Update on Natural Resource Issues

Atmospheric Deposition to the Bay

Atmospheric deposition may be one of the most important non-point sources of nitrogen and trace metals (mercury, lead, zinc, cadmium, arsenic, selenium, etc.) to the Chesapeake Bay. For example, studies suggest that the atmosphere contributes between 25 to 80 percent of the total nitrogen loadings to the Chesapeake. Studies of atmospheric deposition of trace elements suggest that about 50 percent of the total loading to the mainstream of the Chesapeake Bay is from direct deposition to surface waters.

Estimates of atmospheric nitorgen and trace metal loadings to the Bay, however, are highly uncertain, in part because long-range transport mechanisms are not completely understood. Additionally, there is still an incomplete understanding of the retention and transport of atmospheric inputs within the Bay watershed. Long-term modeling and monitoring are helping to improve our understanding of transport and deposition mechanisms.

PPRP is continuing its long history of atmospheric deposition research with a series of monitoring and modeling projects designed to assess the impacts of atmospheric inputs to the Bay watershed from local and distant power plants. A brief review of some of the results of these studies is presented on the following pages.

SECTION HIGHLIGHTS

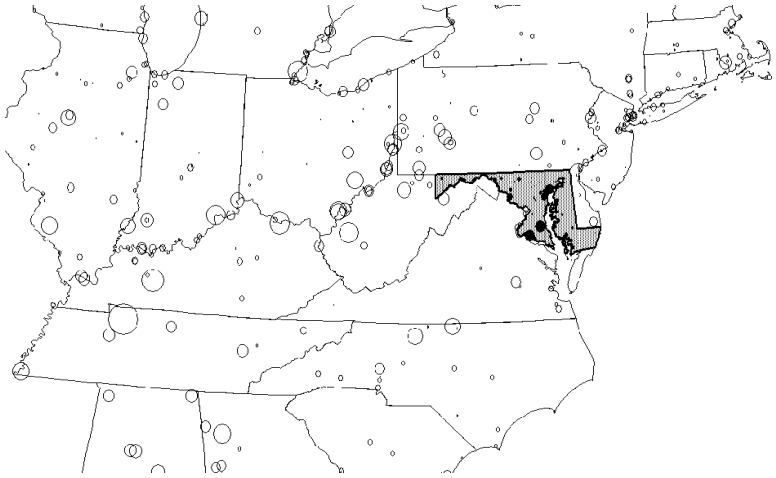
Power plants, along with other industries and also transportation sources, emit air pollutants that can be deposited in the Chesapeake Bay watershed. PPRP has conducted recent modeling studies to determine what sources are the most important contributors to nitrogen deposition in the Bay. Sampling for trace metal deposition has also been undertaken in the Bay's westernmost reaches in Maryland, and the results were used to develop a better understanding of metals transport and deposition patterns.

Nitrogen Transport and Deposition

Recent studies performed by the U.S. EPA have shown that NO_x emitted from air pollution sources, including power plants, are a significant component of the total nitrogen loading to the Bay watershed. These studies suggest that NO_x can travel from distant sources, over hundreds of miles, and still be an important contributor to nitrogen loading in the Bay. In the free atmosphere, NO_x is converted into nitrates, a common plant nutrient. The atmospheric processes by which this nutrient is deposited on the ground or on the surface of a water body are collectively referred to as deposition. Pollutants in the air can reach the ground by either wet deposition — in which pollutants wash out of the air in rain — or by dry deposition — in which pollutant particles or gases impinge onto a surface. Nitrogen deposition onto the water surface is the most direct pathway for airborne nutrients to affect water quality. An indirect pathway involves deposition onto the land surface and subsequent runoff into the waterways.

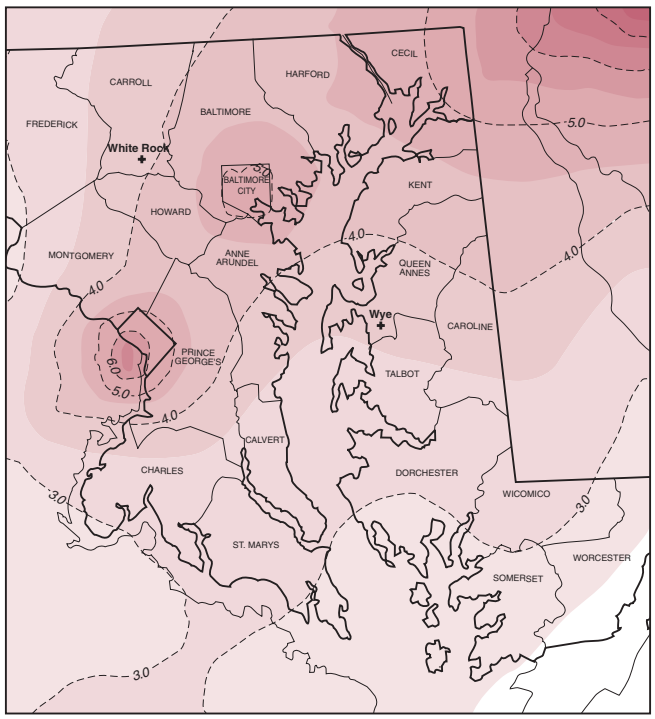
In a recent series of studies, PPRP used the U.S. EPA's new CALPUFF air model to help assess the relative impacts of local Maryland power plants and distant sources on Bay watershed nitrogen loadings. The modeling was also used to evaluate how a variety of potential federal NO_x emissions control initiatives

