Appendix A: Sample Work Products

We have selected four sample work products to illustrate our experience in producing concise technical documents. 1) The Executive Summary for the report *Economic Impacts of Developing New Water Sources for the Central Coast Plain Capacity Use Area* provides an example of how we have briefly summarized major findings from a complex technical analysis. 2) The document *Latest Findings on National Air Quality* shows how we have presented detailed scientific information in a brief format for the general public. 3) The procedure description for Contracting for Full Delivery Projects from Eel's Policies, Processes, and Procedures Manual demonstrates how we have taken detailed information about business processes at an organization and presented various aspects in different ways, including step-by-step descriptions, tables that summarize roles and responsibilities, and flow charts that present visually the sequencing and relationships of steps in the process. 4) The paper "Region-Specific Marginal Abatement Costs for Methane from Coal, Natural Gas, and Landfills through 2030," published in *Greenhouse Gas Control Technologies*, demonstrates that our project team generates peer reviewed, academic quality work.

July 2002

Economic Impacts of Developing New Water Sources for the Central Coastal Plain Capacity Use Area

Executive Summary

Prepared for

Jean Crews-Klein
Vice President of Business and Natural
Resource Development
N.C. Rural Economic Development Center, Inc.
4021 Carya Drive
Raleigh, NC 27610

Prepared by

Katherine Heller
Brooks Depro
Julia Wing
RTI
Health, Social, and Economics Research
Research Triangle Park, NC 27709

RTI Project Number 08288.003

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Executive Summary

ES.1 INTRODUCTION

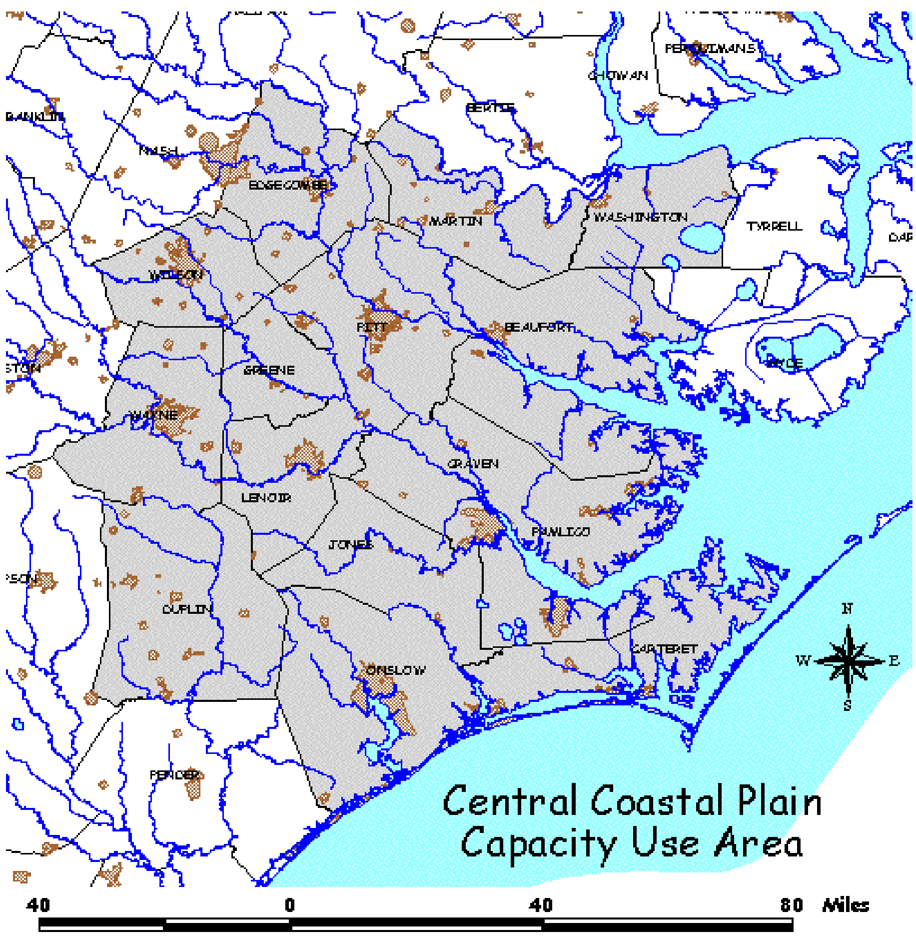
In August 2002, the Central Coastal Plain Capacity Use Area (CCPCUA) Rule (the Rule) will take effect. The Rule is designed to reduce withdrawals from parts of two Cretaceous aquifers, the Upper Cape Fear Aquifer and the Black Creek Aquifer, which have experienced falling water levels and saltwater infiltration because water has been withdrawn from them faster than they can recharge. Over the next 16 years, major water users (mostly utilities and a few industries) will be required to incrementally reduce their use of groundwater from these aquifers by between 30 and 75 percent, depending on aquifer conditions in their location. Users must accordingly identify and develop alternative sources of water. This process will entail direct costs to the utilities and indirect costs to their customers and the rest of the region's economy. The purpose of this study is to identify and estimate the economic impacts to be experienced by water users in the affected region. This change in resource allocation will result in added costs to the water users, which will in turn be passed on to their customers and passed back to their suppliers, causing economic welfare losses throughout the affected region.

Historically, the Central Coastal Plain has been fortunate to have abundant, high-quality groundwater that could be used with little treatment for consumption by households and production of other goods and services. Overuse of this common property resource has led to declining availability and quality (saltwater infiltration) in some parts of the aquifer. Unchecked, these problems will worsen, and coping with them will impose costs on water users. The Rule is designed to fairly allocate the quantity of remaining aquifer water that can sustainably be used and allow the affected areas to plan for alternatives.

ES.2 THE CENTRAL COASTAL PLAIN CAPACITY USE AREA

The CCPCUA includes 15 counties in eastern North Carolina that are underlain by the challenged Cretaceous aquifers. Figure ES-1 shows the counties included in the CCPCUA: Beaufort, Carteret, Craven, Duplin, Edgecombe, Greene, Jones, Lenoir, Martin, Onslow, Pamlico, Pitt, Washington, Wayne, and Wilson.

Figure ES-1. The CCPCUA



Source: North Carolina Department of Environment and Natural Resources, Division of Water Resources. <http://www.ncwater.org/Permits_and_Registration/Capacity_Use/Central_Coastal_Plain/>.

The CCPCUA is a very rural area, with a total population of 912,955 people and an average population density of 114 people per square mile. The CCPCUA is also an area that has historically been plagued by relatively high rates of poverty. There is a large per capita income gap between the CCPCUA and the more urban areas of North Carolina. In 1999 the per capita income of the CCPCUA counties was only 80 percent of the state average per capita income.

This area is very economically diverse, as is the rest of rural North Carolina. There are over 300 different types of economic activity in the CCPCUA (IMPLAN, 1999). Historically, that activity has been primarily agricultural, with nonagricultural jobs concentrated in the manufacturing sector. The military is also a large employer: several military bases, such as Camp Lejeune in Onslow County, are located in the region. In addition, at least 15 universities, colleges, and community colleges in the region are large employers (North Carolina's Eastern Region, 2002).

Most manufacturing jobs in the CCPCUA are in traditional industries, such as textiles and apparel, tobacco, and furniture (North Carolina Rural Economic Development Center, 1999b), and many of these industries have recently been in decline. The tobacco industry has undergone dramatic change as a result of the 1998 Tobacco Settlement, natural disasters, and other economic forces. Between 1988 and 1996, tobacco employment declined by 38 percent. The textile industry has also suffered, with jobs declining 19 percent between 1988 and 1996 (North Carolina Rural Economic Development Center, 1999b). Although only 41 percent of jobs in North Carolina are located in rural areas, almost 60 percent of layoffs occurred there in 1998 and 1999 (North Carolina Rural Economic Development Center, 1999b). Unemployment rates in the CCPCUA are somewhat higher than in the rest of North Carolina.

The region was also devastated in September 1999 by Hurricane Floyd. The hurricane dumped 20 inches of water in eastern North Carolina. Homes, businesses, roads, crops, cars, livestock, and farm equipment were lost or damaged in the flood; 57,000 homes were impacted; and $1 billion in crops, livestock, and farm equipment and buildings were lost (North Carolina Rural Economic Development Center, 1999a; Hurricane Floyd Relief, 1999). Water and wastewater treatment plants were also impacted by the hurricane; many had to temporarily shut down. Overall, Hurricane Floyd cost eastern North Carolina $4.3 billion (Hurricane Floyd Relief, 1999).

In spite of these challenges, the region has the potential for increased prosperity and economic growth. Many cities in the region have vibrant business communities, including Greenville (Pitt), Goldsboro (Wayne), Kinston (Lenoir), New Bern (Craven), Morehead City (Carteret), Jacksonville (Onslow), and Wilson (Wilson). Overall, the CCPCUA is a region with considerable economic potential, but it is also facing economic challenges.

ES.3 GROUNDWATER ISSUES IN THE CCPCUA

Groundwater has been the predominant source of water in the CCPCUA (NC DENR, 1998). Groundwater levels in eastern aquifers are reported to have dropped more than 150 feet in less than 5 years (North Carolina Rural Economic Development Center, 1999b). Data show that water levels have been dropping in these aquifers since the late 1960s. The current rate of withdrawal from the Black Creek and Upper Cape Fear aquifers exceeds the rate at which the water can be replenished. If this rate of withdrawal continues, the CCPCUA will soon be confronted with a water shortage (NC DENR, 1998).

The CCPCUA Rule seeks to mitigate the effects of this impending water shortage by requiring major users of these endangered aquifers to seek alternative sources and conserve the water that they will continue to withdraw from the aquifers. (Details of the Rule's provisions are provided in Section ES.5.) Developing the alternative sources will impose costs on the water users in the CCPCUA. This report examines the economic impacts that are expected as consumers and producers in the CCPUA change their behavior in response to the increased cost of water. It would be wrong to attribute the costs and economic impacts to the Rule itself, rather than to the underlying geology. In fact, for some areas, the ultimate impacts of reduced water availability and uncertainty about supplies (without the Rule) would likely be higher than the impacts of developing alternatives under the Rule's timetable.

ES.4 THE CCPCUA RULE

The CCPCUA Rule will go into effect August 1, 2002.[1] The CCPCUA (shown in Figure ES-1) includes 15 counties in eastern North Carolina located east of Interstate 95 and west of the Pamlico and Albemarle Sounds. Within the CCPCUA, groundwater is supplied by several aquifers, including the Upper and Lower Cape Fear and Black Creek Cretaceous aquifers and the Castle Hayne aquifer. Groundwater from the Lower Cape Fear, Black Creek, and Upper Cape Fear Cretaceous aquifers is being withdrawn at a rate that exceeds the available recharge. The Castle Hayne aquifer supplies groundwater in a portion of the area, but is higher yielding and not at risk. Therefore, this rule only regulates the withdrawal of water from the Cretaceous aquifers (see Figure ES-2).

As shown in Figure ES-2, groundwater users in various parts of the CCPCUA are experiencing different conditions, depending on the part of the aquifer from which they withdraw water. The eastern part of the CCPCUA is experiencing saltwater intrusion, the western part of the CCPCUA is experiencing declining water levels, and the central part of the CCPCUA is experiencing dewatering.

ES.5 PROVISIONS OF THE CCPCUA RULE

The CCPCUA Rule seeks to limit the rate of withdrawal by requiring all users who withdraw more than 100,000 gallons of groundwater a day (except intermittent users[2] and individual household wells[3]) from one of the three withdrawal reduction zones in the Cretaceous aquifer to apply for and obtain a water use permit.[4] These water users will have 180 days after the effective date of the Rule to apply for a permit. Water users will have to report water use and groundwater levels quarterly. An

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[1]The Rule itself is provided for reference in Appendix A of the Report.

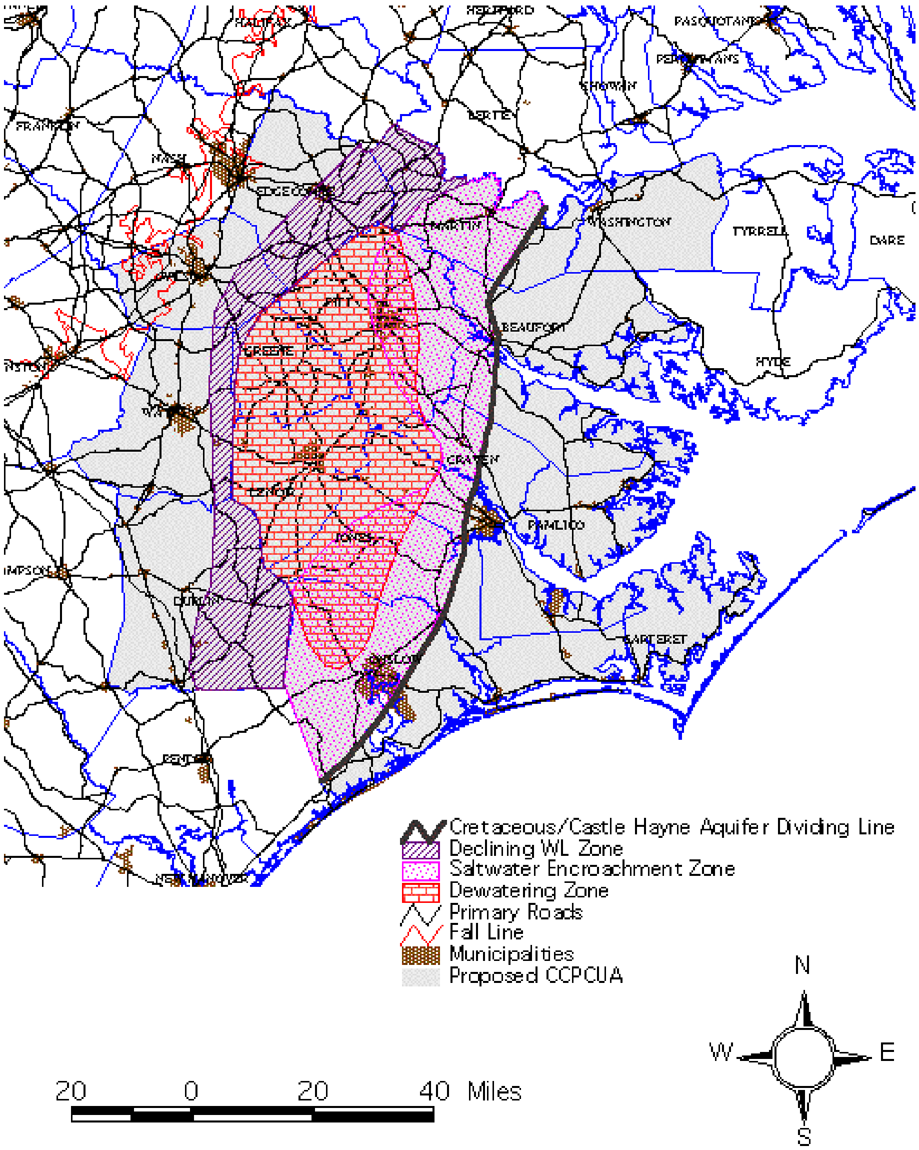
[2]Intermittent users are those who withdraw water fewer than 60 days per year; this will include many agricultural irrigators and fish farms.

[3]Rule 0.0505 3b states that "These requirements do not apply to withdrawals to supply an individual domestic dwelling."

[4]Water users withdrawing more than 10,000 gallons a day but less than 100,000 gallons of ground or surface water are required to register their withdrawals with the Division of Water Resources.

application for a water use permit must include information about the purpose for which the water

Figure ES-2. Map of CCPCUA Cretaceous Aquifer Zones



Source: North Carolina Department of Environment and Natural Resources, Division of Water Resources. <http://www.ncwater.org/Permits_and_Registration/Capacity_Use/Central_Coastal_Plain/ccpcuamap.gif>.

will be used, the location of the withdrawal, and a justification of the quantities needed, and it must document the water conservation measures that the applicant will use.

Water use will be restricted by the issuance of permits for decreasing amounts of permitted withdrawals over a 16-year period. The Rule includes three phases of water use reductions. The reductions will be calculated based on the water user's approved base rate, which the Division of Water Resources will calculate, based on the annual withdrawal from Cretaceous wells during calendar year 1997 or the year extending from August 1, 1999, through July 31, 2000, whichever is larger. At the end of Phase I (6 years after the Rule takes effect), water users will be required to reduce water use from Cretaceous aquifers by either 10 percent or 25 percent, depending on their location (dewatering zone, saltwater encroachment zone, or declining water-level zone). At the end of Phase II (11 years after the Rule takes effect), water users will be required to reduce water use by 20 percent or 50 percent, depending on their location. At the end of Phase III (16 years after the Rule takes effect), water users must reduce water use by 30 percent or 75 percent, again depending on their location (see Table ES-1). Water levels will be evaluated throughout the process to determine whether the mandated water use reductions are adequate, too stringent, or not stringent enough.

Table ES-1. Annual Water Use Reductions from Approved Base Rate

Zone	Phase I Reduction (August 1, 2008)	Phase II Reduction (August 1, 2013)	Phase III Reduction (August 1, 2018)
Dewatering zone	25%	50%	75%
Saltwater encroachment zone	25%	50%	75%
Declining water level zone	10%	20%	30%

Source: Approved CCPCUA Rules. Section 0.0503.

Water-use permit holders will not be allowed to add new wells without prior approval. Permitted water users will be allowed to sell or transfer water and/or a portion of their permitted withdrawal to other users.

All water user types will have some water conservation requirements. Public water system conservation requirements will include water conservation ordinances, leak detection programs, conservation rate structures, plumbing retrofit programs, and public education. Agricultural users will only be required to include a statement that they are using a conservation plan. Commercial water users will need to include an audit schedule of water use by type of activity and an implementation schedule for feasible measures for the conservation and reuse of water at the facility.

ES.6 FINDINGS, CONCLUSIONS, AND RECOMMENDATIONS

The North Carolina Rural Economic Development Center, Inc., hired Golder Associates to examine options and identify alternative water sources, and hired RTI to evaluate the economic costs and impacts that might result from implementing these alternatives. In this section, we present and overview of the analysis findings and recommendations.

Overuse of the Cretaceous Black Creek and Upper Cape Fear aquifers has resulted in decreasing water levels, saltwater infiltration, and dewatering of some parts of the aquifers. Alternative sources of drinking water must be developed for the Central Coastal Plain. The CCPCUA Rule provides a framework for reducing use of the challenged aquifers by monitoring water levels and instituting water conservation measures. Based on 1995 USGS data and 1997 Local Water Supply Plans, we estimate that the CCPCUA Rule will restrict approximately 50 percent of the water withdrawals from groundwater in the affected counties.

Potential alternative sources of water include surface water, surficial aquifers, and other aquifers, especially the Castle Hayne. In consultation with the local water supply systems projected to be most affected, Golder Associates examined and identified several alternatives for each. We selected the single alternative that appeared most promising for each water supply system and examined the impacts that would result from its implementation. In most cases, we selected a joint regional supply alternative, if one is available.

The costs of developing new water supplies include capital costs and operating and maintenance costs. Capital costs include the cost of equipment required to access either surface water or alternative groundwater supplies, treatment equipment, and pipelines to transport the water from the new source to the system. Operating and maintenance costs include the costs of labor, chemicals, power, and other supplies required to operate and maintain the new equipment. For each system, the capital costs of the alternative water supplies are estimated to be between zero (for systems projected to purchase water from regional water and sewer authorities or neighboring systems) and $34 million (for a large regional system) and to total $216 million across all affected systems. The total annual costs of developing new water supplies (including annualized capital costs plus operating and maintenance costs) are projected to total $30.3 million and to range from less than $1,000 to $4.6 million per system, with a median value of $483,000.

To analyze the impacts of the costs of new water supplies, we examined the immediate impact on the water supply systems, and then estimated the impacts on local businesses, households, and the economy of the region. The affected systems hope to be able to fund some of the investment through grants from federal, state, or foundation sources. To examine a "worst-case scenario" in which grant funding is not forthcoming, we analyze a high-cost scenario under which all of the costs must be funded through loans, bonds, or operating revenues.

ES.6.1 Methods and Findings

We analyzed the direct impacts on water systems by comparing costs to items in their current budgets. We found that the capital investment costs were much higher (sometimes more than ten times) compared to the 5-year average of system capital expenditures. Total annual costs of developing and operating new water supplies represented at least a 25 percent increase in system operating costs for roughly 60 percent of the systems. Costs represented at least 25 percent of baseline system revenues for approximately 60 percent of the systems. This suggests that more than half of the systems are likely to raise prices substantially if no grant funding is made available.

We estimated the impacts on households and businesses in the CCPCUA using a market simulation model and an I-O model. We found that impacts on the overall economy are relatively small because water is generally a small share of household budgets and business production costs. Projected impacts on individual sectors vary depending on water's share of each sector's total production costs.

We project that economic output and employment in the CCPCUA in 2020 will be slightly lower (as compared to projected values), as a result of the costs associated with developing new water supplies. Also, the output of goods and services will be about $19 million less than it would have been annually, had new water resources not been needed, and households will have to spend about $16 million more on water. Incorporating these direct impacts into an input-output (I-O) model of the region, we project about $9 million in indirect and induced impacts, which occur as directly affected businesses and households reduce their spending on other locally produced goods and services. Overall, we project that the economic impact of developing new water sources will be about $48 million per year. Compared to $60.2 billion in projected total sales in 2020 for the economies in the CCPCUA, this impact is less than 0.1 percent.

ES.6.2 Conclusions and Recommendations

As discussed above, we project that the overall impact on the economies of the CCPCUA will be relatively small. Individual sectors that are more water-intensive may be harder hit. This means that there will be slightly less employment, output, and income in the CCPCUA region in 2020 than there would have been if new water sources had not been needed. The relatively modest impacts on industries and households should generally be affordable.

Of great concern, however, is the financial burden that developing new water sources will place on the local water supply systems. If no grant funding can be found, local water supply systems will be required to borrow up to $216 million to finance their investments in capital equipment. Many systems have recently undertaken improvements and already have a substantial debt burden. Other systems may need to raise prices by more than 25 percent to cover the costs of developing new water sources or purchasing water from regional WASAs.

To mitigate the financial impacts of developing alternative water sources, local governments within the CCPCUA could take advantage of the capacity-building grants offered by the North Carolina Rural Economic Development Center. These grants could provide funds to support more detailed engineering studies, planning, and the evaluation of alternatives. Systems with the fewest cost-effective options (such as Farmville, Robersonville, and Williamston) may benefit the most from these grants. In addition, systems should be supported as they seek grants from federal sources for the construction and operation of new water supplies.

The Capacity Area Rule will help protect the region's groundwater resources by requiring local governments to be proactive in planning to meet future water needs. Local water supply systems and local governments within the CCPCUA should continue to work together to identify cost-effective ways to meet their future needs. Public education efforts can encourage conservation and increase public understanding of water's value as a resource. Innovative strategies for water resource management, including the Rule's marketable permit options, regionalization and consolidation of systems, water conservation and reclamation, and technologies such as desalination, reverse osmosis, and aquifer storage and recovery may all be useful in achieving efficient, sustainable use of the region's water resources. Planning for economic development must consider the implications of different types of development for water demand. Economic development offices should direct water-intensive industries to areas where surface water or abundant groundwater are available (as Pitt County already does). Local governments may be able to work with existing major industrial users to identify conservation options to minimize the cost of reducing their Cretaceous aquifer use. In general, the CCPCUA must increasingly value its water resources to ensure that adequate water will be available to sustain and enhance the region's economic growth over the next 20 years.

ES.7 REFERENCES

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United States
Environmental Protection
Agency

Latest Findings on National Air Quality

2001 STATUS AND TRENDS

Cover Photo of Mount McKinley, Denali National Park, Alaska, by Kim Ferguson, Waynesville, North Carolina

EPA 454/K-02-001
September 2002

Latest Findings on National Air Quality

2001 STATUS AND TRENDS

Contract No. GS-10F-0283K
Task Order No. TO 1307

U.S. Environmental Protection Agency
Office of Air Quality Planning and Standards
Emissions, Monitoring, and Analysis Division
Research Triangle Park, North Carolina

Contents

More detailed information on air pollution trends is available at
www.epa.gov/airtrends.

Information on global warming and global climate change is available at
www.epa.gov/globalwarming/publications/emissions and
www.epa.gov/globalwarming/publications/car.

National Air Quality

This summary report highlights the U.S. Environmental Protection Agency's (EPA's) most recent evaluation of the status and trends in our nation's air quality.

Highlights

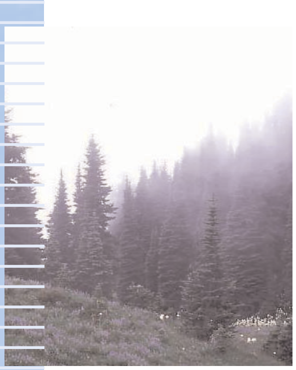
- Since 1970, aggregate emissions of the six principal pollutants tracked nationally have been cut 25 percent. During that same time period, U.S. gross domestic product increased 161 percent, energy consumption increased 42 percent, and vehicle miles traveled increased 149 percent.
- National air quality levels measured at thousands of monitoring stations across the country have shown improvements over the past 20 years for all six principal pollutants.
- Despite this progress, almost 170 million tons of pollution are emitted into the air each year in the United States, and approximately 133 million people live in counties where monitored air in 2001 was unhealthy at times because of high levels of at least one of the six principal air pollutants.
- The vast majority of areas that experienced unhealthy air did so because of one or both of two pollutants—ozone and particulate matter (PM). EPA is focusing its efforts to control these pollutants by implementing more stringent National Ambient Air Quality Standards for ozone and PM and rules reducing emissions from on-road transportation and stationary combustion sources. These rules will bring reductions in emissions over the next few years. Additional reductions will be needed to provide clean air in the future. EPA has submitted to Congress Clear Skies legislation that, if enacted, would mandate reductions of particle- and ozone- forming compounds from power generators by 70 percent from current levels through a nation-wide cap and trade program. EPA also expects to propose nonroad vehicle regulations that would help improve ozone and PM air quality.
- EPA, states, and tribes have only recently begun to measure fine particles (known as $PM_{2.5}$) in the air on a broad national basis. In many locations, EPA now has 3 years of air quality monitoring data to use in comparing to the health-based standards for $PM_{2.5}$. Based on those data, areas across the Southeast, Mid-Atlantic, and Midwest regions and California have air quality that is unhealthy due to fine particles. High PM concentrations in the eastern United States are due to regional emissions from power plants and motor vehicles in combination with local emissions from transportation and other sources. In California, high PM concentrations tend to be due to mobile source emissions.
- Of the six tracked pollutants, progress has been slowest for ground-level ozone. The Northeast and West exhibited the greatest improvement, while the South and North Central regions experienced slower progress in lowering ozone concentrations. Despite this progress in most regions of the country, the average ozone (8-hour) levels in 33 of our national parks have increased over the past 10 years.
- Ground-level ozone is not emitted directly into the air but is formed in the atmosphere by the reaction of volatile organic compounds (VOCs) and nitrogen oxides (NO_x) in the presence of heat and sunlight. Although emissions of VOCs have decreased 16 percent over the past 20 years, the lack of significant reductions in regional-scale emissions of NO_x, a family of chemicals that can contribute to the formation of ozone hundreds of miles downwind, has slowed progress in reducing ozone levels. Between 1982 and 2001, NO_x emissions in the United States increased

EPA tracks air pollution in two ways:

- Air quality measured from over 3,000 locations (over 5,200 monitors) across the nation operated primarily by state, local, and tribal agencies.
- Emissions from all sources going back 30 years.

Six Principal Air Pollutants Tracked Nationally

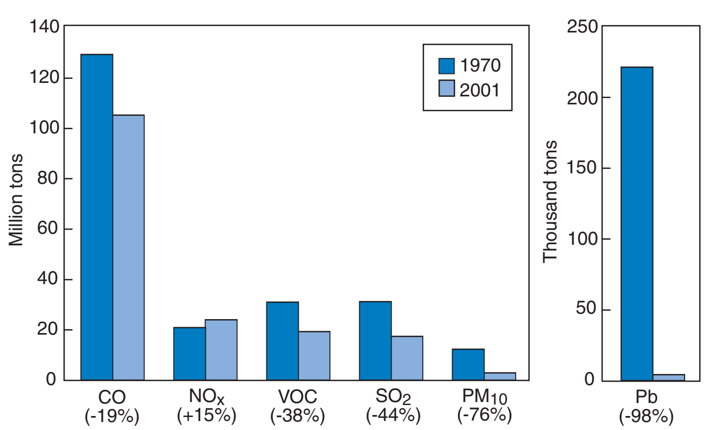
- Nitrogen Dioxide (NO_2)
- Ozone (O_3) - formed by volatile organic compounds (VOCs) and nitrogen oxides (NO_x)
- Sulfur Dioxide (SO_2)
- Particulate Matter (PM) - formed by SO_2, NO_x, ammonia, VOCs, and direct particle emissions
- Carbon Monoxide (CO)
- Lead (Pb)



9 percent (with a 3 percent decrease in the past 10 years). The majority of this increase is attributed to growth in emissions from nonroad engines (like construction and recreation equipment) and diesel vehicles. Emissions of NO_x also contribute to acid rain, haze, particulate matter, and damage to waterbodies like the Chesapeake Bay.

