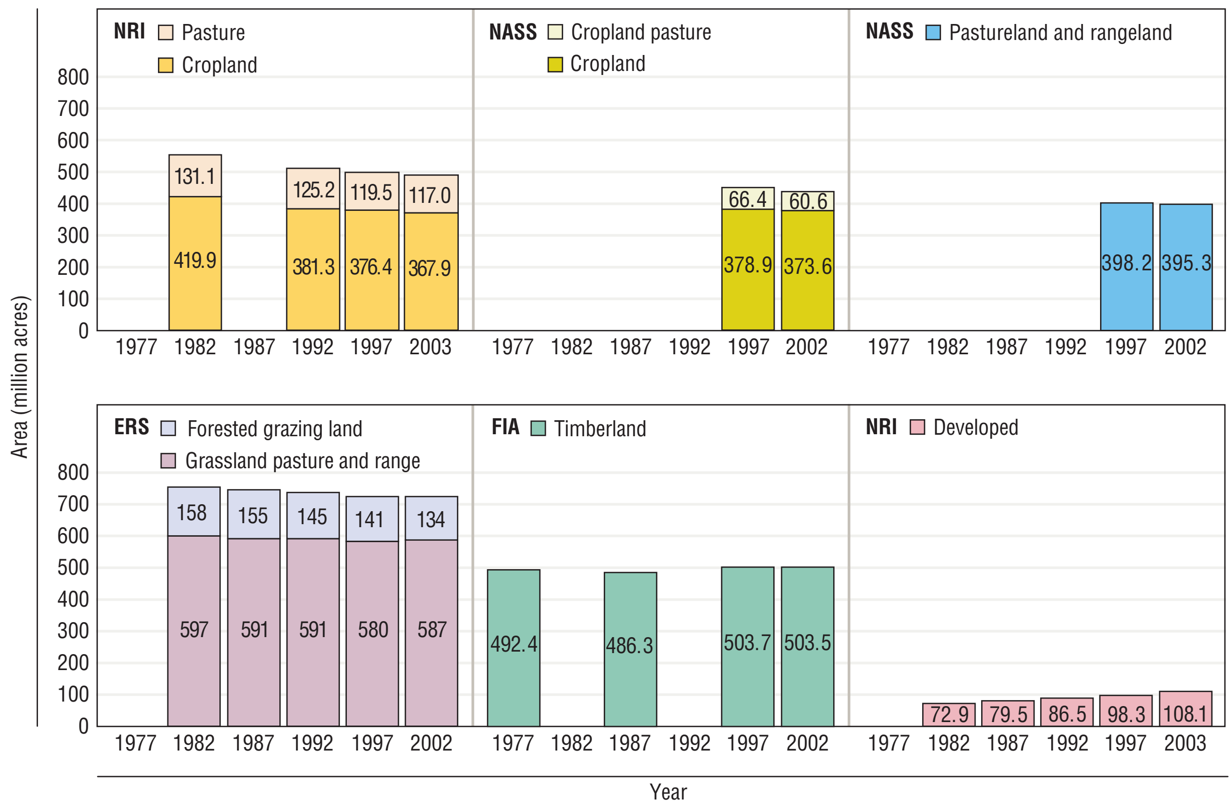
The Forest Inventory and Analysis (FIA) surveys conducted by the USDA Forest Service were used to track trends in forest and timberlands. The FIA surveys include both private and public land in all 50 states. The FIA previously assessed forest and timberland acreage every 10 years, but the data are now updated on a rolling basis using surveys that sample a different portion of FIA sites every year.

The USDA National Agricultural Statistics Service (NASS) Census of Agriculture was used to track trends in the extent of cropland, cropland used only for pasture, pastureland, and rangeland. NASS data are available for 1997 and 2002 only. Data on the extent of grass and forested rangeland (typically "unimproved" grazing land) are available from the USDA Economic Research Service (ERS) for 5-year intervals from 1982 through 2002.

[13] Westbrooks, R.G. 1998. Invasive plants: Changing the landscape of America: Fact book. Washington, DC: Federal Interagency Committee for the Management of Noxious and Exotic Weeds.

[14] Patz, J.A., P. Daszak, G.M. Tabor, A.A. Aguirre, M. Pearl, J. Epstein, N.D. Wolfe, A.M. Kilpatrick, J. Foufopoulos, D. Molyneux, D.J. Bradley, and Members of the Working Group on Land Use Change and Disease Emergence. 2004. Unhealthy landscapes: Policy recommendations on land use change and infectious disease emergence. Environ. Health Persp. 112(10):1092-1098.

Exhibit 4-5. Land use trends in the U.S., 1977-2003[a]



[a]See box on p. 4-16 for definitions of land use categories.

Data source: *Lubowski et al., 2006; Smith et al., 2004; USDA NASS, 2004; USDA NRCS, 2007*

What the Data Show

The acreage of lands used for growing food and forage crops has declined since 1982, while developed land has increased and timberland has remained approximately constant (Exhibit 4-5). As of 2002-2003, estimates from both the NRI (2003 data) and the NASS (2002 data) indicate that between 368 and 374 million acres were used for food crop production, approximately 16 percent of the U.S. land area. Estimates of pasture or land used to support forage for livestock vary, depending on the definitions. The NRI classifies 117 million acres as pasture, while the NASS classifies about 61 million acres as cropland used for pasture. The NASS classifies more than 395 million additional acres as pasture or rangeland for grazing. The broader ERS estimate of land available for grazing totals about 587 million acres, and includes grassland and other non-forested pasture and range. If forest lands used for grazing are also included, the total ERS estimate for these lands is 721 million acres for 2002. The NASS cropland shows a decrease in the extent of cropland (5 million acres), cropland pasture (6 million acres), and pastureland and rangeland (3 million acres) between 1997 and 2002. The NRI data suggest that these declines are part of a longer trend, with NRI cropland and pasture declining by slightly more than 66 million acres (12 percent) between 1982 and 2003. ERS data also show a downward trend for pasture and rangeland between 1982 and 2002, with the largest decrease being a 24-million-acre (15 percent) decline in forest land used for grazing. According to the NRI, 5 percent (108.1 million acres) of U.S. land area was considered developed[15] as of 2003 (Exhibit 4-5). This represents a gain of 48 percent (35.2 million acres) since 1982. While the amount of developed land is a small fraction of the total, its ecological impact can be disproportionately high relative to other land use types. Paving and the creation of other impervious surfaces can change local hydrology, climate, and carbon cycling, leading to increased surface runoff, pollution, and degradation of wetlands and riparian zones.

[15] The land *use* classification for developed land uses NRI data and is considerably different from the land *cover* classification for developed land, which uses NLCD data. See Section 4.2 for more information.

Definitions of Land Use Categories for Exhibits 4-5, 4-6, and 4-7

NRI (USDA NRCS, 2004)

Developed: A combination of land cover/use categories: urban and built-up areas and rural transportation land.

- **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, which meet the definition of urban and built-up areas.
- **Rural transportation land.** A land cover/use category which consists of all highways, roads, railroads and associated right-of-ways outside urban and built-up areas; also includes private roads to farmsteads or ranch headquarters, logging roads, and other private roads (field lanes are not included).

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, for example, hay land or pastureland that is in a rotation with row or close-grown crops. Noncultivated cropland includes permanent hay land and horticultural cropland.

Pastureland: A 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. Management usually consists of cultural treatments: fertilization, weed control, reseeding or renovation, and control of grazing. For the NRI, pastureland includes land that has a vegetative cover of grasses, legumes, and/or forbs, regardless of whether or not it is being grazed by livestock.

FIA (Smith et al., 2004)

Forest land: Land at least 10 percent stocked by forest trees of any size, including land that formerly had such tree cover and that will be naturally or artificially regenerated. Forest land includes transition zones, such as areas between heavily forested and nonforested lands that are at least 10 percent stocked with forest trees and forest areas adjacent to urban and built-up lands. Also included are pinyon-juniper and chaparral areas in the West and afforested areas. The minimum area for classification of forest land is 1 acre. Roadside, streamside, and shelterbelt strips of trees must have a crown width of at least 120 feet to qualify as forest land. Unimproved roads and trails, streams, and clearings in forest areas are classified as forest if less than 120 feet wide.

Timberland: Forest land that is producing or can produce crops of industrial wood and is not withdrawn from timber utilization by statute or administrative regulation. (Areas qualifying as timberland must be able to produce more than 20 cubic feet per acre per year of industrial wood in natural stands. Currently inaccessible and inoperable areas are included.)

NASS (USDA NASS, 2004)

Cropland: A category including cropland harvested, cropland idle or used for cover crops or soil improvement but not harvested and not pastured, cropland on which all crops failed, and cropland in cultivated summer fallow. Not included is cropland used only for pasture or grazing.

Cropland pasture: Cropland used only for pasture or grazing, which could have been used for crops without additional improvement. Also included are acres of crops hogged or grazed but not harvested prior to grazing. However, cropland pastured before or after crops were harvested counts as harvested cropland rather than cropland for pasture or grazing.

Pastureland and rangeland: All grazable land—irrigated or dry—that does not qualify as cropland or woodland pasture. In some areas, this is high-quality pastureland but cannot be cropped without improvements. In others, it can barely be grazed and is only marginally better than waste land.

ERS (Lubowski et al., 2006)

Grassland pasture and range: All open land used primarily for pasture and grazing, including shrub and brush land types of pasture; grazing land with sagebrush and scattered mesquite; and all tame and native grasses, legumes, and other forage used for pasture or grazing. Because of the diversity in vegetative composition, grassland pasture and range are not always clearly distinguishable from other types of pasture and range. At one extreme, permanent grassland may merge with cropland pasture; grassland is also often found in transitional areas with forested grazing land.

Forested land grazed: Forested grazing land consists mainly of forest, brush-grown pasture, arid woodlands, and other areas within forested areas that have grass or other forage growth. The total acreage of forested grazing land includes woodland pasture in farms plus estimates of forested grazing land not in farms. For many states, the estimates include significant areas grazed only lightly or sporadically. The Census of Agriculture, the National Resources Inventory, and the Forest Inventory and Analysis are the principal sources of data.

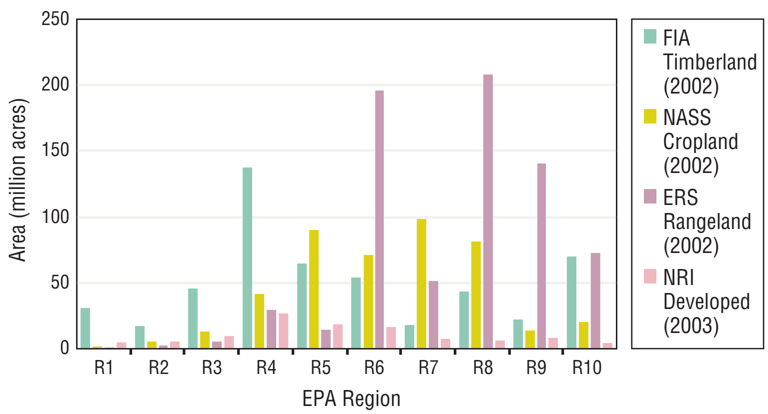
Forest lands are managed by a complex array of interests to meet multiple purposes, including providing habitat for a variety of species, recreation, and timber production. While forest is a land *cover* classification, timberland is a land *use* classification that reflects forest land capable of producing at least 20 cubic feet per acre per year of industrial wood and not withdrawn from timber utilization by statute or regulation. Approximately 504 million acres of U.S. forest land, or 22 percent of the total U.S. land area, qualified as timberland in 2002 (Exhibit 4-5). This total reflects a net gain of about 11 million acres (2 percent) between 1977 and 2002, which the FIA attributes largely to reversion of abandoned lands and reclassification of some National Forest lands to align with classifications used on other land ownerships (Smith et al., 2004).

Land use varies widely by EPA Region (Exhibit 4-6). According to the most recent data for each land use type, Regions 6, 8, and 9 together have more than three-quarters of the nation's grazing land, while Region 4 has the largest portion of timberland (27 percent of total U.S. timberland). Trends also vary widely among regions. About 83 percent of the cropland lost between 1987 and 2003 was in five EPA Regions (Regions 4, 5, 6, 7, and 8) (Exhibit 4-7, panel A). Increases in developed land are responsible for part of this decline; for example, developed land increased by nearly 60 percent from 1987 to 2003 in Region 4 (Exhibit 4-7, panel B). Other factors include the federal Conservation Reserve Program, which has assisted private landowners in converting about 35 million acres of highly erodable cropland to vegetative cover since 1985 (as of 2004) (USDA Farm Service Agency, 2004).

Indicator Limitations

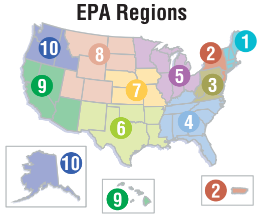
- Estimates are derived from a variety of inventories and samples, conducted over different time periods and for different purposes. This limits the ability to integrate the data and track changes over time.
- The NRI does not report land use data for Alaska, which encompasses 365 million acres of the 2.3 billion acres nationwide. The NRI also does not provide data on federal lands (representing 20 percent of the contiguous U.S. land and one-third of Alaska). Because federal land is seldom used for agriculture or urban development, and there is relatively little developed or agricultural land in

Exhibit 4-6. Land use in the U.S. by EPA Region, 2002-2003[a]



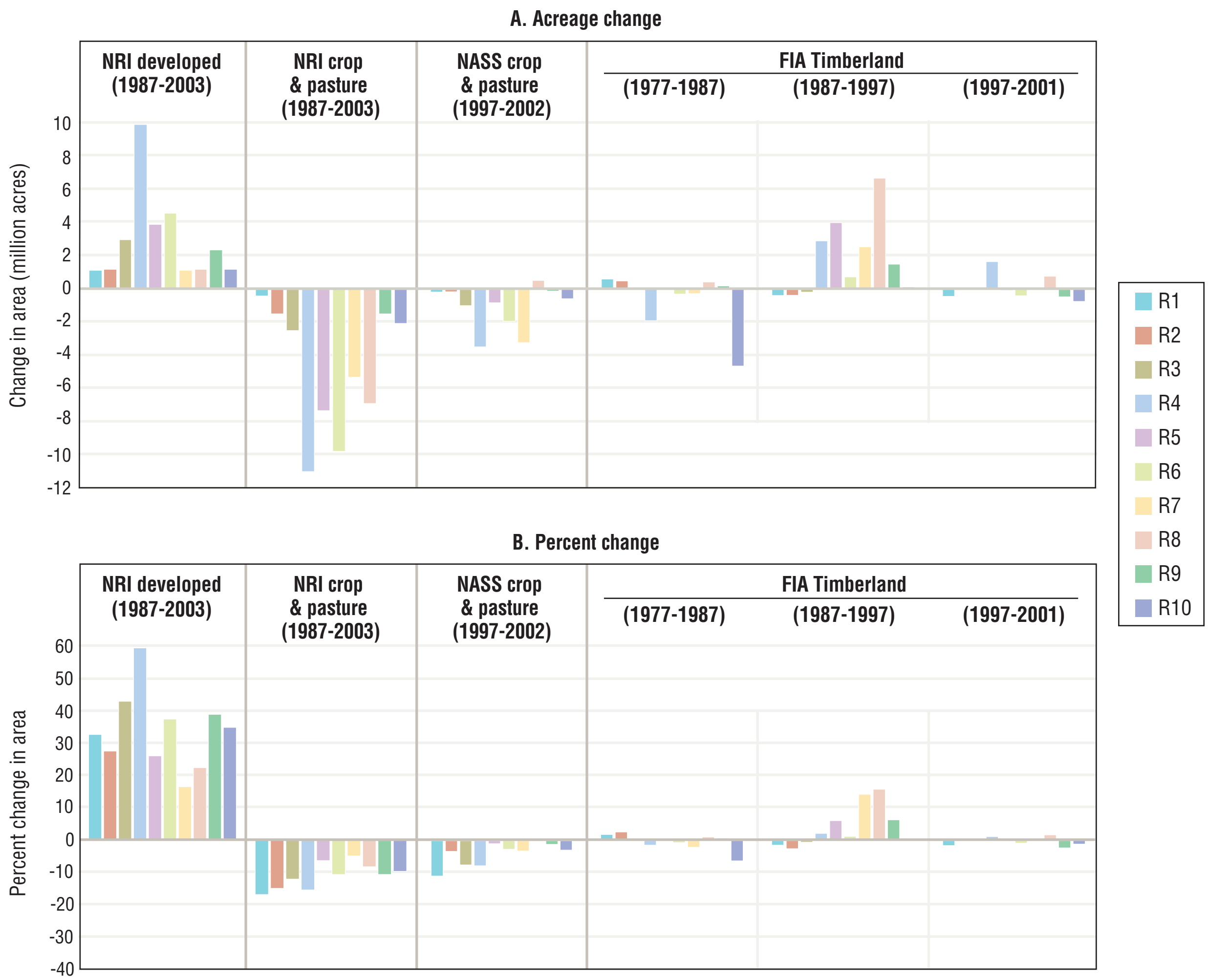
[a]See box on p. 4-16 for definitions of land use categories.

Data source: *Lubowski et al., 2006; Smith et al., 2004; USDA NASS, 2004; USDA NRCS, 2007*

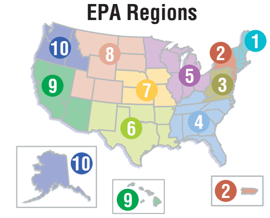


INDICATOR | Land Use *(continued)*

Exhibit 4-7. Changes in land use in the U.S. by EPA Region, 1977-2003[a]



EPA Regions



[a]See box on p. 4-16 for definitions of land use categories.

Data source: *Smith et al., 2004; USDA NASS, 2004; USDA NRCS, 2007*

Alaska, the NRI data likely offer a reasonable approximation of national trends in these categories.

- NRI data use three subcategories of types of developed land: large built-up areas, small built-up areas, and rural transportation land. Because ecological effects from developed land depend on the density of development and many other factors, the limited NRI categories are not discriminating enough to support detailed analyses of ecological effects of developed land.
- The FIA data are aggregated from state inventories in many cases, and dates of data collection for these inventories vary by state—for example, ranging from 1980 to 2001 for reporting 2002 estimates.
- Some land uses may be administratively designated but not physically visible (e.g., lands that are reserved for parks or wilderness may appear similar to lands that are managed for natural resources).

INDICATOR | Land Use (continued)

- Land use designations are most frequently managed and monitored by local governments, each using different approaches and classifications. This makes national summaries difficult.
- The extent of lands used for energy production, resource extraction, or mining is not known and represents a data gap.
- Lands specifically protected for certain uses such as wilderness or parks have been periodically inventoried for the nation. These statistics are currently not reported in a form that allows comparison with other statistics.

Data Sources

Data were obtained from several original sources and compiled by EPA Region. ERS data were obtained from Lubowski et al. (2006). FIA data were obtained from Smith et al. (2004). NASS data were published by the USDA National Agricultural Statistics Service (2004).

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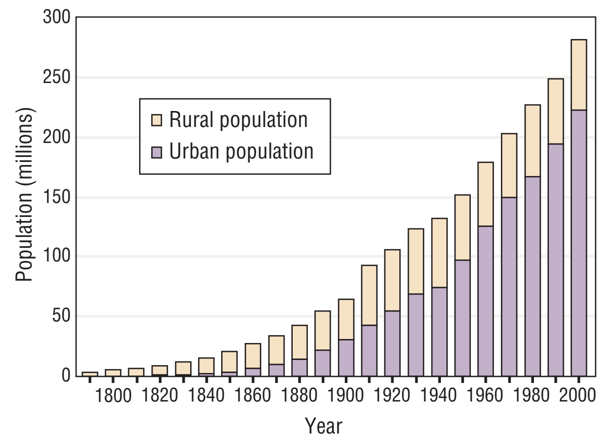
USDA NRCS. 2004. National resources inventory: 2002 annual NRI. <http://www.nrcs.usda.gov/technical/NRI/2002/glossary.html>

INDICATOR | Urbanization and Population Change

The total number of people and their distribution on the landscape can affect the condition of the environment in many ways. Increasing population often means increased urbanization, including conversion of forest, farm, and other lands for housing, transportation, and commercial purposes. In recent years, many communities in the U.S. have seen an increase in developed land (residential, commercial, industrial, and transportation uses) that outpaces population growth. This pattern is of concern for numerous health and environmental reasons (Frumkin et al., 2004). For example, studies indicate that when land consumption rates exceed the rate of population growth, per capita air pollutant emissions from driving tend to be higher. Urbanization and population growth also tend to increase the amount of impervious surfaces and the quantity and types of products that humans produce, use, and discard, thereby affecting waste generation and management, water quality, and chemical production and use.

The information presented in this indicator is based on population data collected and analyzed on a decadal basis by the U.S. Census Bureau—as well as annual "intercensal" population estimates—and data collected by the U.S. Department of Agriculture Natural Resources Conservation Service's

Exhibit 4-8. Population and urbanization in the U.S., 1790-2000[a]

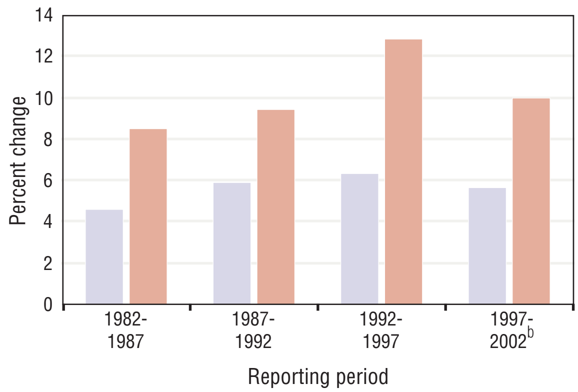


[a]**Coverage:** 50 states and the District of Columbia.

Data source: *U.S. Census Bureau, 1993, 2004*

INDICATOR | Urbanization and Population Change *(continued)*

Exhibit 4-9. Percent change in population and developed land in the contiguous U.S. and Hawaii, 1982-2002[a,b]

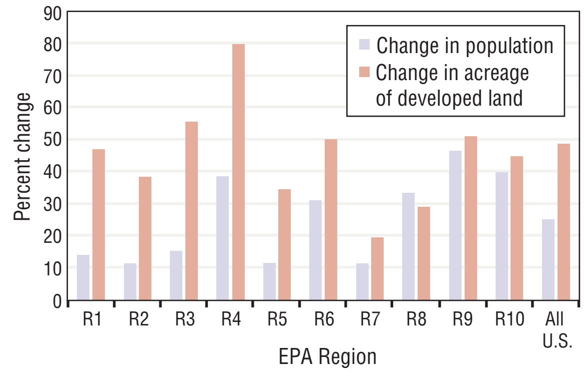


[a]**Coverage:** Contiguous 48 states (excluding the District of Columbia) and Hawaii.

[b]Based on changes in the NRI inventory approach, Hawaii was not sampled in 2002. Thus, the percent change in developed land from 1997 to 2002 is based on the 48 contiguous states only.

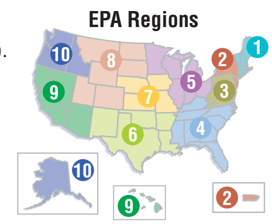
Data source: *U.S. Census Bureau, 1996, 2002b, 2006; USDA NRCS, 2000, 2004*

Exhibit 4-10. Percent change in population and developed land in the contiguous U.S. by EPA Region, 1982-2003[a]



[a]**Coverage:** Contiguous 48 states (excluding the District of Columbia).

Data source: *U.S. Census Bureau, 1996, 2002b, 2006; USDA NRCS, 2000, 2007*



National Resources Inventory (NRI) to track "developed" land. Between 1977 and 1997, the NRI developed estimates every 5 years on non-federal lands in the contiguous U.S. Since 2001 the NRI has developed annual estimates, but based on a smaller sample size. This indicator captures trends in overall population growth for both rural and urban populations; the amount of developed land relative to the amount of population change, nationally and by EPA Region; and overall population density, also nationally and by EPA Region.

What the Data Show

The U.S. population grew from a little over 4 million people in 1790 to over 281 million in 2000; urban population is estimated to have grown a thousandfold over that period (Exhibit 4-8). The population nearly doubled between 1950 and 2000.

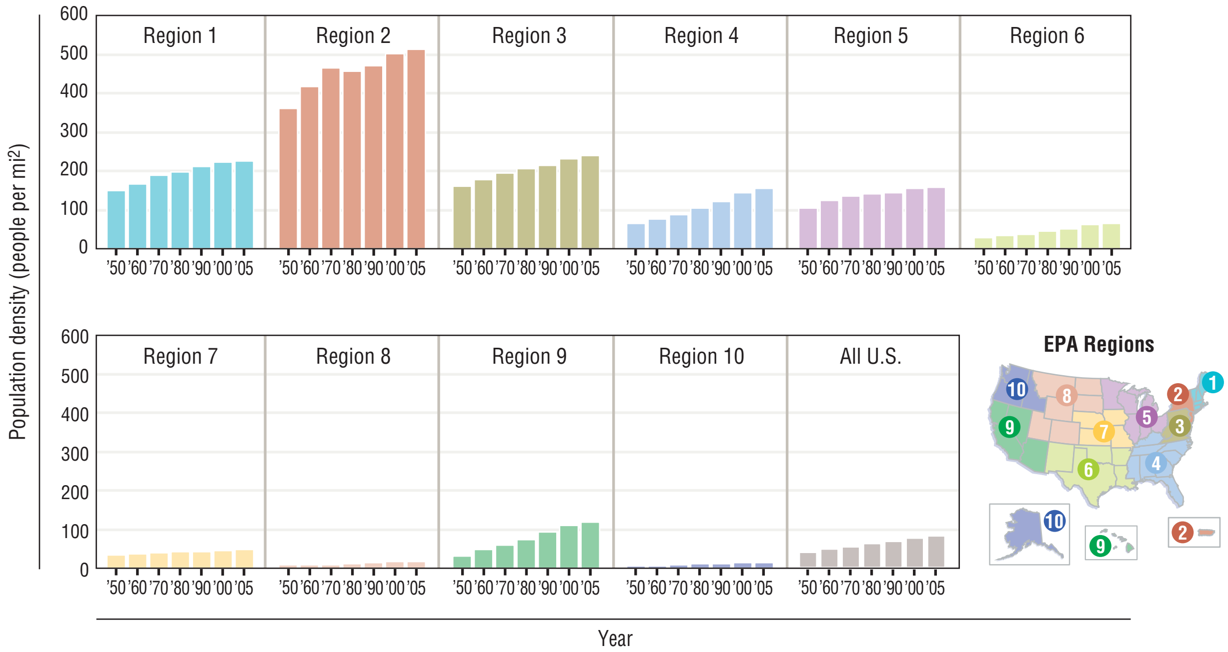
The rates of population and developed land growth over 5-year intervals increased between 1982 and 1997, before declining slightly between 1997 and 2002. Over all four 5-year increments, the amount of developed land increased at nearly twice the rate of the population (Exhibit 4-9). Between 1982 and 2003, the amount of developed land in the U.S. in the 48 contiguous states (not including the District of Columbia) grew by more than 35 million acres, representing a cumulative increase of more than 48 percent.

The Census Bureau estimates that during the same period, the population of the 48 states grew by nearly 58 million people, or just over 25 percent (Exhibit 4-10).

There are substantial variations in population and development trends in different parts of the U.S. (Exhibit 4-10). Between 1982 and 2003, the growth rates for developed land were higher than population growth rates in every region except Region 8. The largest rate of increase in population between 1982 and 2003 occurred in Region 9, where population increased by more than 46 percent (nearly 14 million people). Developed land in Region 9 increased by 51 percent (more than 2.8 million acres). Region 4 had the largest rate of increase in developed land (nearly 80 percent) and the largest absolute increases in both population (15.4 million) and developed land (11.8 million acres).

Although growth rates of population and developed land were high in most Regions, population density varies significantly from one Region to the next (Exhibit 4-11). In 2005, EPA Region 2 was the most densely populated Region, at 512 people per square mile; EPA Region 10 was the least densely populated, with an average of approximately 15 people per square mile (including Alaska). The national average in 2005 was 83.8 people per square mile.

Exhibit 4-11. Population density in the U.S. by EPA Region, 1950-2005[a]



[a]**Coverage:** 50 states and the District of Columbia.

Data source: *U.S. Census Bureau, 2002a,c; 2006*

Indicator Limitations

Census data:

- Intercensal figures are estimates based on administrative records of births, deaths, and migration, and thus differ from the decennial census data in methodology and accuracy.
- Sampling and non-sampling errors exist for all census data as a result of errors that occur during the data collection and processing phases of the census.
- Puerto Rico and Virgin Islands data are not available for all years, and thus have not been included. This affects the accuracy of the statistics for Region 2.
- The criteria for estimating urban population have changed over time as defined by the Census Bureau.

NRI data:

- NRI sampling procedures changed in 2000 to an annual survey of fewer sample sites than had previously been sampled (starting in 1977, the NRI sampled 800,000 points every 5 years). Fewer sample points mean increased variance and uncertainty.
- The NRI collects some data across the entire nation, including Puerto Rico and the Virgin Islands. Land use statistics, however, are not reported on federal lands or for Alaska and the District of Columbia. In Exhibit 4-10, Hawaii is also excluded.

Data Sources

Urban and rural population data for Exhibit 4-8 were obtained from two U.S. Census Bureau publications: data from 1790 to 1990 are from U.S. Census Bureau (1993); 2000 data are from U.S. Census Bureau (2004).

In Exhibit 4-9, population change was calculated from annual population estimates published in U.S. Census Bureau (1996, 2002b, 2006) (estimates for 1982/1987, 1992/1997, and 2002, respectively). Changes in acreage of developed land were calculated based on acreage figures originally reported every 5 years by the NRI and now reported annually. NRI data were obtained from two publications (USDA NRCS, 2000, 2004) (1982-1997 and 2002 data, respectively).

Exhibit 4-10 is based on annual population estimates by state, published in U.S. Census Bureau (1996, 2002b, 2006), and NRI-developed land estimates by state, published in USDA NRCS (2000, 2007). The figure was developed by grouping the published state data by EPA Region, then calculating percent change between 1982 and 2003.

Population density by EPA Region (Exhibit 4-11) was calculated based on three published data sets: population every 10 years from 1900 to 2000 by state (U.S. Census Bureau, 2002a); population estimates for 2005 by state (U.S. Census Bureau, 2006); and land area by state (U.S. Census Bureau, 2002c).

INDICATOR | Urbanization and Population Change *(continued)*

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USDA NRCS. 2000. Summary report: 1997 national resources inventory (revised December 2000). Washington, DC and Ames, IA: USDA Natural Resource Conservation Service. <http://www.nrcs.usda.gov/technical/NRI/1997/summary_report/table1.html>

4.3.3 Discussion

What These Indicators Say About Trends in Land Use and Their Effects on Human Health and the Environment

The indicators point out that the development of land for human residential and commercial purposes is occurring at a rapid pace. In the 21-year period between 1982 and 2003, the acreage of developed land increased by more than 48 percent from its 1982 level. Population in a similar time frame grew at only half the rate of land development (25 percent), indicating that more land is being developed per capita now than 25 years ago. Across EPA regions, such rates of change in developed land and population vary both independently and with respect to each other. Over a similar 20-year time frame (1982-2002), the extent of cropland and pastureland has slowly declined, with larger decreases in those regions experiencing either increased land development or reforestation.

Limitations, Gaps, and Challenges

There is generally a lack of comprehensive data on the types and rates of land use and land cover change, and even less systematic evidence on the causes and consequences of these changes. On a global scale, the National Research Council identified land use dynamics as one of the grand challenges for environmental research.[16]

Two examples of land uses not addressed by the indicators, that can have effects in different ways on condition and extent of land, are the formal protection or reservation of land for habitat or natural resources, and 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 key challenge in answering the land use question is that estimates of the extent of various land uses differ across data sources and each source uses different classifications, measurement approaches, methodologies for analysis and interpretation,

[16] National Research Council, Committee on Grand Challenges in Environmental Sciences. 2001. Grand challenges in environmental sciences. Washington, DC: National Academies Press.

and sampling time frames. The data are collected by many different agencies that manage land for many different purposes. The data collection efforts currently in place are derived from specific interests, such as tracking changes in the extent of agricultural land or farmland, or understanding how much land is used for timber production. These data collection efforts tend to develop and use their own classifications and categorization, making it difficult to integrate and use the data over time, across inventories, or as a national picture.

Another challenge is understanding the effects that trends in land use have on human health. No indicators are available, as effects have not been shown or quantified on a national basis. Urban and landscape planners have conducted site-specific studies on individual land uses, but little is known about overall national trends in land use and potential impacts on human health.

An additional challenge is that a variety of state, county, and municipal laws, regulations, and practices govern the use of land, but aside from regulations addressing protection of species and their habitats, there are no national land use regulations that apply to all non-federal lands. There are also relatively few state-level efforts to organize land use data; most activities occur over specific local, usually urbanizing, geographic areas. This means that land use records are not maintained statewide or nationally, as they are in other nations, which contributes to challenges in tracking and monitoring land use changes. It also means that strategies to plan land use across jurisdictions are difficult to develop.

Finally, a challenge in developing data to determine trends is the difficulty of actually delineating land use. Land use is generally a function of laws, policies, or management designations that may not always be possible to infer from examining the ground via surveys. Analysis of zoning maps or property records at the local level may be necessary.