- Sulfates formed primarily from sulfur dioxide (SO_2) emissions from coal-fired power plants are a major component of fine particles in the eastern United States. SO_2 emissions decreased 25 percent from 1981 to 2001 and 24 percent from 1992 to 2001. Nationally, average SO_2 ambient concentrations have been cut 52 percent from 1982 to 2001 and 35 percent over the more recent 10-year period from 1992 to 2001. Reductions in SO_2 concentrations and emissions since 1990 are primarily due to controls implemented under EPA's Acid Rain Program.
- Based on EPA's recent National-Scale Air Toxics Assessment for 1996, 3 of 32 urban air toxics (chromium, a metallic compound used in industrial processes such as plating; benzene, primarily emitted by mobile sources such as cars and trucks; and formaldehyde, emitted by mobile sources and formed when other compounds chemically react in sunlight) appear to pose the greatest nationwide cancer risk. One air toxic, acrolein — a by product of combustion in mobile and industrial sources — is estimated to pose the highest potential on a nationwide basis for significant chronic adverse effects other than cancer.
- Scientific evidence shows that the Montreal Protocol has been effective in reducing stratospheric ozone depletion. Measurements have shown that atmospheric concentrations of methyl chloroform are falling, indicating that emissions have been greatly reduced. Concentrations of other ozone-depleting substances in the upper layers of the atmosphere, like chlorofluorocarbons (CFCs), are also beginning to decrease.

Comparison of 1970 and 2001 Emissions



Air Pollution

The Concern

The average person breathes 3,400 gallons of air each day. Exposure to air pollution is associated with numerous effects on human health, including respiratory problems, hospitalization for heart or lung diseases, and even premature death. Children are at greater risk because they are generally more active outdoors and their lungs are still developing. The elderly and people with heart or lung diseases are also more sensitive to some types of air pollution.

Air pollution can also significantly affect ecosystems. For example, ground-level ozone has been estimated to cause over $500 million in annual reductions of agricultural and commercial forest yields, and airborne releases of NO_x are one of the largest sources of nitrogen pollution in certain water-bodies such as the Chesapeake Bay.

The Causes

Air pollution comes from many different sources. These include stationary sources such as factories, power plants, and smelters; smaller sources such as dry cleaners and degreasing operations; mobile sources such as cars, buses, planes, trucks, and trains; and natural sources such as windblown dust and wildfires.

Six Principal Pollutants

Under the Clean Air Act, EPA establishes air quality standards to protect public health, including the health of "sensitive" populations such as people with asthma, children, and the elderly. EPA also sets limits to protect public welfare, including protection against decreased visibility and damage to animals, crops, vegetation, and buildings.

EPA has set national air quality standards for six principal air pollutants (also referred to as criteria pollutants): nitrogen dioxide (NO_2), ozone (O_3), sulfur dioxide (SO_2), particulate matter (PM), carbon monoxide (CO), and lead (Pb). Four of these pollutants (CO, Pb, NO_2, and SO_2) result primarily from direct emissions from a variety of sources. PM results from direct emissions, but is also commonly formed when emissions of nitrogen oxides (NO_x), sulfur oxides (SO_x), ammonia, organic compounds, and other gases react in the atmosphere. Ozone is not directly emitted but is formed when NO_x and volatile organic compounds (VOCs) react in the presence of sunlight.

Percent Change in Air Quality

	1982-2001	1992-2001
NO_2	-24	-11
O_3 1-h	-18	-3
8-h	-11	0
SO_2	-52	-35
PM_{10}	—	-14
$PM_{2.5}$	Trend data not available	
CO	-62	-38
Pb	-94	-25

Percent Change in Emissions

	1982-2001	1992-2001
NO_x	+9	-3
VOC	-16	-8
SO_2	-25	-24
PM_{10}*	-51	-13
$PM_{2.5}$*	—	-10
CO	0	+6
Pb	-93	-5

*Includes only directly emitted particles.

Negative numbers indicate improvements in air quality or reductions in emissions. Positive numbers show where emissions have increased.

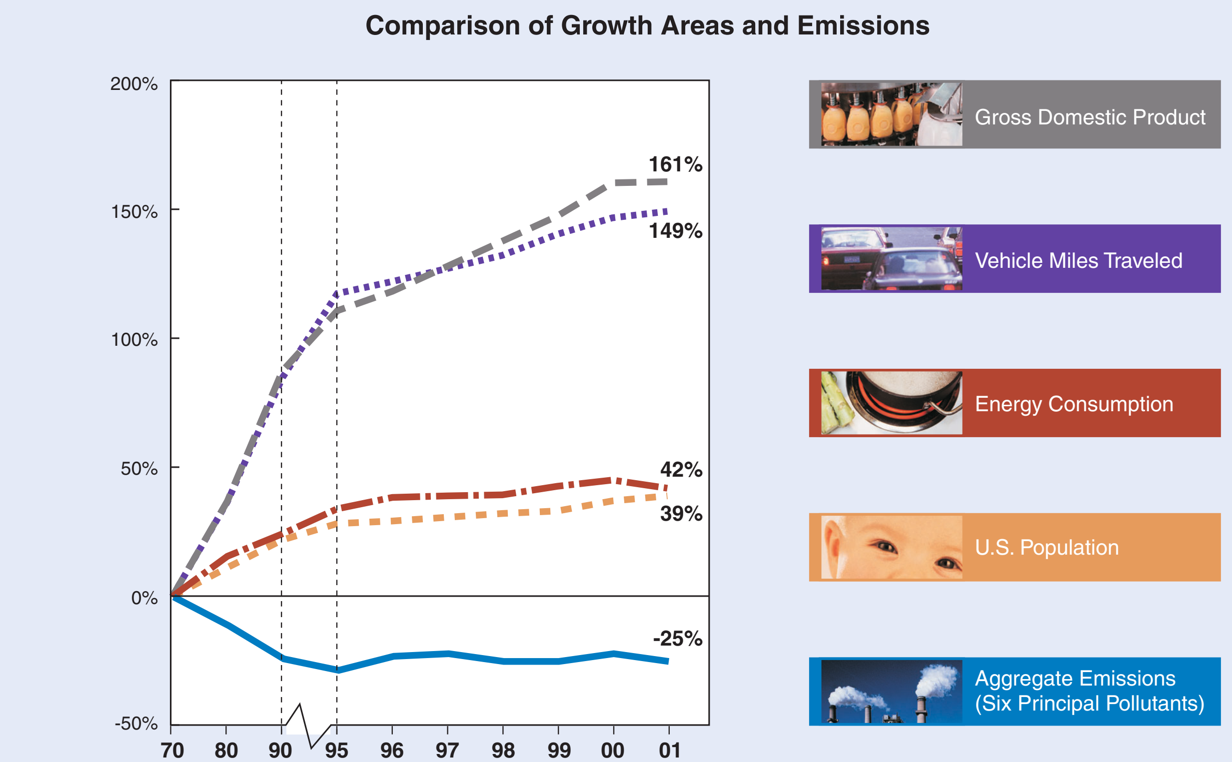
Air quality concentrations do not always track nationwide emissions. There are several reasons for this. First, most monitors are located in urban areas so air quality is most likely to track changes in urban air emissions rather than in total emissions. Second, not all of the principal pollutants are emitted directly to the air. Ozone and many particles are formed after directly emitted gases react chemically to form them. Third, the amount of some pollutants measured at monitoring locations depends on the chemical reactions that occur in the atmosphere during the time it takes the pollutant to travel from its source to the monitoring station. Finally, weather conditions often contribute to the formation and buildup of pollutants in the ambient air. For example, peak ozone concentrations typically occur during hot, dry stagnant summertime conditions.

Each year EPA examines changes in levels of these ambient pollutants and their precursor emissions over time and summarizes the current air pollution status.

Summary of Air Quality and Emissions Trends

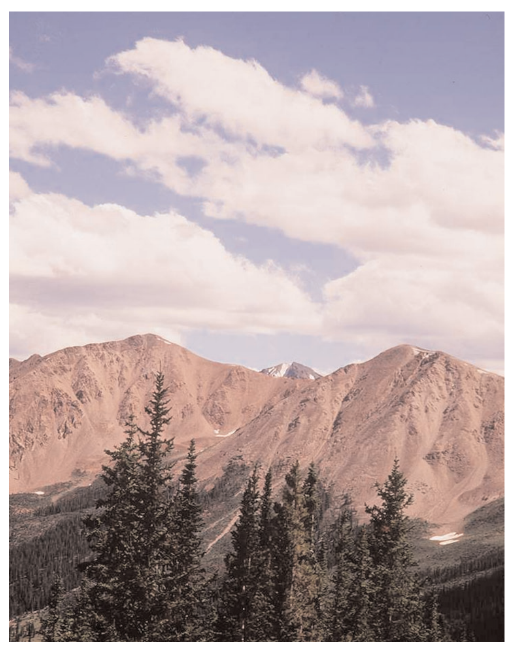
EPA tracks trends in **air quality** based on actual measurements of pollutant concentrations in the ambient (outside) air at monitoring sites across the country. Monitoring stations are operated by state, tribal, and local government agencies as well as some federal agencies, including EPA. Trends are derived by averaging direct measurements from these monitoring stations on a yearly basis. The tables to the left show that the air quality based on concentrations of the principal pollutants has improved nationally over the past 20 years (1982–2001).

EPA estimates nationwide **emissions** of ambient pollutants and their precursors based on actual monitored readings or engineering calculations of the amounts and types of pollutants emitted by vehicles, factories, and other sources. Emission estimates are based on many factors, including the level of industrial activity, technology developments, fuel consumption, vehicle miles traveled, and other activities that cause air pollution.



Between 1970 and 2001, gross domestic product increased 161 percent, vehicle miles traveled increased 149 percent, energy consumption increased 42 percent, and U.S. population increased 39 percent. At the same time, total emissions of the six principal air pollutants decreased 25 percent.

Emission estimates also reflect changes in air pollution regulations and installation of emission controls. The 2001 emissions reported in this summary are projected numbers based on available 2000 information and historical trends. Emission estimation methods continue to evolve and improve over time. Methods have changed for many significant categories beginning with the years 1985, 1990, and 1996, and, consequently, the estimates are not consistently developed across all years in this trend period. Because emissions estimation methods for many significant categories have changed over time, comparisons of the estimates for a given year in this report to the same year in a previous report may not be appropriate. Check **www.epa.gov/ttn/chief** for updated emissions information.

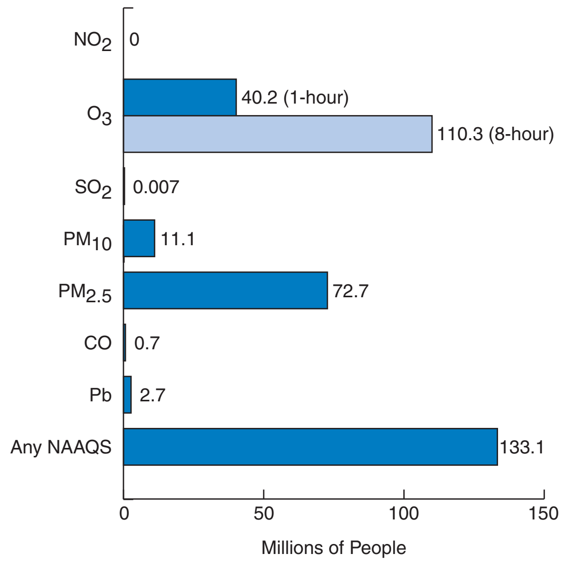


Emissions of all principal pollutants except NO_x have decreased or remained essentially unchanged over the past 20 years (1982–2001), while all air quality measures for the six principal pollutants have gone down. Although NO_x emissions have increased, air quality measurements for NO_2 across the country are below the national air quality standards. NO_x plays an important role in a number of air pollution issues. These compounds contribute to the formation of ozone and particles as well as the deposition of acids and nutrients and visibility impairment.

The improvements are a result of effective implementation of clean air laws and regulations, as well as improvements in the efficiency of industrial technologies.

Despite great progress in air quality improvement, approximately 133 million people nationwide still lived in counties with pollution levels above the National Ambient Air Quality Standards (NAAQS) in 2001. This annual "snapshot" view of the nation's air quality can be used to show levels that people might currently be experiencing across the county. There are still 130 nonattainment areas out of the 230 originally resulting from the 1990 Clean Air Act Amendments designation process.

Number of People Living in Counties with Air Quality Concentrations above the Level of the NAAQS in 2001



Multiple years of data are generally used to determine if an area attains the NAAQS.

The Clean Air Act

The Clean Air Act provides the principal framework for national, state, tribal, and local efforts to protect air quality. Under the Clean Air Act, EPA has a number of responsibilities, including

- Setting NAAQS for the six principal pollutants that are considered harmful to public health and the environment.
- Ensuring that these air quality standards are met (in cooperation with the state, tribal, and local governments) through national standards and strategies to control air pollutant emissions from vehicles, factories, and other sources.
- Reducing emissions of SO_2 and NO_x that cause acid rain.
- Reducing air pollutants such as PM, SO_x, and NO_x that can cause visibility impairment across large regional areas, including many of the nation's most treasured parks and wilderness areas.
- Ensuring that sources of toxic air pollutants that may cause cancer and other adverse human health and environmental effects are well controlled and that the risks to public health and the environment are substantially reduced.
- Limiting the use of chemicals that damage the stratospheric ozone layer in order to prevent increased levels of harmful ultraviolet radiation.

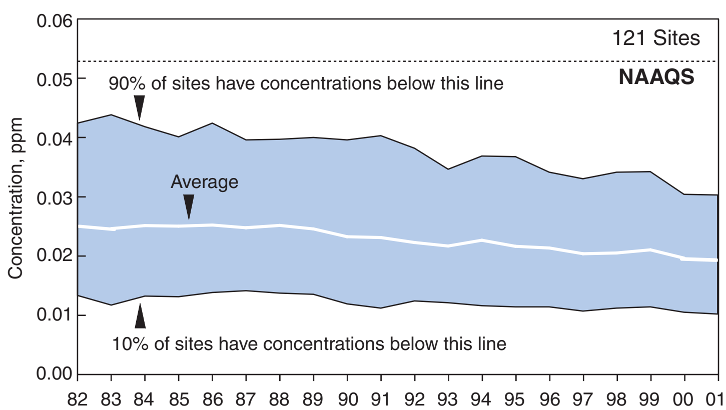
NITROGEN DIOXIDE (NO_2)

Nature and Sources of the Pollutant

Nitrogen dioxide is a reddish brown, highly reactive gas that is formed in the ambient air through the oxidation of nitric oxide (NO). Nitrogen oxides (NO_x), the term used to describe the sum of NO, NO_2, and other oxides of nitrogen, play a major role in the formation of ozone, particulate matter, haze, and acid rain. While EPA tracks national emissions of NO_x, the national monitoring network measures ambient concentrations of NO_2 for comparison to national air quality standards. The major sources of man-made NO_x emissions are high-temperature combustion processes, such as those that occur in automobiles and power plants. Home heaters and gas stoves can also produce substantial amounts of NO_2 in indoor settings.

NO_2 Air Quality, 1982–2001

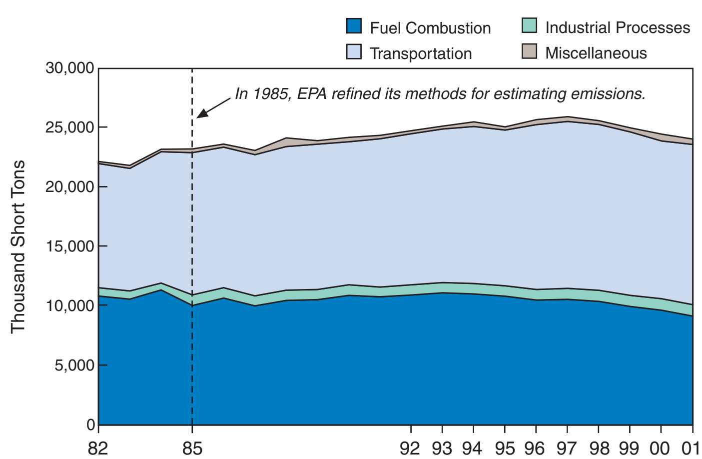
Based on Annual Arithmetic Average



1982–01: 24% decrease
1992–01: 11% decrease

Air quality concentrations do not always track nationwide emissions. For a detailed explanation, see page 3.

NO_x Emissions, 1982–2001



1982–01: 9% increase
1992–01: 3% decrease

Health and Environmental Effects

Short-term exposures (e.g., less than 3 hours) to low levels of NO_2 may lead to changes in airway responsiveness and lung function in individuals with preexisting respiratory illnesses and increases in respiratory illnesses in children. Long-term exposures to NO_2 may lead to increased susceptibility to respiratory infection and may cause irreversible alterations in lung structure. NO_x reacts in the air to form ground-level ozone and fine particle pollution, which are both associated with adverse health effects.

NO_x contributes to a wide range of environmental effects directly and/or when combined with other precursors in acid rain and ozone (see environmental discussion under Ozone and Acid Rain). Nitrogen inputs to terrestrial and wetland systems can alter existing competitive relationships among plant species, leading to changes in community composition and diversity. Similarly, direct nitrogen inputs to aquatic ecosystems such as those found in estuarine and coastal waters (e.g., Chesapeake Bay) can lead to eutrophication (a condition that promotes excessive algae growth, which can lead to a severe depletion of dissolved oxygen and increased levels of toxins harmful to fish and other aquatic life). Nitrogen, alone or in acid rain, also can acidify soils and surface waters. Acidification of soils causes the loss of essential plant nutrients and increased levels of soluble aluminum that are toxic to plants. Acidification of surface waters creates conditions of low pH and levels of aluminum that are toxic to fish and other aquatic organisms. Finally, NO_x is a contributor to visibility impairment.

Trends in NO_2 Levels and NO_x Emissions

Over the past 20 years, monitored levels of NO_2 have decreased 24 percent. All areas of the country that once violated the NAAQS for NO_2 now meet that standard. While air quality levels of NO_2 around urban monitors have fallen, national emissions of NO_x have actually increased over the past 20 years by 9 percent. This increase is the result of a number of factors, the most significant being an increase in NO_x emissions from nonroad engines and diesel vehicles. This increase is of concern because NO_x emissions contribute to the formation of ground-level ozone (smog), but also to other environmental problems like acid rain and nitrogen loadings to waterbodies.

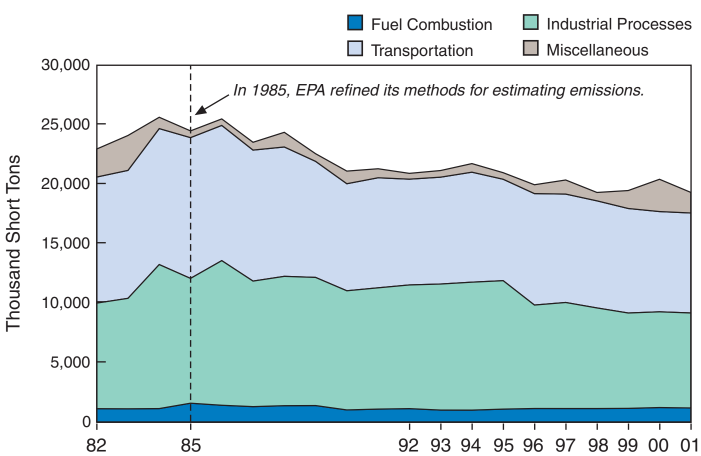
Nature and Sources of the Pollutant

Ground-level ozone (the primary constituent of smog) continues to be a pollution problem throughout many areas of the United States.

Ozone is not emitted directly into the air but is formed by the reaction of VOCs and NO_x in the presence of heat and sunlight. Ground-level ozone forms readily in the atmosphere, usually during hot summer weather. VOCs are emitted from a variety of sources, including motor vehicles, chemical plants, refineries, factories, consumer and commercial products, and other industrial sources. NO_x is emitted from motor vehicles, power plants, and other sources of combustion. Changing weather patterns contribute to yearly differences in ozone concentrations from region to region. Ozone and the pollutants that form ozone also can be transported into an area from pollution sources found hundreds of miles upwind.

> Ozone occurs naturally in the stratosphere and provides a protective layer high above the Earth. See page 23 for more information on the stratospheric ozone layer.

VOC Emissions, 1982–2001



1982–01: 16% decrease
1992–01: 8% decrease

Air quality concentrations do not always track nationwide emissions. *For detailed explanation, see page 3.*

Health and Environmental Effects

Short-term (1- to 3-hour) and prolonged (6- to 8-hour) exposures to ambient ozone have been linked to a number of health effects of concern. For example, health effects attributed to ozone exposure include significant decreases in lung function and increased respiratory symptoms such as chest pain and cough. Exposures to ozone can make people more susceptible to respiratory infection, result in lung inflammation, and aggravate preexisting respiratory diseases such as asthma. Also, increased hospital admissions and emergency room visits for respiratory problems have been associated with ambient ozone exposures. These effects generally occur while individuals are actively exercising, working, or playing outdoors. Children, active outdoors during the summer when ozone levels are at their highest, are most at risk of experiencing such effects. Other at-risk groups include adults who are active outdoors (e.g., some outdoor workers) and individuals with preexisting respiratory disease such as asthma and chronic obstructive pulmonary disease. In addition, longer-term exposures to moderate levels of ozone present the possibility of irreversible changes in the lung structure, which could lead to premature aging of the lungs and worsening of chronic respiratory illnesses.

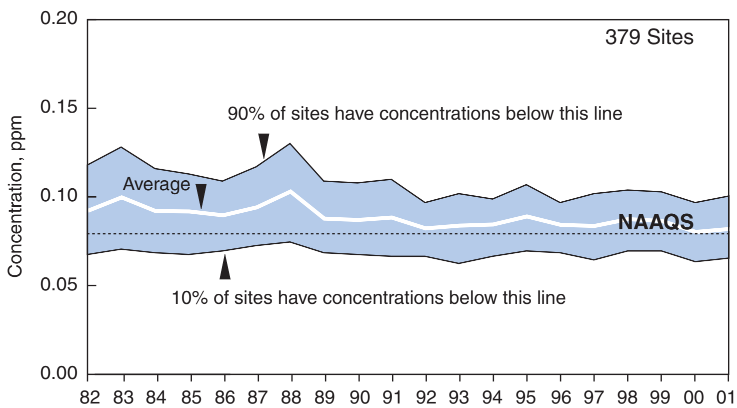
Ozone also affects vegetation and ecosystems, leading to reductions in agricultural crop and commercial forest yields, reduced growth and survivability of tree seedlings, and increased plant susceptibility to disease, pests, and other environmental stresses (e.g., harsh weather). In long-lived species, these effects may become evident only after several years or even decades, thus having the potential for long-term effects on forest ecosystems. Ground-level ozone damage to the foliage of trees and other plants can also decrease the aesthetic value of ornamental species as well as the natural beauty of our national parks and recreation areas.

Trends in Ozone Levels and Related Emissions

In 1997, EPA revised the NAAQS for ozone by setting new 8-hour 0.08-ppm standards. Currently, EPA is tracking trends based on both 1-hour and 8-hour data.

Over the past 20 years, national ambient ozone levels decreased 18 percent based on 1-hour data and 11 percent based on 8-hour data. Between 1982 and 2001, emissions of VOCs decreased 16 percent. During that same time period, emissions of NO_x increased 9 percent.

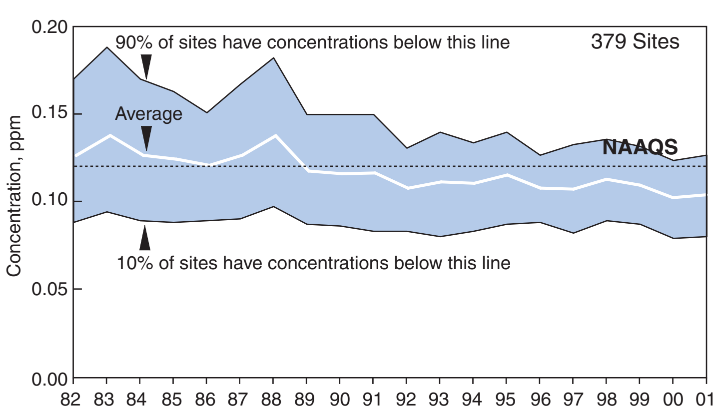
Ozone Air Quality, 1982–2001
Based on Annual 4th Maximum 8-Hour Average



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

Air quality concentrations do not always track nationwide emissions. For a detailed explanation, *see page 3.*

Ozone Air Quality, 1982–2001
Based on Annual 2nd Maximum 1-Hour Average



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

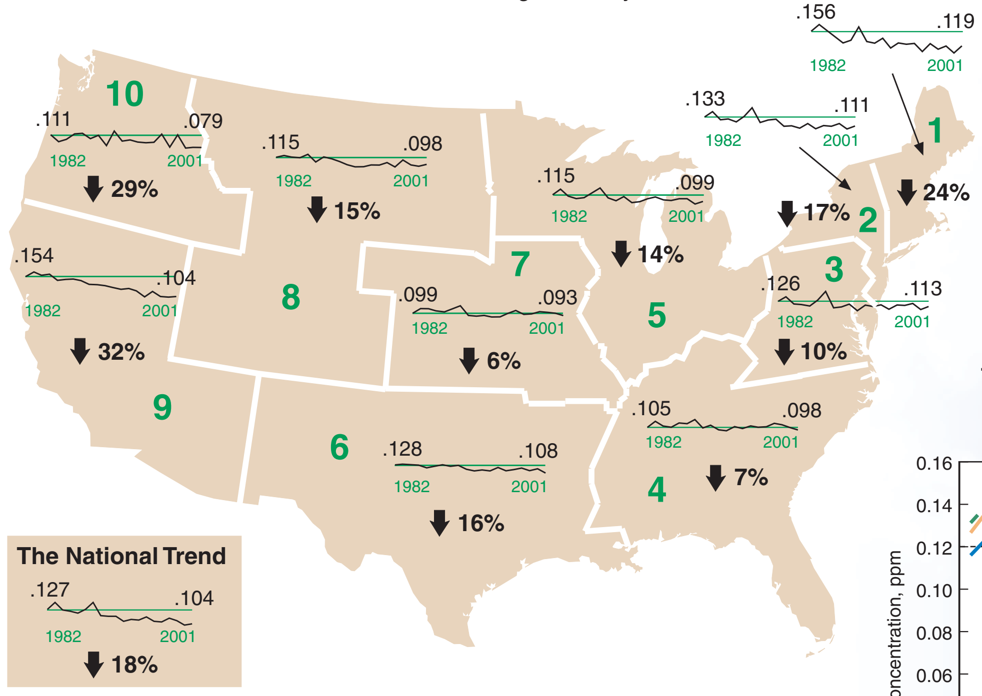
For the period 1982 to 2001, the downward trend in 1-hour ozone levels seen nationally is reflected in every broad geographic area in the country. The Northeast and West exhibited the most substantial improvement, while the South and North Central regions experienced the least rapid progress in lowering ozone concentrations. Similar to the 1-hour ozone trends, all regions experienced improvements in 8-hour ozone levels between 1982 and 2001 except the North Central region, which showed little change during this period. Again, the West and Northeast have exhibited the most substantial reductions in 8-hour ozone levels for the past 20 years.

Across the country, the highest ambient 1-hour ozone concentrations are typically found at suburban sites, consistent with the downwind transport of emissions from urban centers. During the past 20 years, ozone concentrations decreased approximately 20 percent at urban and suburban sites. In the past 10 years, urban sites show declines of approximately 5 percent and suburban sites show a 6 percent decrease. However, at rural monitoring locations, national improvements have slowed. One-hour ozone levels for 2001 are 11 percent lower than those for 1982 but less than 1 percent below 1992 levels. In 2001, for the sixth consecutive year, rural 1-hour ozone levels, on average, are greater than the levels observed for the urban sites, but they are still generally lower than levels observed at suburban sites.