4.4 What Are the Trends in Wastes and Their Effects on Human Health and the Environment?

4.4.1 Introduction

Every resident, organization, and human activity in the U.S. generates some type of waste. Many different types of wastes are generated, including municipal solid waste, agricultural and animal waste, medical waste, radioactive waste, hazardous waste, industrial non-hazardous waste, construction and demolition debris, extraction and mining waste, oil and gas production waste, fossil fuel combustion waste, and sewage sludge (see the glossary in Appendix A for detailed descriptions of these wastes). In general, waste generation represents inefficient use of materials. These materials, some of which are hazardous, must be managed through reuse, recycling, storage, treatment, and disposal. Hazardous wastes are either specifically listed as hazardous by EPA or a state, or exhibit one or more of the following characteristics: ignitability, corrosivity, reactivity, or toxicity. Generation and management of hazardous wastes have the potential to contaminate land, air, and water and negatively affect human health and environmental conditions. Tracking trends in the quantity, composition, and effects of these materials provides insight into the efficiency with which the nation uses (and reuses) materials and resources and provides a means to better understand the effects of wastes on human health and ecological condition.

The amount of waste produced is influenced by economic activity, consumption, and population growth. Affluent societies, such as the U.S., generally produce large amounts of municipal solid waste (e.g., food wastes, packaged goods, disposable goods, used electronics) and commercial and industrial wastes (e.g., demolition debris, incineration residues, refinery sludges). Among industrialized nations, the U.S. generates the largest amounts of municipal solid waste per person on a daily basis.[17]

Current approaches to waste management evolved primarily due to health concerns and odor control. Waste often was deposited outside developed areas on nearby lands, frequently wetlands. Excavation of land specifically for deposition of wastes followed, often accompanied by burning of wastes to reduce volume, a practice eventually determined to be a contributor to degraded air quality in urban areas. Burning of wastes occurred at multiple levels, from backyard burning to large, open-burning dumps of municipal solid wastes to onsite burning of commercial and industrial wastes. Land disposal created problems such as ground water contamination, methane gas formation and migration, and disease vector hazards.

The amount of land being used to manage the many types of waste generated is not known. Most municipal solid wastes and hazardous wastes are managed in land disposal units. Land disposal of hazardous wastes includes landfills, surface impoundments, land treatment, land farming, and underground injection. Modern landfill facilities are engineered with containment systems and monitoring programs. Waste management practices prior to the Resource Conservation and Recovery Act (RCRA) regulations left legacies of contaminated lands in many cases, which are addressed in Section 4.6 of this chapter.

Landfills represent one of the largest human-related sources of methane gas in the U.S. Between 1997 and 2003, landfills accounted for slightly more than one-fourth of the estimated methane emissions attributed to human activity.[18] Methane gas is released as wastes decompose, as a function of the total amount and makeup of the wastes as well as management

[17] Clark, R., and E. Capponi, eds. 2005. OECD in figures 2005: Statistics on the member countries. Organization for Economic Cooperation and Development (OECD) Observer. Paris, France.

[18] U.S. Environmental Protection Agency. 2006. Inventory of U.S. greenhouse gas emissions and sinks: 1990-2004. EPA/430/R-06/002. <http://yosemite.epa.gov/oar/globalwarming.nsf/content/ResourceCenterPublicationsGHGEmissionsUSEmissionsInventory2006.html>

[19] More information on air emissions related to waste management practices, including nitrogen oxides (NO_x) and carbon monoxide (CO), is included in Chapter 2.

facility location, design, and practices.[19] EPA is interested because gas emissions can be affected by recycling and changing product use. For example, recycling aluminum or office paper can reduce environmental effects (e.g., by reducing the need to mine bauxite or harvest trees), and it will also create positive environmental benefits, such as reductions in energy consumption and greenhouse gases (e.g., emissions associated with the production of products from virgin materials).[20]

Although data do not exist to directly link trends in waste with effects on human health and the environment, the management of waste may result in waste and chemicals in waste entering the environment. Hazardous waste, by definition, has the potential to negatively affect human health and the environment, which is why it is so strictly regulated. The effects associated with waste vary widely and are influenced by the substances or chemicals found in waste and how they are managed. For chemicals found in waste, EPA has been tracking a list of Priority Chemicals. These Priority Chemicals are documented contaminants of air, land, water, plants, and animals. Between 1991 and 2001, quantities of 17 of the Priority Chemicals were reduced by more than 50 percent.[21,22]

4.4.2 ROE Indicators

The ROE indicators for this question focus on the national trends in the amount of municipal solid waste and hazardous waste generated and their management practices (Table 4-4). Municipal solid waste trends are presented for more than four decades. Trends in the generation and management of municipal solid waste are based on estimations from a materials flow or mass balance approach since 1960. Changes in the amount of RCRA hazardous waste generated and managed are based on mandated biennial submissions from generators and treatment, storage, and disposal facilities.

Table 4-4. ROE Indicators of Trends in Wastes and Their Effects on Human Health and the Environment

National Indicators	Section	Page
Quantity of Municipal Solid Waste Generated and Managed	4.4.2	4-24
Quantity of RCRA Hazardous Waste Generated and Managed	4.4.2	4-26

INDICATOR | Quantity of Municipal Solid Waste Generated and Managed

Municipal solid waste (also called trash or garbage) is defined at the national level as wastes consisting of everyday items such as product packaging, grass clippings, furniture, clothing, bottles and cans, food scraps, newspapers, appliances, consumer electronics, and batteries. These wastes come from homes, institutions such as prisons and schools, and commercial sources such as restaurants and small businesses. EPA's definition of municipal solid waste (MSW) does not include municipal wastewater treatment sludges, industrial process wastes, automobile bodies, combustion ash, or construction and demolition debris. Once generated, MSW must be collected and managed, including reuse, recovery for recycling (which includes composting), combustion, and landfill disposal. Many wastes that are disposed in landfills represent a loss of materials that could be reused, recycled, or converted to energy to displace the use of virgin materials.

Prior to the 1970s, MSW disposal generally consisted of depositing wastes in open or excavated landfills, accompanied by open burning to reduce waste volumes. Often industrial wastes were co-disposed with municipal garbage and refuse in urban and rural landfills. Historically, environmental problems associated with landfills have included ground water contamination, emissions of toxic fumes and greenhouse gases, land contamination, and increases in vector populations (e.g., rodents, flies, mosquitoes). Wastes have the potential to cause various types of environmental concerns depending on the way in which they are disposed. When mismanaged, potentially hazardous ingredients in some products can migrate into the environment, possibly posing harm to human health and biota; stockpiled scrap tires may ignite, often burning for months and causing air pollution; waste piles can create habitats for pests and disease vectors such as rodents and

[20] U.S. Environmental Protection Agency. 2006. Solid waste management and greenhouse gases: A life-cycle assessment of emissions and sinks. Third edition. Washington, DC. <http://www.epa.gov/climatechange/wycd/waste/SWMGHGreport.html>

[21] U.S. Environmental Protection Agency. 2005. National Priority Chemicals Trends Report (1999-2003). EPA/530/R-05/022.

[22] U.S. Environmental Protection Agency. 2007. National Priority Chemicals Trends Report (2000-2004). EPA/530/R-07/001. <http://www.epa.gov/epaoswer/hazwaste/minimize/trends.htm#report>

mosquitoes; and the physical presence of a waste management area can disrupt an ecosystem. Most wastes generated in the U.S. are disposed in landfills, which are subject to federal or state requirements to minimize environmental impacts. MSW landfills are discrete areas of land or excavations that receive trash/garbage, as well as various other types of wastes that are not included in this indicator, such as non-hazardous sludges, hazardous wastes from small quantity generators, non-hazardous industrial wastes, municipal wastewater treatment sludges, and construction and demolition debris.

This indicator shows trends in the national generation and management of MSW on an annual basis from 1960 to 2006. The information presented on MSW consists of estimates generated annually using a materials flow methodology and mass balance approach that relies on production data (by weight) for materials and products that eventually enter the waste stream. These data are collected from industry associations, businesses, and government agencies.

What the Data Show

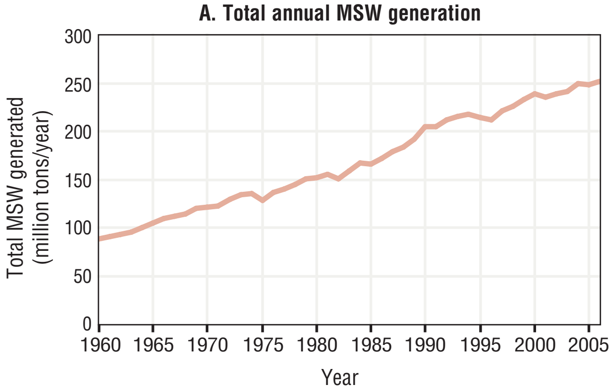
The quantity of MSW generated grew steadily from 88 million tons (MT) in 1960 to over 251 MT in 2006, an increase of 185 percent (Exhibit 4-12, panel A). During this time, the U.S. population increased by 66 percent. On a per capita basis, MSW generation increased from 2.7 pounds per person per day in 1960 to 4.6 pounds per person per day in 2006 (panel B).

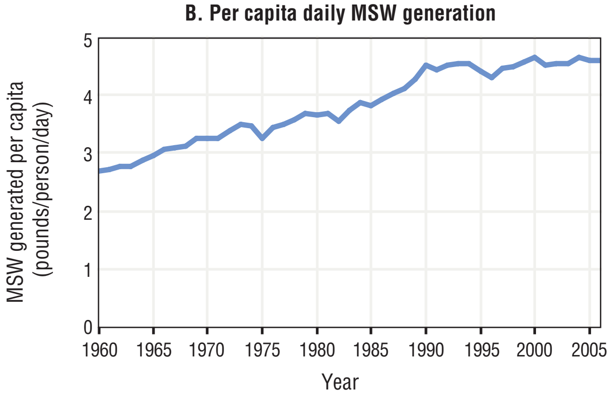
Of the 88 MT of MSW generated in 1960, 6 percent was recovered through recycling and 94 percent was landfilled (Exhibit 4-13). MSW quantities sent to landfills or other disposal peaked in 1990 at 142 MT and then began to decline as recycling and combustion increased. The quantity of MSW disposed in landfills has averaged about 135 MT annually since 2000, a 4.9 percent decrease from 1990. In 2006, of the 251 MT generated, 32.5 percent was recycled (including composting), 13 percent combusted with energy recovery, and 55 percent landfilled. Since 1990, the percentage of MSW generated that was sent to landfills dropped from 69 to 55 percent, the percentage recycled rose from 14 to 24 percent, the percentage composted rose from 2 to 8 percent, and the percentage combusted with energy-recovery ranged from 13 to 15 percent.

Indicator Limitations

- The data in this indicator are derived from economic statistics on materials generation and estimates of the life cycle of goods, rather than on direct measurements of wastes disposed of. As a result of this methodology and especially of differences in definitions, the figures reported in this indicator do not match estimates of

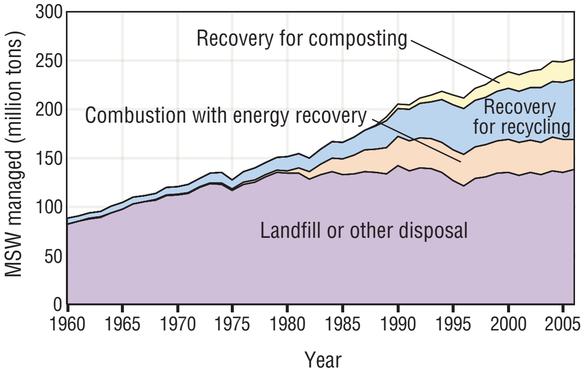
Exhibit 4-12. Municipal solid waste generation in the U.S., 1960-2006





Data source: *U.S. EPA, 2007*

Exhibit 4-13. Municipal solid waste management in the U.S., 1960-2006



Data source: *U.S. EPA, 2007*

INDICATOR | Quantity of Municipal Solid Waste Generated and Managed *(continued)*

MSW reported elsewhere (e.g., *BioCycle,* which includes construction and demolition debris, industrial wastes, agricultural wastes, etc., in its estimates). However, the waste categories in this indicator are rigorously defined and consistent from year to year, therefore allowing for reliable long-term trend analyses.

- The data presented on landfills represent the amount of waste disposed in landfills, but do not indicate the capacity or volume of landfills or the amount of land used for managing MSW. Land used for recycling facilities and waste transfer stations also is not included in this indicator. Data to describe the amount of land used or total capacity of landfills are not available nationally.
- The data also do not indicate the status or effectiveness of landfill management or the extent to which contamination of nearby lands does or does not occur.

Data Sources

Exhibits 4-12 and 4-13 are derived from data published in U.S. EPA (2007). The report provides tables with numerical values for certain key years during the period of record (1960, 1970, 1980, 1990, 1995, 2000, 2002, and 2004-2006). However, the full 44-year data set is not publicly available.

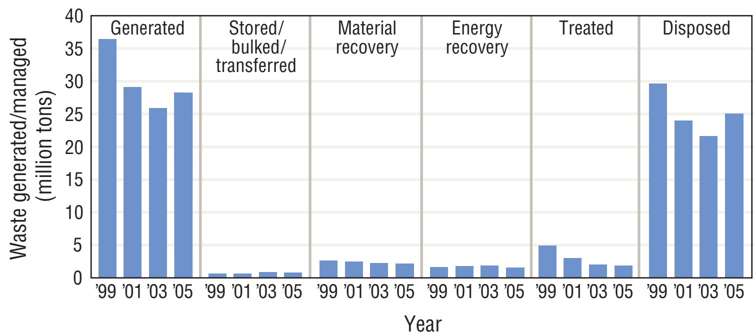
References

U.S. EPA (United States Environmental Protection Agency). 2007. Municipal solid waste generation, recycling, and disposal in the United States: Facts and figures for 2006. <http://www.epa.gov/epaoswer/non-hw/muncpl/msw99.htm>

INDICATOR | Quantity of RCRA Hazardous Waste Generated and Managed

Hazardous waste is waste with a chemical composition or other property that makes it capable of causing illness, death, or some other harm to humans and other life forms when mismanaged or released into the environment. Uncontrolled dumping of wastes, including hazardous industrial wastes, was commonplace in history, with numerous entities handling and disposing of these materials. Landfills and surface impoundments containing these materials were unlined and uncovered, resulting in contaminated ground water, surface water, air, and soil. Even with tight control of hazardous wastes from generation to disposal, the potential exists for accidents that could result in the release of hazardous wastes and their hazardous constituents into the environment. Through the Resource Conservation and Recovery Act (RCRA) and the subsequent 1984 Hazardous and Solid Waste Amendments, Congress sought to better control waste management and disposal and to conserve valuable materials and energy resources.

Exhibit 4-14. RCRA hazardous waste generation and management in the U.S., 1999-2005[a]



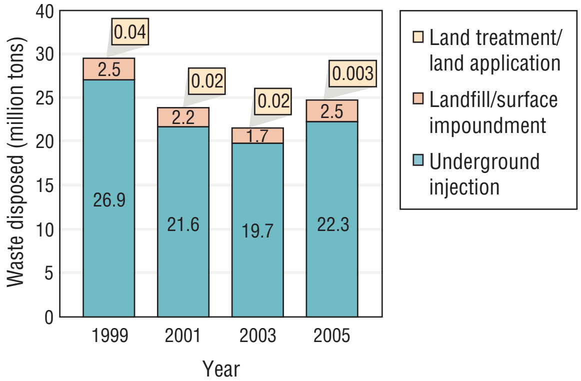
[a]Individual management practice quantities do not add up to the total quantity generated. See text for details.

Data source: *U.S. EPA, 2007b*

Facilities that treat, store, or dispose of hazardous wastes are termed RCRA treatment, storage, and disposal facilities (TSDFs). Some hazardous waste generators treat, store, and dispose of their hazardous waste onsite, while others ship their waste to TSDFs. Most hazardous wastes are eventually disposed in landfills, surface impoundments (which eventually become landfills), land application units, or by deep well injection. All hazardous wastes disposed of must meet certain treatment standards required by the Land Disposal Restrictions prior to disposal.

INDICATOR | Quantity of RCRA Hazardous Waste Generated and Managed *(continued)*

Exhibit 4-15. RCRA hazardous waste disposal to land in the U.S. by practice, 1999-2005



Data source: *U.S. EPA, 2007b*

EPA, in partnership with the states, collects extensive data on the RCRA hazardous waste generation and management practices of TSDFs and large quantity generators (businesses that generate more than 2,200 pounds of RCRA hazardous waste, 2.2 pounds of RCRA acute hazardous waste, or 220 pounds of spill cleanup material contaminated with RCRA acute hazardous waste in 1 month). These data are collected every 2 years; this indicator tracks changes in RCRA hazardous wastes generated and managed for the years 1999, 2001, 2003, and 2005.

What the Data Show

Between 1999 and 2005, the quantity of RCRA hazardous wastes generated decreased by 22 percent from 36.1 million tons (MT) to 28.0 MT (Exhibit 4-14). Included in the amount generated are material recovery, energy recovery, treatment, and wastes disposed by deep well injection. Due to RCRA hazardous waste regulations and data collection procedures, the individual management categories discussed below cannot be added together to obtain the total quantity generated. For example, under RCRA, all hazardous waste must be treated to meet technology-based land disposal treatment standards before it is placed in or on the ground, unless it meets those standards as generated. To minimize double-counting, the quantities of waste stored, bulked, transferred, or disposed by landfill, land treatment, or land application after treatment are not included in the total quantity generated, but are shown in the "Disposed" section of Exhibit 4-14 (along with wastes disposed by deep well injection).