Over the past 10 years, the average 8-hour ozone level in 33 of our national parks increased almost 4 percent. Six monitoring sites in five of these parks experienced statistically significant upward trends in 8-hour ozone levels: Great Smoky Mountains (Tennessee), Craters of the Moon (Idaho), Mesa Verde (Colorado), Mammoth Cave (Kentucky), and Yellowstone (Wyoming). Monitoring data for two parks showed statistically significant improvements over the same time period: Saguaro (Arizona) and Sequoia (California). For the remaining 26 parks where ozone monitoring takes place, the 8-hour ozone levels at 18 increased only slightly between 1992 and 2001, while 5 showed decreasing levels and 3 were unchanged.

Trend in 1-Hour Ozone Levels, 1982–2001, Averaged across EPA Regions*

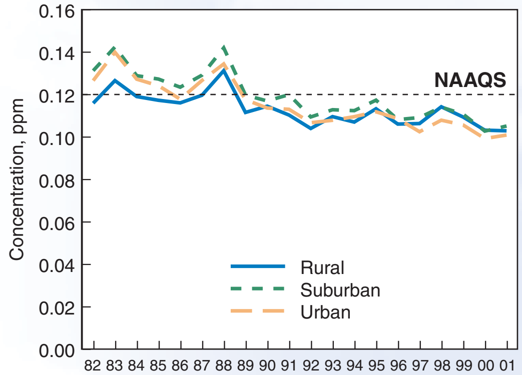
Based on Annual 2nd Highest Daily Maximum



*EPA Regional Office contacts can be found at www.epa.gov/epahome/locate2.htm.

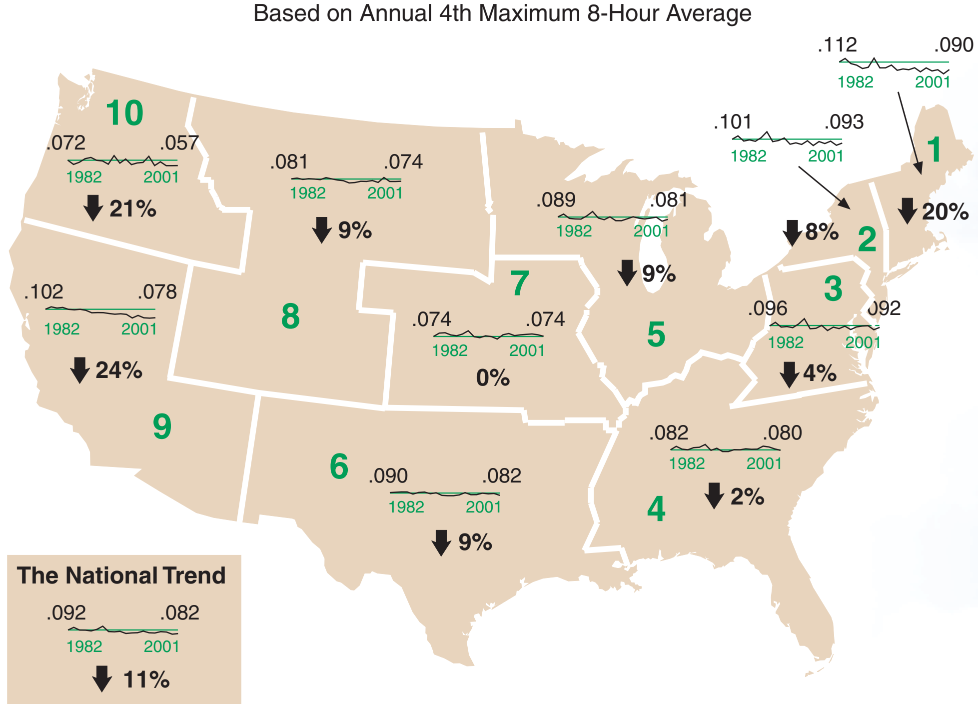
Trend in 1-hour Ozone Levels, 1982–2001, by Location of Site

Based on Annual 2nd Highest Daily Maximum



Trend in 8-Hour Ozone Levels, 1982–2001, Averaged across EPA Regions

Based on Annual 4th Maximum 8-Hour Average



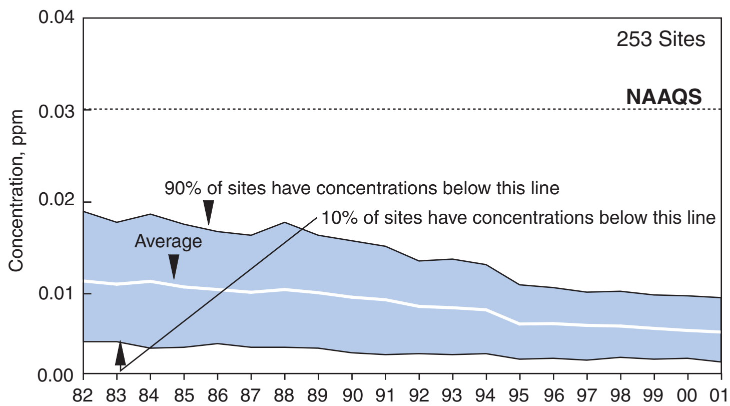
Concentrations are in parts per million (ppm).

SULFUR DIOXIDE (SO_2)

Nature and Sources of the Pollutant

Sulfur dioxide belongs to the family of SO_x gases. These gases are formed when fuel containing sulfur (mainly coal and oil) is burned and during metal smelting and other industrial processes. Most SO_2 monitoring stations are located in urban areas. The highest monitored concentrations of SO_2 are recorded in the vicinity of large industrial facilities. Fuel combustion, largely from coal-fired power plants, accounts for most of the total SO_2 emissions.

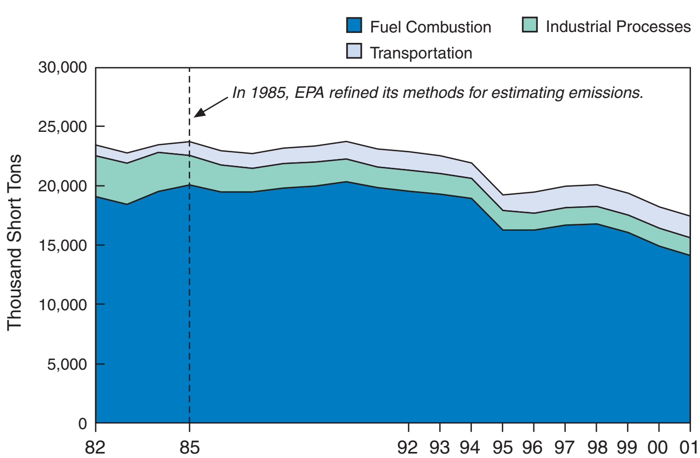
SO_2 Air Quality, 1982–2001
Based on Annual Arithmetic Average



1982–01: 52% decrease
1992–01: 35% decrease

Air quality concentrations do not always track nationwide emissions. For a detailed explanation, see page 3.

SO_2 Emissions, 1982–2001



1982–01: 25% decrease
1992–01: 24% decrease

Health and Environmental Effects

High concentrations of SO_2 can result in temporary breathing impairment for asthmatic children and adults who are active outdoors. Short-term exposures of asthmatic individuals to elevated SO_2 levels during moderate activity may result in breathing difficulties that can be accompanied by symptoms such as wheezing, chest tightness, or shortness of breath. Other effects that have been associated with longer-term exposures to high concentrations of SO_2, in conjunction with high levels of PM, include aggravation of existing cardiovascular disease, respiratory illness, and alterations in the lungs' defenses. The subgroups of the population that may be affected under these conditions include individuals with heart or lung disease, as well as the elderly and children.

Together, SO_2 and NO_x are the major precursors to acidic deposition (acid rain), which is associated with the acidification of soils, lakes, and streams and accelerated corrosion of buildings and monuments. SO_2 also is a major precursor to $PM_{2.5}$, which is a significant health concern as well as a main contributor to poor visibility. (See Acid Rain section, page 16, for a more detailed discussion.)

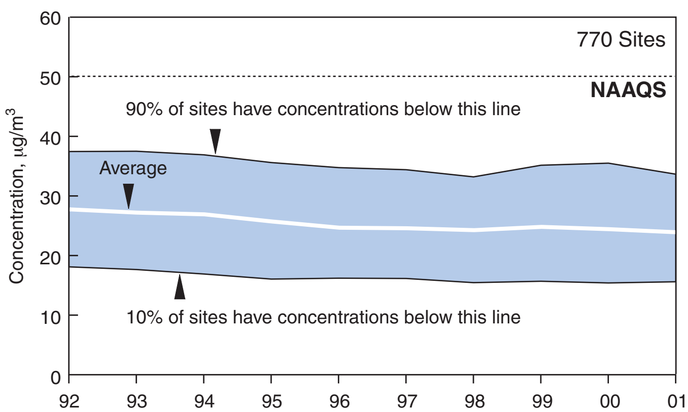
Trends in SO_2 Levels and Emissions

Nationally, average SO_2 ambient concentrations have decreased 52 percent from 1982 to 2001 and 35 percent over the more recent 10-year period 1992 to 2001. SO_2 emissions decreased 25 percent from 1982 to 2001 and 24 percent from 1992 to 2001. Reductions in SO_2 concentrations and emissions since 1990 are due, in large part, to controls implemented under EPA's Acid Rain Program beginning in 1995.

Nature and Sources of the Pollutant

Particulate matter is the general term used for a mixture of solid particles and liquid droplets found in the air. Some particles are large enough to be seen as dust or dirt. Others are so small they can be detected only with an electron microscope. $PM_{2.5}$ describes the "fine" particles that are less than or equal to 2.5 µm in diameter. "Coarse fraction" particles are greater than 2.5 µm, but less than or equal to 10 µm in diameter. PM_{10} refers to all particles less than or equal to 10 µm in diameter. A particle 10 µm in diameter is about one-seventh the diameter of a human hair. PM can be emitted directly or form in the atmosphere. "Primary" particles, such as dust from roads or elemental carbon (soot) from wood combustion, are emitted directly into the atmosphere. "Secondary" particles are formed in the atmosphere from primary gaseous emissions. Examples include sulfates, formed from SO_2 emissions from power plants and industrial facilities, and nitrates, formed from NO_x emissions from power plants, automobiles, and other types of combustion sources. The chemical composition of particles depends on location, time of year, and weather. Generally, coarse PM is composed largely of primary particles and fine PM contains many more secondary particles.

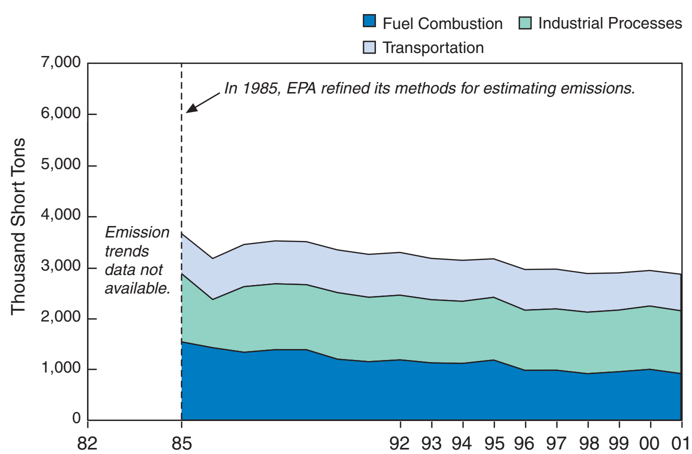
PM_{10} Air Quality, 1992–2001
Based on Seasonally Weighted Annual Average



1992–01: 14% decrease

Air quality concentrations do not always track nationwide emissions. For a detailed explanation, see page 3.

PM_{10} Emissions, 1982–2001



1992–01: 13% decrease

Health and Environmental Effects

Particles that are small enough to get into the lungs (those less than or equal to 10 µm in diameter) can cause numerous health problems and have been linked with illnesses and deaths from heart and lung diseases. Various health problems have been associated with long-term (e.g., multi-year) exposures as well as daily and even, potentially, peak (e.g., 1-hour) exposures to particles. Particles can aggravate respiratory conditions such as asthma and bronchitis and have been associated with cardiac arrhythmias (heartbeat irregularities) and heart attacks. Particles of concern can include both fine and coarse-fraction particles, although fine particles have been more clearly linked to the most serious health effects. People with heart or lung disease, the elderly, and children are at highest risk from exposure to particles. In addition to health problems, PM is the major cause of reduced visibility in many parts of the United States. Airborne particles also can impact vegetation and ecosystems and can cause damage to paints and building materials. (See Acid Rain, NO_2, and SO_2 sections.)

Trends in PM_{10} Levels and Direct Emissions

Between 1992 and 2001, average PM_{10} concentrations decreased 14 percent, while direct PM_{10} emissions decreased 13 percent.

If enacted, President Bush's Clear Skies Initiative would decrease PM concentrations by dramatically reducing emissions of SO_2 and NO_x. This initiative would also reduce mercury emissions (www.epa.gov/clearskies).

Trends in $PM_{2.5}$ Levels and Direct Emissions

The chart at right shows that direct $PM_{2.5}$ emissions from man-made sources decreased 10 percent nationally between 1992 and 2001. This chart tracks only directly emitted particles and does not account for secondary particles formed when emissions of NO_x, SO_2, ammonia, and other gases react in the atmosphere. The principal types of secondary particles are sulfates and nitrates, which are formed when SO_2 and NO_x react with ammonia.

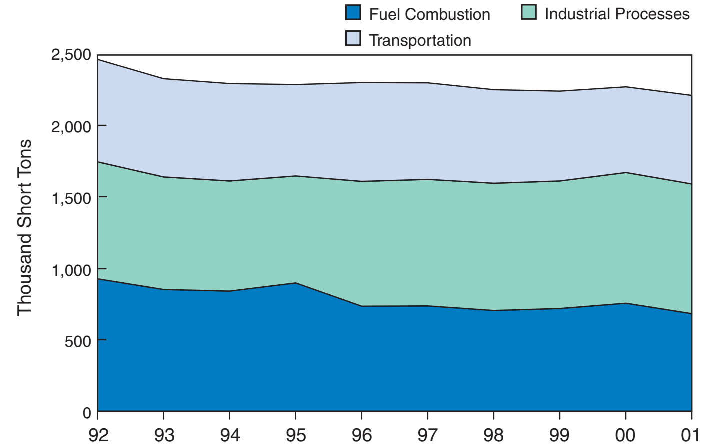
The maps at right show how sulfates and nitrates, along with other components, contribute to $PM_{2.5}$ concentrations. The first map represents the most recent year of data available from the Interagency Monitoring of Protected Visual Environments (IMPROVE) network, which was established in 1987 to track trends in pollutants, such as $PM_{2.5}$, that contribute to visibility impairment. Because the monitoring sites are located in rural areas throughout the country, the network is a good source for assessing regional differences in $PM_{2.5}$. The second map represents the most recent year of data from EPA's urban speciation network, which was established in 1999. All of these sites are located in urban areas.

Sites in the rural East typically have higher annual average $PM_{2.5}$ concentrations than those in the rural West, as shown by the larger circles in the East. Most of this regional difference is attributable to higher sulfate concentrations in the eastern United States. Sulfate concentrations in the East largely result from SO_2 emissions from coal-fired power plants.

Sites in urban areas, as shown in the circles in the map at right, generally have higher annual average $PM_{2.5}$ concentrations than nearby rural areas. Carbon from soot and organic compounds accounts for much of the difference, while sulfate concentrations are about the same. Sites in central California show that nitrates, in addition to carbon, are responsible for higher urban concentrations in that region.

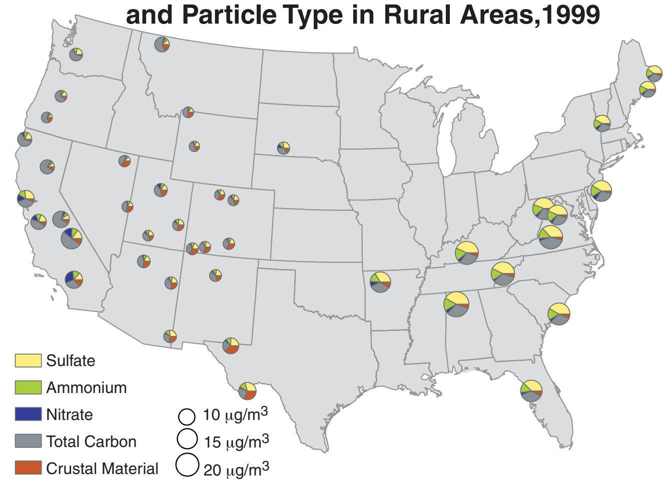
Trends in rural $PM_{2.5}$ concentrations can be examined with data from the IMPROVE network. At the time of this report, 2000 and 2001 data were not available. However, 36 sites have enough data to assess trends from 1992 to 1999. In the East, where sulfates contribute most to rural $PM_{2.5}$, the

Direct $PM_{2.5}$ Emissions, 1992–2001



1992–01: 10% decrease

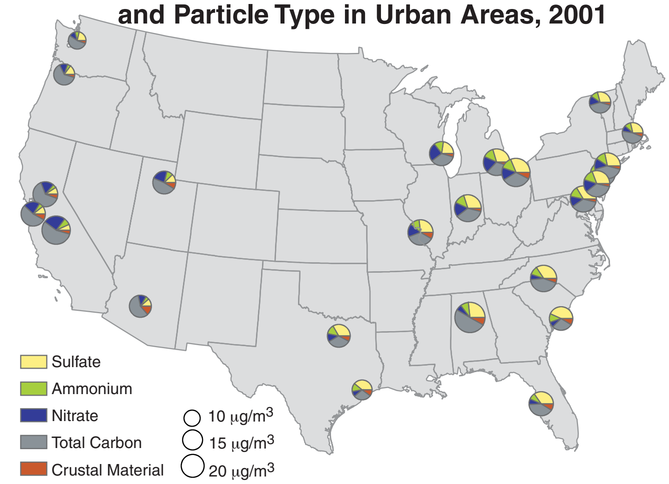
Annual Average $PM_{2.5}$ Concentrations (µg/m^3) and Particle Type in Rural Areas, 1999



Source: Interagency Monitoring of Protected Visual Environments Network, 1999.

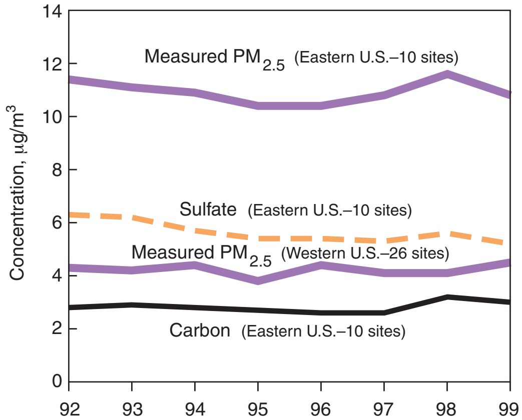
Note: Direct comparisons of the information in these two maps should take into consideration: the fact that they represent different years; that one is an urban network and the other is a rural network; and that there are also differences in instruments and measurement methods.

Annual Average $PM_{2.5}$ Concentrations (µg/m^3) and Particle Type in Urban Areas, 2001



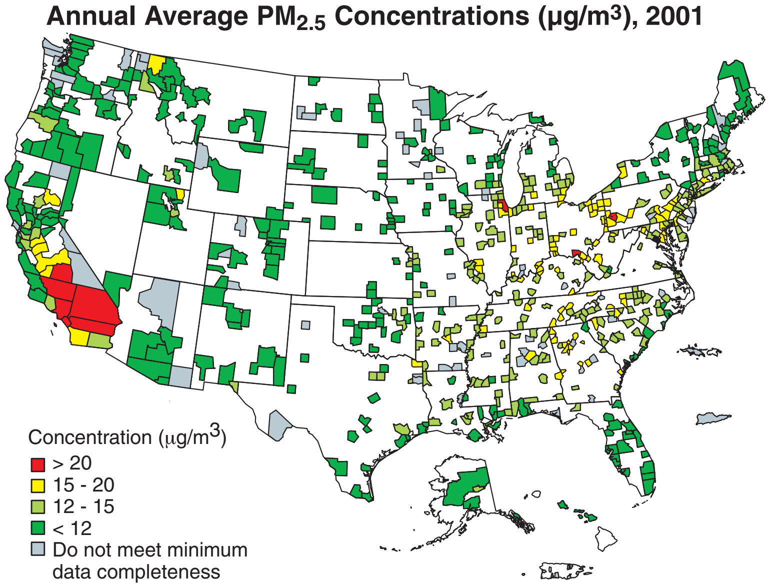
Source: EPA Speciation Network, 2001.

Annual Average $PM_{2.5}$ Concentrations in Rural Areas



Source: Interagency Monitoring of Protected Visual Environments Network, 1999.

Annual Average $PM_{2.5}$ Concentrations (µg/m³), 2001



Source: U.S. EPA AIRS databases as of 7/8/02.
Minimum 11 samples per calendar quarter required.

Note: The NAAQS for $PM_{2.5}$ is 15 µg/m³ but is based on the average of 3 years of monitoring data. In addition, $PM_{2.5}$ concentration measurements from the new nationwide monitoring network are not directly comparable to the measurements from the IMPROVE network due to differences in instruments and measurement methods.

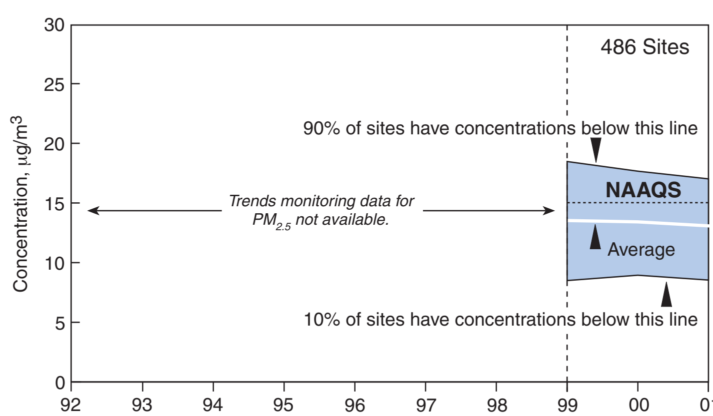
annual average across the 10 sites decreased 5 percent from 1992 to 1999. The peak in 1998 is associated with increases in sulfates and carbon from soot and organic compounds. Average $PM_{2.5}$ concentrations across the 26 sites in the West were less than one-half of the levels measured at eastern sites from 1992 to 1999.

In 1999, EPA and its state, tribal, and local air pollution control partners deployed a monitoring network to begin measuring $PM_{2.5}$ concentrations nationwide. The map at left shows annual average $PM_{2.5}$ concentrations by county. This map also indicates that $PM_{2.5}$ concentrations vary regionally. Based on the monitoring data, parts of California and much of the eastern United States have annual average $PM_{2.5}$ concentrations above the level of the annual $PM_{2.5}$ standard, as indicated by the orange and red on the map. With few exceptions, the rest of the country generally has annual average concentrations below the level of the annual $PM_{2.5}$ health standard.

Now that there are 3 years of monitoring data available, we have begun to examine trends at the national level. Annual average $PM_{2.5}$ concentrations decreased 5 percent nationally from 1999 to 2001, with much of that decrease occurring between 2000 and 2001. This decrease may or may not represent a trend, given the few years of data available at this time. The Southeast was responsible for most of that reduction, where the monitored levels of $PM_{2.5}$ decreased 10 percent from 2000 to 2001. Lower 2001 annual average concentrations in the Southeast are due, in part, to less demand on utilities during a very warm winter. This is illustrated by the reduction in direct emissions of SO_2 and $PM_{2.5}$ from fuel combustion in 2001.

$PM_{2.5}$ Air Quality, 1999–2001

Based on Seasonally Weighted Annual Average

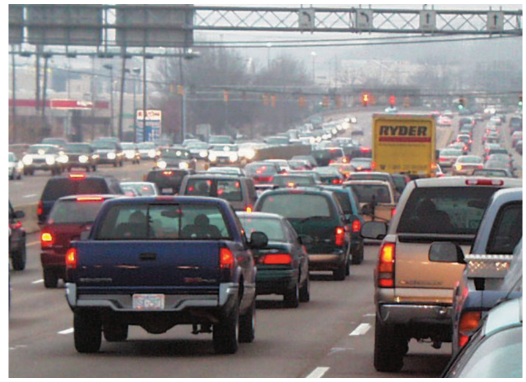


1999–01: 5% decrease

CARBON MONOXIDE (CO)

Nature and Sources of the Pollutant

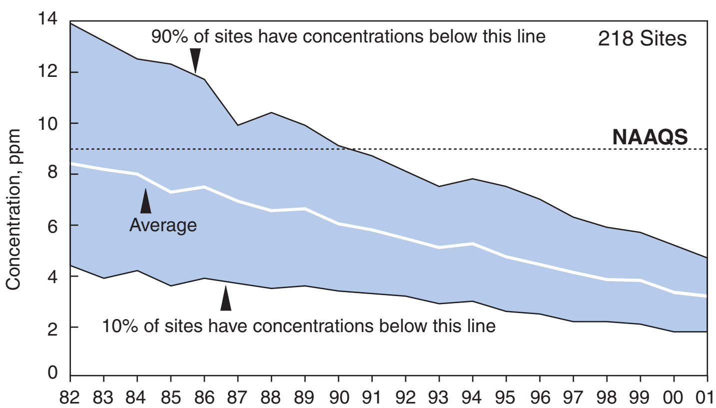
Carbon monoxide is a colorless and odorless gas, formed when carbon in fuel is not burned completely. It is a component of motor vehicle exhaust, which contributes about 60 percent of all CO emissions nationwide. Nonroad vehicles account for the remaining CO emissions from transportation sources. High concentrations of CO generally occur in areas with heavy traffic congestion. In cities, as much as 95 percent of all CO emissions may come from automobile exhaust. Other sources of CO emissions include industrial processes,



nontransportation fuel combustion, and natural sources such as wildfires. Peak CO concentrations typically occur during the colder months of the year when CO automotive emissions are greater and nighttime inversion conditions (where air pollutants are trapped near the ground beneath a layer of warm air) are more frequent.

CO Air Quality, 1982–2001

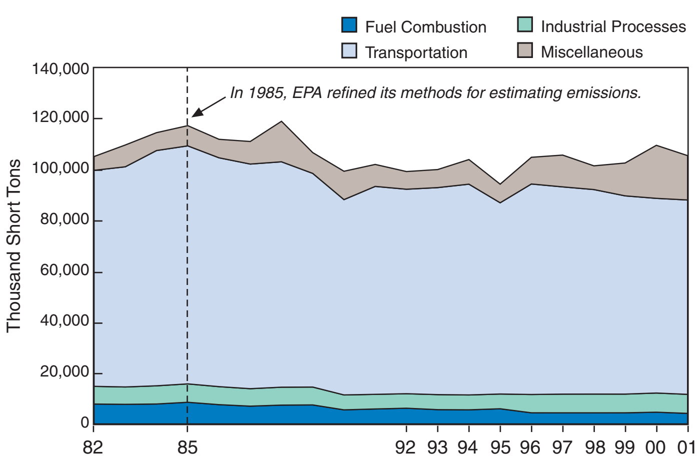
Based on Annual 2nd Maximum 8-hour Average



1982–01: 62% decrease
1992–01: 38% decrease

Air quality concentrations do not always track nationwide emissions. For a detailed explanation, see page 3.

CO Emissions, 1982–2001



1982–01: 0% change
1992–01: 6% increase

Health and Environmental Effects

CO enters the bloodstream through the lungs and reduces oxygen delivery to the body's organs and tissues. The health threat from levels of CO sometimes found in the ambient air is most serious for those who suffer from cardiovascular disease, such as angina pectoris. At much higher levels of exposure not commonly found in ambient air, CO can be poisonous, and even healthy individuals may be affected. Visual impairment, reduced work capacity, reduced manual dexterity, poor learning ability, and difficulty in performing complex tasks are all associated with exposure to elevated CO levels.

Trends in CO Levels and Emissions

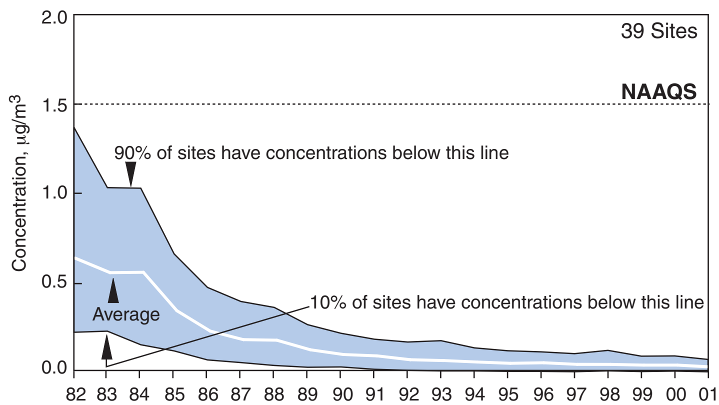
Nationally, the 2001 ambient average CO concentration is almost 62 percent lower than that for 1982 and is the lowest level recorded during the past 20 years. CO emissions from transportation sources, the major contributor to ambient CO concentration, have decreased slightly during this period. Between 1992 and 2001, ambient CO concentrations decreased 38 percent. This air quality improvement occurred despite an approximately 35 percent increase in vehicle miles traveled in the United States during this 10-year period and an increase in total CO emissions of 6 percent. The recent increase in CO emissions was caused by an extremely serious wildfire season in 2000. Nearly twice the number of U.S. acres burned in 2000 compared to the average year since 1982.