In addition to the 36.1 MT of RCRA waste generated in 1999, 0.7 MT were stored/bulked/transferred for some time prior to final disposition (at which time they would be included in wastes recovered, treated, or disposed) (Exhibit 4-14). In 2005, the number stored/bulked/transferred rose to 0.8 MT.

Looking at management activities prior to disposal, in 1999, 7 percent of RCRA hazardous waste was sent to material recovery activities such as metal or solvent recovery, while 8 percent fell into this category in 2005 (Exhibit 4-14). The proportion of RCRA hazardous waste sent for energy recovery increased from 4 percent of RCRA wastes generated in 1999 to 6 percent in 2005. The proportion sent to treatment declined from 14 percent in 1999 to 7 percent in 2005.

The quantity of RCRA hazardous wastes ultimately disposed dropped between 1999 and 2005, from 29.5 MT to 24.9 MT; however, the proportions of waste in the three disposal categories remained fairly stable (Exhibit 4-15). In the four reporting cycles shown, the percentage of disposed RCRA hazardous wastes deep-well injected ranged from 90 to 92 percent of all waste disposed on land. The proportion disposed in landfills or surface impoundments that became landfills ranged between 8 and 10 percent. The land application and land treatment categories represent a very small percentage of disposal and dropped from 0.1 percent in 1999 to 0.01 percent of the RCRA hazardous waste disposed in 2005.

Indicator Limitations

- Data are not collected from small quantity generators, but some wastes coming from these sources *are* included in the RCRA hazardous waste management data from treatment, storage, and disposal facilities that receive the wastes.
- Data are limited to wastes referred to as "RCRA hazardous waste" which are either specifically listed as hazardous or meet specific ignitability, corrosivity, reactivity, or toxicity criteria found in the U.S. Code of Federal Regulations Title 40, Part 261. Materials that are not wastes, whether hazardous or not, are not regulated by RCRA, and therefore are not included in the data summarized here.
- States have the authority to designate additional wastes as hazardous under RCRA, beyond those designated in the national program. State-designated hazardous wastes are not tracked by EPA or reflected in the aggregated information presented.
- The comparability of year-to-year amounts of RCRA hazardous waste generated and managed can be influenced by factors such as delisting waste streams (i.e., determining that a particular listed waste stream coming from a particular facility is not hazardous) or removing the hazardous characteristic of a waste stream.

INDICATOR | Quantity of RCRA Hazardous Waste Generated and Managed *(continued)*

- The data summarized and shown in Exhibits 4-14 and 4-15 were derived from the data and information collected and reported in the Biennial RCRA Hazardous Waste Report Forms (U.S. EPA, 2007a). As a result of methodology and criteria used to derive the results for these two exhibits, the quantities presented in this indicator do not match those individual generation or management quantities presented in each reporting cycle of the National Biennial Reports. The National Biennial Reports are prepared for individual reporting cycles and may not be comparable between reporting cycles due to different reporting requirements or methods of aggregation in each cycle.
- Most hazardous waste generated in the U.S. is in the form of wastewater. The majority of these wastewaters are sent untreated to publicly owned treatment works (POTWs), treated and sent to a POTW, or discharged directly to surface waters through a National Pollutant Discharge Elimination System (NPDES) permit. Hazardous wastewaters generated and subsequently sent to POTWs or discharged through a NPDES permit are not included in this indicator. Any materials generated from these processes, such as sludge, that are considered hazardous waste are managed under hazardous waste regulations.

Data Sources

This indicator is based on the publicly available data sets compiled by EPA. The data sets compiled from individual reporting facilities for this indicator can be found in National Biennial RCRA Hazardous Waste Data Files in EPA's RCRAInfo national database (U.S. EPA, 2007b) (http://www.epa.gov/epaoswer/hazwaste/data/index.htm#rcra-info; ftp://ftp.epa.gov/rcrainfodata).

Exhibits 4-14 and 4-15 are derived from reported data stored in these data files of the RCRAInfo national database. The versions of data sets from each reporting cycle to derive the results for this indicator were downloaded from the FTP site between February 2007 and August 2007. The analyses based on the data sets downloaded were conducted in October 2007.

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U.S. EPA. 2007b. RCRAInfo national database. Accessed December 2007. <ftp://ftp.epa.gov/rcrainfodata>

4.4.3 Discussion

What These Indicators Say About Trends in Wastes and Their Effects on Human Health and the Environment

The indicators show that municipal solid waste generation in the U.S. continued to rise between 1960 and 2006, in absolute terms. On a per capita basis, rates rose from 1960 to 1990; however, since 1990, the daily per capita generation of municipal solid waste has been relatively constant, showing that the total increase in waste may be primarily a function of population growth. Hazardous waste, which is generated primarily through industrial processes, decreased in the time period shown from 1999 to 2005, although there was a small rise between 2003 and 2005.

Materials recovery, or recycling, is an important component of waste management, as it takes materials that might be considered waste and removes them from the waste disposal path to generate reusable marketable materials. Recycling efforts related to municipal solid waste have increased over the last four decades, showing the steepest increases between 1980 and 2000. Municipal solid waste recycling efforts have been steady since 2000, with nearly a third of all municipal solid waste being recycled or composted.

Recycling (material recovery and energy recovery) of hazardous wastes has remained relatively constant over the time span represented by the indicators, although there has been a slight decrease in the amount of waste sent for materials recovery.

While recycling and composting have increased over the past several decades, most wastes are disposed. Disposal of municipal solid wastes in landfills saw a rise in absolute amount from 1960 to 1990, with declines since then. Landfill as a percentage of total waste generated, however, has seen a steady decline from 1960 to 2006. Similarly, most hazardous wastes are also land-disposed, although they are required to meet strict standards for protecting human health and the environment prior to disposal.

Limitations, Gaps, and Challenges

While numerous waste-related data collection efforts exist at the local, state, and national levels, none of these efforts result in nationally consistent or comprehensive data to provide a full understanding of the amount and locations of waste generation and management.

The two types of waste addressed in the indicators represent only a small percentage of the total amount of waste generated in the U.S.—the national amounts and percentage of total waste are unknown. Quantities of "end-of-stream" wastes, such as municipal solid waste, provide an indication

of changing trends in consumption and economic activities, but do not provide information on the other amounts of waste generated by upstream activities, including resource extraction and manufacturing. EPA is interested in better understanding the comparative amounts of the various types of waste generated, but national data are dated, inconsistent, or generally not available in common units to develop a comprehensive picture of the waste generated in the U.S.

The amount of waste generated and managed may describe ambient conditions in terms of wastes in the environment, but does not provide any indication of the effects on human health or environmental condition. There have been changes in the management of wastes over the past few decades, designed to reduce hazardous and potential exposures, but data that more concretely measure the overall exposure (and thus effects on human health and the environment caused by wastes and waste management practices) are still lacking.

4.5 What Are the Trends in Chemicals Used on the Land and Their Effects on Human Health and the Environment?

4.5.1 Introduction

Many chemicals and chemical products are considered essential to modern life because of the benefits they provide. Some break down quickly, while others persist for long periods of time in the environment and may bioaccumulate in the food chain (e.g., persistent, bioaccumulative, and toxic chemicals [PBTs]).

Introduction of chemicals into the environment occurs through acts of nature (e.g., volcanoes, hurricanes), spills on land, emissions to air, and discharges to water. Chemicals can be released through large- and small-scale industrial and manufacturing activity, in the production and storage of food and consumer products, in efforts to manage or eradicate insect-borne diseases (e.g., West Nile virus, Lyme disease), or through personal actions such as the use and improper disposal of household products (e.g., lawn care materials, pharmaceuticals, cleaning products, batteries, paint, automotive products) or wastes. Deliberate application of chemicals to the land is widespread in agricultural production to increase crop yields and control fungi, weeds, insects, and other pests.

Tracking trends in the use and disposition of chemicals in the U.S. is important to better understand the potential for those chemicals to affect human health and the environment. Many chemicals pose little known hazard to human health or environmental condition, while others pose risk. Many chemicals are recognized as carcinogens.[23] The effects of chemicals on human health and other ecological receptors through environmental exposure can be acute and very toxic, subtle and cumulative over time, or nonexistent. Chemicals can be of concern because of their pervasiveness, potential to accumulate, possibilities of interaction, and often long-term unknown effects on people and the environment (e.g., cancer, mercury in fish). Humans and wildlife may be affected by certain chemicals through direct exposure, including accidental ingestion or inhalation, accumulation and uptake through the food chain, or dermal contact.

Similarly, ecosystems and environmental processes may be compromised or contaminated through the migration and accumulation of chemicals (e.g., via uptake by plants, fugitive dust and volatilization, and migration to water supplies). For example, excessive nutrient loading from over-fertilization can result in runoff that causes adverse effects in aquatic ecosystems.[24] Widespread exposure to, or misuse of, pesticides can harm non-targeted plants and animals (including humans), as well as lead to development of pesticide-resistant pest species.

It is difficult to make generalizations about the effects of chemicals and chemical usage, not only because there are thousands of chemicals, but also because individual chemicals have unique ways of being absorbed and handled by living organisms. The risks associated with chemicals are dependent on many factors, including exposure and toxicity—which can be acute or chronic, and can occur at multiple stages of the chemical life cycle. Different stages in the life cycle of chemicals, such as manufacturing, transport, application or use, runoff, or accumulation, pose different hazards to humans and the environment.

4.5.2 ROE Indicators

The amounts and types of chemicals applied or released to land through agricultural fertilizers are examined as a National Indicator displayed at EPA Regional scale. Three other National Indicators are examined, including toxic chemicals in production-related wastes, pesticide residues in food, and occurrences of pesticide-related incidents reported to poison control centers (Table 4-5).

Trends in the amount of fertilizer used are based on sales data provided by major crop-producing states through a survey conducted each year since 1960. Acreage estimates are from an agricultural census of the 48 contiguous states conducted every 5 years since 1954. Trends in the quantities of Toxics Release Inventory-reported chemical releases are based on annual reports required since 1998 from facilities that meet certain size and usage criteria. Trends in the detection of pesticide residues in food are derived from randomly sampled data collected daily since 1993 from participating states for over 50 different commodities. Trends in reported pesticide incidents are from a pesticide surveillance system that collects data annually from poison control centers around the nation.

[23] U.S. Department of Health and Human Services. 2005. Report on carcinogens. Eleventh edition. Washington, DC: Public Health Service, National Toxicology Program.

[24] Boesch, D.F., D.M. Anderson, R.A. Horner, S.E. Shumway, P.A. Tester, and T.E. Whitledge. 1997. Harmful algal blooms in coastal waters: Options for prevention, control, and mitigation. NOAA Coastal Ocean Program Decision Analysis Series No. 10.

Table 4-5. ROE Indicators of Trends in Chemicals Used on the Land and Their Effects on Human Health and the Environment

National Indicators	Section	Page
Fertilizer Applied for Agricultural Purposes (N/R)	4.5.2	4-30
Toxic Chemicals in Production-Related Wastes Combusted for Energy Recovery, Released, Treated, or Recycled	4.5.2	4-33
Pesticide Residues in Food	4.5.2	4-37
Reported Pesticide Incidents	4.5.2	4-39

N/R = National Indicator displayed at EPA Regional scale

INDICATOR | Fertilizer Applied for Agricultural Purposes

Commercial fertilizers are applied to agricultural crops to increase crop yields. Prior to the 1950s, most farming occurred on small family farms with limited use of chemicals. The shift since then to larger corporate farms has coincided with the use of chemical fertilizers in modern agricultural practices. The three major types of commercial fertilizer used in the U.S. are nitrogen, phosphate, and potash.

Nitrogen (N) is found primarily in the organic form in soils, but can also occur as nitrate. Because nitrate is extremely soluble and mobile, it can lead to nuisance algal growth, mostly in downstream estuaries, and cause contamination of drinking water. Phosphorus (P) occurs in soil in several forms, both organic and inorganic. Phosphorus loss due to erosion is common and phosphate, while less soluble than nitrate, can easily be transported in runoff. Phosphorus/phosphate runoff can lead to nuisance algae and plant growth, often in freshwater streams, lakes, and estuaries. Potash is the oxide form of potassium (K) and its principal forms as fertilizer are potassium chloride, potassium sulfate, and potassium nitrate. When used at recommended application rates, there are few to no adverse effects from potassium, but it is a common component of mixed fertilizers used for high crop yields and is tracked in the fertilizer use surveys conducted.

This indicator shows use of the three major fertilizers in pounds per acre of land per year (expressed as N, P, or K) used for crop production from 1960 to 2005. Data are from an annual survey for agricultural crops conducted by the U.S. Department of Agriculture (USDA) National Agricultural Statistics Service (NASS) and from the Economic Research Service (ERS) Major Land Use series. Acreage used for crop production includes cropland harvested and crop failure as estimated in the ERS series. Cropland estimates as used in this indicator are a subset of agricultural land estimates discussed in the Land Cover and Land Use indicators. NASS also produces an annual *Agricultural Chemical Usage* report on four to five targeted field crops, based on data compiled from the Agricultural Resources Management Survey (ARMS). The ARMS surveys farmers in major agriculture-producing states that together account for a large percentage of crop acreage for corn, soybeans, cotton, and wheat. Results are presented for the years 2005-2006 by EPA Region.

What the Data Show

Based on fertilizer sales data, total use of the three major commercial fertilizers has steadily increased, from 46.2 nutrient pounds per acre per year (lbs/acre/yr) in 1960 to 138 lbs/acre/yr in 2005, an increase of 199 percent (Exhibit 4-16). During this period, cropland used for crop production generally has fluctuated between 290 and 360 million acres with the largest changes occurring between 1969 (292 million acres) and 1981 (357 million acres) (Lubowski et al., 2006). Since 1996, cropland used for crop production has ranged between 321 and 328 million acres (Lubowski et al., 2006). Since 1996, aggregate commercial fertilizer use has fluctuated between 129 and 145 lbs/acre/yr with peak usage in 2004. Since 1960, nitrogen accounted for the steepest increase in use, from 17.0 lbs/acre/yr in 1960 to 81.6 lbs/acre/yr in 2004. Nitrogen currently accounts for about 56 percent of total fertilizer use, up from 37 percent in 1960. During the same period, phosphate and potash use grew more slowly; they remained steady between 25 and 36 lbs/acre/yr each since the late 1960s and now account for approximately 21 percent and 23 percent of total fertilizer usage, respectively.

The four major crops in the U.S.—corn, cotton, soybeans, and wheat—account for about 60 percent of the principal crop acreage and receive over 60 percent of the N, P, and K used in the U.S. Estimates from annual NASS

Acreage reports show that from 1995 to 2006, between 76 and 80 million acres of corn were planted annually. In 2007, nearly 93 million acres were planted (USDA NASS, 2007a). A total of 76.5 million acres of corn were planted during the survey year (2005-2006). Corn acreage is concentrated in the center of the country (EPA Regions 5 and 7), but most EPA Regions grow some corn. Corn typically accounts for more than 40 percent of commercial fertilizer used (Daberkow and Huang, 2006).

The acreage of land planted in cotton was 12.4 million acres in the most recent ARMS survey year (2006) and has ranged between 11 and 16 million acres since 1990. Major cotton-producing states include 17 southern states located in EPA Regions 4, 6, and 9.

Production of winter, durum, and other spring wheat occurred on about 57 million acres in 2006 and is distributed across EPA Regions 5, 6, 7, 8, and 10. Wheat typically accounts for about 10 percent of all commercial fertilizer used (Daberkow and Huang, 2006).

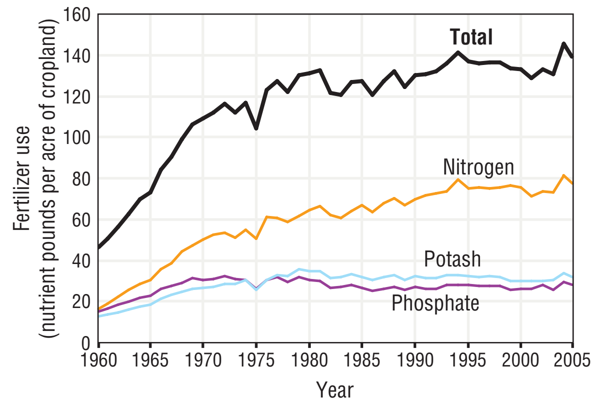
Soybeans were the fastest-growing crop in total acreage, increasing from 57.8 million acres in 1990 to 75.5 million acres in 2006 (USDA NASS, 2007c). The majority of soybean acreage (80 percent) is concentrated in the upper Midwest in EPA Regions 5 and 7. Soybeans require the least fertilizer per acre of the four crops described here.

Overall, production of these four crops in the ARMS states used slightly more than 13.25 million tons per year (MT/yr) of fertilizer in 2005-2006 (Exhibit 4-17) of the 21.7 MT/yr estimated (2005-2006 average) by ERS for all crops produced in the entire U.S. Of this amount, slightly less than half (5.8 MT/yr) was applied in EPA Region 5 (Exhibit 4-17), most of which was used for corn. An additional 3.7 MT/yr was applied in EPA Region 7, primarily on corn or soybeans.