Nature and Sources of the Pollutant

In the past, automotive sources were the major contributor of lead emissions to the atmosphere. As a result of EPA's regulatory efforts to reduce the content of lead in gasoline, however, the contribution of air emissions of lead from the transportation sector, and particularly the automotive sector, has greatly declined over the past two decades. Today, industrial processes, primarily metals processing, are the major source of lead emissions to the atmosphere. The highest air concentrations of lead are usually found in the vicinity of smelters and battery manufacturers.

Lead Air Quality, 1982–2001

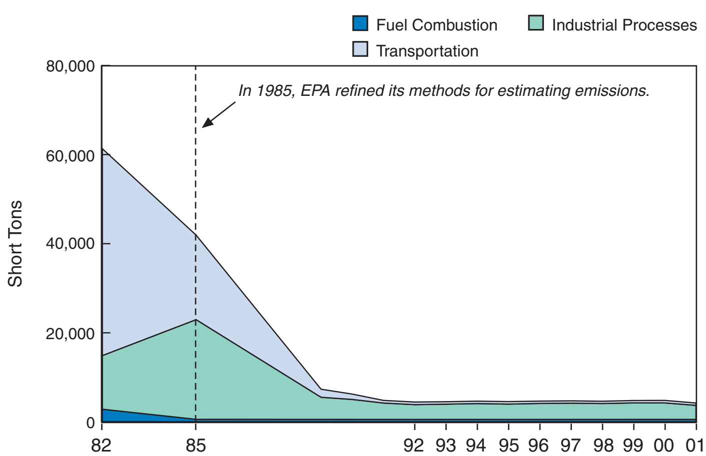
Based on Annual Maximum Quarterly Average



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

Air quality concentrations do not always track nationwide emissions. For a detailed explanation, see page 3.

Lead Emissions, 1982–2001



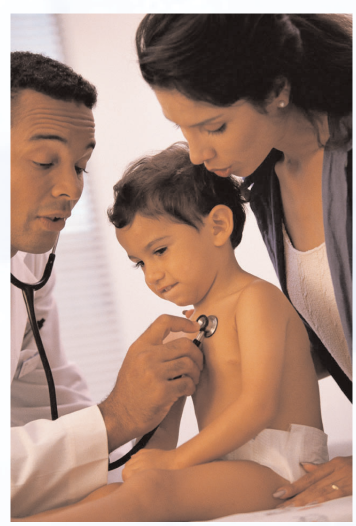
1982–01: 93% decrease

Health and Environmental Effects

Exposure to lead occurs mainly through inhalation of air and ingestion of lead in food, water, soil, or dust. It accumulates in the blood, bones, and soft tissues and can adversely affect the kidneys, liver, nervous system, and other organs. Excessive exposure to lead may cause neurological impairments such as seizures, mental retardation, and behavioral disorders. Even at low doses, lead exposure is associated with damage to the nervous systems of fetuses and young children, resulting in learning deficits and lowered IQ. Recent studies also show that lead may be a factor in high blood pressure and subsequent heart disease. Lead can also be deposited on the leaves of plants, presenting a hazard to grazing animals and humans through ingestion.

Trends in Lead Levels and Emissions

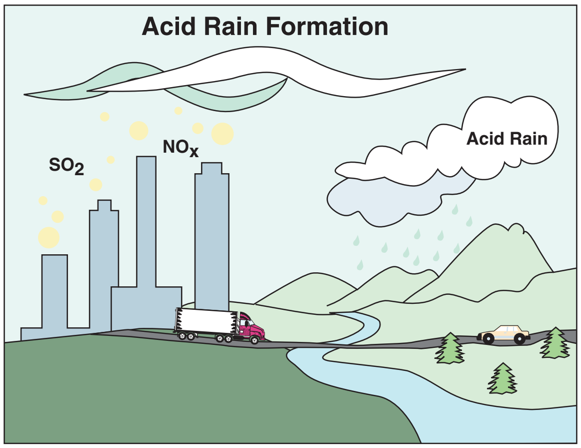
Because of the phaseout of leaded gasoline, lead emissions and concentrations decreased sharply during the 1980s and early 1990s. The 2001 average air quality concentration for lead is 94 percent lower than in 1982. Emissions of lead decreased 93 percent over that same 20-year period. Today, the only violations of the lead NAAQS occur near large industrial sources such as lead smelters and battery manufacturers. Various enforcement and regulatory actions are being actively pursued by EPA and the states for cleaning up these sources.



Acid Rain

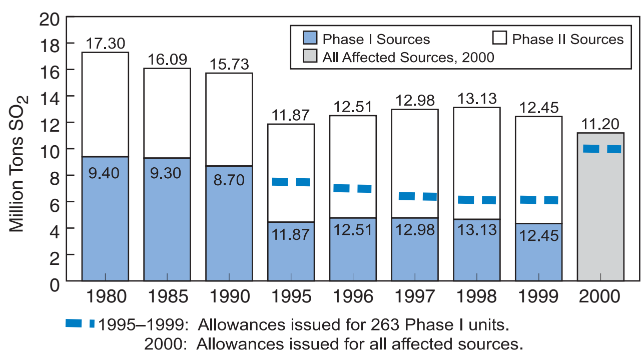
Nature and Sources of the Problem

Acidic deposition or "acid rain" occurs when emissions of sulfur dioxide and nitrogen oxides in the atmosphere react with water, oxygen, and oxidants to form acidic compounds. These compounds fall to the Earth in either dry form (gas and particles) or wet form (rain, snow, and fog). Some are carried by the wind, sometimes hundreds of miles, across state and national borders. In the United States, about 64 percent of annual SO_2 emissions and 26 percent of NO_x emissions are produced by electric utility plants that burn fossil fuels.

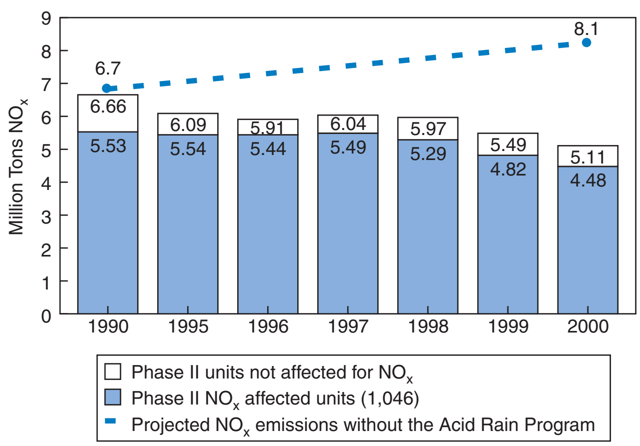


Coal-fired electric utilities and other sources that burn fossil fuels emit SO_2 and NO_x.

SO_2 Emissions Covered under the Acid Rain Program



NO_x Emissions Covered under the Acid Rain Program



Health and Environmental Effects

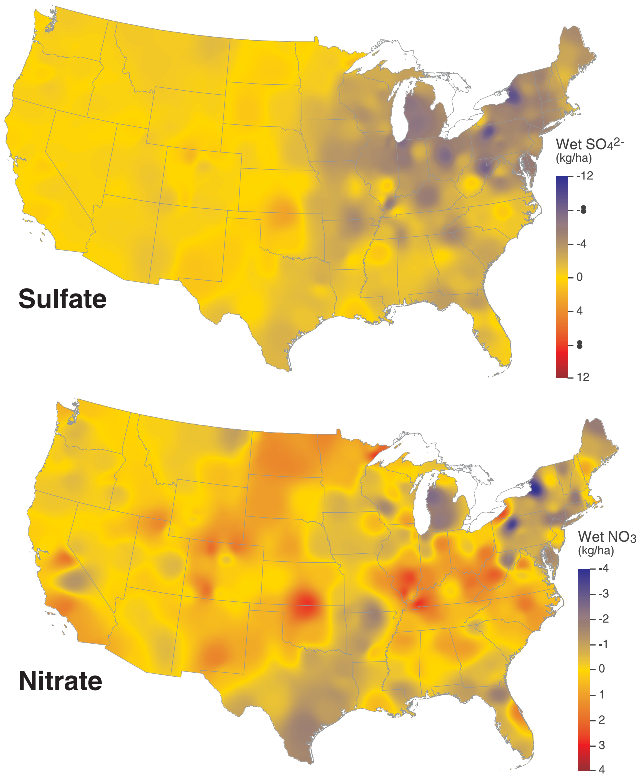
In the environment, acid deposition causes soils and waterbodies to acidify (making the water unsuitable for some fish and other wildlife) and damages some trees, particularly at high elevations. It also speeds the decay of buildings, statues, and sculptures that are part of our national heritage. The nitrogen portion of acid deposition contributes to eutrophication in coastal ecosystems, the symptoms of which include algal blooms (some of which may be toxic), fish kills, and loss of plant and animal diversity. Finally, acidification of lakes and streams can increase the amount of methyl mercury available in aquatic systems. Most exposure to mercury comes from eating contaminated fish. Reductions in SO_2 and NO_x have begun to reduce some of these negative environmental effects and are leading to significant improvements in public health (described previously).

Program Structure

The goal of EPA's Acid Rain Program, established by the Clean Air Act, is to improve public health and the environment by reducing emissions of SO_2 and NO_x. The program was implemented in two phases: Phase I for SO_2 began in 1995 and targeted the largest and highest-emitting coal-fired power plants. Phase I for NO_x began in 1996. Phase II for both pollutants began in 2000 and sets restrictions on Phase I plants as well as smaller coal-, gas-, and oil-fired plants. Over 2,000 sources are now affected by the Acid Rain Program.

The Acid Rain Program will reduce annual SO_2 emissions by 10 million tons from 1980 levels by 2010. The program sets a permanent cap of 8.95 million tons on the total amount of SO_2 that may be emitted by power plants nationwide, about half the amount emitted in 1980. It employs an emissions trading program to reach that emissions cap more efficiently and cost-effectively. Sources are allocated allowances efficiently each year (one allowance equals 1 ton of SO_2 emissions), which can be bought or sold or banked for future use.

Change in Deposition from Precipitation 1990–1994 to 1996–2000



Source: U.S. EPA analysis of National Atmospheric Deposition Program data.

This approach gives sources the flexibility and incentive to reduce emissions at the lowest cost while ensuring that the emission cap is met.

The NO_x component of the Acid Rain Program limits the emission rate for all affected utilities, resulting in a 2 million ton NO_x reduction from 1980 levels by 2000. There is no cap on total NO_x emissions, but under this program a source can choose to over-control at units where it is technically easier to control emissions, average these emissions with those at their other units, and thereby achieve overall emissions reductions at lower cost.

Emissions and Atmospheric Trends

SO_2 emissions reductions have been significant in the first 6 years of EPA's Acid Rain Program. The first year of compliance with Phase II of the Acid Rain Program was 2000. Sources in the Acid Rain Program emitted 11.2 million tons in 2000, down from 16 million tons in 1990. Emissions of SO_2 dropped 1 million tons between 1999 and 2000. Sources began drawing down the bank of unused allowances in 2000, resulting in emissions levels greater than the allowances allocated in 2000 but still lower than emissions during any previous year.

Actual NO_x emissions, as shown in the graph on the bottom left of page 16, have also declined since 1990. NO_x emissions decreased steadily from 6 tons in 1997 to just over 5 tons in 2000. The more than 1,000 sources affected by Phase II emitted 4.5 tons in 2000, over 1 million tons (almost 20 percent) less than they did in 1990. NO_x emissions in 2000 were somewhat lower (7 percent) than in 1999 and almost half of what emissions were projected to have been in 2000 without the Acid Rain Program.

For all years from 1995 through 2000, sulfate deposition exhibited dramatic and unprecedented reductions over a large area of the eastern United States. Average sulfate deposition in 1996–2000 compared to 1990-1994 was 10 percent lower nationwide and 15 percent lower in the East. Similarly, sulfate air concentrations, which contribute to human health and visibility problems, were reduced significantly, especially in the East. Nitrate deposition decreased slightly in some places but increased in others, causing an overall average increase in nitrate deposition between 1990–1994 and 1996–2000 of 3 percent.

These reductions in acid precipitation are directly related to the large regional decreases in SO_2 and NO_x emissions resulting from the Acid Rain Program. The largest reductions in sulfate concentrations occurred along the Ohio River Valley and in states immediately downwind. The largest reductions in wet sulfate deposition occurred across the Mid-Appalachian and Northeast regions of the country. Reductions in the East in hydrogen ion concentrations, the primary indicator of precipitation acidity, were similar to those of sulfate concentrations, both in magnitude and location. The largest reductions in wet nitrate deposition were in the northeastern United States, Michigan, and Texas. The Midwest, the Southeast, and California showed the highest increases in deposition even though emissions from acid rain sources have not increased substantially there. Acid rain sources account for only one-third of nationwide nitrogen emissions, so emissions trends in other source categories, especially agriculture and mobile sources, affect air concentrations and deposition.

Visibility

In 2000, the IMPROVE Monitoring Network, used to track visibility trends at national parks and wilderness areas, started an expansion from 30 to 110 monitoring sites. The expansion work was completed in the fall of 2001. However, due to the level of resources required to complete the network expansion, reporting of 2000 IMPROVE data will occur while this brochure is being finalized. Therefore, no update is provided for visibility trends reported in the *1999 Status and Trends Brochure*. Reporting of 2000 and 2001 visibility trends are scheduled to be included in U.S. EPA's 2001 *National Air Quality and Emission Trends Report*.

Nature and Sources of the Problem

Visibility impairment is one of the most obvious effects of air pollution and occurs at many of the best known and most treasured natural parks and wilderness areas, such as the Grand Canyon, Yosemite, Yellowstone, Mount Rainier, Shenandoah, and the Great Smoky Mountain National Park, as well as in urban areas.

Visibility impairment results from the scattering and absorption of light by air pollution, including particles and gases. The scattering and absorption by air pollution limits the distance we can see and can also degrade the color, clarity, and contrast of scenes. The same fine particles that are linked to serious health effects and premature death can also significantly affect our ability to see.

Some particles that contribute to visibility impairment are emitted directly into the atmosphere from their sources, such as dust from roads or elemental carbon (soot) from wood combustion. In other cases, particles are formed in the atmosphere from primary gaseous emissions such as SO_2 emissions from power plants and other industrial facilities and nitrates formed from NO_x emissions from power plants, automobiles, and other types of combustion sources. These types of particles are referred to as secondarily formed particles. In the eastern United States, reduced visibility is mainly attributable to secondarily formed sulfates. Although these secondarily formed particles still account for a significant amount of particulate loading in the West, primary emissions from sources like wood smoke contribute a larger percentage of the total particulate loading than in the East.

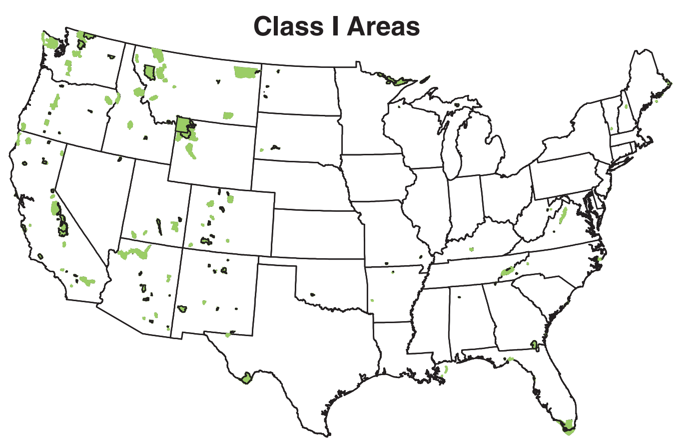
Also, humidity can significantly increase the effect of pollution on visibility, causing some particles to become more efficient at scattering light and causing visibility impairment. Annual average relative humidity levels are 70 to 80 percent in the East as compared to 50 to 60 percent in the West. Poor summer visibility in the eastern United States is primarily the result of high sulfate concentrations combined with high humidity levels.

	East	West
Sulfates	60–86%	25–50%
Organic Carbon	10–18%	25–40%
Nitrates	7–16%	5–45%
Elemental Carbon (soot)	5–8%	5–15%
Crustal Material (soil dust)	5–15%	5–25%

This table shows pollutants that contribute to visibility impairment in the eastern and western parts of the United States. Sulfates are generally the largest contributor in both the East and the West.

Program Structure

The Clean Air Act provides for the protection of visibility in national parks and wilderness areas, also known as Class I areas. The Clean Air Act's national goal calls for remedying existing visibility impairment and preventing future impairment in these 156 Class I areas across the country.



The Clean Air Act provides for the protection of visibility in our national parks and wilderness areas, also known as Class I areas. There are 156 Class I areas across the United States as shown.

In 1987, the IMPROVE visibility network was established as a cooperative effort among EPA, states, National Park Service, U.S. Forest Service, Bureau of Land Management, and U.S. Fish and Wildlife Service. Data are collected and analyzed from this network to determine the type of pollutants primarily responsible for reduced visibility

Shenandoah National Park under bad and good visibility conditions. The visual range in the top photo is 25 km while the visual range in the bottom photo is 180 km.

Yosemite National Park under bad and good visibility conditions. The visual range in the top photo is 111 km while the visual range in the bottom photo is greater than 208 km.

and to track progress toward the Clean Air Act's national goal.

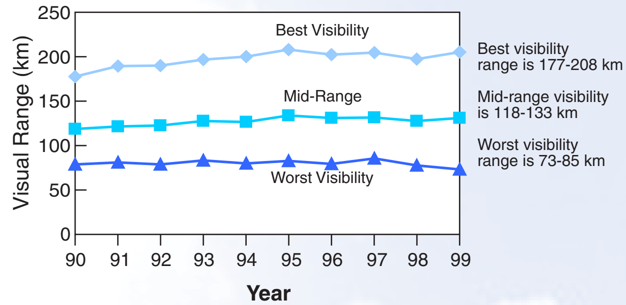
In April 1999, EPA initiated a new regional haze program. The program addresses visibility impairment in national parks and wilderness areas caused by numerous sources located over broad regions. The program sets a framework for states to develop goals for improving visibility on the worst visibility days each year and to adopt emission strategies to meet these goals. Because fine particles are frequently transported hundreds of miles, pollution that occurs in one state may contribute to the visibility impairment in another state. For this reason, EPA encourages states to coordinate through regional planning organizations to develop regional strategies to improve visibility and to reduce pollutants that contribute to fine particles and ground-level ozone. States are also required to review progress every 5 years and revise any strategies as necessary.

Visibility Trends

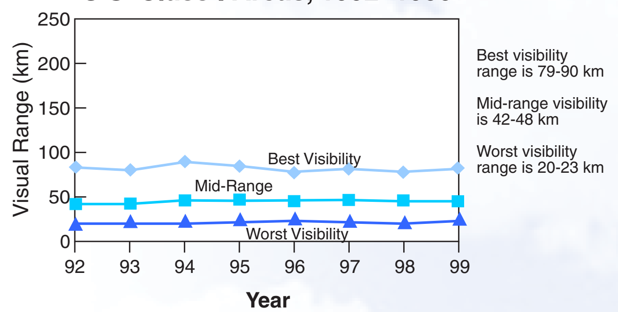
Without the effects of pollution, a natural visual range in the United States is approximately 75 to 150 km (45 to 90 miles) in the East and 200 to 300 km (120 to 180 miles) in the West.

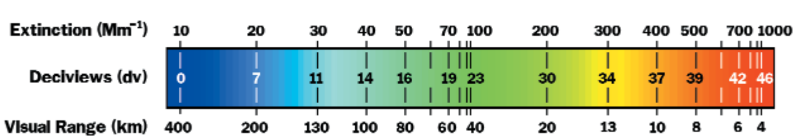
Data collected by the IMPROVE network show visibility impairment for the worst visibility in the West is similar to days with the best visibility in the East. In 1999, mean visual range for the worst days in the East was only 24 km (14.4 miles) compared to 84 km (50.4 miles) for the best visibility. In the West, visibility impairment for the worst days remained relatively unchanged over the 1990s, with the mean visual range for 1999 (80 km) nearly the same as the 1990 level (86 km).

Visibility Trends for Western U.S. Class I Areas, 1990–1999



Visibility Trends for Eastern U.S. Class I Areas, 1992–1999





***Visibility Metrics**. Comparisons of extinction (Mm^{-1}), deciviews (dv), and visual range (km). Notice the difference in the three scales: 10 Mm^{-1} corresponds to about 400 km visual range and 0.0 dv, while 1,000 Mm^{-1} is about 4 km visual range and 46 dv.*

Toxic Air Pollutants

Nature and Sources of the Problem

Toxic air pollutants, or air toxics, are those pollutants that cause or may cause cancer or other serious health effects, such as reproductive effects or birth defects. Air toxics may also cause adverse environmental and ecological effects. Examples of toxic air pollutants include benzene, found in gasoline; perchloroethylene, emitted from some dry cleaning facilities; and methylene chloride, used as a solvent by a number of industries. Most air toxics originate from man-made sources, including mobile sources (e.g., cars, trucks, construction equipment) and stationary sources (e.g., factories, refineries, power plants), as well as indoor sources (e.g., some building materials and cleaning solvents). Some air toxics are also released from natural sources such as volcanic eruptions and forest fires. The Clean Air Act identifies 188 air toxics from industrial sources. EPA has identified 20 of these pollutants that are associated with mobile sources and one additional mobile source air toxic designated "diesel particulate matter and diesel exhaust organic gases."

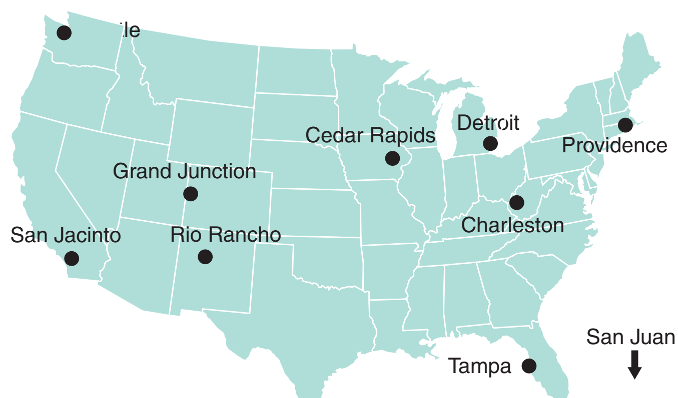
Health and Environmental Effects

People exposed to toxic air pollutants at sufficient concentrations may experience various health effects, including cancer, damage to the immune system, as well as neurological, reproductive (e.g., reduced fertility), developmental, respiratory, and other health problems. In addition to exposure from breathing air toxics, risks also are associated with the deposition of toxic pollutants onto soils or surface waters, where they are taken up by plants and ingested by animals and eventually magnified up through the food chain. Like humans, animals may experience health problems due to air toxics exposure.

Trends in Toxic Air Pollutants

EPA and states do not maintain an extensive nationwide monitoring network for air toxics as they do for many of the other pollutants discussed in this report. While EPA, states, tribes, and local air regulatory agencies collect monitoring data for a number of toxic air pollutants, both the chemicals monitored and the geographic coverage of the monitors vary from state to state. EPA is working with these regulatory partners to build upon the existing monitoring sites to create a national monitoring network for a number of toxic air pollutants. The goal is to ensure that those compounds that pose the greatest risk are measured. The available monitoring data help air pollution control agencies track trends in toxic air pollutants in various locations around the country. EPA began a pilot city monitoring project in 2001 and is scheduled to include at least 12 months of sampling in four urban areas and six small city/rural areas (see map below). This program is intended to help answer several important national network design questions (e.g., sampling and analysis precision, sources of variability, and minimal detection levels). In addition, an initial 11-city trends network is being established that will help develop national trends for several pollutants of concern. For the latest information on national air toxics monitoring, see **www.epa.gov/ttn/amtic/airtxfil.html**.

EPA also compiles an air toxics inventory as part of the National Emissions Inventory (NEI, formerly the National Toxics Inventory) to estimate and track national emissions trends for the 188 toxic air pollutants regulated under the Clean Air Act. In the NEI, EPA divides emissions into four types of sectors:

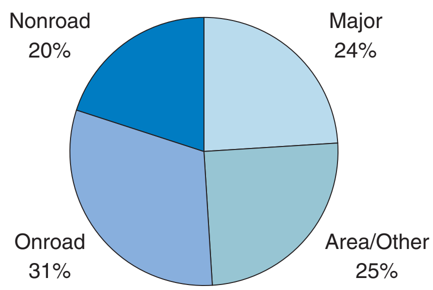


Map of 10 cities in monitoring pilot project

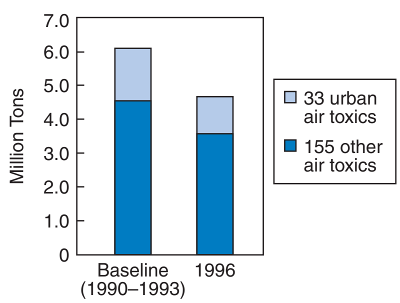
(1) major (large industrial) sources; (2) area and other sources, which include smaller industrial sources like small dry cleaners and gasoline stations, as well as natural sources like wildfires; (3) onroad mobile sources, including highway vehicles; and (4) nonroad mobile sources like aircraft, locomotives, and construction equipment.

As shown in this pie chart, based on 1996 estimates, the most recent year of available data, the emissions of toxic air pollutants are relatively equally divided between the four types of sources. However, this distribution varies from city to city.

National Air Toxics Emissions, 1996
4.7M Tons



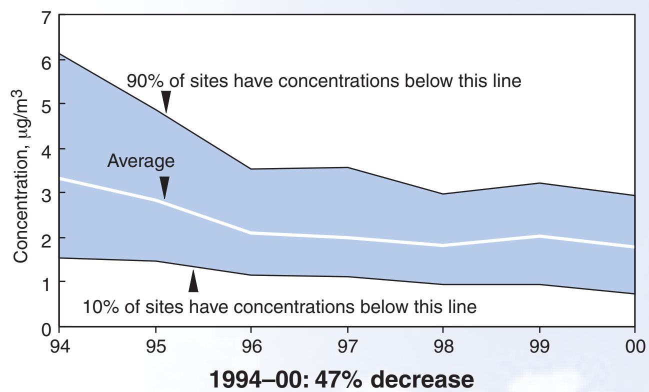
National Air Toxics Emissions
Total for 188 Toxic Air Pollutants



Based on the data in the NEI, estimates of nationwide air toxics emissions have dropped approximately 24 percent between baseline (1990–1993) and 1996. Thirty-three of these air toxics, which pose the greatest threat to public health in urban areas, have similarly dropped 31 percent. Although changes in how EPA compiled the national inventory over time may account for some differences, EPA and state regulations, as well as voluntary reductions by industry, have clearly achieved large reductions in overall air toxic emissions.

Trends for individual air toxics vary from pollutant to pollutant. Benzene, which is the most widely monitored toxic air pollutant, is emitted from cars, trucks, oil refineries, and chemical processes. The graph below shows measurements of benzene taken from 95 urban monitoring sites around the country. These urban areas generally have higher levels of benzene than other areas of the country. Measurements taken at these sites show, on average, a 47 percent drop in benzene levels from 1994 to 2000. During this period, EPA phased in new (so-called "tier 1") car emission standards; required many cities to begin using cleaner burning gasoline; and set standards that required significant reductions in benzene and other pollutants emitted from oil refineries and chemical processes. EPA estimates that, nationwide, benzene emissions from all sources dropped 20 percent from 1990 to 1996.