Indicator Limitations

- USDA national estimates of fertilizer use are based on sales data provided by states, not actual fertilizer usage, and are susceptible to differing reporting procedures or accuracy from state to state.
- Data to identify cropland used for crop production are from the major land use series discussed in the Land Cover and Land Use indicators (pp. 4-7 and 4-14, respectively) and do not include Alaska and Hawaii.
- Within the ARMS, not all states report fertilizer data every year for each crop type, making it difficult to establish year-to-year trends (a decrease in fertilizer use for a specific crop might be attributed to failure of a state to report, rather than an actual decrease of use).
- ARMS sampling is limited to program states, which represent 82 to 99 percent of crop acreage (across all surveyed crops) for the years 2005 and 2006, depending on crop type.

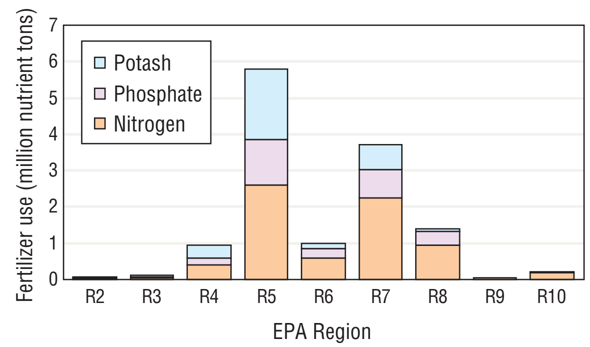
Exhibit 4-16. Commercial fertilizer use in the U.S., 1960-2005[a]



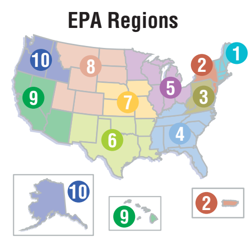
[a]Based on sales data. Per-acre use based on the acreage of harvested or failed cropland, as determined by USDA's National Agricultural Statistics Service.

Data source: *Lubowski, 2006; Wiebe and Gollehon, 2006*

Exhibit 4-17. Fertilizer use for four common crops (corn, cotton, soybeans, and wheat) in major agriculture-producing states, by EPA Region, 2005-2006[a]



[a]**Coverage:** States surveyed by USDA's Agricultural Resource Management Survey (ARMS) Program in 2005-2006 for corn, cotton, soybeans, and wheat. Each commodity was surveyed in a different subset of states, which together account for a substantial portion of the nation's production of that particular commodity. No states in Region 1 were surveyed by the ARMS Program for corn, cotton, soybeans, or wheat.



Data source: *USDA NASS, 2006b, 2007b*

- The NASS *Acreage* report has estimates of acreage in production for the entire nation by crop, while fertilizer sales data are based only on USDA program states. Even though USDA program states represent the majority of U.S. planted acreage (often over 90 percent), the ability to generalize the data to the country as a whole is unknown, as non-program states, while representing a small percentage of a crop, might have much different application rates due to climate, weather, etc.
- Fertilizer applied to trees that are considered agricultural crops (e.g., nut-producing trees) is included in field crop summaries, but fertilizer applied in silviculture (e.g., southern pine plantations) is not covered by the NASS data collection system.
- Loading of nutrients in aquatic systems is not necessarily correlated directly with fertilizer use, but rather with the levels of fertilizer applied in excess of amounts used by crops, natural vegetation, and soil biota.

Data Sources

Exhibit 4-16 is based on two sets of summary data from ERS. Annual estimates of fertilizer use from 1960 through 2005, by nutrient, were obtained from Wiebe and Gollehon (2006) (see summary tables, http://www.ers.usda.gov/Data/FertilizerUse/). Fertilizer use per acre was calculated based on annual estimates of the amount of cultivated (harvested or failed) cropland from 1960 to 2005 published in Lubowski et al. (2006) (see summary tables, http://www.ers.usda.gov/Data/MajorLandUses/MLUsummarytables.pdf).

Exhibit 4-17 is based on fertilizer use data from USDA's 2005 and 2006 ARMS survey, which were obtained from USDA NASS (2006b, 2007b). The published data are by state, so additional aggregation was required to report by EPA Region (USDA NASS, 2001, 2004, 2005a,b, 2006a).

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INDICATOR | Toxic Chemicals in Production-Related Wastes Combusted for Energy Recovery, Released, Treated, or Recycled

Toxic chemicals are contained in waste materials produced by a wide variety of industrial activities, in both public (e.g., sewage treatment plants) and private facilities. These chemical wastes are really a composite matrix of various chemicals, some of which may be hazardous or toxic, and therefore are subject to reporting under the Toxics Release Inventory (TRI) program. Some of these chemicals are released onsite or offsite to air, water, or land (including surface impoundments and underground injection wells). The rest are treated, recycled, or combusted for energy recovery. Reductions in the quantities of TRI chemicals are desirable from both environmental and economic perspectives. TRI chemicals have known toxic properties, rendering them potentially hazardous to workers in both production and waste management facilities, and more generally to ecosystems and human health. As elements of overall business strategies, companies target waste reduction in ways that reduce costs and increase profits.

This indicator tracks trends in the amounts of toxic chemicals in production-related wastes that contain reported TRI chemicals which are either released to the environment or treated, recycled, or combusted for energy recovery. Toxic chemicals in non-production-related waste, such as might be associated with catastrophic events and remedial actions (cleanup), are not included in this indicator because they are not directly related to routine production practices.

TRI contains information on more than 650 chemicals and chemical categories from nine industry sectors, including manufacturing operations, certain service businesses, and federal facilities. Facilities are required to report to TRI if they employ 10 or more employees, are covered by a North American Industry Classification System code corresponding to a TRI-covered Standard Industrial Classification code, and manufacture more than 25,000 pounds, and/or process more than 25,000 pounds, and/or otherwise use more than 10,000 pounds of a TRI-listed non-persistent, bioaccumulative, toxic (non-PBT) chemical during a calendar year. In addition, EPA has lowered the TRI reporting thresholds for certain PBT chemicals (i.e., to 100 pounds or 10 pounds, except for dioxin and dioxin-like compounds, which have a threshold of 0.1 gram) and added certain other PBT chemicals to the TRI list of toxic chemicals. These PBT chemicals are of particular concern not only because they are toxic but also because they remain in the environment for long periods of time, are not readily destroyed, and build up or accumulate in body tissue (U.S. EPA, 2002b). EPA currently requires reporting of 16 PBT chemicals and four PBT chemical compound categories (U.S. EPA, 2007b). In 2005, 23,500 facilities reported to TRI (U.S. EPA, 2007d).

TRI is national in coverage and includes all U.S. territories. Because the reporting requirements for TRI have varied somewhat between 1998 and 2005 (the most recent year for which annual data reports are available in TRI), chemicals that were reported consistently from year to year over this period are presented separately in this indicator. Facilities that manufacture, process, or otherwise use PBT chemicals have lower reporting thresholds as established in 2000 and 2001; hence these data are depicted separately in the exhibits. Similarly, metal mining sector land releases are analyzed separately because a 2003 court decision altered the scope of TRI reporting of these quantities (U.S. EPA, 2007a).[25]

What the Data Show

In 2005 the quantities of TRI non-PBT chemicals associated with production-related wastes tracked in this indicator totaled 23.6 billion pounds (Exhibit 4-18, panel A). These quantities have decreased by more than 4 billion pounds (15.7 percent) since 1998. The decrease was gradual over time with the exception of the year 2000, which saw an increase of 4.3 billion pounds from the previous year. The 2000 increase is attributed to a few facilities that reported large amounts of onsite treatment and onsite recycling (U.S. EPA, 2002a). The amount of TRI non-PBT chemicals reported as treated varied between 1998 to 2005, from a high of nearly 13 billion pounds in the year 2000 to a low of 8 billion pounds in 2002. In 2005, the amount treated was 8.6 billion pounds or 2.9 percent more than in 1998. The amount of TRI non-PBT chemicals recycled declined by 1 billion pounds (11.6 percent) from 1998 to 2005, varying from a high of 9.6 billion pounds in 2000 to the low of 8.2 billion pounds in 2005. TRI non-PBT chemicals managed through energy recovery processes showed a decline of 0.62 billion pounds (17.2 percent) in the 8-year period, fluctuating between 3.0 and 3.7 billion pounds. Some of the year-to-year fluctuations may reflect changes in aggregate production levels in the national economy.

Reported PBT chemicals totaled 1.13 billion pounds in 2005, having declined by 0.18 billion pounds (13.9 percent) over recent years since 2001 (Exhibit 4-18, panel B). The amount of PBT chemicals recycled declined by 26.6 percent between 2001 and 2005 (0.22 billion pounds).

Excluding metal mining and PBT chemical releases, approximately 3.1 billion pounds of toxic chemicals were

[25] The metal mining sector consists of facilities that fall within Standard Industrial Classification Code 10 and must report to TRI in accordance with Section 313 of the Emergency Planning and Community Right to Know Act.

INDICATOR | Toxic Chemicals in Production-Related Wastes Combusted for Energy Recovery, Released, Treated, or Recycled *(continued)*

released offsite or onsite to air, land, or water in 2005. The 3.1 billion pounds of releases in 2005 are 18.6 percent less than the amount reported in 1998 (Exhibit 4-19, panel A). The remaining 19.6 billion pounds of non-PBT chemicals from all TRI sectors except metal mining were managed (onsite or offsite) through treatment, recycling, and energy recovery processes and represent an 8 percent decline from 1998.

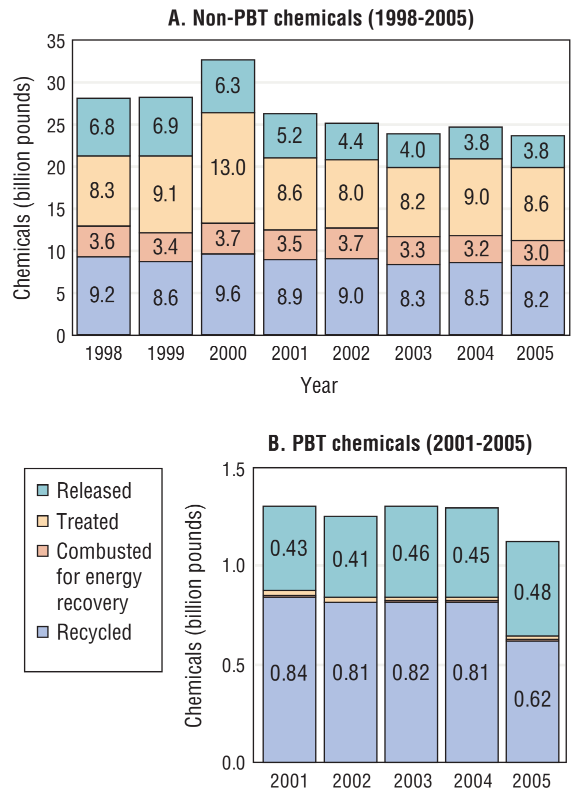
Excluding metal mining releases, nearly 0.082 billion (82 million) pounds of PBTs were released offsite or onsite to air, land, or water in 2005 (Exhibit 4-19, panel B). The remaining approximately 0.725 billion (725 million) pounds were managed (onsite or offsite) through treatment, recycling, and energy recovery processes. The amounts of reported PBT releases (excluding metal mining) have fluctuated, ranging from approximately 110 million pounds in 2003 to 79 million pounds in 2004 and 83 million pounds in 2005.

Between 1998 and 2005 there were also distinct trends in media-specific and offsite releases of non-PBT toxic chemicals (Exhibit 4-19, panel A). All of these releases exclude metal mining. Air releases declined by 28.1 percent (585 million pounds) between 1998 and 2005. Releases to surface waters decreased by 2 percent (nearly 6 million pounds) and land releases dropped by nearly 18 percent (183 million pounds). Offsite releases, which cannot be apportioned by medium in TRI, rose by 72 million pounds or 18 percent from 1998 to 2005.

PBT chemicals (also excluding metal mining) released to air increased nearly 108 percent (3 million pounds) (Exhibit 4-19, panel B). PBT releases to land decreased 24 percent (14 billion pounds) and to water 22 percent (0.035 million pounds). Offsite PBT releases increased nearly 8 percent (2.3 million pounds).

Excluding PBT chemicals, the metal mining sector accounted for 35 percent of the total production-related wastes released to the environment over the 8-year period from 1998 through 2005, releasing approximately 14 billion pounds of total production-related wastes (Exhibit 4-20, panel A) compared to 27 billion pounds reported by all other industry sectors (Exhibit 4-19, panel A). Nearly all of the production-related wastes managed by metal mining facilities were releases to land. There is a downward trend for the quantities of total releases reported by the metal mining sector from 2001 to 2005 (Exhibit 4-20, panel A). In 2001, the metal mining industry reported nearly 2 billion pounds in total releases, and in 2005, only 0.77 billion pounds were reported. Part of this trend can be attributed to the court decision (*Barrick Goldstrike Mines, Inc., v. EPA*) in 2003, in which the court determined that non-PBT chemicals present in the waste rock below concentrations of 1 percent (or 0.1 percent for Occupational Safety and Health Administration defined carcinogens) are eligible for

Exhibit 4-18. Quantities of toxic chemicals combusted for energy recovery, released, recycled, and treated in the U.S., as reported to EPA's Toxics Release Inventory, 1998-2005[a,b,c]



	2001	2002	2003	2004	2005
Released	0.43	0.41	0.46	0.45	0.48
Treated	0.02	0.03	0.02	0.02	0.02
Combusted for energy recovery	0.01	0.01	0.004	0.01	0.01
Recycled	0.84	0.81	0.82	0.81	0.62
Total	**1.31**	**1.25**	**1.30**	**1.29**	**1.13**

[a]**Coverage:** Production-related waste from facilities required to report to TRI, including more than 650 chemicals and chemical categories. Persistent, bioaccumulative, and toxic (PBT) chemicals are presented separately because reporting thresholds were changed partway through the period of record.

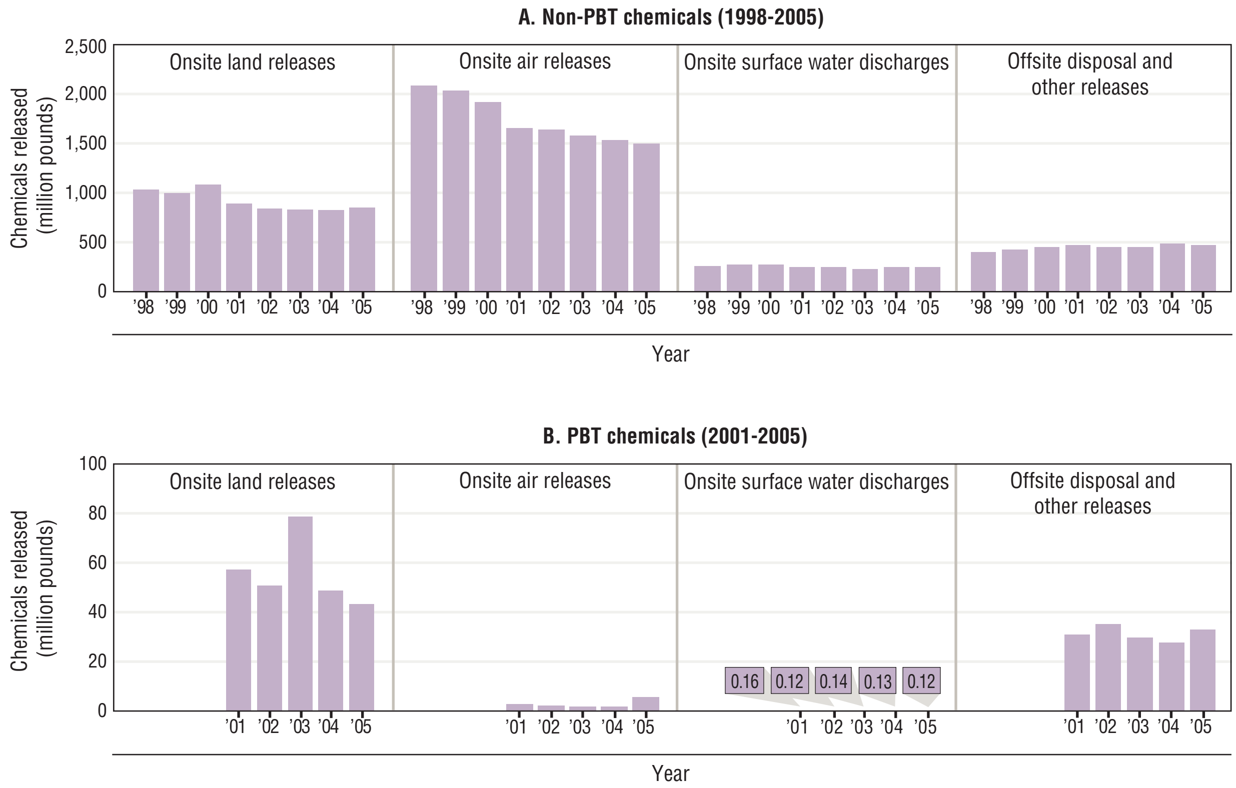
[b]Some waste quantities may be double-counted when waste has been transferred from one TRI facility (which has counted waste as offsite disposal or as other releases) to another TRI facility (which has counted transferred waste as onsite disposal or as releases to air, land, or water).