Ambient Benzene, Annual Average Urban Concentrations, Nationwide, 1994–2000



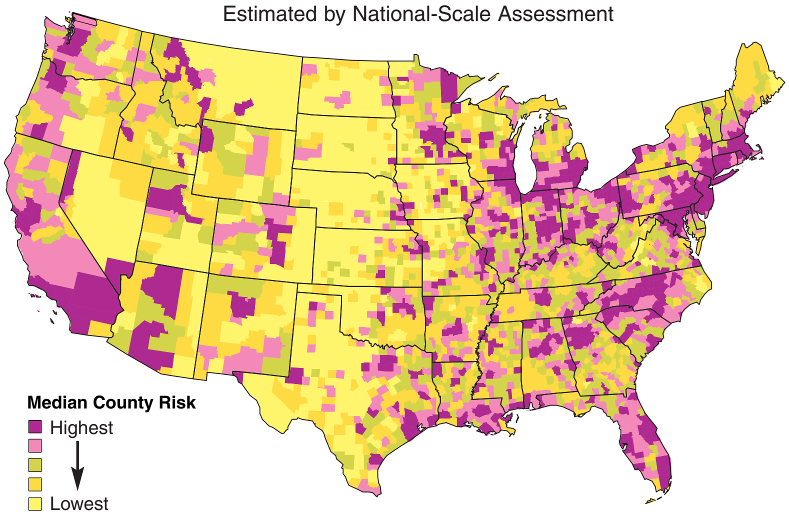
Risk Assessment

EPA has developed a National-Scale Air Toxics Assessment, which is a nationwide analysis of air toxics. It uses computer modeling of the 1996 NEI air toxics data as the basis for developing health risk estimates for 33 toxic air pollutants (a subset of the Clean Air Act's list of 188 air toxics plus diesel PM). The national-scale assessment is intended to provide state, local, and tribal agencies and others with a better understanding of the risks from inhalation exposure to toxic air pollutants from outdoor sources. It will help EPA and states prioritize data and research needs to better assess risk in the future and will provide a baseline to help measure future trends in estimated health risks. The next national-scale analysis will focus on 1999 data and will be released by the end of 2003.

The following map shows a pattern of the distribution of relative cancer risk across the continental United States as estimated by the national-scale assessment. The highest ranking 20 percent of counties in terms of risk (622 counties) contain almost three-fourths of the U.S. population. Three air toxics (chromium, benzene, and formaldehyde) appear to pose the greatest nationwide carcinogenic risk. This map does not include the potential risk from diesel exhaust emissions. This is because existing health data are not sufficient to develop a numerical estimate of cancer risk for this pollutant. However, exposure to diesel exhaust is widespread and EPA has concluded that diesel exhaust is a likely human carcinogen and ranks with the other substances that the national-scale assessment suggests pose the greatest relative risk. One air toxic, acrolein, is estimated to pose the highest potential nationwide for significant chronic adverse effects other than cancer. For more information, visit **www.epa.gov/ttn/atw/nata**.

County Risk Comparison

Estimated by National-Scale Assessment



This technical assessment represents an important step toward characterizing air toxics nationwide. It is designed to help identify general patterns in air toxics exposure and risk across the country and is not recommended as a tool to characterize or compare risk at local levels (e.g., to compare risks from one part of a city to another). More localized assessments, including monitoring and modeling, are under way to help characterize local-level risk.

Programs to Reduce Air Toxics

Since 1990, EPA's technology-based emission standards for industrial sources (e.g., chemical plants, oil refineries, and dry cleaners) have proven extremely successful in reducing emissions of air toxics. Once fully implemented, these standards will cut annual emissions of toxic air pollutants by nearly 1.5 million tons from 1990 levels. EPA has also put into place important controls for motor vehicles and their fuels, including introduction of reformulated gasoline and low sulfur diesel fuel, and is continuing to take additional steps to reduce air toxics from vehicles. Furthermore, air toxics emissions will further decline as the motor vehicle fleet turns over, with newer vehicles replacing older higher emitting vehicles. By the year 2020, these requirements are expected to reduce emissions of a number of air toxics (benzene, formaldehyde, acetaldehyde, and 1,3-butadiene) from highway motor vehicles by about 75 percent and diesel PM by over 90 percent from 1990 levels.

EPA has begun to look at the risk remaining (i.e., the residual risk) after emission reductions for industrial sources take effect and is also investigating new standards for nonroad engines such as construction equipment.

In addition to national regulatory efforts, EPA's program includes work with communities on comprehensive local assessments, as well as federal and regional activities associated with protecting waterbodies from air toxics deposition (e.g., the Great Waters program, which includes the Great Lakes, Lake Champlain, Chesapeake Bay, and many coastal estuaries) and EPA initiatives concerning mercury and other persistent and bioaccumulative toxics. For indoor air toxics, EPA's program has relied on education and outreach to achieve reductions. Information about indoor air activities is available at **www.epa.gov/iaq/**.

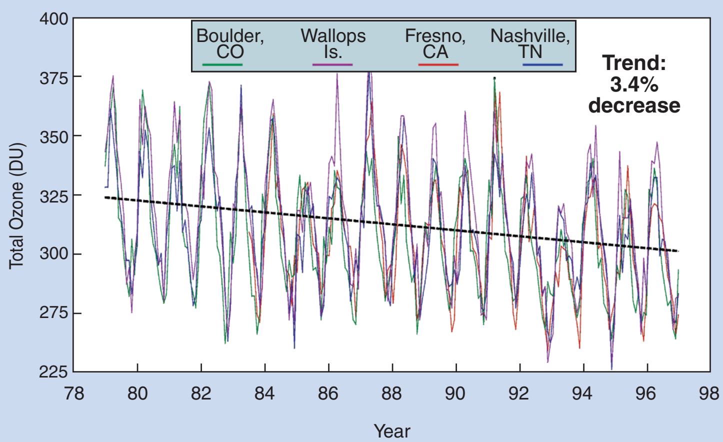
For more information about EPA's air toxics program, visit the Agency's Web site at **www.epa.gov/ttn/atw**.

Stratospheric Ozone

Nature and Sources of the Problem

The stratosphere, located about 6 to 30 miles above the Earth, contains a layer of ozone gas that protects living organisms from harmful ultraviolet radiation (UV-b) from the sun. Over the past three decades, however, it has become clear that this protective shield has been damaged. Each year, an "ozone hole" forms over the Antarctic, and ozone levels there can fall to 60 percent below normal. Even over the United States, ozone levels are about 3 percent below normal in the summer and 5 percent below normal in the winter.

As the ozone layer thins, more UV-b radiation reaches the Earth. The 1998 Scientific Assessment of Stratospheric Ozone firmly established the link between decreased ozone and increased UV-b radiation. In the 1970s, scientists had linked several substances associated with human activities to ozone depletion, including the use of chlorofluorocarbons (CFCs), halons, carbon tetrachloride, methyl bromide, and methyl chloroform. These chemicals are emitted from commercial air conditioners, refrigerators, insulating foam, and some industrial processes. Strong winds carry them through the lower part of the atmosphere, called the troposphere, and into the stratosphere. There, strong solar radiation releases chlorine and bromine atoms that attack protective ozone molecules. Scientists estimate that one chlorine atom can destroy 100,000 ozone molecules.



Source: National Oceanic and Atmospheric Administration (NOAA), 1998.

Monthly average total ozone measured in Dobson units (DU) at four mid-latitude stations across the United States from 1979 to 1997. The trend line shows a 3.4 percent decrease in average total ozone over mid-latitudes in the United States since 1979. The large annual variation shown in each of the four cities is a result of ozone transport processes that cause increased levels in the winter and spring and lower ozone levels in the summer and fall at these latitudes.

Health and Environmental Effects

Some UV-b radiation reaches the Earth's surface even with normal ozone levels. However, because the ozone layer normally absorbs most UV-b radiation from the sun, ozone depletion is expected to lead to increases in harmful effects associated with UV-b radiation. In humans, UV-b radiation is linked to skin cancer, including melanoma, the form of skin cancer with the highest fatality rate. It also causes cataracts and suppression of the immune system.

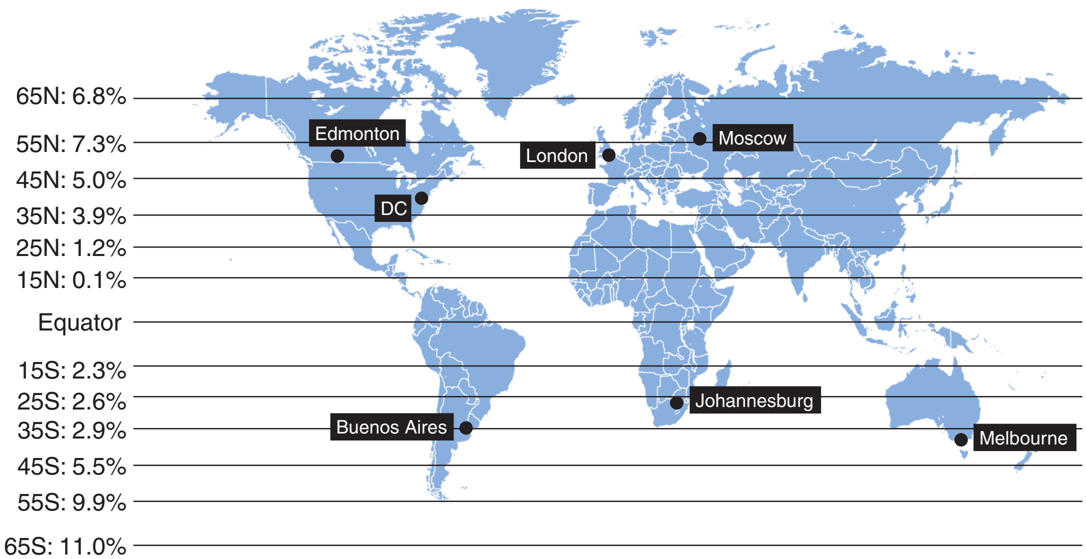
The effects of UV-b radiation on plant and aquatic ecosystems are not well understood. However, the growth of certain food plants can be slowed by excessive UV-b radiation. In addition, some scientists suggest that marine phytoplankton, which are the base of the ocean food chain, are already under stress from UV-b radiation. This stress could have adverse consequences for human food supplies from the oceans.

Programs to Restore the Stratospheric Ozone Layer

In 1987, 27 countries, including the United States, signed the Montreal Protocol, a treaty that recognized the international nature of ozone depletion and committed the world to limiting the production of ozone-depleting substances. Today, more than 180 nations have signed the Protocol, which has been strengthened five times and now calls for the elimination of those chemicals that deplete stratospheric ozone.

The 1990 Clean Air Act Amendments established a U.S. regulatory program to protect the stratospheric ozone layer. In January 1996, U.S. production of many ozone-depleting substances virtually ended, including CFCs, carbon tetrachloride, and methyl chloroform. Production of halons ended in January 1994. Many new products that either

UV-b Radiation Increases by Latitude



A 1996 study using satellite-based analyses of UV-b trends demonstrated that UV-b level had increased at ground level. This figure shows the percent increases in average annual UV-b reaching the surface from 1986 to 1996. UV-b incidence is strongly dependent on latitude. At latitudes that cover the United States, UV-b levels are 4 to 5 percent higher than they were in 1986.

do not affect or are less damaging to the ozone layer are now gaining popularity. For example, computer makers are using ozone-safe solvents to clean circuit boards, and automobile manufacturers are using HFC-134a, an ozone-safe refrigerant, in new motor vehicle air conditioners. In some industries, the transition away from ozone-depleting substances has already been completed. EPA is also emphasizing new efforts like the UV Index, a daily forecast of the strength of UV radiation to which people may be exposed outdoors, to educate the public about the health risks of overexposure to UV radiation and the steps they can take to reduce those risks.

Trends in Stratospheric Ozone Depletion

Scientific evidence shows that the approach taken under the Montreal Protocol has been effective to date. Measurements have shown that atmospheric concentrations of methyl chloroform are falling, indicating that emissions have been greatly reduced. Concentrations of other ozone-depleting substances in the upper layers of the atmosphere, like CFCs, are also beginning to decrease. It takes several years for these substances to reach the stratosphere and release chlorine and bromine. For this reason, stratospheric chlorine levels are currently peaking and are expected to slowly decline in the years to come. Because of the stability of most ozone-depleting substances, chlorine will be released into the stratosphere for many years, and the ozone layer will not fully recover until the second half of this century. All nations that signed the Protocol must complete implementation of ozone protection programs if full repair of the ozone layer is to happen.

Conclusions

The Clean Air Act has resulted in many improvements in the quality of the air in the United States. Scientific and international developments continue to have an effect on the air pollution programs that are implemented by the U.S. Environmental Protection Agency and state, local, and tribal agencies. New data help identify sources of pollutants and the properties of these pollutants. Although much progress has been made to clean up our air, work must continue to ensure steady improvements in air quality, especially because our lifestyles create more pollution sources. Many of the strategies for air quality improvement will continue to be developed through coordinated efforts with EPA, state, local and tribal governments, as well as industry and other environmental organizations.

Acronyms

CFCs	chlorofluorocarbons
CO_2	carbon dioxide
CO	carbon monoxide
DU	Dobson units
EPA	U.S. Environmental Protection Agency
FCCC	Framework Convention on Climate Change
IMPROVE	Interagency Monitoring of Protected Visual Environments
IPCC	Intergovernmental Panel on Climate Change
km	kilometers
NAAQS	National Ambient Air Quality Standards
NAS	National Academy of Sciences
NCDC	National Climatic Data Center
NEI	National Emissions Inventory
NESDIS	National Environmental Satellite Data and Information Service
NO_2, NO_x	nitrogen dioxide, nitrogen oxides
NO	nitric oxide
NOAA	National Oceanic and Atmospheric Administration
O_3	ozone
Pb	lead
PM_{10}, $PM_{2.5}$	particulate matter (10 µm or less, 2.5 µm or less in diameter)
ppm	parts per million
SO_2, SO_x	sulfur dioxide, sulfur oxides
VOCs	volatile organic compounds
UV	ultraviolet

For Further information

Detailed information on Air Pollution Trends: **www.epa.gov/airtrends**

Real-Time Air Quality Maps and Forecasts: **www.epa.gov/airnow**

On-line Air Quality Data: **www.epa.gov/air/data/index.html**

Office of Air and Radiation: **www.epa.gov/oar**

Office of Air Toxics: **www.epa.gov/ttn/atw**

Office of Air Quality Planning and Standards: **www.epa.gov/oar/oaqps**

Office of Transportation and Air Quality: **www.epa.gov/otaq**

Office of Atmospheric Programs: **www.epa.gov/air/oap.html**

Office of Radiation and Indoor Air: **www.epa.gov/air/oria.html**

Global Warming Emissions Information: **www.epa.gov/globalwarming/index.html**

Acid Rain Web site: **www.epa.gov/airmarkets/arplindex.html**

Acid Rain Hotline: **(202) 564-9620**

Energy Star (Climate Change) Hotline: **(888) STAR-YES**

Mobile Sources National Vehicles and Fuel Emissions Lab: **(734) 214-4200**

Ozone Depletion Web site: **www.epa.gov/ozone/**

United States
Environmental Protection
Agency

Office of Air Quality and Standards
Air Quality Strategies and Standards Division
Research Triangle Park, NC

EPA Publication No. EPA 454/K-02-001

1.0 PURPOSE AND SCOPE

1.1 Purpose. The purpose of this procedure is to select a contractor and issue a contract for full delivery projects.

1.2 Scope. This procedure applies to full delivery projects.

1.3 Participants. This procedure applies to the following personnel:

- Full Delivery Project (FDP) Manager
- DENR Division of Purchase and Services (DP&S)
- EEP Implementation Supervisor
- Project Review Committee (FDP Manager plus two Implementation Staff)
- EEP Design and Construction Supervisor
- EEP Operations Director
- Construction Firm
- EEP Director
- EEP Budget Officer.

2.0 PROCEDURE STEPS

All Technical Proposals that were received by the specified deadline will be opened, and those that that meet the Department's length and format requirements will be distributed to the Full Delivery Project (FDP) Manager.

2.1 Receive packet from DP&S. The FDP Manager receives packet from the DENR Division of Purchase and Services (DP&S).

2.2 Select Project Review Committee. The FDP Manager coordinates with the Implementation Supervisor to select two Implementation Staff members to be on the Project Review Committee with the FDP Manager.

2.3 Review technical proposals. The Project Review Committee members individually review the Technical Proposal, qualifications of the firm, and project approach.

The Technical Proposal must include the following:

Part 1–Executive Summary. The executive summary shall consist of the proposal cover letter highlighting the general contents of the proposal and bearing the authorized representative's signature.

Part 2–Corporate Background and Experience. This section shall include background information on the firm submitting the proposal, the firm's ability to carry out all phases of the proposal, information concerning similar mitigation projects completed in North Carolina and other states, the firm's office locations, the experience of the project manager, the firm's multidisciplinary approach to the project, the resumes of key personnel for the primary vendor and subcontractors, and Small, Disadvantaged Business Enterprise/Historically Underutilized Business (DBE/HUB) participation.

Part 3–Technical Approach. The Construction Firm's technical proposal must include a description of the project goals and how the potential ecological benefits of the proposed site will achieve those goals. The Construction Firm must state the expected ecological benefits and goals of the project as related to water quality, water quantity/flood attenuation, and habitat. Unless otherwise specified in the request for proposals (RFP), the proposed ecological benefits of the site may be determined at the discretion of the Construction Firm. If a proposed site provides more then one of these goals, that will be taken into consideration in the site rating. The Technical Proposal must also fully describe the specific details of the proposed mitigation and include, at a minimum, (1) a detailed description of the proposed Site(s); (2) the amount (in acres or feet) of proposed mitigation; (3) the current ownership of the property(ies) proposed; (4) the means by which the proposed changes will be made; (5) the phasing (including time schedule) of such changes; and (6) the vegetative and hydrological success criteria. A proposed schedule for completing each task shall be included with the Technical Proposal.

Maps, diagrams, and photographs may be used to supplement the text and may be printed on one side. The length of the Technical Proposal must not exceed 50 pages, printed on both sides of recycled paper. Photographs, maps, and diagrams will count toward the 50-page total. Any Technical Proposal that exceeds 50 pages and is not printed on both sides of recycled paper will not be considered. One original and five copies of the Technical Proposal must be submitted. If a Technical Proposal does not meet all of the Department's requirements, it will be rejected and the corresponding Cost Proposal will not be opened.

For proposed wetland mitigation sites that have not been designated as prior converted cropland, sufficient information must be provided in the Technical Proposal to demonstrate that areas proposed for restoration consist predominantly of hydric soils and are not currently jurisdictional wetlands.

For stream mitigation sites, information must be provided in the Technical Proposal to demonstrate that all reaches of streams proposed for mitigation are perennial. Information concerning perennial streams is found in Section 3 of this PPPM, Terms and Definitions.

2.4 Develop draft proposal rating. The Project Review Committee members meet as a group to develop a draft proposal rating. Technical Proposals will be evaluated based on the criteria shown in Table 1. Please note that these criteria are provided as a guide to the Project Review Committee for use in its evaluation of the proposals. Because of the potential differences in sites and the goals established for them, these criteria may be weighted differently to suit the specific proposal to which they are being applied. However, the maximum number of points available within a particular category for a specific proposal will remain the same.

Table 1 Proposal Evaluation Criteria

1	**Potential for Water Quality Benefit**	**Maximum Points**
	Project is in a EEP Targeted Watershed	A maximum total of **40** points will be assigned to the first three criteria. These may be distributed among the three criteria as determined by the goals for the site as stated in the **Technical Proposal**.
	Project Involves Work on a 303d-listed Stream or its Watershed	
	Project is Located in a Water Supply Watershed	
	Adjacent to Land that Produces WQ Problems (impervious surfaces, nutrients, sediments)	
	Opportunity for Pollutant Removal from Adjacent Land	
	Exceeds Minimum Buffer Requirements (on Stream and Buffer Projects)	
2	**Potential for Water Quantity Benefit and/or Flood Storage**	
	% Impervious Surface in Watershed	
	Landscape Position (Headwaters, Pulse Attenuation, etc.)	
3	**Potential for Habitat Benefit**	
	Use of Appropriate Plant Communities	
	Potential Habitat Improvement for Listed Species	
	Potential Habitat Improvement for Anadromous Species	
	Potential to Connect Adjacent Natural Habitats	
	Adjacent to Existing Natural Heritage Areas	
4	**Ability to Meet Project Goals**	**20**
	Percent of Mitigation Proposed Relative to Requested Amount	
	Are Preferences Listed in RFP Likely to be Met?	
5	**Likelihood of Success**	**20**
	Lack of Physical Constraints	
	Noxious Species Control Plan	
	EEP Agreement with Amount & Type of Mitigation Proposed (R vs. E vs. P, I vs. P)	
	Ability to Meet Specified Project Requirements (Specified Project Goals)	
	Project Timeline	
6	**Qualifications & Experience of Construction Firm**	**20**
	Similar Mitigation Projects Completed in NC	
	Similar Mitigation Projects Completed in Other States	
	Firm has Office in NC	
	Experience of Project Manager	
	Multidisciplinary Team Approach to Project	
	DBE/WBE/Minority Involvement	
	Similar Project References	

7	**Bonus Points – Stage of Project Implementation**	**25**
	Restoration Plan Complete and required permits obtained – 10 Points	
	Site Built – 10 Points	
	Monitoring Complete – 1 Point for Each Year, Maximum = 5	
	Maximum Possible Score	**125**
	Proposal Rating (Maximum Possible Score x 0.01)	**1.25**

As a result of the technical evaluation, a Proposal Rating (PR) between 0.0 and 1.25 (with 1.25 being the highest) will be determined by the Project Review Committee for each proposal.

If the committee determines the proposal meets minimum criteria, then the FDP Manager schedules a site visit within a month, or less, as determined by the Operations Director. (If the proposal does not meet minimum criteria, the process stops for that particular proposal. The FDP Manager records all of the draft rating scores.)

2.5 Conduct site visit. A minimum of two Project Review Committee members conduct the site visit within 30 days of the completion of step 4, or as determined by the FDP Manager or Operations Director.

During the site visit, the Project Review Committee members validate that the site reflects what was written in the proposal and could serve as mitigation under regulatory guidance. If the site visit team determines that the site does not reflect the proposal or regulatory guidance, the process stops for that particular site proposal. The Project Review Committee documents that the site did not meet criteria.

2.6 Conduct oral presentations. For each proposal remaining under consideration, the FDP Manager contacts the Construction Firm to give them the opportunity to make a 30-minute or shorter presentation to the Project Review Committee within 30 days of completion of step 5, or as determined by the Operations Director. The presentation must focus only on clarification of the information provided in the Technical Proposal. No new or additional information may be provided during the presentation. The presentation must focus on the technical features of the proposal, not on the qualifications of the Construction Firm. Also, the Construction Firm must display a map showing the location of each site relative to adjacent cities, towns, communities, and significant natural features, in addition to a detailed map of each site. **No information concerning costs may be discussed during the presentation.**

2.7 Develop final proposal ratings. The Project Review Committee develops a final proposal rating based on site visit and oral presentation. If it is determined that the site does not meet criteria, the process stops.

The FDP Manager puts together all sites that meet the criteria and develops ratings to be used as guidance.

2.8 Review ratings. The FDP Manager reviews the ratings with the DCS and the Operations Manager for final approval.

2.9 Send packet to DP&S. The FDP Manager puts together a packet with the selected site proposals and sends it to DENR DP&S.

2.10 Open cost proposals. DP&S opens the cost proposals for all proposals still under consideration.

2.11 Send cost proposals to FDP Manager. DP&S sends the costs proposals to the FDP Manager.

2.12 Perform adjusted unit cost analysis. The FDP Manager performs an adjusted unit cost analysis by dividing mitigation units and costs by the proposal rating.

a. Determine unit and adjusted unit costs. The Adjusted Unit Cost is defined as the Unit Cost divided by the Proposal Rating (PR), and is a combined technical and cost measure. A proposal with the lowest Unit Cost will not necessarily have the lowest Adjusted Unit Cost.

The Adjusted Unit Cost is a best value determination by EEP after evaluating all factors in the Technical Proposal and then evaluating the Cost Proposal. The accepted site(s) will be based upon a combination of the lowest Adjusted Unit Cost, the availability of funding, and what is in the best interest of the State of North Carolina.

b. Determine Mitigation Units. Mitigation units include Wetland Mitigation Units (WMUs), Stream Mitigation Units (SMUs), Buffer Mitigation Units (BMUs)

WMUs are the unit of measurement of the extent of wetland mitigation being offered in a proposal; the WMU value for a site is the sum of the restoration acres, one-third of the creation acres, one-half of the Enhancement acres, and one-fifth of the preservation acres

WMUs are determined by using the following formula:

$$WMU = R + (C/3.0) + (E/2.0) + (P/5.0)$$

where

R = Restoration acres

C = Creation acres
E = Enhancement acres
P = Preservation acres.

The terms Restoration, Enhancement, Creation and Preservation are defined at 15A NCAC 2H .0506(h)(4)(A)–(D).

Example: A wetland restoration project consisting of 70 acres of Restoration, 30 of Enhancement, and 30 acres of Preservation has 91 Wetland Mitigation Units (70 + 30/2 + 30/5 = 91).

Wetland proposals that consist of less than 75 percent (in WMUs) restoration as defined at 15A NCAC 2H .0506(h)(4)(A) will not be considered.

Example: The site in the above example (with 91 WMUs) contains 70 WMUs proposed for Restoration. Since the site consists of 76.9 percent Restoration (70/91 = 76.9 percent), this site would be considered.

SMUs are determined by using the following formula:

SMU = (Restoration/1.0) + (Enhancement Level I /1.5) + (Enhancement Level II /2.5) + (Preservation/5.0)

The terms Preservation, Enhancement Levels I and II, and Preservation are defined in the Stream Mitigation Guidelines (U.S. Army Corps of Engineers, Wilmington District, April, 2003) available at http://www.saw.usace.army.mil/wetlands/Mitigation/stream_mitigation.html

Example: A stream mitigation project consisting of 1,000 feet of Restoration, 2,000 feet of Enhancement Level II, and 1,500 feet of Preservation has 2,100 SMUs (SMU = 1,000 + 0 + 800 + 300)

Stream proposals that consist of less than 75 percent Restoration, Enhancement I, and Enhancement II (combined SMUs) as defined in the Stream Mitigation Guidelines (April 2003) will not be considered.

Example: The site in the above example (with 2,100 SMUs) contains 1,000 SMUs proposed for Restoration and 800 proposed for Enhancement Level II. Since the site contains at least 75 percent Restoration and ELII SMUs (1,800/2,100 = 85.79 percent), this site would be considered.

BMUs are determined by using the following formula:

BMU = Restoration/1.0 + (Enhancement/3.0)

Example: A buffer mitigation project consisting of 40 acres of Buffer Restoration and 30 acres of Buffer Enhancement has 50 Buffer Mitigation Units (BMU = 40 + [30/3] = 50).

Buffer proposals that consist of less than 75 percent Restoration, will not be considered.

Example: The site in the above example (with 50 BMUs) contains 40 BMUs proposed for Restoration and 10 BMUs proposed for Enhancement. Since the site contains at least 75 percent Restoration (40/50 = 80 percent), this site would be considered.

2.13 Rank submittals. The FDP Manager ranks the submittals based on lowest Adjusted Unit costs, availability of funding, and the best interest of the State of North Carolina.

The EEP recognizes that a Construction Firm might not be able to find one site that provides the total amount of mitigation requested. Therefore, proposals may be accepted within any of the following categories:

- One or more sites providing all of the requested restoration; or
- One or more sites providing a portion of the requested restoration; or
- Available credits from an approved mitigation bank that provide some or all of the requested restoration.

The Department may enter into one or more contracts to produce the needed amount of mitigation. Should more than one site be selected from one Construction Firm, a separate contract will be executed for each site.

Unless the Construction Firm specifically states in the Technical Proposal a willingness to accept a contract for an amount of mitigation less than the full proposal, the Department shall only consider the full proposal amount and will not extend an offer to contract for less than the full amount indicated in the proposal. However, in order for the Department to acquire the requested amount of mitigation without acquiring significantly more than needed, the Department may accept two or more proposals from one or more Construction Firm(s) that do not total more than 125 percent of the amount requested. However, no single proposal may be for more than the requested amount.

Proposals will not be accepted using the following types of sites:

- Property purchased with Clean Water Management Trust Funds (CWMTF); or

- Property that is enrolled in the Conservation Reserve Enhancement Program, Conservation Reserve Program, Wetlands Reserve Program, or any other state or federal program that provides funds for any of the tasks outlined in this RFP; or

- Property that has been used for compensatory mitigation under Section 404 or 401 of the Clean Water Act, unless the proposed site is part of an approved mitigation bank and documentation is provided to demonstrate that the mitigation bank contains credits that have not been used to satisfy the compensatory mitigation requirements under Section 404 or 401 of the Clean Water Act.

The State of North Carolina will *not* accept fee simple title to any property for full delivery project RFPs. Selected properties must be protected by a conservation easement; a copy of the easement that must be used (except for proposals that offer mitigation credits obtained from an approved mitigation bank) can be found at http://h2o.enr.state.nc.us/wrp/pdf/conease.pdf.