[c]Percentages reported in the "What the Data Show" section are based on the original data, which include more significant figures than shown in this exhibit.

Data source: *U.S. EPA, 2007e*

INDICATOR | Toxic Chemicals in Production-Related Wastes Combusted for Energy Recovery, Released, Treated, or Recycled *(continued)*

Exhibit 4-19. Quantities of toxic chemicals released in the U.S., by type of release (excluding metal mining), as reported to EPA's Toxics Release Inventory, 1998-2005[a,b]



[a]**Coverage:** Production-related waste from facilities required to report to TRI, including more than 650 chemicals and chemical categories. Persistent, bioaccumulative, and toxic (PBT) chemicals are presented separately because reporting thresholds were changed partway through the period of record.

[b]Some waste quantities may be double-counted when waste has been transferred from one TRI facility (which has counted waste as offsite disposal or as other releases) to another TRI facility (which has counted transferred waste as onsite disposal or as releases to air, land, or water).

Data source: *U.S. EPA, 2007e*

the *de minimis* exemption. For TRI reporting purposes, the *de minimis* exemption allows facilities to disregard certain minimal concentrations of non-PBT chemicals in mixtures or other trade name products when making threshold determinations and release and other waste management calculations (U.S. EPA, 2007a,c).

The 1.8 billion pounds of released PBT chemicals associated with metal mining make up 80 percent of all PBT chemicals released between 2001 and 2005 (Exhibit 4-20, panel B). Nearly all of these (99.9 percent) are associated with releases to land. Releases of PBTs by the metal mining sector were 16.6 percent higher (56.7 million pounds) in 2005 than in 2001.

Indicator Limitations

- TRI data reflect only "reported" chemicals, and not all chemicals with the potential to affect human health and the environment. TRI does not cover all toxic chemicals or all industry sectors. The following are not included in this indicator: (1) toxic chemicals that are not on the list of approximately 650 toxic chemicals and toxic chemical categories, (2) wastes from facilities within industrial categories that are not required to report to TRI, and (3) releases from small facilities with fewer than 10 employees or that manufactured or processed less than the threshold amounts of chemicals.

INDICATOR | Toxic Chemicals in Production-Related Wastes Combusted for Energy Recovery, Released, Treated, or Recycled *(continued)*

- TRI chemicals vary widely in toxicity, meaning that some low-volume releases of highly toxic chemicals might actually pose higher risks than high-volume releases of less toxic chemicals. The release or disposal of chemicals also does not necessarily result in the exposure of people or ecosystems.
- Vanadium releases were measured beginning in 2001; because the overall amounts were small relative to the other wastes, they are included in the 2001 to 2005 data for non-PBTs.
- National trends in toxic chemicals in wastes released to the environment are frequently influenced by a dozen or so large facilities in any particular reporting category. These trends may not reflect the broader trends in the more than 23,000 smaller facilities that report to TRI each year.
- Some facilities report offsite transfers for release to other TRI-covered facilities that report these quantities as onsite releases. This double-counting of release quantities is taken into account in the case of release for all sectors in total, but not for releases within individual sectors. This may cause some discrepancy in certain release numbers for specific sectors when compared with release data on all sectors.

Data Sources

This indicator is based on data and information from EPA's TRI Explorer database (U.S. EPA, 2007e), an online tool that allows users to generate customized reports on toxic releases reported to TRI and other online resources (U.S. EPA, 2005).

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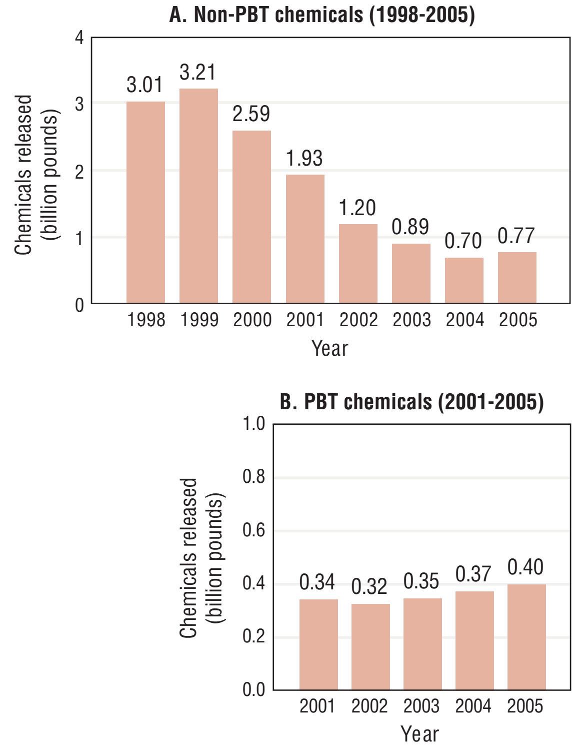
Exhibit 4-20. Quantities of toxic chemicals released in the U.S. by the metal mining sector, as reported to EPA's Toxics Release Inventory, 1998-2005[a,b,c]



[a]**Coverage:** Production-related waste from facilities required to report to TRI, including more than 650 chemicals and chemical categories. Persistent, bioaccumulative, and toxic (PBT) chemicals are presented separately because reporting thresholds were changed partway through the period of record.

[b]Some waste quantities may be double-counted when waste has been transferred from one TRI facility (which has counted waste as offsite disposal or as other releases) to another TRI facility (which has counted transferred waste as onsite disposal or as releases to air, land, or water).

[c]Percentages reported in the "What the Data Show" section are based on the original data, which include more significant figures than shown in this exhibit.

Data source: *U.S. EPA, 2007e*

U.S. EPA. 2002a. 2000 Toxics Release Inventory (TRI) public data release report. EPA/260/R-02/003. <http://www.epa.gov/tri/tridata/tri00/index.htm>

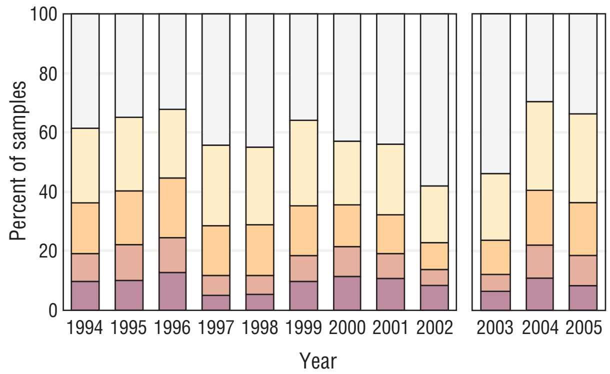
U.S. EPA. 2002b. 2000 Toxics Release Inventory (TRI) public data release report, Executive Summary. EPA/260/S-02/001 <http://www.epa.gov/tri/tridata/tri00/press/execsummary_final.pdf>

INDICATOR | Pesticide Residues in Food

Pesticides are substances or mixtures of substances intended for preventing, destroying, repelling, or mitigating plant or animal pests and may include herbicides, insecticides, fungicides, and rodenticides. More than a 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 (Aspelin, 2003). Some of these compounds can be harmful to human health if sufficient quantities are ingested, inhaled, or otherwise contacted (see the Urinary Pesticide indicator, p. 5-22). Potential health effects and primary exposure routes vary by chemical. The most common routes of exposure for the general population are ingestion of a treated food source and contact with applications in or near residential sites. Pesticides may also be harmful in the environment when non-target organisms are exposed (U.S. EPA, 2007).

This indicator represents data from the U.S. Department of Agriculture's Pesticide Data Program (PDP), which measures residue levels for hundreds of pesticides and their metabolites in fruits, vegetables, grains, meat, and dairy products from across the country, sampling different combinations of commodities each year. The analysis examines pesticides currently on the market and also includes continued testing for some persistent and bioaccumulative pesticides that have been banned since the 1970s, such as aldrin/dieldrin, heptachlors, and DDT and its metabolites. PDP data collection began in 1991 and includes both domestic and foreign-produced commodities. Results are published in annual reports, which include statistics on the number of pesticide residues detected, the number of residues exceeding the tolerance established by EPA for a given pesticide-commodity pair (Code of Federal Regulations, Title 40, Part 180), and the number of residues detected for which no tolerance has been established. This indicator depicts data from 1994 to 2005; data from before 1994 are considered less reliable. Between 1994 and 2005, the number of food samples analyzed per year ranged from 5,771 (1996) to 13,693 (2005), with a general increase over time.

Exhibit 4-21. Pesticide detections in food in the U.S., 1994-2005[a,b]



[a]**Coverage:** Based on a survey of fruits, vegetables, grains, meat, and dairy products across the U.S., with different combinations of commodities sampled in different years. Samples were analyzed for more than 290 pesticides and their metabolites.

[b]Data from 2003 to 2005 are not comparable to prior years due to a difference in how detects were counted. Prior to 2003, each compound detected was counted as a separate "residue." Beginning in 2003, parent compounds and their metabolites were combined to report the number of "pesticides." For example, a sample with positive detections for endosulfan I, endosulfan II, and endosulfan sulfate would have been counted as three residues in 2002. In 2003, this sample would have been counted as one pesticide detection.

Number of residues detected:[b]
- 0
- 1
- 2
- 3
- 4 or more

Data source: *USDA Agricultural Marketing Service, 1996-2006a,b*

What the Data Show

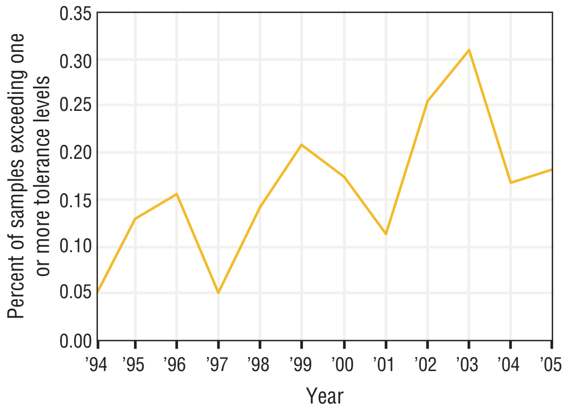
The percent of samples with no detectable pesticide residues generally increased during the period from 1994 to 2002 (Exhibit 4-21). Samples with no detects accounted for 38.5 percent of samples analyzed in 1994 and rose to 57.9 percent of samples in 2002. Data for 2003 and thereafter cannot be compared directly to the previous years' data due to a change in the way that detects are counted. Data for 2004 and 2005 show a lower percentage of samples with no detects than 2003 data, going from 53.9 percent of samples in 2003 to 29.5 percent in 2004 and 33.7 percent in 2005. The largest jump in detects in the 2003-2004 time frame was in those samples with detection of one pesticide or metabolite. These trends in number of detections have occurred at the same time that analytical limits of detection for various compounds have been decreasing, allowing the instruments to pick up ever smaller concentrations.

Exhibit 4-22 illustrates the percentage of samples in which at least one pesticide residue was detected at a concentration exceeding the tolerance established by EPA for a given pesticide-commodity pair. The percentage of samples exceeding EPA tolerance values increased from 0.05 percent in 1994 to 0.31 percent in 2003. Compared to 2003, the last 2 years of data show a drop in exceedances, with 0.17 percent in 2004 and 0.18 percent in 2005.

Indicator Limitations

- As Exhibit 4-21 explains, pesticide detection data from 2002 and earlier cannot be compared directly with data gathered after 2002. (Before 2003, each compound detected was counted separately; beginning in 2003, measurement of a parent compound and/or any of its metabolites was counted as a single detect.)

Exhibit 4-22. Pesticides exceeding EPA tolerance levels in food in the U.S., 1994-2005[a]



[a]**Coverage:** Based on a survey of fruits, vegetables, grains, meat, and dairy products across the U.S., with different combinations of commodities sampled in different years. Samples were analyzed for more than 290 pesticides and their metabolites.

Data source: *USDA Agricultural Marketing Service, 1996-2006a,b*

- The PDP does not sample all commodities over all years, so some gaps in coverage exist. Differences in the percent of detections for any given pesticide class might not be due to an increase (or decrease) in the predominance of detectable residues. Instead, these differences might simply reflect the changing nature and identity of the commodities selected for inclusion in any given time frame.
- The indicator measures pesticide residue related to dietary intake, which does not directly correlate to toxicological effects in humans or effects on the environment.

Data Sources

Data for this indicator were obtained from a series of annual summary reports published by the PDP (USDA Agricultural Marketing Service, 1996-2006). These reports are all available from http://www.ams.usda.gov/science/pdp/. The Food and Drug Administration also collects data (not reported here) on pesticide residues in cooked food that may be a source of chemicals in human diets. These data are available at http://www.cfsan.fda.gov/~dms/pesrpts.html.

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INDICATOR | Reported Pesticide Incidents

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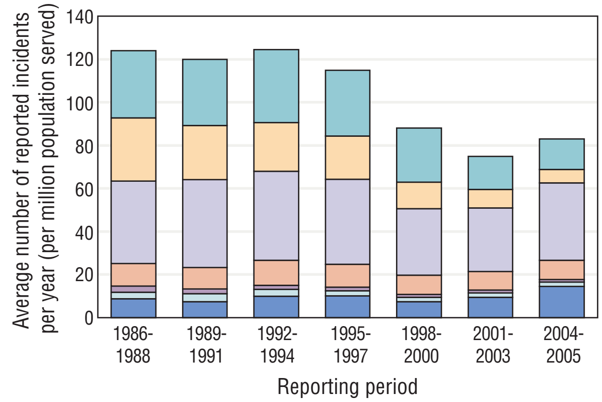
Although pesticides play a role in protecting human health, food, and crops, they pose a risk of poisoning when not used and/or stored properly. The American Association of Poison Control Centers (AAPCC) collects statistics on poisonings and represents the single largest source of information on acute health effects of pesticides resulting in symptoms and requiring health care (Calvert et al., 2001). The data include incidents related to individual pesticides and to mixtures of products (about 8 percent of reports). The data also include intentional exposures (suicide attempts and malicious use), which account for less than 3 percent of reports. The AAPCC uses the Toxic Exposure Surveillance System (TESS) to collect information on all reported incidents.

This indicator is based on data from TESS-published reports for the years 1986 through 2005. During this period, at least 50 percent of the U.S. population was covered by poison control centers (PCCs) reporting to the national database. Annual reports of incidents were divided by the percent of U.S. population served to estimate the total incidents nationwide, and divided by the total U.S. population to develop the incidence rate. Only calls with known outcomes are reported here; this may introduce some bias, because the percent of all reported pesticide incidents with a known outcome declined from 71 percent in 1986-1988 to just 41 percent in 2004-2005. The 2004-2005 data are averaged over 2 years; all other data are grouped into 3-year periods and presented as average annual rates to facilitate identification of trends.

Exhibit 4-23. Reported pesticide incidents per million U.S. population by type of pesticide, 1986-2005[a,b]



[a]This indicator tracks pesticide incidents reported to poison control centers (PCCs) that report to the AAPCC national database. The rate of reported incidents is calculated based on the population served by these PCCs.

[b]The 2004-2005 data are averaged over 2 years. All other data are averaged over 3-year intervals.

Data source: *Lai et al., 2006; Litovitz et al., 1987-2002; Watson et al., 2003-2005*

What the Data Show

Between the 1986-1988 and 2001-2003 periods, there was an overall 40 percent decline in reported pesticide incidents in the U.S. In 2004-2005, however, there was a slight rise compared to 2001-2003, primarily in the "other insecticides" and "all other pesticides" categories (Exhibit 4-23). The single largest decline occurred for the category of organophosphate (OP) insecticides, which saw nearly a 79 percent drop in reported incidents between 1986-1988 and 2004-2005. Part of the decline in reported OP-related incidents may be due to the substitution of other, less toxic insecticides for some of the OPs over time.

Indicator Limitations

- Misclassification of incidents may occur when incidents reported over the phone are not verified by laboratory tests. For example, a child found holding a pesticide container may not have actually been exposed, but if a call is received by a PCC poison specialist who determines that the reported symptoms were consistent with the toxicology, dose, and timing of the incident, the call will be registered as an incident. About 13 percent of calls to PCCs arise from health care professionals, but the majority are calls made by victims or their relatives or caretakers. Although some misclassification can be expected to occur, it is assumed to be non-differential among the different types of pesticides.
- Only calls with known outcomes are reported in this indicator. This may introduce some bias, because the percent of all reported pesticide incidents with known outcomes declined from 71 percent in 1986-1988 to just 41 percent in 2004-2005.
- The data collection process is standardized for PCCs, but is a passive system. Under-reporting of incidents is a serious shortcoming. Studies show that medical facilities generally report between 24 and 33 percent of incidents from all substances to PCCs (Chafee-Bahamon et al., 1983; Harchelroad et al., 1990; Veltri et al., 1987).
- Data are collected by multiple poison centers, with follow-up likely performed in different ways.