Wetland Restoration Plans for specific river basins may assign high priority status to certain hydrologic units within the area covered in a full delivery project RFP. EEP encourages mitigation sites to be located in these targeted hydrologic units. Sites located within targeted hydrologic units are preferred and will receive higher proposal ratings than sites not in the targeted hydrologic units. The targeted hydrologic units for each river basic can be found at http://h2o.enr.state.nc.us/wrp/plans/maps/riverbasinmap5.htm.

Proposals that include Restoration, Enhancement, Creation and/or Preservation of wetlands and/or streams will be considered, with preference given to those proposals that consist primarily of Restoration. The definitions of wetland Restoration, Enhancement, Creation, and Preservation can be found at 15A NCAC 2H .0506(h)(4)(A) – (D).

2.14 Provide proposals and ratings to EEP Director and Operations Director. The FDP Manager presents the proposals and rating selection to the EEP Director and the Operations Director, who finalize the selection. If a site is not selected, process stops.

2.15 Send selected proposals to DP&S. The FDP Manager sends the selected proposals and final rating sheet(s) to DP&S

2.16 Issue contract. DP&S issues a contract to the selected Construction Firm.

2.17 Send signed contract to FDP Manager. DP&S sends a signed copy of the contract to the FDP Manager

2.18 Give contract to EEP Budget Officer. The FDP Manager gives the contract to the EEP Budget Officer for filing.

Begin FDP Implementation and Oversight Procedures (IMP.PRO.01.01.01).

3.0 RESPONSIBILITIES AND AUTHORITIES

Table 2 summarizes the responsibilities and authorities of key participants in this procedure.

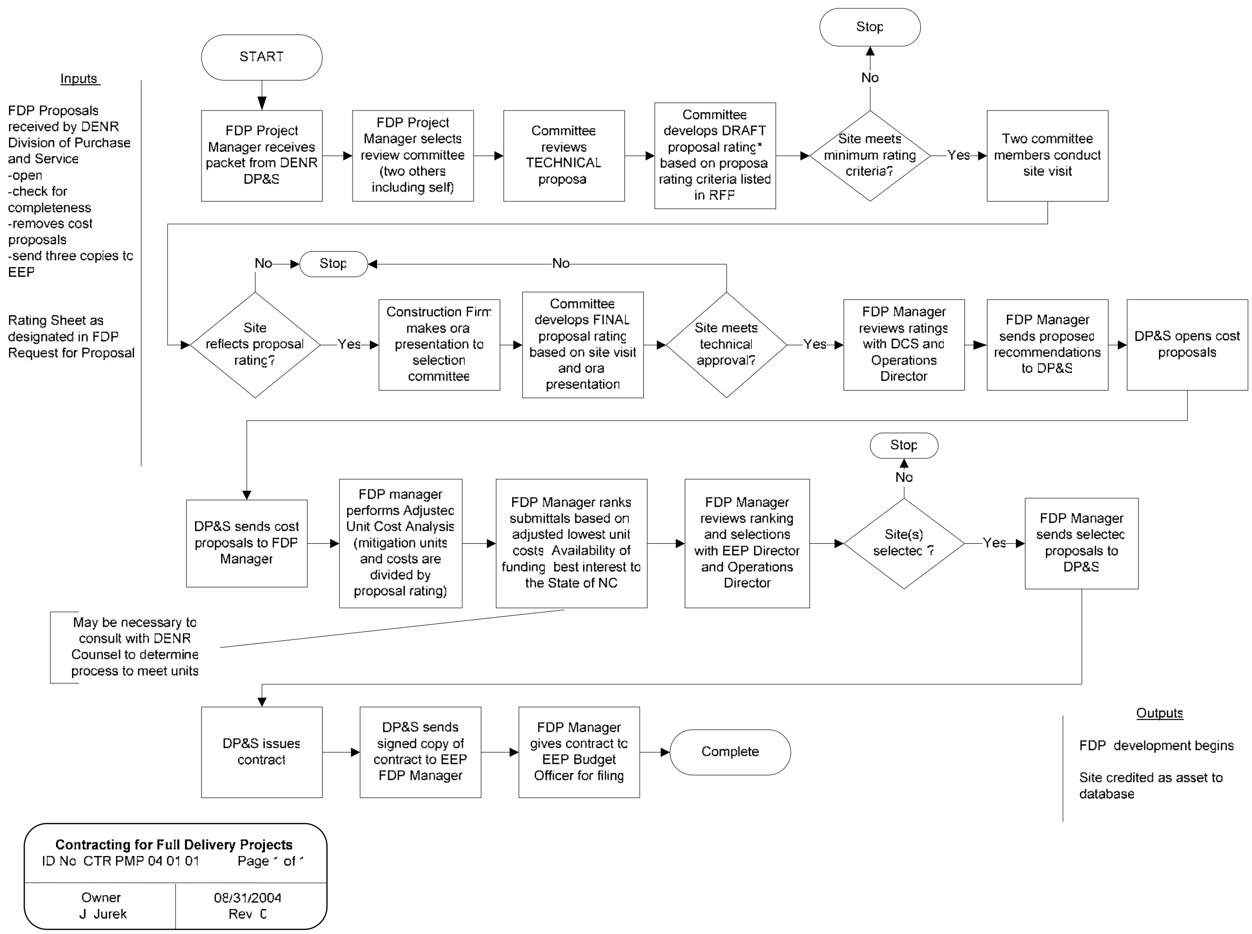
Table 2. Responsibilities and Authorities

Step #	Procedure Step	EEP FDP Manager	DENR DP&S	EEP Implementation Supervisor	Project Review Committee	EEP Design & Construction Supervisor	EEP Operations Director	Construction Firm	EEP Director	EEP Budget Officer
1	Receive packet from DP&S	P	A							
2	Select Project Review Committee	P		A						
3	Review technical proposals				P					
4	Develop draft proposal rating	A			P		A			
5	Conduct site visit	A			P		A			
6	Conduct oral presentations	P						N		
7	Develop final proposal ratings	A			P					
8	Review ratings	P				RA	RA			
9	Send packet to DP&S	P								
10	Open cost proposals		P							
11	Send cost proposals to FDP Manager	S	P							
12	Perform adjusted unit cost analysis	P								
13	Rank submittals	P								
14	Provide proposals and ratings to EEP Director and Operations Director	P					S		S	
15	Send selected proposals to DP&S	P	S							
16	Issue contract		P						RA	
17	Send signed contract to FDP Manager	S	P							
18	Give contract to EEP Budget Officer	P								S

Legend:

P = **P**rimary responsibility
A = **A**ssist
RI = **R**eview to provide **I**nput
RA = **R**eview and **A**pprove
N = **N**otify
S = **S**ubmit final output to this person

4.0 PROCEDURE FLOW DIAGRAM



5.0 REFERENCES

Conservation Easement, http://h2o.enr.state.nc.us/wrp/pdf/conease.pdf

River-basin-specific Watershed Restoration Plans, http://h2o.enr.state.nc.us/wrp/plans/maps/riverbasinmap5.htm.

6.0 FORMS

None.

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Table 1 Proposal Evaluation Criteria

1	**Potential for Water Quality Benefit**	**Maximum Points**
	Project is in a EEP Targeted Watershed	A maximum total of **40** points will be assigned to the first three criteria. These may be distributed among the three criteria as determined by the goals for the site as stated in the **Technical Proposal**.
	Project Involves Work on a 303d-listed Stream or its Watershed	
	Project is Located in a Water Supply Watershed	
	Adjacent to Land that Produces WQ Problems (impervious surfaces, nutrients, sediments)	
	Opportunity for Pollutant Removal from Adjacent Land	
	Exceeds Minimum Buffer Requirements (on Stream and Buffer Projects)	
2	**Potential for Water Quantity Benefit and/or Flood Storage**	
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	Use of Appropriate Plant Communities	
	Potential Habitat Improvement for Listed Species	
	Potential Habitat Improvement for Anadromous Species	
	Potential to Connect Adjacent Natural Habitats	
	Adjacent to Existing Natural Heritage Areas	
4	**Ability to Meet Project Goals**	**20**
	Percent of Mitigation Proposed Relative to Requested Amount	
	Are Preferences Listed in RFP Likely to be Met?	
5	**Likelihood of Success**	**20**
	Lack of Physical Constraints	
	Noxious Species Control Plan	
	EEP Agreement with Amount & Type of Mitigation Proposed (R vs. E vs. P, I vs. P)	
	Ability to Meet Specified Project Requirements (Specified Project Goals)	
	Project Timeline	
6	**Qualifications & Experience of Construction Firm**	**20**
	Similar Mitigation Projects Completed in NC	
	Similar Mitigation Projects Completed in Other States	
	Firm has Office in NC	
	Experience of Project Manager	
	Multidisciplinary Team Approach to Project	
	DBE/WBE/Minority Involvement	
	Similar Project References	

7	**Bonus Points – Stage of Project Implementation**	**25**
	Restoration Plan Complete and required permits obtained – 10 Points	
	Site Built – 10 Points	
	Monitoring Complete – 1 Point for Each Year, Maximum = 5	
	Maximum Possible Score	**125**
	Proposal Rating (Maximum Possible Score x 0.01)	**1.25**

As a result of the technical evaluation, a Proposal Rating (PR) between 0.0 and 1.25 (with 1.25 being the highest) will be determined by the Project Review Committee for each proposal.

If the committee determines the proposal meets minimum criteria, then the FDP Manager schedules a site visit within a month, or less, as determined by the Operations Director. (If the proposal does not meet minimum criteria, the process stops for that particular proposal. The FDP Manager records all of the draft rating scores.)

2.5 Conduct site visit. A minimum of two Project Review Committee members conduct the site visit within 30 days of the completion of step 4, or as determined by the FDP Manager or Operations Director.

During the site visit, the Project Review Committee members validate that the site reflects what was written in the proposal and could serve as mitigation under regulatory guidance. If the site visit team determines that the site does not reflect the proposal or regulatory guidance, the process stops for that particular site proposal. The Project Review Committee documents that the site did not meet criteria.

2.6 Conduct oral presentations. For each proposal remaining under consideration, the FDP Manager contacts the Construction Firm to give them the opportunity to make a 30-minute or shorter presentation to the Project Review Committee within 30 days of completion of step 5, or as determined by the Operations Director. The presentation must focus only on clarification of the information provided in the Technical Proposal. No new or additional information may be provided during the presentation. The presentation must focus on the technical features of the proposal, not on the qualifications of the Construction Firm. Also, the Construction Firm must display a map showing the location of each site relative to adjacent cities, towns, communities, and significant natural features, in addition to a detailed map of each site. **No information concerning costs may be discussed during the presentation.**

2.7 Develop final proposal ratings. The Project Review Committee develops a final proposal rating based on site visit and oral presentation. If it is determined that the site does not meet criteria, the process stops.

The FDP Manager puts together all sites that meet the criteria and develops ratings to be used as guidance.

2.8 Review ratings. The FDP Manager reviews the ratings with the DCS and the Operations Manager for final approval.

2.9 Send packet to DP&S. The FDP Manager puts together a packet with the selected site proposals and sends it to DENR DP&S.

2.10 Open cost proposals. DP&S opens the cost proposals for all proposals still under consideration.

2.11 Send cost proposals to FDP Manager. DP&S sends the costs proposals to the FDP Manager.

2.12 Perform adjusted unit cost analysis. The FDP Manager performs an adjusted unit cost analysis by dividing mitigation units and costs by the proposal rating.

a. Determine unit and adjusted unit costs. The Adjusted Unit Cost is defined as the Unit Cost divided by the Proposal Rating (PR), and is a combined technical and cost measure. A proposal with the lowest Unit Cost will not necessarily have the lowest Adjusted Unit Cost.

The Adjusted Unit Cost is a best value determination by EEP after evaluating all factors in the Technical Proposal and then evaluating the Cost Proposal. The accepted site(s) will be based upon a combination of the lowest Adjusted Unit Cost, the availability of funding, and what is in the best interest of the State of North Carolina.

b. Determine Mitigation Units. Mitigation units include Wetland Mitigation Units (WMUs), Stream Mitigation Units (SMUs), Buffer Mitigation Units (BMUs)

WMUs are the unit of measurement of the extent of wetland mitigation being offered in a proposal; the WMU value for a site is the sum of the restoration acres, one-third of the creation acres, one-half of the Enhancement acres, and one-fifth of the preservation acres

WMUs are determined by using the following formula:

$$WMU = R + (C/3.0) + (E/2.0) + (P/5.0)$$

where

R = Restoration acres

C = Creation acres
E = Enhancement acres
P = Preservation acres.

The terms Restoration, Enhancement, Creation and Preservation are defined at 15A NCAC 2H .0506(h)(4)(A)–(D).

Example: A wetland restoration project consisting of 70 acres of Restoration, 30 of Enhancement, and 30 acres of Preservation has 91 Wetland Mitigation Units (70 + 30/2 + 30/5 = 91).

Wetland proposals that consist of less than 75 percent (in WMUs) restoration as defined at 15A NCAC 2H .0506(h)(4)(A) will not be considered.

Example: The site in the above example (with 91 WMUs) contains 70 WMUs proposed for Restoration. Since the site consists of 76.9 percent Restoration (70/91 = 76.9 percent), this site would be considered.

SMUs are determined by using the following formula:

SMU = (Restoration/1.0) + (Enhancement Level I /1.5) + (Enhancement Level II /2.5) + (Preservation/5.0)

The terms Preservation, Enhancement Levels I and II, and Preservation are defined in the Stream Mitigation Guidelines (U.S. Army Corps of Engineers, Wilmington District, April, 2003) available at http://www.saw.usace.army.mil/wetlands/Mitigation/stream_mitigation.html

Example: A stream mitigation project consisting of 1,000 feet of Restoration, 2,000 feet of Enhancement Level II, and 1,500 feet of Preservation has 2,100 SMUs (SMU = 1,000 + 0 + 800 + 300)

Stream proposals that consist of less than 75 percent Restoration, Enhancement I, and Enhancement II (combined SMUs) as defined in the Stream Mitigation Guidelines (April 2003) will not be considered.

Example: The site in the above example (with 2,100 SMUs) contains 1,000 SMUs proposed for Restoration and 800 proposed for Enhancement Level II. Since the site contains at least 75 percent Restoration and ELII SMUs (1,800/2,100 = 85.79 percent), this site would be considered.

BMUs are determined by using the following formula:

BMU = Restoration/1.0 + (Enhancement/3.0)

Example: A buffer mitigation project consisting of 40 acres of Buffer Restoration and 30 acres of Buffer Enhancement has 50 Buffer Mitigation Units (BMU = 40 + [30/3] = 50).

Buffer proposals that consist of less than 75 percent Restoration, will not be considered.

Example: The site in the above example (with 50 BMUs) contains 40 BMUs proposed for Restoration and 10 BMUs proposed for Enhancement. Since the site contains at least 75 percent Restoration (40/50 = 80 percent), this site would be considered.

2.13 Rank submittals. The FDP Manager ranks the submittals based on lowest Adjusted Unit costs, availability of funding, and the best interest of the State of North Carolina.

The EEP recognizes that a Construction Firm might not be able to find one site that provides the total amount of mitigation requested. Therefore, proposals may be accepted within any of the following categories:

- One or more sites providing all of the requested restoration; or
- One or more sites providing a portion of the requested restoration; or
- Available credits from an approved mitigation bank that provide some or all of the requested restoration.

The Department may enter into one or more contracts to produce the needed amount of mitigation. Should more than one site be selected from one Construction Firm, a separate contract will be executed for each site.

Unless the Construction Firm specifically states in the Technical Proposal a willingness to accept a contract for an amount of mitigation less than the full proposal, the Department shall only consider the full proposal amount and will not extend an offer to contract for less than the full amount indicated in the proposal. However, in order for the Department to acquire the requested amount of mitigation without acquiring significantly more than needed, the Department may accept two or more proposals from one or more Construction Firm(s) that do not total more than 125 percent of the amount requested. However, no single proposal may be for more than the requested amount.

Proposals will not be accepted using the following types of sites:

- Property purchased with Clean Water Management Trust Funds (CWMTF); or

- Property that is enrolled in the Conservation Reserve Enhancement Program, Conservation Reserve Program, Wetlands Reserve Program, or any other state or federal program that provides funds for any of the tasks outlined in this RFP; or

- Property that has been used for compensatory mitigation under Section 404 or 401 of the Clean Water Act, unless the proposed site is part of an approved mitigation bank and documentation is provided to demonstrate that the mitigation bank contains credits that have not been used to satisfy the compensatory mitigation requirements under Section 404 or 401 of the Clean Water Act.

The State of North Carolina will *not* accept fee simple title to any property for full delivery project RFPs. Selected properties must be protected by a conservation easement; a copy of the easement that must be used (except for proposals that offer mitigation credits obtained from an approved mitigation bank) can be found at http://h2o.enr.state.nc.us/wrp/pdf/conease.pdf.

Wetland Restoration Plans for specific river basins may assign high priority status to certain hydrologic units within the area covered in a full delivery project RFP. EEP encourages mitigation sites to be located in these targeted hydrologic units. Sites located within targeted hydrologic units are preferred and will receive higher proposal ratings than sites not in the targeted hydrologic units. The targeted hydrologic units for each river basic can be found at http://h2o.enr.state.nc.us/wrp/plans/maps/riverbasinmap5.htm.

Proposals that include Restoration, Enhancement, Creation and/or Preservation of wetlands and/or streams will be considered, with preference given to those proposals that consist primarily of Restoration. The definitions of wetland Restoration, Enhancement, Creation, and Preservation can be found at 15A NCAC 2H .0506(h)(4)(A) – (D).

2.14 Provide proposals and ratings to EEP Director and Operations Director. The FDP Manager presents the proposals and rating selection to the EEP Director and the Operations Director, who finalize the selection. If a site is not selected, process stops.

2.15 Send selected proposals to DP&S. The FDP Manager sends the selected proposals and final rating sheet(s) to DP&S

2.16 Issue contract. DP&S issues a contract to the selected Construction Firm.

2.17 Send signed contract to FDP Manager. DP&S sends a signed copy of the contract to the FDP Manager

2.18 Give contract to EEP Budget Officer. The FDP Manager gives the contract to the EEP Budget Officer for filing.

Begin FDP Implementation and Oversight Procedures (IMP.PRO.01.01.01).

3.0 RESPONSIBILITIES AND AUTHORITIES

Table 2 summarizes the responsibilities and authorities of key participants in this procedure.

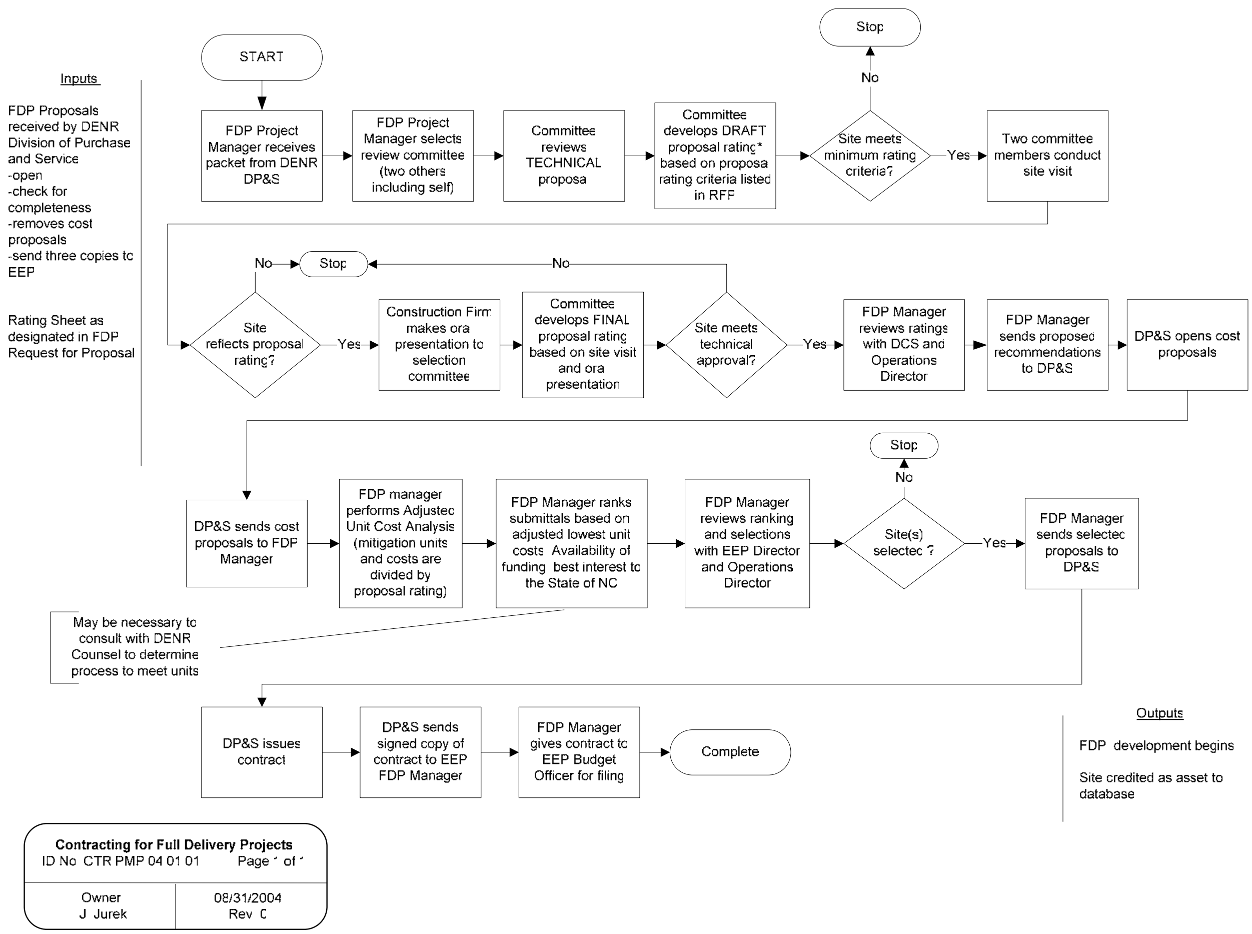
Table 2. Responsibilities and Authorities

Step #	Procedure Step	EEP FDP Manager	DENR DP&S	EEP Implementation Supervisor	Project Review Committee	EEP Design & Construction Supervisor	EEP Operations Director	Construction Firm	EEP Director	EEP Budget Officer
1	Receive packet from DP&S	P	A							
2	Select Project Review Committee	P		A						
3	Review technical proposals				P					
4	Develop draft proposal rating	A			P		A			
5	Conduct site visit	A			P		A			
6	Conduct oral presentations	P						N		
7	Develop final proposal ratings	A			P					
8	Review ratings	P				RA	RA			
9	Send packet to DP&S	P								
10	Open cost proposals		P							
11	Send cost proposals to FDP Manager	S	P							
12	Perform adjusted unit cost analysis	P								
13	Rank submittals	P								
14	Provide proposals and ratings to EEP Director and Operations Director	P					S		S	
15	Send selected proposals to DP&S	P	S							
16	Issue contract		P						RA	
17	Send signed contract to FDP Manager	S	P							
18	Give contract to EEP Budget Officer	P								S

Legend:

P = **P**rimary responsibility
A = **A**ssist
RI = **R**eview to provide **I**nput
RA = **R**eview and **A**pprove
N = **N**otify
S = **S**ubmit final output to this person

4.0 PROCEDURE FLOW DIAGRAM



5.0 REFERENCES

Conservation Easement, http://h2o.enr.state.nc.us/wrp/pdf/conease.pdf

River-basin-specific Watershed Restoration Plans, http://h2o.enr.state.nc.us/wrp/plans/maps/riverbasinmap5.htm.

6.0 FORMS

None.

REGION-SPECIFIC MARGINAL ABATEMENT COSTS FOR METHANE FROM COAL, NATURAL GAS, AND LANDFILLS THROUGH 2030

Michael Gallaher,[1,*] Casey Delhotal,[2] and Jeffrey Petrusa[1]

[1]RTI International (RTI International is a trade name of Research Triangle Institute),
3040 Cornwallis Road, Research Triangle Park, NC 27709
[2]U.S. Environmental Protection Agency, 1200 Pennsylvania Avenue NW, 6202J, Washington, DC 20460

Abstract

Modeling the cost of abating non-carbon dioxide (CO_2) greenhouse gases (GHGs) from anthropogenic sources is crucial in demonstrating an economy's ability to adapt and reduce emissions cost-effectively. The U.S. Environmental Protection Agency (EPA) has developed marginal abatement curves (MACs) reflecting the cost of mitigating methane emissions for major methane-emitting sectors and countries [1,2]. Marginal abatement cost curves can be incorporated into economic models, allowing the abatement options for these gases to be compared with CO_2 abatement [3,4]. Previous analysis has been static, based on current average costs applied to a single representative firm. This analysis goes beyond the previous studies and incorporates firm-level data and constructs a framework for adjusting MACs to account for technical change and decreasing costs of abatement over time. Estimates of technical change incorporate increased efficiency in current technologies and reduction of cost of mitigation technologies over time and the entrance of new technologies into the market. The data are based on official government documentation of each industry, official emission projections or IPCC guidelines for estimating emissions, existing engineering-economic studies, and available country- or region-specific economic data such as labor costs and energy prices. The results of the analysis are presented as marginal abatement cost curves for 2010, 2020, and 2030 for the coal, natural gas, and solid waste sectors.

1. Introduction

Traditionally, economic analysis of greenhouse gas (GHG) mitigation has focused on carbon dioxide (CO_2) from utilities. Because of the linkage between energy production and CO_2 emissions, reduction of CO_2 has proven to be costly, affecting economic performance across industries, particularly in the short to medium run. In light of this, increasing attention has been focused on the benefits of reducing emissions of non-CO_2 GHGs, particularly methane. Methane, as well as other non-CO_2 GHGs, can be reduced cost-effectively. Changes in production processes can also result in cost savings and increased efficiency of the production process or capturing and selling fugitive emissions of these gases can result in revenues for the firm. . The inclusion of these relatively cheap GHG reduction options lowers the overall cost of a climate change policy [6-8].

Recent climate economic studies, such as the Energy Modeling Forum 21 (EMF21) multigas study, have used static marginal abatement curves (MACs) for non-CO_2 [10]. The data used in the EMF21 study are country- or region-specific marginal abatement cost curves based on country- or region-specific labor rates, energy system infrastructure, energy prices, policy structure, and the latest emissions data. However, this analysis has limitations. The first is the static approach to the abatement cost assessment. The analysis does not account for technological change over time, which would reduce the cost of abatement and increase the efficiency of the abatement options. Second, the study used only limited regional data. Although the original analytical framework is flexible enough to incorporate regional differences in the characteristics and applicability of various abatement options at the time of the study, limited data were available to make use of this flexibility.

The objective of this study is to correct for the limitations of the EMF 21 analysis. This analysis constructs a new framework that accounts for technological changes in mitigation options, the reduction of mitigation costs over time, and the inclusion of country-specific, firm-level data. The results presented are a set of MAC by 10-year interval, by country, and by sector. The sectors covered in this analysis include coal, natural gas, and solid waste.

2. Marginal Abatement Curves and Shifts Over Time

We generate MACs by calculating the "breakeven" carbon price where the revenues from the project equal the costs of the project (i.e., the price at which the net present value [NPV] calculation equals 0) [9]. After the abatement potential and breakeven price are computed, we construct the MAC curve by ordering, from least expensive (lowest breakeven price) to most expensive (highest breakeven price), all of the technology options across

*Corresponding author: Tel. (919) 541-5935; Fax: (919) 541-6683; Email: mpg@rti.org

all entities. The MAC approaches the total technically feasible abatement potential asymptotically as the carbon price becomes extremely large (i.e., as the options become very expensive).

Unlike previous international analyses, this analysis incorporates entity-level data where available. To build up the MACs, each entity selects the technologies that are economically viable based on their individual characteristics (i.e., their unique cost of installing and maintaining the technology and the amount of methane recovered for reuse) and the carbon price. This calculation changes over time as developing countries switch from foreign-produced technologies to domestically produced technologies. The total quantity abated is then obtained by summing across all entities to obtain tons of carbon equivalents (TCEs) for a given carbon price.

This analysis also explicitly models changes in input costs, productivity, and reduction efficiency of abatement options over time. One-time capital costs and operation and maintenance (O&M) costs are broken into their factor inputs (capital, materials, labor and energy) so that individual technology trends (changes in prices and productivity) can be applied (see Table 1 [a] and [b]). Changes in these input factors are expressed in terms of the annual percentage change in price and productivity. Price trends reflect changes in production/input costs, and productivity trends reflect advances in technologies and processes that make constant levels of production possible with fewer inputs. The price and productivity trends over time are then used to adjust one-time capital costs and O&M costs, which in turn affects the economic viability of the option (i.e., the breakeven price) [7,9].