Data Sources

This indicator is based on summary data from annual reports published by the TESS (Litovitz et al., 1987-2002; Watson et al., 2003-2005; Lai et al., 2006) (available from http://www.aapcc.org/poison1.htm). Annual data from these reports were grouped into 3-year periods, with the exception of 2004-2005 where only 2 years of data were grouped together, and incidence rates were calculated from the population served by participating PCCs; population figures can also be found in the annual reports. Only summary data are publicly available; raw data from individual cases are considered confidential.

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4.5.3 Discussion

What These Indicators Say About Trends in Chemicals Used on the Land and Their Effects on Human Health and the Environment

These indicators provide information on aspects of chemical use and effects. Data are presented on the amounts and types of chemical usage for two large sectors of the U.S. economy—agriculture and manufacturing. The disposition of pesticides in food and the number of reported pesticide incidents are examined. Two indicators describe stressors to the environment from chemical usage.

The amount of chemicals deliberately applied to agricultural land as commercial fertilizer has increased over the last 40 years (Agricultural Fertilizer indicator, p. 4-30). Per acre total fertilizer use has nearly tripled since 1960, with peak usage occurring in 2004. Total nitrogen use has more than quadrupled over the same period. While fertilizers themselves are not inherently harmful, when applied improperly or in quantities above the level taken up by crops, streamside vegetation, or soil biota, they have the potential to contaminate ground water and surface water in agricultural watersheds and estuaries. Fertilizer usage in recent years, for major crops, appears concentrated in the states surrounding the Mississippi River.

The Toxics Release Inventory (TRI) data (Toxic Chemicals in Wastes indicator, p. 4-33) show a small but steady decline in the quantities of TRI chemicals released to all media between 1998 and 2005, with the exception of offsite releases (persistent, bioaccumulative, and toxic or otherwise), which increased slightly.

Residues of potentially harmful substances used in food production, such as some pesticides, are assessed under food protection programs. While national-level indicators on the use and application of pesticides and pesticide loads in soil are lacking, the Pesticide Residues in Food indicator (p. 4-37) is an indirect measure of ambient conditions, providing insight into potential exposures from the most widely used pesticide products on the market. The indicator shows that between 2003 and 2005 (after a change in sampling technique), pesticide residues were detected in 46 percent of the food commodities tested in 2003 and in 66 to 71 percent of the food commodities tested in 2004 and 2005. Currently available technology used in the U.S. Department of Agriculture's Pesticide Data Program sampling can detect pesticide residues at concentrations that are orders of magnitude lower than those determined to have potential human health effects. Therefore, the number of pesticide detections that exceed federally established tolerance levels is perhaps more relevant. Results over the years suggest less than 1 percent of commodities tested were above tolerance levels.

Similarly, the Pesticide Incidents indicator (p. 4-39) provides information on the potential for human exposure to toxic substances through misuse. Reported incidents of pesticide exposure, which represent accidental exposure to a pesticide that is readily available to the public, declined between 1986 and 2003, then rose slightly in 2004-2005. The largest decline occurred in organophosphate compounds, a group of insecticides that are acutely toxic to humans (and other vertebrates) but do not accumulate in the environment, unlike other toxic materials (or compounds containing them) such as chromium, arsenic, and heavy metals.

LAND

Limitations, Gaps, and Challenges

While chemicals in soil or on plants may be an initial pathway into the environment, it is the movement and concentration of chemicals through the food chain that are often of greatest concern, as well as exposures from other media such as contaminated water or air. The indicators provide information on a relatively small universe of toxic chemicals and only limited information on the potential exposures humans may experience as a consequence of chemical use.

Fertilizer use in agriculture has been identified as one of the principal uses of chemicals responsible for nutrient loading into non-targeted water bodies and for nonpoint source loading of nutrients within agricultural watersheds.[26] Actual fertilizer use data are not available nationally. The Agricultural Fertilizer indicator (p. 4-30) is supported by sales data that do not consider mitigating factors (e.g., slow-release formulations) or agricultural practices that reduce runoff. The cost of fertilizer accounts for a relatively high percentage of agricultural costs, so it is generally assumed that purchased products eventually are applied in agricultural operations. Agricultural sources of fertilizer, however, are only estimated to be 85 percent of all sources, with the remaining being primarily professional lawn care, consumer retail, and golf courses. The usage patterns associated with these nonagricultural sources are unknown. Additionally, the urban and suburban watersheds, where these non-tracked uses occur, are also locations where nutrient runoff may result from other sources such as turf runoff, septic systems, and sewage treatment plants.

The indicators do not provide information related to the land application of sludges[27] that may contain toxic metals and other persistent bioaccumulative substances. Sludges may be applied as fertilizer on agricultural or forest land in accordance with EPA requirements, but the implications for wildlife, aquatic organisms, and movement through the food chain are unknown. Additionally, the indicators reported provide only limited information on the potential exposures that target organisms other than humans may experience as a consequence of chemical use.

TRI data include information on a range of chemical categories such as arsenic, cyanide, dioxin, lead, mercury, and nitrate compounds, but do not reflect a comprehensive total of toxic releases nationwide. They do not include all toxic chemicals with the potential to affect human health and the environment, nor do they include all sources of potential releases. Facilities report release and other waste management data using various techniques, which include estimations based on emission factors, mass balancing approaches, engineering calculations, and actual monitoring. Estimation techniques and factors considered may vary widely, making it difficult to ensure the accuracy of reporting. TRI data only represent a portion of the chemical life cycle (e.g., wastes as a result of production) and do not take into account amounts of chemicals incorporated into industrial and/or consumer products that also have the potential to affect the environment and human health when they are used, discarded, or recycled.

There is no existing reporting system that provides information on the volume, distribution, and extent of pesticide use in the U.S. Estimates are developed based on information available through a variety of reports from multiple governmental and non-governmental entities on pesticide sales, crop profiles, and expert surveys. The Pesticide Residues in Food indicator (p. 4-37) provides information on one aspect of the potential for human exposure from pesticides (dietary intake from the commercial food supply), but does not provide a complete picture of all the ways in which humans can be exposed to pesticides, which include contaminated drinking water, pesticide drift, and dermal contact.

4.6 What Are the Trends in Contaminated Land and Their Effects on Human Health and the Environment?

4.6.1 Introduction

There are many settings for contaminated lands, ranging from abandoned buildings in inner cities to large areas contaminated with toxic materials from past industrial or mining activities. Contaminated lands include sites contaminated by improper handling or disposal of toxic and hazardous materials and wastes, sites where toxic materials may have been deposited as a result of wind or flood, and sites where improper handling or accidents resulted in release of toxic or hazardous materials that are not wastes.

Land contamination can result from a variety of intended, accidental, or naturally occurring activities and events such as manufacturing, mineral extraction, abandonment of mines, national defense, waste disposal, accidental spills, illegal dumping, leaking underground storage tanks, hurricanes, floods, pesticide use, and fertilizer application. Sites are categorized in a variety of ways, often based on the level and type of contamination and the regulations under which they are monitored and cleaned up. Box 4-1 provides an overview of the common types of contaminated sites. With the exception of accidental spills and contamination that result from naturally occurring and other unanticipated events, most land contamination is the result of historical activities that are no longer practiced. Hazardous material and waste management and disposal are now highly regulated.

[26] Howarth, R.W., D. Walker, and A. Sharpley. 2002. Sources of nitrogen pollution to coastal waters of the United States. Estuaries 25:656-676.

[27] Sludges are the nutrient-rich organic materials resulting from sewage and wastewater treatment processes. Sludges contain many of the nutrients required for improved plant growth (nitrogen, phosphorus, and potassium) and other organic matter that can improve overall soil condition and increase productivity.

Contaminated soils can leach toxic chemicals into nearby ground or surface waters, where these materials can be taken up by plants and animals, contaminate a human drinking water supply, or volatilize and contaminate the indoor air in overlying buildings. In dry areas, contamination in soil can be further distributed through wind-borne dusts. Once soil contamination migrates to waterways, it may also accumulate in sediments, which can be very difficult to remediate and may affect local ecosystems and human health. Humans can be harmed by contact with toxic and hazardous materials on a contaminated site via exposure to contaminated land, air, surface water, and ground water. When contaminated lands are not properly managed, humans and wildlife can be exposed to contaminants through inhalation, ingestion, or dermal contact. The risks of human exposure are site-specific and difficult to generalize at the national level. Potential effects may be acute or chronic.

Some contaminated sites pose little risk to human health and the environment, because the level of contamination is low and the chance of exposure to toxic or hazardous contaminants is also low. Other contaminated sites are of greater concern because of the chemicals that may be present and their propensity to persist in or move through the environment, exposing humans or the environment to hazards. These sites must be carefully managed through containment or cleanup to prevent hazardous materials from causing harm to humans, wildlife, or ecological systems, both on- and offsite.

Nationally, there are thousands of contaminated sites of varying size and significance. Many sites, particularly the largest

Box 4-1. Categorizing Contaminated Lands

Superfund National Priorities List sites: These sites are seriously contaminated and include industrial facilities, waste management sites, mining and sediment sites, and federal facilities such as abandoned mines; nuclear, biological, chemical, and traditional weapons productions plants; and military base industrial sites (e.g., used for aircraft and naval ship maintenance).

Resource Conservation and Recovery Act (RCRA) Cleanup Baseline facilities: The RCRA Cleanup Baseline is a priority subset of a broader universe of facilities that are subject to cleanup under RCRA due to past or current treatment, storage, or disposal of hazardous wastes and have historical releases of contamination.

Underground storage tanks/leaking underground storage tanks: Businesses, industrial operations, gas stations, and various institutions store petroleum and hazardous substances in large underground storage tanks that may fail due to faulty materials, installation, operating procedures, or maintenance systems, causing contamination of soil and ground water.

Accidental spill sites: Each year, thousands of oil, gas, and chemical spills occur on land and in water from a variety of types of incidents, including transportation (e.g., rail, barges, tankers, pipeline) and facility releases.

Sites contaminated by natural disasters or terrorist activities: Disasters of any sort, naturally occurring or caused by humans, have the potential to contaminate lands and cause problems at already-contaminated sites.

Land contaminated with radioactive and other hazardous materials: Many sites spanning a large area of land in the U.S. are contaminated with radioactive and other hazardous materials as a result of activities associated with nuclear weapons production, testing, and research.

Brownfields: Brownfields are real property where expansion, redevelopment, or reuse may be complicated by the presence or potential presence of a hazardous substance, pollutant, or contaminant. Brownfields are often found in and around economically depressed neighborhoods.

Military bases and defense sites: Some of the millions of acres of land used by the Department of Defense are contaminated from releases of hazardous substances and pollutants; discarded munitions, munitions constituents, and unexploded ordnance; and building demolition and debris.

Low-level area-wide contamination: Some soil contamination problems involve low to moderate levels of contamination that encompass large geographic areas ranging in size from several hundred acres to many square miles. Low-level, area-wide contamination can occur from emissions related to past industrial operations (e.g., smelters), widespread agricultural pesticide applications, combustion of gasoline, and deterioration of lead-based paint.

Past waste management sites and illegal dumping sites: Prior to the 1970s, solid waste was typically placed in unlined landfills that were not adequately designed to prevent adverse environmental impacts to ground water or surface water. Separately, illegal dumping of materials such as construction waste, abandoned automobiles, appliances, household waste, and medical waste, has occurred for decades and still occurs because of convenience and the cost of legal disposal.

Abandoned and inactive mine lands: Abandoned and inactive mines may not have been properly cleaned up, and may have features ranging from exploration holes to full-blown, large-scale mine openings, pits, waste dumps, and processing facilities.

and most severely contaminated, are tracked at the national level, but many others are tracked only at state or local levels. The number and status of contaminated sites changes frequently as sites are newly contaminated (e.g., via spills or hurricanes), discovered, documented, and cleaned up.

4.6.2 ROE Indicators

The ROE indicators for this question focus on the trends in reducing potential threats to human health associated with site contamination at some lands contaminated by a variety of industrial and other activities and from current and past waste management activities (Table 4-6). The indicators address sites on the Superfund National Priorities List and facilities on the Resource Conservation and Recovery Act Cleanup Baseline where human exposure to contamination and migration of contaminated ground water have been documented to be within acceptable established health-based levels.

Trends in the spread of contaminated ground water and potential human exposure to contaminants in excess of health-based standards are assessed through site-specific monitoring and modeling data collected by site personnel. Site data and conditions are generally reviewed and confirmed by federal and/or state program managers annually, or more frequently if site conditions warrant.

Table 4-6. ROE Indicators of Trends in Contaminated Land and Their Effects on Human Health and the Environment

National Indicators	Section	Page
Current Human Exposures Under Control at High-Priority Cleanup Sites	4.6.2	4-44
Migration of Contaminated Ground Water Under Control at High-Priority Cleanup Sites	4.6.2	4-47

INDICATOR | Current Human Exposures Under Control at High-Priority Cleanup Sites

The EPA Superfund and Resource Conservation and Recovery Act (RCRA) Programs conduct a number of activities to address the nation's most severely contaminated lands. The Programs investigate and collect data on potentially contaminated sites to determine whether they are contaminated and require cleanup. When a potentially hazardous waste site is reported to EPA, trained inspectors determine whether the site presents a hazard to human health and the environment. Sites that pose the greatest threat are placed on the Superfund National Priorities List (NPL) or RCRA Cleanup Baseline. For RCRA, "sites" are more commonly referred to as RCRA Corrective Action Facilities.

One of the priorities for both the NPL and RCRA Cleanup Baseline sites is safeguarding against human exposures to site contamination. EPA and state officials determine whether there is a reasonable expectation that humans are exposed to site contamination and if interim actions are needed to reduce or eliminate all current human exposure in excess of health-based standards. Such activities may include removing and/or isolating contaminated media, providing alternative water supplies, and restricting access or other land use controls. Exposure at levels below the standards is considered protective (i.e., under control). Although these standards may vary from state to state, EPA believes that they fall within an acceptable range for gauging whether human health is protected (U.S. EPA, 2005b). Determinations of human exposure at levels of concern are based on site-specific characterization information and monitoring data (usually many analytical samples) pertaining to relevant environmental media (e.g., soil, indoor air, outdoor air, ground water, and surface water), current human activity patterns, and actions taken to prevent human exposure. All potential exposure routes are assessed, including inhalation, dermal contact, and ingestion of the contaminated media or food affected by contaminated media (U.S. EPA, 1999, 2005b).

This indicator describes the numbers of NPL Indicator Baseline sites and RCRA Cleanup Baseline sites for which government officials have determined that (1) humans are *not* exposed to contamination in excess of health-based standards (i.e., exposure is under control); (2) humans are reasonably expected to be exposed to contamination in excess of health-based standards; or (3) insufficient information exists to make a finding of exposure to contamination in excess of health-based standards. The intention of the indicator is not to capture an "action" or "administrative determination" on the part of EPA, but to characterize environmental conditions relevant to the risk to human health from contaminants at RCRA Cleanup Baseline and NPL Indicator Baseline sites.

What the Data Show

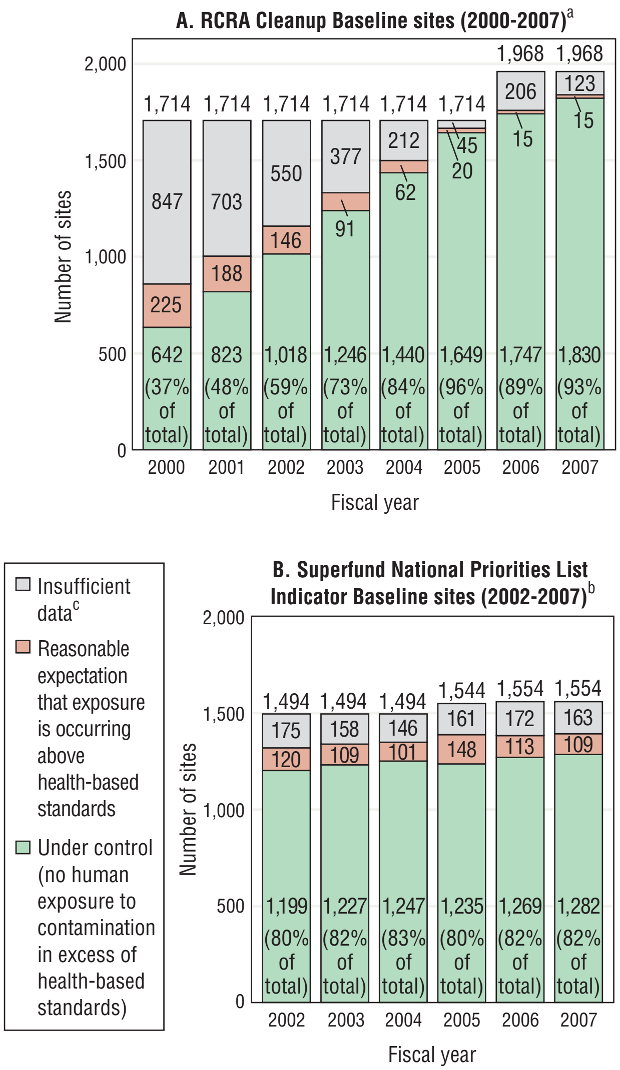
In 2007, there were 1,968 sites on the RCRA Cleanup Baseline (U.S. EPA, 2007a). Of these, the percentage of sites where human exposure to contamination was under control increased from 37 percent (642 sites out of 1,714) in fiscal year (FY) 2000 to 93 percent (1,830 sites out of 1,968) in FY 2007 (Exhibit 4-24, panel A). This increase represents a combination of sites where mitigation has prevented exposure to contaminants and sites where there are sufficient data to show that exposure to contaminated media was not a problem, regardless of mitigation. The percentage of sites where officials had reasonable expectations that humans were exposed to contamination in excess of health-based standards has decreased from 13 percent (225 sites out of 1,714) in FY 2000 to less than 1 percent (15 sites out of 1,968) in FY 2007.

As of September 2007, there were 1,554 sites on the NPL that were categorized as "Final" or "Deleted" (U.S. EPA, 2007b,c). These are referred to as the Superfund NPL Indicator Baseline. The Superfund NPL Indicator Baseline sites where human exposure to contamination was under control increased as a percentage of the total: 80 percent (1,199 of 1,494 sites) in 2002 and 82 percent (1,282 of 1,554 sites) in 2007 (Exhibit 4-24, panel B). As of the end of FY 2007, officials determined that there were reasonable expectations that humans were exposed to contamination in excess of health-based standards at 7 percent (109 out of 1,554) of the NPL Indicator Baseline sites. This is a decrease from 2002, when the percentage was 8 percent (120 out of 1,494). In 2007, there was insufficient information to confirm whether humans were exposed to contamination in excess of health-based standards at 10 percent (163 out of 1,554) of the sites.

Indicator Limitations

- The NPL does not represent all of the contaminated or potentially contaminated sites listed in the Comprehensive Environmental Response, Compensation, and Liability Information System (CERCLIS) database, which contains information on thousands of hazardous waste sites, potential hazardous waste sites, and remedial activities across the nation. A small percentage (less than 1 percent) of the total number of final and deleted NPL sites are excluded from the Indicator Baseline for reasons of consistency.

Exhibit 4-24. Status of current human exposures under control at high-priority cleanup sites in the U.S., fiscal years 2000-2007



[a]The RCRA Cleanup Baseline changed in 2006 from 1,714 to 1,968 sites.

[b]The Superfund NPL Indicator Baseline changed in 2005 from 1,494 to 1,544 sites and in 2006 from 1,544 to 1,554 sites.

[c]For RCRA Cleanup Baseline sites and Superfund NPL Indicator Baseline sites, "insufficient data" includes sites officially classified as "insufficient data" or "no status."

Data source: *U.S. EPA, 2005a, 2006, 2007a,b,c*

INDICATOR | Current Human Exposures Under Control at High-Priority Cleanup Sites *(continued)*

- The indicator results are presented for the 1,714 RCRA Cleanup Baseline sites tracked from 2000 to 2005 and the 1,968 sites tracked in 2006 and 2007, and not the entire group of approximately 3,476 hazardous waste management facilities currently believed to be subject to RCRA Corrective Action requirements (e.g., initial assessments and if needed more thorough investigations and cleanups) (see http://www.epa.gov/epaoswer/hazwaste/ca/lists/2020scc.pdf).
- The indicator does not typically make measurements of exposure biomarkers among potentially exposed individuals at the NPL Indicator Baseline or RCRA Cleanup Baseline sites, but relies on environmental measures at or near the point of exposure and activities that should prevent exposure to contaminants.
- Concentrations of toxic and hazardous contaminants that must not be exceeded to designate a site as having/not having human exposures to contamination in excess of health-based standards vary from state to state, although they fall within a range determined to be acceptable to EPA (U.S. EPA, 2005a,b).
- The indicator is based on certification by a responsible official that the criteria necessary to designate a site as having/not having human exposures to contamination in excess of health-based standards have been met (U.S. EPA, 1999, 2005a,b). The trend in the number of sites may be underestimated to the extent that certification lags behind the potential human exposure to contamination or certification is delayed due to insufficient or outdated information.
- This approach may not take into account certain risks (e.g., endocrine disruptors) where specific risk levels (e.g., to human health) may not have been established.
- Some new sites (e.g., those created with the "reportable quantity" spill response program) as well as other known sites (e.g., spills) are not included in this indicator.

Data Sources

Data for this indicator were provided by EPA's Office of Solid Waste and Emergency Response (OSWER). A list showing the current status of every RCRA baseline site is published online (U.S. EPA, 2007a). A discussion of NPL indicators is available (U.S. EPA, 2005a); information on the current status of any individual NPL site can be queried using EPA's CERCLIS database (U.S. EPA, 2006) (http://cfpub.epa.gov/supercpad/cursites/srchsites.cfm). Data for previous years are not publicly accessible, however, and must be requested from OSWER.

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U.S. EPA. 1999. Interim-final guidance for RCRA corrective action environmental indicators. <http://www.epa.gov/epaoswer/hazwaste/ca/eis/ei_guida.pdf>

INDICATOR | Migration of Contaminated Ground Water Under Control at High-Priority Cleanup Sites

The EPA Superfund and Resource Conservation and Recovery Act (RCRA) Programs conduct a number of activities to address the nation's most severely contaminated lands. The Programs investigate and collect data on potentially contaminated sites to determine whether they are contaminated and require cleanup. When a potentially hazardous waste site is reported to EPA, trained inspectors determine whether the site presents a hazard to human health and the environment. Sites that pose the greatest threat are placed on the National Priorities List (NPL) or RCRA Cleanup Baseline.

One of the priorities for both the NPL and RCRA Cleanup Baseline sites is preventing the continued spread of contaminated ground water, often referred to as "plumes" of contaminated ground water. Protecting the ground water is especially important in areas where it is the primary source for drinking water and irrigation, or a potential source for future water supplies.

EPA and state officials determine that the migration of contaminated ground water is under control (i.e., not continuing to spread in concentrations above levels of concern) when ongoing monitoring shows that the contaminant plume is not expanding or negatively impacting surface waters (U.S. EPA, 1999). Preventing further migration of contaminated ground water may result from an action taken, such as installation of a "pump and treat" or subsurface barrier system, or because of natural attenuation of the contaminants. A determination of whether migration has been prevented is based on monitoring data (usually from hundreds of analytical samples) collected from ground water wells located within and surrounding the spatial extent of the ground water plume (U.S. EPA, 1999, 2005c).

This indicator describes the percentage of NPL Indicator Baseline sites and RCRA Cleanup Baseline sites where government officials have determined that contaminated ground water is not continuing to spread in concentrations above levels of concern (e.g., that exceed the appropriate drinking water standards). This indicator covers both "Final" and "Deleted" NPL Indicator Baseline sites, and all 1,968 RCRA Cleanup Baseline sites. The percentage of sites where ground water contamination continues to spread is also noted, as well as the number of sites where there are insufficient data to make a finding. The intention of the indicator is not to capture an "action" or "administrative determination" on the part of EPA, but to convey the underlying pressure on the environment and potential for human health effects resulting from contaminated ground water.

What the Data Show

In 2007, there were 1,968 sites on the RCRA Cleanup Baseline. Of the high-priority RCRA Cleanup Baseline sites, the percentage of sites where contaminated ground water has been determined to be under control increased from 32 percent (554 out of 1,714 sites) in fiscal year (FY) 2000 to 79 percent (1,548 out of 1,968 sites) in FY 2007 (Exhibit 4-25, panel A). This increase represents a combination of sites where mitigation has halted the spread of contaminated ground water and sites where sufficient data have been collected to show that contaminated ground water migration was not continuing, regardless of mitigation activities. The percentage of sites where officials have determined that contaminated ground water was spreading above levels of concern decreased from 18 percent (306 out of 1,714 sites) in FY 2000 to less than 5 percent (94 out of 1,968 sites) in FY 2007. These sites, and the remaining 326 sites for which there are still insufficient data to make a determination at the end of FY 2007, tend to be very complex sites where the appropriate data have yet to be collected due to high costs or technical difficulties.

Ground water has not been an issue at all Superfund NPL sites. Of those Final and Deleted NPL Indicator Baseline sites where ground water contamination is present, the percentage where contaminated ground water has been determined to be under control increased from 61 percent (772 of 1,275 sites) in FY 2002 to 70 percent (977 of 1,392 sites) (Exhibit 4-25, panel B). As of the end of FY 2007, contaminated ground water was confirmed to be spreading above levels of concern at 15 percent (213) of these NPL sites, while the remaining 15 percent (202 sites) had insufficient data to confirm whether contaminated ground water is spreading above levels of concern. These percentages do not include NPL Indicator Baseline sites classified as "non-ground water" sites.

Indicator Limitations

- The NPL does not represent all of the contaminated or potentially contaminated sites listed in the Comprehensive Environmental Response, Compensation, and Liability Information System (CERCLIS) database, which contains information on thousands of hazardous waste sites, potential hazardous waste sites, and remedial activities across the nation. A small percentage (less than 1 percent) of the total number of final and deleted NPL sites are excluded from the NPL Indicator Baseline for reasons of consistency.
- The indicator covers the 1,714 RCRA Cleanup Baseline sites tracked from 2000 to 2005 and the 1,968 sites tracked in 2006 and 2007, and not the entire group of 3,746 hazardous waste management sites currently believed to be subject to RCRA Corrective Action requirements (i.e., initial assessments, and if needed more thorough investigations and cleanups).

INDICATOR | Migration of Contaminated Ground Water Under Control at High-Priority Cleanup Sites *(continued)*

- The extent to which people have been affected, or could be affected, by the contaminated ground water at NPL or RCRA Cleanup Baseline sites is not considered in this indicator, but is addressed in the Current Human Exposures Under Control at High-Priority Cleanup Sites indicator (p. 4-44).
- The indicator does not address ground water contaminated at other types of sites, such as sites with leaking underground storage tanks and other sites being addressed solely by state cleanup programs.
- Concentrations of toxic and hazardous contaminants in ground water that must not be exceeded to designate a site as under control vary somewhat from state to state, though they fall within a range determined to be acceptable to EPA (U.S. EPA 2005a,c).
- This indicator is based on the certification by a responsible official that the criteria necessary to designate whether contaminated ground water is continuing to spread above levels of concern have been met (U.S. EPA, 1999, 2005a,b). Trends in the number of sites where the spread of contaminated ground water has been shown to occur above levels of concern may be underestimated to the extent that certification lags behind the migration of contaminated ground water or certification is delayed due to insufficient or outdated information.

Data Sources

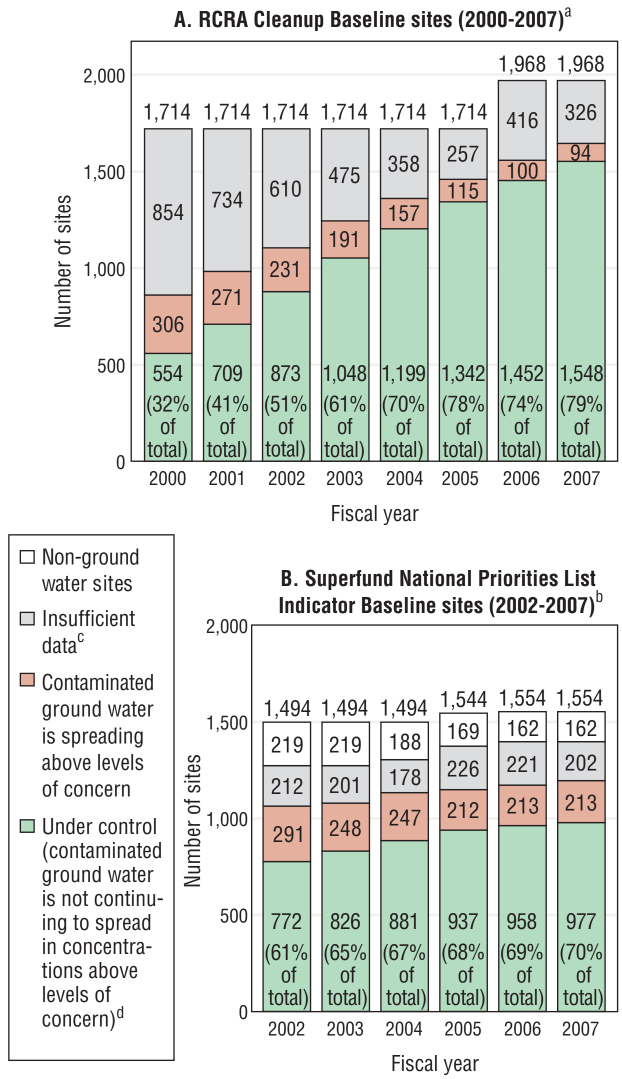
Data for this indicator were provided by EPA's Office of Solid Waste and Emergency Response (OSWER). A list showing the current status of every RCRA baseline site is published online (U.S. EPA, 2007). A summary of the status of Superfund NPL sites is available online (U.S. EPA, 2005c); information on the current status of any individual NPL site can be queried using EPA's CERCLIS database (U.S. EPA, 2006) (http://cfpub.epa.gov/supercpad/cursites/srchsites.cfm). Data for previous years are not publicly accessible, however, and must be requested from OSWER.

References

U.S. EPA (United States Environmental Protection Agency). 2007. Facilities on the RCRA 2008 GPRA corrective action baseline. Report generated 10/25/2007. <http://www.epa.gov/epaoswer/hazwaste/ca/lists/base08st.pdf>

U.S. EPA. 2006. CERCLIS database. Accessed September 14, 2006. <http://cfpub.epa.gov/supercpad/cursites/srchsites.cfm>

Exhibit 4-25. Status of migration of contaminated ground water under control at high-priority cleanup sites in the U.S., fiscal years 2000-2007



[a]The RCRA Cleanup Baseline changed in 2006 from 1,714 to 1,968 sites.

[b]The Superfund NPL Indicator Baseline changed in 2005 from 1,494 to 1,544 sites and in 2006 from 1,544 to 1,554 sites.

[c]For RCRA Cleanup Baseline sites and Superfund NPL Indicator Baseline sites, "insufficient data" includes sites officially classified as "insufficient data" or "no status."

[d]For calculating the percentage of Superfund NPL Indicator Baseline sites in the "under control" category, the total does not include "non-ground water" sites.

Data source: *U.S. EPA, 2005c, 2006, 2007*

INDICATOR | Migration of Contaminated Ground Water Under Control at High-Priority Cleanup Sites *(continued)*

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4.6.3 Discussion

What These Indicators Say About Trends in Contaminated Lands and Their Effects on Human Health and the Environment

The indicators provide insights into trends in protecting humans and ground water from the nation's most contaminated lands. In 2007, 93 percent of the facilities on the Resource Conservation and Recovery Act (RCRA) Cleanup Baseline sites showed that human exposure to contamination in excess of health-based standards was being prevented, while ground water was not spreading above levels of concern at 79 percent of the facilities. Similarly in 2007, the Superfund National Priorities List (NPL) Indicator Baseline sites showed that human exposure to contamination in excess of health-based standards has been prevented at 82 percent of the sites, and ground water has been prevented from spreading above levels of concern at 70 percent of the sites with ground water contamination.

Limitations, Gaps, and Challenges

The two ROE indicators are limited in their ability to address the question. Currently, there is no single information source that tracks the extent of contaminated land nationwide. A substantial amount is known about thousands of the most contaminated sites on the Superfund NPL Indicator Baseline sites and facilities on the RCRA Cleanup Baseline, which have been the focus of in-depth studies and resource-intensive cleanup operations. Although these facilities are some of the most seriously contaminated sites in the country, they do not reflect the full universe of contaminated sites or even the full universe of seriously contaminated sites. EPA would like to have information on other sites that require extensive cleanup, including sites contaminated with radioactive materials from historical nuclear weapons production, sites with leaking underground storage tanks, smaller accidental spill sites, and other cleanup sites managed by a variety of local, state, and federal authorities. Collectively, these contaminated sites outnumber the combined Superfund NPL Indicator Baseline sites and RCRA Cleanup Baseline facilities.

EPA would also like to have information on the actual or potential acreage of contaminated land and is developing data for sites subject to Agency cleanup programs. Additionally, EPA would like to better understand the types of contamination from all sources nationally. Even where national data on contaminated sites are available, the affected area and the types and severity of contamination vary widely from site to site, making accurate trend analysis, aggregation, and generalization difficult or impossible. There is no comprehensive data source to determine the extent of these lands, populations that may be affected, and the potential for contamination to have harmful human health or ecological effects. Further, EPA is interested in knowing how much previously contaminated land has been returned to productive uses. Data associated with the use of previously contaminated land could help answer the question of trends and effects of contaminated land and the question of trends and effects of land use.

Current gaps in data on contaminated lands stem from a variety of factors and challenges, including the multi-jurisdictional responsibilities for identifying, managing, and cleaning up contaminated lands; a focus in most contaminated lands data sets on measures of regulatory compliance and associated activities; high costs to identify, inventory, study, and clean up large, complicated sites; and complexity in the effects of contaminated lands on human health and the environment, including unique site characteristics and the inability to generalize information over large geographic areas.