TABLE 1: SUMMARY OF KEY INPUTS AND TREND PARAMETERS

Economic Trends [4]	Capital	Labor	Materials	Natural Gas	Electricity
(a) Factor Input Shares by Technology Sector					
Coal	50%	30%	11%	*N/A	9%
Natural Gas	52%	34%	10%	*N/A	4%
Landfills	77%	8%	5%	*N/A	11%
(b) Technology Trends on Factor Inputs [11-16]					
Productivity	–0.01	–0.02	–0.01	N/A	–0.01
Real Price	–0.02	0.02	–0.02	0.02	–0.01
(c) Share of Domestic Inputs in 2000 [17]					
Coal					
Emerging Countries**	0%	75%	50%	100%	100%
Developed Countries***	50%	80%	75%	100%	100%
Natural Gas					
Emerging Countries	40%	75%	50%	100%	100%
Developed Countries	50%	80%	75%	100%	100%
Landfills					
Emerging Countries	0%	75%	50%	100%	100%
Developed Countries	50%	80%	75%	100%	100%

*N/A: Not applicable

** Emerging countries include China, Mexico, South Africa, and Venezuela.

*** Developed countries include Russia, Ukraine, and Poland.

In addition, baseline prices and trends in prices and productivity for factor inputs vary by country in this analysis. Because the domestic prices for labor and some capital and materials inputs are typically less expensive in developing countries, input prices used to calculate the breakeven price for abatement options in these countries are adjusted based on regional shares of domestic verses foreign inputs and regional price indices in 2000. Based on interviews with industry experts [17], the share of domestic inputs in 2000 is between 0 and 50 percent for capital, 75 to 80 percent for labor, and 50 to 75 percent for materials (see Table 1 [c]). This is projected to grow to approximately 90 to 100 percent by 2030. For gas, electric, labor, and materials, international price factors were obtained from EPA's International Marginal Abatement Curve (IMAC) Model [1]. For capital, import shares [18] were used to weight international capital price factors [19]. For example, skilled labor in the natural gas sector may be in short supply in developing countries, requiring the use of imported labor services. However, through knowledge transfer, the share of imported labor used to support mitigation options will likely decrease over time. Similarly, high tech abatement capital currently being imported from developed countries may be supplied domestically in the future in developing countries.

3. Sectors and Countries Included in the Analysis

Three major methane-emitting sectors are modeled: coal mining, natural gas, and solid waste. For each sector, we selected up to five countries to be included in the analysis based on the magnitude of their current and future emissions. Table 2 lists the countries modeled for each sector and the cumulative share of methane emissions within the sector for these countries. For each sector and country, we applied the general methodology presented in Section 2 to estimate the shift in MACs over time. However, data availability greatly influenced the underlying details of each sector analysis.

TABLE 2: SECTORS AND COUNTRIES INCLUDED IN THE ANALYSIS

	Coal Mining	**Natural Gas**	**Solid Waste**
Countries Included	United States, China, Russia, Poland	United States, Russia, China, Ukraine, Venezuela	United States, China, Ukraine, South Africa, Mexico
Share of Global Methane Emissions in 2000 [20]	63%	99%	43%
Projected Emissions in 2030 [20]	65%	75%	48%

The analysis includes three coal mine abatement options: (1) degasification (degas), where holes are drilled and methane is captured (not vented) before mining operations begin; (2) enhanced degas, where advanced drilling technologies are used and captured low-grade gas is purified; and (3) ventilation abatement methane (VAM), where low concentrations of methane ventilation air exhaust flows are oxidized to generate heat for process use [21]. Engineering costs for each abatement option were calculated based on individual mine characteristics, such as annual mine production, gassiness of the coal deposits, and methane concentration in ventilation flows. Information was available on 56 underground U.S. coal mines for 2000 [22]. We used EPA's Coal Mining Abatement Cost Model to estimate the one-time investment costs, annual O&M costs, and benefits from using the captured methane for each of the 56 mines. The model also dissagregated costs into capital, labor, materials, and energy.

In addition to costs, several additional factors change over time as a result of enhancements to existing technologies or introduction of new processes and procedures. For example, in the United States, advances in surface mining are projected to decrease underground mining activities, reducing the technical potential for methane abatement. Also, VAM technology is projected to improve over the next 20 years, decreasing the technical applicability concentration level below 0.15 percent methane [17]. The information on coal production and methane liberated for individual mines for China, Russia, and Poland was extracted from several international methane reports provided by EPA [23-25].

Detailed engineering cost information was not available for non-U.S. underground coal mines. Thus, we estimated costs as a function of mine production and liberated methane [22]. We used regression analysis to estimate cost relationships based on the known costs for the given 56 U.S. mines as a function of coal production and/or methane liberated. Individual regressions were run for each cost component/factor (e.g., annual drilling costs, one-time compressor costs), and separate sets of regressions were run for each of the three abatement options. We then applied the coefficients to the known value of coal production and methane liberated for non-U.S. mines [23-25] to generate cost components for each abatement technology [9].

EPA's economic cost model of the natural gas sector reports emission factors at the facility or equipment level [26]. Abatement options for the natural gas sector are associated with five general segments of the natural gas system (production, processing, transmission, storage, and distribution) and are typically applied to a facility (e.g., central wells, gathering facilities, gas plants, transmission pipeline networks, storage tanks) or specific piece of equipment in the natural gas system (e.g., wellheads, compressors, heaters) [26]. Also included in the economic cost model is an estimate of the total population for each type of equipment and facility. The model includes 118 different abatement options applied across the five segments of the natural gas sector. Options range from inspection and detection techniques to upgrading compressors and pipes contained in the system. The natural gas economic cost model does not provide information on capital, materials, labor, and energy costs. To obtain this information we used documentation from EPA's *Lessons Learned* [27] and interviews with industry experts to develop the distribution rules for input factor costs.

While EPA's natural gas economic cost model provided a highly detailed characterization of the United States' natural gas infrastructure, significantly less information is available on natural gas systems for other countries, such as Russia, China, Ukraine, and Venezuela [28-31]. As a result, we characterized the natural gas infrastructure for foreign countries using available data from the United States in combination with international production and consumption values reported in the Foreign Country Briefs published by the Energy Information Administration [32-35]. We estimated the size of the infrastructure related to production, processing, and transmission activities as a function of a country's natural gas production and the size of the infrastructure related to storage and distribution as a function of a country's natural gas consumption. From this estimation process, we estimated the population of facilities, equipment (e.g., compressors, dehydrators), and miles of pipe. In addition, there are differences in the age and level of maintenance of the natural gas infrastructure in each country. This was accounted for by creating country-specific emission factors that adjusted the level of "leakiness" of natural gas systems. Based on a report published by the IPCC [36], we developed emission factors for several regions for production and processing and for transportation and distribution.

We used EPA's Landfill Population Model to generate a set of landfills for which abatement options might be applied. The U.S. federal government currently requires all large landfills to have a method for abating methane in place [37]. Thus, for the United States, we filtered the landfill population dataset used for MAC analysis to remove all landfills with a design capacity greater than 3.5 million megagrams (or 3.9 million short tons) attempt to adequately capture all landfills that are not subject to regulation. The MAC model models the investment decision relating to abatement technologies only for those landfills that have a choice.

Abatement options for the landfill sector include a landfill gas collection system, flare, direct-use pumping system, or some mechanism such as a turbine, for generating energy through the combustion of landfill methane gas. Equipment required includes wells, wellheads and gathering pipeline, compressor, dehydrator unit, and pipelines to direct-use sites. EPA's engineering cost model reports total estimated methane generation, one-time capital costs, annual O&M fees, and the annual electricity produced or the quantity of gas sold for process heat through the direct-use option. EPA's Landfill Inventory Database provided detailed information that characterized the U.S. landfill population. However, significantly less information is available for landfills in other countries, such as China, South Africa, Mexico, and Ukraine. As a result, all countries' landfill population distribution is based on US landfill characteristics and then scaled up to meet EPA's estimates for landfill emissions in these countries.

4. Results

Applying the trends described above, shifts in the MACs for each country–sector listed in Table 2 were developed for 10-year intervals from 2000 to 2030. We discuss two of the MACs below to illustrate differences from previously developed EMF 21 data and highlight factors underlying the shifts in the curves over time. Figure 1 and Figure 2 show the MACs for 2000, 2010, 2020, and 2030 for the U.S. coal mining and the Mexico landfill sectors. The magnitude of the shifts reflects both changes in costs and benefits of abatement technologies and technical changes, such as increased reduction efficiency and trends in production. For example, after 2020, the shift in the U.S. MACs slows because underground mine production is projected to decrease slightly. However, technology improvements continue, driving down costs. In contrast, the MACs for landfills in Mexico shift out and downward steadily, reflecting the decreasing technology costs and the projected growth in landfills. It should also be noted that the results reflect a financial analysis and do not capture all the factors influencing the adoption of mitigation technologies. If unobservable transition costs or geopolitical barriers to adoption were included, we would not expect the "no-regrets" options to increase so dramatically over time.

Individual country methane MACs for 2020 are provided in Table 3. The percentages in Table 3 indicate the share of abatement for a given breakeven price. Abatement for breakeven prices less than or equal to zero are referred to as "no regret" options. The large number of no regret options reflect adoption factors not included in our financial breakeven analysis. This may include missing information barriers, transaction costs or geopolitical constraints affecting the timing of adoption of mitigation options. Table 4 summarize the factors driving the shifts in the MACs for the coal mining, natural gas, and solid waste sectors, in terms of percentage changes from 2000 to 2020. As shown in the tables, over time the cost of abatement options decreases while their reduction efficiency increases. These factors combine to increase economic viability of the mitigation options, hence lowering their breakeven price and shifting downward. As shown in these tables, the change in reduction efficiency is technology specific and thus constant across countries, increasing on average between 11 and 14 percent by 2002. However, changes in costs vary greatly across each country because of the changing shares of domestic versus foreign inputs over time.

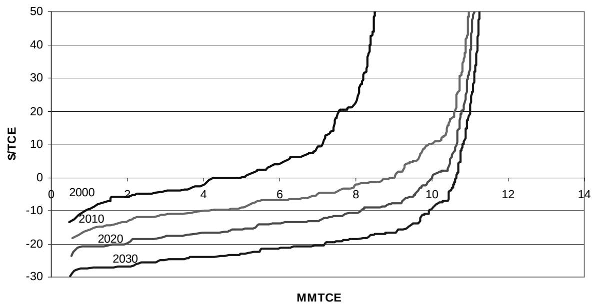


Figure 1: Shift in the U.S.'s MAC for the coal mining sector over 30 years

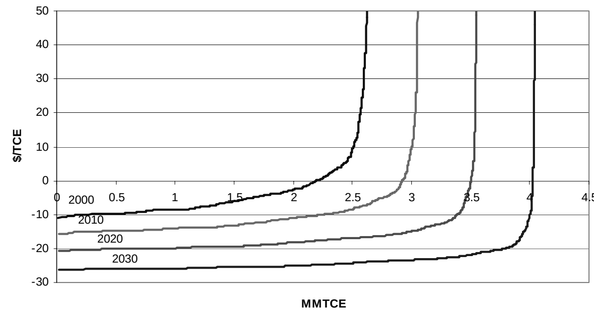


Figure 2: Shift in Mexico's MAC for landfill sector over 30 years

TABLE 3: 2020 MACS FOR COUNTRIES INCLUDED IN THE ANALYSIS

	Breakeven Prices ($/TCE)							
Sector	**–$20**	**–$10**	**$0**	**$10**	**$20**	**$30**	**$40**	**$50**
Coal Mining								
United States	11.7%	47.8%	58.0%	61.9%	62.6%	63.5%	63.9%	64.4%
China	0.0%	35.8%	72.3%	81.8%	85.5%	86.7%	88.9%	89.8%
Russia	0.0%	0.0%	8.0%	8.4%	8.4%	8.4%	8.4%	8.4%
Poland	3.0%	3.2%	3.2%	3.2%	3.2%	3.2%	3.2%	3.2%
Natural Gas								
United States	8.4%	9.3%	9.4%	10.6%	11.9%	12.1%	12.3%	12.4%
China	0.0%	11.1%	12.6%	12.7%	12.7%	12.8%	12.8%	12.9%
Russia	0.0%	9.6%	14.4%	14.6%	14.7%	14.7%	14.7%	14.7%
Ukraine	11.4%	11.9%	11.9%	12.0%	12.0%	12.0%	12.0%	12.0%
Venezuela	8.9%	11.2%	11.8%	12.2%	12.4%	12.4%	12.5%	12.5%
Solid Waste								
United States	28.2%	54.1%	61.7%	65.1%	67.1%	67.5%	68.3%	68.6%
China	0.0%	62.9%	64.2%	64.4%	64.5%	64.5%	64.5%	64.5%
Ukraine	61.3%	64.4%	64.5%	64.5%	64.5%	64.5%	64.5%	64.5%
Mexico	13.6%	54.1%	55.9%	56.4%	56.5%	56.6%	56.6%	56.7%
South Africa	50.1%	51.7%	52.3%	52.6%	52.6%	52.7%	52.8%	52.8%

Table 4 shows the percentage changes for the coal mining sector that result from the trends implemented in our analysis. U.S. one-time costs and annual costs decrease by 37 percent and 9 percent, respectively, as a result of applying price and productivity trends. The difference in the rate of change between one-time and annual costs is due to their relative level of capital versus labor intensity. Because the real wage rate is projected to increase, offsetting labor productivity, labor-intensive activities are not projected to have as large a decrease in costs as capital-intensive activities. And, for all the coal mining abatement options, one-time costs are capital intensive, and annual costs are labor intensive.

China, Russia, and Poland have greater decreases in costs because this analysis assumes that they are currently importing most inputs, but they are projected to increase the use of significantly lower-cost domestic capital, labor, and materials over time. This results in greater downward shifts in these countries' curves over time relative to the United States. The changes in costs are also a function of each country's relative prices. For example, the percentage change in annual costs is not as great in Russia and Poland, compared to China, because China has lower wages than these countries and, thus, experiences a greater decrease in annual costs when switching to domestic labor. The results are similar for the natural gas and solid waste sectors.

TABLE 4: PERCENTAGE REDUCTION BY 2020 IN FACTORS DRIVING THE SHIFTS IN THE COAL MINING MACS

Sector	Change in One-Time Costs	Change in Annual Costs	Change in Reduction Efficiency
Coal Mining			
U.S.	37%	9%	10.0%
China	69%	60%	10.0%
Russia	72%	36%	10.0%
Poland	74%	27%	10.0%
Natural Gas			
U.S.	18%	17%	9.6%
China	68%	58%	9.6%
Russia	64%	41%	9.6%
Ukraine	68%	41%	9.6%
Venezuela	57%	45%	9.6%
Solid Waste			
U.S.	18%	27%	7.8%
China	68%	46%	7.8%
South Africa	38%	34%	7.8%
Ukraine	68%	68%	7.8%
Mexico	53%	39%	7.8%

4.1 Comparison to EMF 21 MACs

The effect of the above approach can be illustrated by comparing the curves in this paper (referred to as "enhanced" curves) with the MACs produced for the EMF 21 multigas study [4]. Table 5 shows the percentage methane abatement in 2020 at different carbon prices for both the EMF 21 and enhanced projections. The comparison between the EMF projections and the enhanced curves in 2020 reflects differences in building the baseline MACs using entity-level data and the influence of shifting the curves over time to account for technical change. For U.S. coal mining, the comparison indicates that the enhanced approach leads to more abatement at lower breakeven prices. For example, the EMF 21 estimates no abatement at –$10 whereas the enhanced approach estimates 48 percent abatement. However at higher breakeven prices, the EMF 21 estimates project a larger abatement percentage, 86 percent at $50, compared to 66 percent at $50 for the enhanced approach. This is because the enhanced approach incorporates different assumptions about technical applicability or potential market penetration. For example, the enhanced MACs use mine-level data to determine if VAM is technically applicable for each mine in 2020, instead of assuming all mines are eligible.

Similar trends are seen in the natural gas and landfill sectors. The enhanced approach estimates more abatement potential at lower breakeven points when entity-level data are used and technical change reduces costs and increases reduction efficiency. "No regrets" abatement is approximately 15 percent for natural gas and approximately 60 percent for landfills using the enhanced approach in 2020. As in the coal mining sector, at higher breakeven prices, differences in assumptions regarding technical potential lead to differences in the maximum abatement potential (i.e., the vertical asymptote for the MACs) for the natural gas and landfill sectors. At higher breakeven prices, the enhanced approach yields less abatement compared to the EMF 21 estimates for natural gas. The difference is due to more conservative assumptions being used for technical applicability of natural gas mitigation options in the enhanced approach. In contrast, for landfills, the enhanced approach yields a higher maximum potential, reflecting increases in reduction efficiency by 2020.

TABLE 5: COMPARISON WITH EMF 21 MACS

Sector	Breakeven Prices ($/TCE)							
	–$20	–$10	$0	$10	$20	$30	$40	$50
Coal								
United States								
EMF 21	0.0%	0.0%	49.2%	49.2%	66.5%	86.0%	86.0%	86.0%
Enhanced	11.7%	47.8%	58.0%	61.9%	62.6%	63.5%	63.9%	64.4%
China								
EMF 21	0.0%	0.0%	0.0%	0.8%	49.7%	84.5%	84.5%	84.5%
Enhanced	0.0%	35.8%	72.3%	81.8%	85.5%	86.7%	88.9%	89.8%
Natural Gas								
United States								
EMF 21	1.9%	5.6%	14.5%	14.5%	18.9%	18.9%	19.2%	19.2%
Enhanced	8.4%	9.3%	9.4%	10.6%	11.9%	12.1%	12.3%	12.4%
Russia								
EMF 21	0.0%	0.0%	3.8%	9.2%	25.0%	26.6%	26.6%	26.9%
Enhanced	0.0%	9.6%	14.4%	14.6%	14.7%	14.7%	14.7%	14.7%
Landfill								
United States								
EMF 21	0.0%	0.0%	10.0%	10.0%	31.4%	31.4%	42.1%	42.1%
Enhanced	28.2%	54.1%	61.7%	65.1%	67.1%	67.5%	68.3%	68.6%
Mexico								
EMF 21	0.0%	0.0%	10.0%	20.7%	31.4%	42.1%	42.1%	42.1%
Enhanced	13.6%	54.1%	55.9%	56.4%	56.5%	56.6%	56.6%	56.7%

4.2 Sensitivity Analysis

The MAC curves presented in Figure 1 and Figure 2 are the result of simultaneously applying several technology feasibility, efficiency, and import trends. Each contributes to lowering the cost and/or increasing the benefits associated with abatement technologies and hence shifts the MACs. We conducted sensitivity analysis to investigate which trends have the most significant impact on the MACs over time. The sensitivity analyses showed that the MACs are most sensitive to the share of domestic versus foreign labor, capital, and materials used in the mitigation options. By varying domestic labor estimates from 85 to 100 percent; domestic capital estimates by 40 to 100 percent and domestic materials by 69 to 100 percent, an upper and a lower bound are estimated as shown in Figure 3. In this example, the range of variation is due to the abundant availability of low-wage labor in China resulting in a large decrease in the cost as more domestic labor is used in mitigation projects.

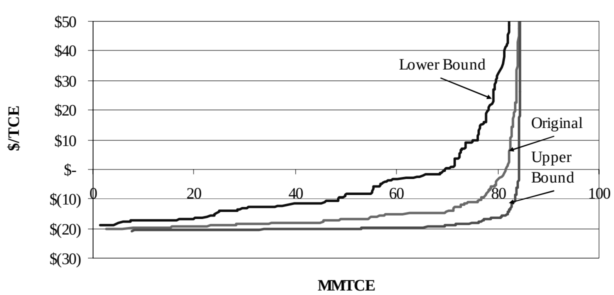


Figure 3: Sensitivity analysis for China coal mining 2030

5. Conclusions and Next Steps

The methodology outlined above presents a bottom-up engineering approach for developing regional and sector-specific MACs. Compared to previous analyses, the current analysis improves the estimates by incorporating better sector- or firm-level data. Instead of modeling abatement costs using average firm costs and applying the average cost to one representative firm in each country or region, this methodology applies specific costs to a distribution of representative firms or, in the case of natural gas, an estimated natural gas infrastructure in each country or region. The current analysis also moves away from the static estimates generated in the previous studies. In this analysis, energy prices change over time, engineering efficiencies of the abatement technologies improve over time, and the cost of abatement technologies decreases over time. In addition, the percentage of domestic inputs, both labor and capital, used in the abatement option increases over time for developing countries.

Sensitivity analysis shows that resulting MACs are most sensitive to the rate of growth in the share of domestic inputs used in the mitigation options, more so than the improved efficiency of the technology. However, cost data on technologies produced outside of the EU and the United States, as well as the domestic market penetration of these technologies, are limited. A better understanding of the current mix and potential future trends of domestic versus imported technology use and labor division is needed.

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Appendix B: Resumes for Key Personnel

MICHAEL P. GALLAHER

Summary of Professional Experience

Dr. Gallaher is the director of RTI's Technology, Energy, and the Environment Program and has over 10 years of experience leading projects for the U.S. Environmental Protection Agency (EPA), and other federal agencies modeling the economic impact environmental regulations and mitigation technologies. Dr. Gallaher specializes in combining economic analysis with engineering cost analysis from which incremental abatement costs and benefits can be measured. Most of the projects he has led have involved modeling the adoption of new technologies and assessing the barriers to adoption. Dr. Gallaher has led over 30 economic impact assessments for agencies such as EPA and the National Science Foundation (NSF), assessing the implications of technology adoption in the construction, automotive, iron and steel, and chemical industries. Dr. Gallaher has published a book on R&D in the service sector and published articles in the *Journal of Technology Transfer*, *Environmental Sciences*, and the *Journal of Law and Policy for the Information Society*. He has also made numerous presentations at professional conferences and to federal committees and industry associations, and has provided economic analysis support for Federal Advisory Committee Act (FACA) activities.

Education

Ph.D., Economics, Boston College, Chestnut Hill, Massachusetts, 1992
Dissertation: *R&D and Liquidity: A Model of Investment Financing with Asymmetric Information*
M.S., Economics, Southern Illinois University, Edwardsville, Illinois, 1987
B.S., Computer Science, Southern Illinois University, Edwardsville, Illinois, 1987
B.S., Aerospace Engineering, University of Notre Dame, Notre Dame, Indiana, 1983

Selected Project Management Experience

- "Integrating Technical Change into Marginal Abatement Curves for Methane" (U.S. Environmental Protection Agency, Office of Atmospheric Programs, Climate Change Division)
- "Redesign of the Pollution Abatement Cost and Expenditure (PACE) Survey" (U.S. Environmental Protection Agency)
- "Economic Impact of the Toxics Rule" (U.S. Environmental Protection Agency, Office of Transportation Air Quality)
- "Inadequate Interoperability Cost Analysis of the U.S. Construction Industry" (National Institute for Standards and Technology)
- "The Economic Impact Assessment of the International Standard for the Exchange of Product Model Data (STEP)" (National Institute for Standards and Technology)
- "Economic Impact of the Nonroad Diesel Rule" (U.S. Environmental Protection Agency, Office of Transportation and Air Quality)

- Regulatory Impact Analysis of Air Pollution Regulations: Iron, Steel, and Coke Industries" (U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards)

- Regulatory Impact Analysis of Air Pollution Regulations: Iron, Steel, and Coke Industries" (U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards)

- "Economic Impact Analysis of Air Pollution Regulations: Boilers" (U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards)

- "Economic Impact Analysis of Air Pollution Regulations: Turbines" (U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards)

- "Economic Impact Analysis of Proposed Commercial and Industrial Solid Waste Incinerator Regulation" (U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards)

- "Economic Impact Analysis of Proposed Other Solid Waste Incinerator Regulation" (U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards)

- "NESHAP for Miscellaneous Organic Chemical (MON) Production and Processes: Economic Analysis" (U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards)

- "Cost of RCRA Compliance and Economic Incentives for Silver Recovery" (U.S. Environmental Protection Agency, Office of Solid Waste)

- "Revisions to Economic Analysis for Proposed Standards and Guidelines for Municipal Waste Combustion" (U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards)

Selected Publications

Gallaher, M.P., E.R. Delong, and J.E. Petrusa. 2005. "Region-Specific Marginal Abatement Costs for Methane from Coal, Natural Gas, and Landfills through 2030." In *Greenhouse Gas Control Technologies*, E.S Rubin, D.W. Keith and C.F. Gilboy (eds.) Boston: Elsevier.

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RANDALL C. DODD

Education

M.E.M., Environmental Management, Duke University, 1983.

B.S., Zoology, University of North Carolina at Chapel Hill, 1981.

Employment History

1983 to 1989. NC Division of Water Quality, Raleigh, NC. <u>Environmental Supervisor/Modeler/Engineer</u>.

1989 to date. RTI, Research Triangle Park, NC. <u>Research Environmental Scientist</u>.

Areas of Technical Expertise

Mr. Dodd has extensive experience in providing technical support and managing projects that provide targeted information to support watershed and water quality management decision making. His areas of technical expertise include watershed and landscape assessment, water quality modeling, water quality management, Geographic Information Systems, data management/database development, decision support systems, and water quality outreach and reporting. Examples include the development of software tools and research support for highway stormwater runoff, statewide and national water quality monitoring and assessment programs, and watershed to national scale nutrient management strategies and technology assessments, with a focus on North Carolina.

Summary of Work Experience

Mr. Dodd has provided technical support to state agencies and local and regional governments in North Carolina; several offices in the U.S. Environmental Protection Agency (EPA); and other state and federal agencies. With the NCDWQ, Mr. Dodd supported point source regulatory programs, nonpoint source nonregulatory programs, and basinwide management initiatives by completing technical analyses of pollution sources, developing and applying modeling tools and analyzing water quality data. In North Carolina, he has supported NCDOT's Highway Stormwater Program, a nitrogen total maximum daily load (TMDL) for Jordan Lake, the Tar-Pamlico Nutrient Trading Program, the Neuse River Nutrient Sensitive Waters designation, the Albemarle-Pamlico Estuarine Study, a technology and economic assessment of the swine industry, basin management plans, and nonpoint source programs. On a national scale, his work has supported a study of wadeable streams, strategies for nutrient criteria development, animal feeding operations, nutrient assessments, and stormwater TMDLs. On a local scale, his work has supported management of and planning for reservoirs, and land use and riparian planning and conservation.

Selected Publications and Presentations

Dodd, R.C., Bruhn, M., Cutrofello, M., McDaniel, M., Lauffer, M., Jacobson, B. Assessing Highway and Road Stormwater Impacts in North Carolina. Presented at 2006 AWRA Annual Conference, November 7, 2006. Baltimore, MD

Dodd, R.C. 2006. *Database Support for Estuary Nutrient Criteria*. Presented at EPA workgroup meeting, Crystal City, VA, January.

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Murray, B.C., G.L. Van Houtven, M.E. Deerhake, R.C. Dodd, M.I. Lowry, C. Yao, A. Miles, D. Phaneuf, A.J. Sommer, J.C. Cajka, J. Coburn, and S.R. Patil. 2003. *Economic Feasibility Assessment of the Smithfield Foods Agreement: Environmental Modeling and Benefits Components*. Presented at the NCSU Animal Waste Workshop, Raleigh, NC, October 16–17.

RTI. 2003. *Delivery of Nonpoint Source Nutrients in the Jordan Lake Watershed.* Prepared for Tetra Tech, Inc., and North Carolina Division of Water Quality. June.

Butcher, J., N. Flanagan, K. Little, and R.C. Dodd. 2002. *Jordan Lake Nutrient Response Model Calibration*. Presented at WRRI Annual Conference, Raleigh, NC, April.

Unger, S.J., and R.C. Dodd. 2000. *Watershed Scale Tools for Quantifying the Effectiveness of Buffers to Reduce Nutrient Inputs to Surface Waters.* Presented at Riparian Buffer Conference, North Carolina State University, Raleigh, NC, May.

Dodd, R.C. 1998. *Decision Support for Nutrient Management in the Neuse River Basin*. Presented at the Air and Waste Management Association Environmental Permitting Symposium, Research Triangle Park, NC, February.

Dodd, R.C., S.J. Unger, and T. Bondelid. 1997. *A River Management Decision Support System (RIMDESS) for the Neuse River Basin*. Presented at Water Resources Research Institute Workshop on Modeling and Decision Support in the Neuse River Basin, September 18.

Dodd, R.C. 1996. *Eutrophication Modeling for the Proposed Randleman Reservoir*. Prepared for the North Carolina Division of Water Quality. RTI, Research Triangle Park, NC. August.

Dodd, R.C. 1995. *Perspectives on Nutrient Management Issues in Eastern North Carolina*. Presented at the North Carolina Nutrient Summit, Raleigh, NC.

Tippett, J.P., and R.C. Dodd. 1995. *Cost-effectiveness of Agricultural BMPs in the Tar-Pamlico River Basin*. Prepared for North Carolina Department of Environment, Health, and Natural Resources, Raleigh, NC. RTI, Research Triangle Park, NC.

Dodd, R.C., J.P. Tippett, and S. Stichter. 1995. *Nutrient Modeling and Management in the Tar-Pamlico River Basin*. Prepared for North Carolina Department of Environment, Health, and Natural Resources, Raleigh, NC. RTI, Research Triangle Park, NC.

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Dodd, R.C., and G. McMahon. 1992. *Watershed Planning in the Albemarle-Pamlico Study Area. Report 1: Areawide Nutrient Budgets*. Prepared for Albemarle-Pamlico Estuarine Study, Raleigh, NC. RTI, Research Triangle Park, NC.

Dodd, R.C., J. Smith, and D. Vogt. 1988. A phosphorus management strategy for two Piedmont impoundments in North Carolina. *Lake and Reservoir Management 4*(2):243–252.

KATHERINE B. HELLER

Education

M.S., Economics, University of North Carolina at Chapel Hill, 1989.

B.A., Economics, The College of William and Mary, 1973.

Summary of Work Experience

Ms. Heller has expertise in the economic evaluation of environmental policy and has led numerous economic analyses of environmental regulations. In these analyses, she uses the tools of regulatory impact analysis, including economic impact analysis, benefit-cost analysis, company financial analysis, and cost-effectiveness analysis. She has analyzed the economic impacts of groundwater use restrictions in North Carolina's Central Coastal Plain. She also assessed the economic impacts of alternative water level management scenarios for reservoirs behind power-generation dams along the Yadkin River in North Carolina. For U.S. Environmental Protection Agency (EPA) air and water regulations, Ms. Heller has developed market simulation models and aggregated the results of facility/market analyses to the owner-company level to estimate company-level impacts, including changes in company profitability, weighted average cost of capital, and likelihood of bankruptcy. She has also conducted regulatory flexibility analyses and cost-effectiveness analyses of various regulatory options. Ms. Heller has also analyzed the geographic and demographic distribution of impacts of environmental policies. Ms. Heller's research interests also include evaluating the institutions and instruments used to implement environmental policy. In this area, she has identified the factors that promote and inhibit sustainable development and innovative environmental solutions in an industrialized community and program evaluations of innovative environmental permitting programs in several states.

Professional Experience

1985 to date	RTI International, Research Triangle Park, NC. Environmental Economist.
1979 to 1981	North Carolina State University, Department of Economics and Business, Raleigh, NC. Economics Instructor
1977 to 1978	The College of William and Mary, Department of Economics, Williamsburg, VA. Visiting Assistant Professor

Selected Project Experience

- **Economic Impacts of Developing Alternative Sources of Water for the Central Coastal Plain Capacity Use Area.** For the NC Rural Economic Development Center, analyzed the economic impacts of limiting withdrawals from two Cretaceous Aquifers in the Central Coastal Plain of North Carolina. Identified alternative water sources and, using costs developed by engineering contractor, estimated the impacts of developing the sources on business and communities in the region. With Rural Center project director and engineering contractor, presented findings to stakeholders and the legislature.

- **Economic Impacts of Alcoa Power Generating Inc. (APGI) Yadkin River Project on Five Surrounding Counties.** Leading a project to analyze the economic and property value impacts of reservoirs associated with the four hydroelectric dams operated by APGI as part of stakeholder involvement for dam relicensing under the Federal Energy Regulatory Commission. Conducting interviews of stakeholders to gather information on impacts on businesses of reservoir operations. Conducting a hedonic price analysis to assess the impact on property value of proximity to the reservoirs and reservoir operations. Presenting progress reports, and ultimately, findings, to APGI and Issue Advisory Group.

- **Economic Analysis of Redevelopment Options for Garner Road Industrial Area.** Analyzed the economic impacts of several redevelopment scenarios for the Garner Road Industrial Area, under a Brownfields Redevelopment Grant to the City of Raleigh, NC. Engaged stakeholder working group in developing and refining several alternative visions for the site, including a mix of industrial, park, and mixed-use alternatives.

- **Economic Analysis of Coastal Nonpoint Source Pollution Controls: Urban Sources, Hydromodifications, and Wetlands.** For the EPA Office of Science and Technology, analyzed the economic achievability of nonpoint pollution controls on urban and hydromodification nonpoint sources of polluted runoff, such as stormwater runoff, construction, and septic systems.

- **Encouraging Innovation Through Umbrella Permitting.** Under an EPA Office of Research and Development Environmental Technology Initiative grant, evaluated the impact of more flexible facility-wide environmental permitting on firm operating and investment decisions. Studied state programs that allow facilities to make operating changes without permit modifications if the changes do not result in violations of a facility-wide cap on emissions, to determine if firms responded by making more frequent process changes, investing in capital equipment, or undertaking pollution prevention activities. Conducted a qualitative analysis through interviews with recipients of facility-wide permits. Supervised a quantitative assessment of the program through the use of a model simulating refinery performance under alternative permit designs. Assessed the effect of a New Jersey program to streamline and coordinate environmental permitting on costs and administrative burdens experienced by permitted facilities and permit writers.

- **Economic Analysis of Water Pollution Regulations: Centralized Waste Treatment Guidelines.** Analyzed the regulatory impacts of an effluent guideline for centralized waste treatment facilities for the EPA Office of Water. Surveyed waste treatment facilities subject to the proposed guideline; and used the data in a mathematical simulation model of to estimate changes in prices and quantities of waste treatment services provided, changes in facility profitability and employment, changes in company profitability, and social cost of the regulation. Conducted a cost-effectiveness analysis to screen possible control options and identify those that are cost-effective. Analyzed effects on communities of both the employment impacts and the health and recreational benefits of the regulation to assess the regulation’s impact on environmental justice.

- **Economic Analysis of Air Pollution Regulations: National Emission Standards for Hazardous Air Pollutants.** For EPA’s Office of Air Quality Planning and Standards, conducted economic impact analyses of federal air emissions regulations for a variety of industries, including Taconite, Refractories, Fabric Coatings, Miscellaneous Organic Chemicals Manufacturing (MON), and Asphalt Roofing.

- **Preventing Pollution in Industrial Communities: Strategies for Sustainability.** For To identify policies that promote environmental protection without damaging the economy, assessed interactions between environmental regulations and the economy in three urban New Jersey counties for EPA’s Office of Policy, Planning, and Evaluation.

- **Analysis of the Employment Impacts of Federal Infrastructure Investment Programs.** Led a project for EPA’s Office of Water to analyze the employment impacts of water infrastructure spending using several macroeconomic modeling methods. Conducted input/output analysis and computable general equilibrium analyses in-house, and coordinated with another contractor who conducted an analysis using a macroeconomic model. Prepared a report compiling, comparing, and synthesizing the results of the three approaches.

David J. Hirschman
Manager of Stormwater Services

Area of Expertise

Expertise in planning and implementing water resources projects, including stormwater ordinances and design standards, watershed assessments, stream assessments, stormwater plans and retrofits, water quality monitoring, and municipal programs. Experience with developing and conducting training, education, and outreach programs.

Experience

Present Position

Manager of Stormwater Services, Center for Watershed Protection (Oct. 2005-Present)

Work on a variety of stormwater and watershed projects, including guidance on stormwater program development, watershed vulnerability analyses, stream assessments, retrofit inventories, code development and analysis, and watershed plans. Conduct training for municipal staff, watershed organizations, government agencies, and other audiences. Representative projects include:

- Project manager working with TetraTech and the Environmental Protection Agency to produce national guidance on the development and implementation of local post-construction stormwater programs. Work includes development of a national stormwater model ordinance.
- Project manager for Building a Cleaner James River; working with the James River Association, University of Virginia, Virginia Tech, and Virginia Commonwealth University to analyze local development codes for each local government within the James River Basin.
- Program development and training to support CWP Stormwater Institutes, including stormwater program development, stormwater maintenance, code development.
- Project manager for Fauquier County Water Resources Management Plan; teaming with Emery & Garrett Groundwater, Inc. to undertake a comprehensive water management plan, including working with a stakeholder committee, collecting and analyzing water resources and water supply data, and drafting an Implementation Plan and code recommendations.
- Project manager for "Technical Assistance for Sound Land Use Tools." Researched innovative land planning techniques in Virginia and assisted the Robert E. Lee Soil & Water Conservation District and Amherst County with the update of the County's Comprehensive Plan.
- Project team for Watershed Training Assistance for Land-Based Sources of Pollution to Coral Reefs; serve as Puerto Rico team lead to work with local agencies to assess and evaluate programs to control land-based sources of pollution, including erosion and sediment control practices and interagency coordination.
- Project manager for the James River Vulnerability Analysis; working with the James River Association to analyze watershed data and identify restoration and protection opportunities in a priority subwatershed.

Previous Positions

Water Resources Specialist, Biohabitats of Virginia, 2004-2005: Provided consulting services on innovative water management for sites and master plans, including water resources plans and ordinances, groundwater assessments, low-impact development, identification of environmentally-sensitive areas, stormwater solutions, and watershed planning. Conducted staff development, training, and education programs for municipal water resources staff, environmental organizations, and the general public.

Water Resources Manager, Albemarle County, Virginia, 1993-2004: Responsible for all facets of water resources program, including stream protection, stormwater management, groundwater, comprehensive planning, policy coordination, and grants/budget management. Spearheaded development of water protection program; authored ordinance and design manual for implementation of streamside buffers, best management practices, and groundwater assessments. Coordinated stream assessment, stormwater master planning, and NPDES Phase II projects.

Research Associate, Department of Urban Affairs & Planning, Virginia Tech, 1990-1992: Designed and implemented demonstration projects in five Virginia communities, including water supply planning, river corridor management, groundwater protection, citizen participation, and application of GIS technology. Authored several technical publications on various water resources topics

Director, Service Training for Environmental Progress, Vanderbilt University, 1986-1987: Responsible for day-to-day operation of university-affiliated non-profit environmental agency. Delivered technical assistance to community groups on wide range of water quality, waste management, and regulatory issues.

Education

Master of Urban & Regional Planning, Virginia Tech, 1990
BA, Biology, Duke University, 1983

Selected Publications

Biohabitats, Inc., *Bioretention Guidance Manual*, Lake County, OH, 2005
Biohabitats of Virginia, Inc., *Stormwater Guidance Manual for the Water Protection Ordinance*, City of Charlottesville, VA, 2005
Hirschman Water & Environment, *Stream Buffer Mitigation Manual for the Water Protection Ordinance*, City of Charlottesville, VA, 2004
Hirschman, D., *Technology Choices for Water & Wastewater: Albemarle County's Rural Areas*, 2003
Hirschman, D., *Interim Design Manual for Albemarle County's Water Protection Ordinance*, 1998, updated 1999.
Scala, M.J. and Hirschman, D., *Albemarle County Comprehensive Plan, Chapter Two: Natural Resources and Cultural Assets*, 1999
Ross, B.B., Goodman, C.W., Hirschman, D.J., Parrott, K.R., and McCaskill, C.D., *Evaluation of Household Water Quality in Albemarle County, Virginia*, 1996, Virginia Tech Department of Biological Systems Engineering.
Hirschman, D., *Pilot Groundwater Study for the North Fork/South Fork Hardware Watershed*, 1994, Albemarle County & DCR-DSWC.
Hirschman, D., Randolph, J., and Flynn, J., *The Can-Do Book of Local Water Resources Management in Virginia*, 1992, Virginia Tech, College of Architecture and Urban Studies.
Hirschman, D. and Roth, R., *Case Studies of Local Water Resources Management in Virginia*, 1991, Virginia Tech, College of Architecture and Urban Studies.
Owens, W., and Hirschman, D., *Managing Water Resources at the Local Level: Regulatory and Nonregulatory Programs*, 1991, Virginia Tech, College of Architecture and Urban Studies.
Hirschman, D. and Conn, D., *Recycling of Municipal Solid Waste: A Guidebook for Virginia Localities*, 1989, Virginia Tech, College of Architecture and Urban Studies.
Hirschman, D., *Community Health and PCB Exposure in Minden, West Virginia*, 1989, Service Training for Environmental Progress, Virginia Tech.
Hirschman, D. and Crate, S., *A Citizens' Guide to Water Quality in North Carolina*, 1985, North Carolina Public Interest Research Group.

Selected Awards

2004 Finalist, Virginia Environmental Leadership Award, Virginia Military Institute
1998 Award for Community Innovation, The Chesapeake Bay Local Government Advisory Committee, for development of Albemarle County's Water Protection Ordinance
1995 Meritorious Professional Planning Project Award, Virginia Chapter of the American Planning Association, for the Pilot Groundwater Study (Albemarle County)

WILLIAM F. HUNT, PH.D., PE

Education

Ph.D., Agricultural and Biological Engineering, Pennsylvania State University, 2003

M.S., Biological and Agricultural Engineering, North Carolina State University, 1997

B.S., Economics, North Carolina State University, 1995.

B.S., Civil Engineering, North Carolina State University, 1994.

Summary of Work Experience

Dr. Hunt has extensive experience with the benefits and costs of stormwater management practices. Since 1997, he has either designed, constructed, or monitored over 70 innovative stormwater practices including stormwater wetlands, innovative wet ponds, bioretention, sand filters, level spreaders, green roofs, cistern/rainwater harvesting systems, and permeable pavements. His research has led to changes in NC DENR standards for bioretention nutrient credit, permeable pavement runoff reduction credit, and level spreader – riparian buffer system design. Additionally, Dr. Hunt and his NCSU stormwater colleagues have delivered approximately 15 workshops and short courses per year for the stormwater management design community. The courses, offered throughout the state, have often concentrated on stormwater wetlands, wet ponds and bioretention cells. Dr. Hunt has also co-developed an inspection and maintenance certification program for stormwater management practices. This program has been offered to over 150 design and landscape professionals to help develop a well-trained maintenance community. Dr. Hunt has partnered with faculty from the NCSU agricultural and resource economics department to conduct cost and benefit research on stormwater management practices. His work involved the development of construction and maintenance costs for wet ponds, wetlands, bioretention, and sand filters He is currently working on an economic analysis of a Low Impact Development in Brunswick County. Dr. Hunt also teaches several courses at NC State University including the Design of Stormwater Management Practices (BAE 575), Introduction to Ecological Engineering (BAE 495K), and Introduction to Engineering (E101).

Professional Experience

2003 to date	North Carolina State University, Department of Biological and Agricultural Engineering, Raleigh, NC. Assistant Professor and Extension Specialist
1997 to 2003	North Carolina State University, Department of Biological and Agricultural Engineering, Raleigh, NC. Extension Associate

Selected Papers and Reports

Wossink. G and *W.F. Hunt*. 2003. The Economics of Structural Stormwater BMPs in North Carolina. WRRI Report # 344 of the Water Resources Research Institute of North Carolina. Raleigh, NC.

W.F. Hunt, A.R Jarrett, J.T. Smith, L.J. Sharkey. 2006. Evaluating Bioretention Hydrology and Nutrient Removal at Two Field Sites in North Carolina. *Journal of Irrigation and Drainage Engineering*. Vol. 132(6): 600-608.

W.F. Hunt, C.S. Apperson, S.G. Kennedy, B.A. Harrison, W.G. Lord. 2006. Occurrence and relative abundance of mosquitoes in stormwater retention facilities in North Carolina, USA. *Water Science and Technology*. Vol. 152(6-7): 315-321.

E.Z. Bean, *W.F. Hunt*, D.A. Bidelspach. 2007. A Field Survey of Permeable Pavement Surface Infiltration Rates. *Journal of Irrigation and Drainage Engineering*. Vol. 133(3).

W.F. Hunt, R. W. Skaggs, G. M. Chescheir, and D. M. Amatya. 2001. Examination of the Wetland Hydrologic Criterion and its Application in Determination of Wetland Hydrologic Status. Water Resources Research Institute Report. Report #333. Raleigh, NC. 119 p.

Selected Project Experience

- **Comparing Costs of a Traditional Development to a Low Impact Development in Brunswick County, NC.** Funded by the NC Coastal Federation. Construction costs for an innovative "Low Impact Development" were developed and compared to those of a conventional development. The 4-acre drainage area was reconfigured to accommodate an additional residence (adding an 11th home) because several bioretention cells and permeable pavement replaced a standard wet pond. Responsible for cost development and re-design of development.

- **Cost Effectiveness of Agricultural and Urban BMPs for NC**. Funded by NC DENR **–** Division of Soil and Water Conservation. Developed construction costs for residential and small commercial stormwater practices including stormwater wetlands, bioretention, permeable pavement, cisterns/water harvesting systems, green roofs, and swales. The cost guidance will be used by the Division of Soil and Water Conservation to establish cost sharing rates.

- **Developing Standards and Associated Costs for Stormwater BMP Inspection and Maintenance**. Funded by the WRRI **–** Urban Stormwater Consortium. Inspection and maintenance costs were developed for several stormwater management practices: stormwater wetlands, wet ponds, bioretention, permeable pavements, sand filters, green roofs, swales, and level spreaders- riparian buffer systems. Costs were developed on a task-by-task basis, determining the frequency of task, amount of time expended to complete the task, and the amount of resources (personnel, materials, equipment).

- **Retrofitting Stormwater BMPs in the Tar-Pamlico and Neuse River Basins**. Funded by a USEPA 319(h) grant administered by NCDENR. Several stormwater practices were retrofitted in the Tar-Pamlico basin, including 3 pocket wetlands and 4 bioretention cells. Costs for each practice were obtained and several of the practices were monitored to help determine future bioretention design guidance.

- **Selection, Design, and Installation, Supervision of Design and Installation, Monitoring, and Technical Workshops of Innovative Stormwater Treatment Practices in the Neuse and Tar-Pamlico Basins**. Funded by NC DENR - Ecosystem Enhancement Program. Sixteen retrofit sites were identified throughout the Neuse and Tar-Pamlico Basins. Three projects were designed for monitoring and one was sent out to bid. By project's end 5-10 management practices are expected be installed and construction and design costs obtained.

Selected Accomplishments

Professional Engineer (license # 23060) in North Carolina since 2001
USDA and CSREES Team Awards (2000)
USEPA Friend of Wetlands: Region IV (2003)
Outstanding Extension Specialist, North Carolina Cooperative Extension (2004)

KIMBERLY Y. MATTHEWS

Education

M.S., Natural Resources, North Carolina State University, 2003

B.A., Biology, Wittenberg University, 1996

Summary of Work Experience

Ms. Matthews is a water resources scientist with 10 years or experience in the environmental field. She has experience conducting field surveys and water quality monitoring, performing data management and analysis, and producing reports. Ms. Matthews has coordinated with state and federal agencies to ensure that projects comply with applicable environmental permits and regulations such as Sections 401 and 404 of the Clean Water Act (CWA) and Section 7 of the Endangered Species Act. These projects included use of ArcGIS to create maps and summarize data for inclusion of reports. Ms. Matthews has assisted in the preparation of National Environmental Policy Act (NEPA) documents and has participated in public hearings and interagency meetings.

Professional Experience

2006 to date. RTI International, Research Triangle Park, NC. Research Environmental Scientist.

2002 to 2006. ARCADIS G&M of North Carolina, Raleigh, NC. Biologist.

2001 to 2002. Center for Transportation and the Environment, Raleigh, NC. Research Assistant (part-time).

1996 to 2000. City of Greensboro, Greensboro, NC. Water Quality Monitoring Technician.

Selected Project Experience

Ms. Matthews has 10 years of experience working in the public and private sector on various natural resources projects. She collected, analyzed, and evaluated data on a broad range of topics and has a firm understanding of the relationship among these different resources.

- **Defense Coastal/Estuarine Resource Program (DCERP) (2006 to date).** Assists the project leader in developing tracking tables, preparing workshop materials for five module teams, and working with the ecosystem module teams. Includes coordinating documents and comments from 40 team members and assist in developing Strategic Plan, Baseline Monitoring Program, and Research Plans for investigating air, aquatic and terrestrial resources on a military base.

- **North Carolina Ecosystem Enhancement Program (NCEEP) (2006 to date).** Assists project team with developing a Forecasting and Accounting Module. Conducts training sessions for NCDNR staff on how to use the new information management system.

- **North Carolina Department of Transportation Highway Stormwater Program (2006 to date).** Assists the project leader in developing the final phase of this project to assess the contribution of highway stormwater runoff to developing targeted TMDLs.

- **Wildlife Habitat Management Plan (2006)**. Prepared and updated a wildlife habitat management plan for a 1,600-acre industrial site in eastern North Carolina.

- **Natural Resources Technical Reports (2003–2006).** Conducted field investigations and delineations for several NCDOT Transportation Improvement Projects totaling more than 100 miles of new alignment and road widening corridors. Projects were in the North Carolina mountain, piedmont, and coastal physiographic regions with special concerns ranging from trout waters, buffer regulations, andramous fish habitat, essential fish habitat, neotropical migratory birds, and tidal waters. Produced impact analysis of corridor options to assist transportation decision makers.

- **Environmental Impact Statement and Environmental Assessment for National Park Service and Federal Highway Administration, (2003–2006).** Assisted in the assessment of existing conditions and determination of potential impacts from up to 35 miles of new alignment roadway for one project and for 14 miles of road improvements for another project. Topics covered included wetlands, streams, water quality, aquatic wildlife, terrestrial wildlife (specifically black bears and migratory birds), invasive/exotics species, and protected species. Data used for this report was obtained from field surveys and various state and federal agencies. Required extensive coordination with the clients, other agencies, and the public.

- **Stream and Wetland Restoration Design Plan (2003–2005).** Assisted the project manager with various components for final mitigation plan of a third order, piedmont stream and floodplain wetland for the North Carolina Ecosystems Enhancement Program. Tasks performed for this project include describing existing soil characteristics, determining existing channel morphology and restoration design based on the Rosgen's classification system, installing and monitoring water table gages, and delineating existing wetlands and vegetation communities. The final product was a plan to restore natural channel dynamics, floodplain hydrology, and bottomland hardwood forest vegetation.

- **Functional Assessment of a Floodplain Stormwater Treatment Wetland (2000-2002).** Characterized in-stream stormwater concentrations of sediment and nutrients, determined geomorphic properties of the stream channel upstream, within, and downstream of the wetland, established baseline water table hydrology on the floodplain, and determined the composition of the existing forest stand

- **Removal Efficiencies of Best Management Practices for Stormwater Treatment (1998-2000).** Conducted water quality sampling to determine the pollutant removal efficiencies of urban treatment systems. Wet detention ponds and biorentention cells in commercial and residential landscapes were studied. This project focused on suspended solids, nutrients (nitrogen and phosphorus), and heavy metals.

Thomas R. Schueler
Center for Watershed Protection
8391 Main Street
Ellicott City, Maryland 21043
Phone: (410)-461-8323
Fax: (410)-461-8324
e-mail: trs@cwp.org

Key Skills:

Expert in practical aspects of urban stormwater runoff control, stream restoration, riparian reforestation, stormwater retrofitsand comprehensive watershed restoration. Experienced in the design and implementation of innovative urban watershed research strategies.

Experience:

Director of Watershed Research and Practices, Center for Watershed Protection (1992 to the present)

Co-founded a national nonprofit organization dedicated to protection of streams, lakes and estuaries through improved stewardship of urban and rural watersheds. Responsible for Center development, management, research, technical support and educational training. Manage a staff of 17 full-time watershed professionals. Past accomplishments include development of a stormwater management design manual for the State of Maryland, preparation of a manual on rapid watershed planning methods, research on stormwater treatment practices, writing and editing the Center's journal *Watershed Protection Techniques*, research on better site design techniques, training workshops, and local watershed partnerships for watershed protection and restoration.

Chief, Anacostia Restoration Team (1982-1992)
Metropolitan Washington Council of Governments
777 North Capitol Street, Washington, DC 20002

Directed an interdisciplinary staff of ten professionals that provided support to local governments in the metropolitan Washington region in the areas of urban watershed restoration, and nonpoint source pollution control. Architect of the first major urban watershed restoration effort in the nation. Designed a comprehensive plan to implement over 400 watershed restoration projects in the Anacostia, including stormwater retrofits, stream restoration, fish barrier removal, tidal and non-tidal wetland creation, riparian reforestation, and citizen stewardship projects. Spearheaded a consortium of over 60 local, state and federal agencies to implement the long term plan. Roles included conducting restoration inventories, concept design, permitting, interagency coordination, monitoring, technical analysis, grantsmanship and watershed planning. Directed an effective outreach program to obtain political, media, and public support for long term restoration effort.

Thomas R. Schueler,   The Center for Watershed Protection

Education

M.S Candidate. University of Maryland. Marine, Environmental and Estuarine Science Program. Sea Grant Fellow. 1986 (DNF)
B.S. George Washington University. Environmental Studies. 1982

Other Experience

Member, National Research Council Panel "Evaluation of Watershed Management in New York Water Supply Watersheds" 1997-1999
Peer Review Committee Member. Lake Whatcom Stormwater Management Study 2000

Selected Publications

Watershed Management for Lakes and Reservoirs. 2001. Center for Watershed Protection, US Environmental Protection Agency. Ellicott City, MD 98 pp.

The Practice of Watershed Protection: techniques for protecting and restoring urban watersheds. 2001. Center for Watershed Protection. US Environmental Protection Agency. Ellicott City, MD. 840 pp.

Rapid Watershed Planning Manual. 1998. (w/ other CWP staff). Center for Watershed Protection. US Environmental Protection Agency. Ellicott City, MD. 404 pp.

Better Site Design: a handbook for changing development rules in your community. Center for Watershed Protection. US EPA and Turner Foundation. Ellicott City, MD. 212 pp.

National Urban BMP Performance Monitoring Database. 1997. (w/ Whitney Brown). First Edition. Center for Watershed Protection. Chesapeake Research Consortium 188 pp.

Maryland Stormwater Design Manual. Volumes 1 and 2. 1999. Center for Watershed Protection. Maryland Department of Environment. 368 pp.

Cost of Urban BMPs In the Mid-Atlantic Region 1997. (w/ Whitney Brown). Center for Watershed Protection. Chesapeake Research Consortium. 66 pp/

Design of Stormwater Filtering Systems. 1997 (w/ Rich Claytor). Center for Watershed Protection. Chesapeake Research Consortium. 188 pp.

Design of Stormwater Wetland Systems--guidelines for creating diverse and effective wetlands in the Mid-Atlantic region. 1993. Metropolitan Washington Council of Governments. Washington, DC. 148 pp.

Stormwater Management Recommendations for the Auckland, New Zealand Region. 1991. Rivers and Erosion Control Branch of Auckland Water Board. Auckland, New Zealand. 220 pp.

Effectiveness of Sediment Traps and Basins in Suburban Maryland. 1987. Maryland Department of Environment. MWCOG. 172 pp.

The Quality of Trapped Sediments and Pool Water in Oil-Grit Separators in Suburban Maryland. 1991. MWCOG. Maryland Department of Environment. 56 pp.

Controlling Urban Runoff--a practical manual for planning and designing urban best management practices. 1987. MWCOG. 276 pp.

Thomas R. Schueler, The Center for Watershed Protection

Appendix C: Letter of Commitment

CENTER FOR WATERSHED PROTECTION

8390 Main Street, 2nd Floor
Ellicott City, MD 21043
410.461.8323
fax 410.461.8324
email center@cwp.org
www.cwp.org
www.stormwatercenter.net

December 29, 2006

Michael P. Gallaher, Ph.D.,
Director
Technology Economics and Policy
Research Triangle Institute
3040 Cornwallis Road, Hobbs Building
Research Triangle Park, NC 27709-2194

Re: Commitment to Team on the RFP
Self-Sustainability of the NOFFP

Dear Mike:

The Center for Watershed Protection is extremely pleased to team with the Research Triangle Institute to provide technical support and economic analysis to evaluate the sustainability of the Nutrient Offset Fee Payments Program. Our staff has conducted extensive research on stormwater pollutant loadings, BMP removal rates and the economics of stormwater treatment and retrofit practices. We have several ongoing research projects that will provide updated and peer-reviewed data to support the review of NOFFP. Dave Hirschman and I will work directly on the project; our experience and the Center's qualifications are attached.

In closing, we look forward to the opportunity to collaborate with you on this important endeavor to improve the quality of North Carolina waters.

Sincerely,

Tom Schueler
Director of Practices

Attachment