Figure 5-1
Location and Relative Magnitude of Power Plant NO_x Sources Modeled to Assess Deposition Impacts in Maryland



might affect nitrogen loadings to the Chesapeake Bay. The CALPUFF model uses a "puff" approach to modeling pollutant releases — that is, it simulates the release of pollutants from a stack or other type of emission source as a series of discrete puffs. This model is useful for deposition research because it allows the tracking of pollutants over hundreds of miles, and can differentiate between wet deposition and dry deposition.

Figure 5-2
Total Nitrogen Deposition (Kilograms of Nitrogen/Hectare/Year)



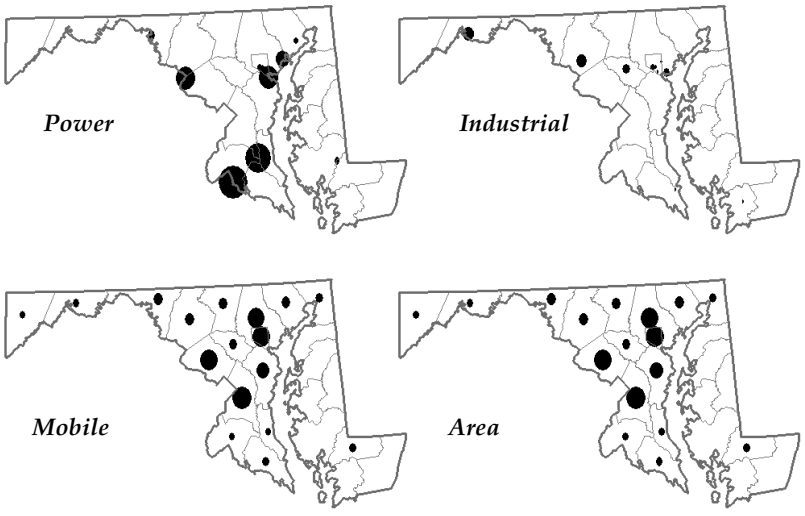
It is known that emissions of nitrogen compounds can travel hundreds of miles with winds in the atmosphere before being deposited to the ground. However, researchers have not yet fully characterized the magnitude and extent of this "regional transport" and deposition. To improve our understanding of regional transport issues, PPRP conducted a study using CALPUFF to evaluate the potential impacts to the Bay watershed from various types of NO_x emissions sources. These sources included power plants, other industrial stack sources, mobile sources (cars and trucks), and area sources, located throughout the eastern half of the United States. Figure 5-1 illustrates the location and relative magnitude of power plant NO_x sources modeled in the study. Each circle on the map corresponds to a power plant, while the relative sizes of the circles indicate each plant's comparative NO_x emissions. The largest circle on the map represents daily emissions of 452 tons of NO_x.

Results of the CALPUFF modeling reveal some interesting spatial patterns of NO_x deposition. Figure 5-2 shows the spatial distribution of total predicted nitrogen deposition around the northern Chesapeake Bay. The areas of higher deposition (darker shaded areas) around urban centers illustrate the important role that mobile sources of NO_x (i.e., cars and trucks) play in deposition. The impact from power plants is significant as well, but tends to be less concentrated and extends over a wider area than the impact from mobile sources.

In a second study, PPRP focused locally, and used CALPUFF to determine the contribution that NO_x emissions sources in Maryland have on nitrogen deposition in the Chesapeake Bay watershed. Figure 5-3 shows the location and relative magnitudes of Maryland sources of NO_x emissions.

Maryland sources of NO_x of all types combined accounted for about 3 percent of the overall total NO_x emitted in the eastern half of the United States. CALPUFF

Figure 5-3
Location of Maryland NO_x Emissions Sources



Source symbol size scaled to annual NO_x emissions
Largest symbol = 22,463 tons/year
Based on OTAG National Emissions Inventory — 1990

further predicts that Maryland sources of NO_x account for about 16 percent of the nitrogen deposited to the Baltimore portion of the Bay watershed.

A number of other observations can be made about nitrogen deposition patterns from this modeling study:

- *Approximately 63 percent of Maryland sources' nitrogen deposition in the entire watershed occurs in the Baltimore area.*
- *Mobile source deposition quantities are a substantial part of the overall total for Maryland sources, and are due primarily to dry deposition. Highest deposition rates occur quite close to the emissions sources.*
- *Deposition from utility sources in Maryland tends to occur over a wider area and maximum long-term deposition rates tend to be less than for ground-level mobile and area sources. Utility deposition quantities are dominated by wet deposition.*
- *Industry (non-power plant) contribution to overall totals is small, although deposition rates are high in a relatively small area close to Baltimore.*

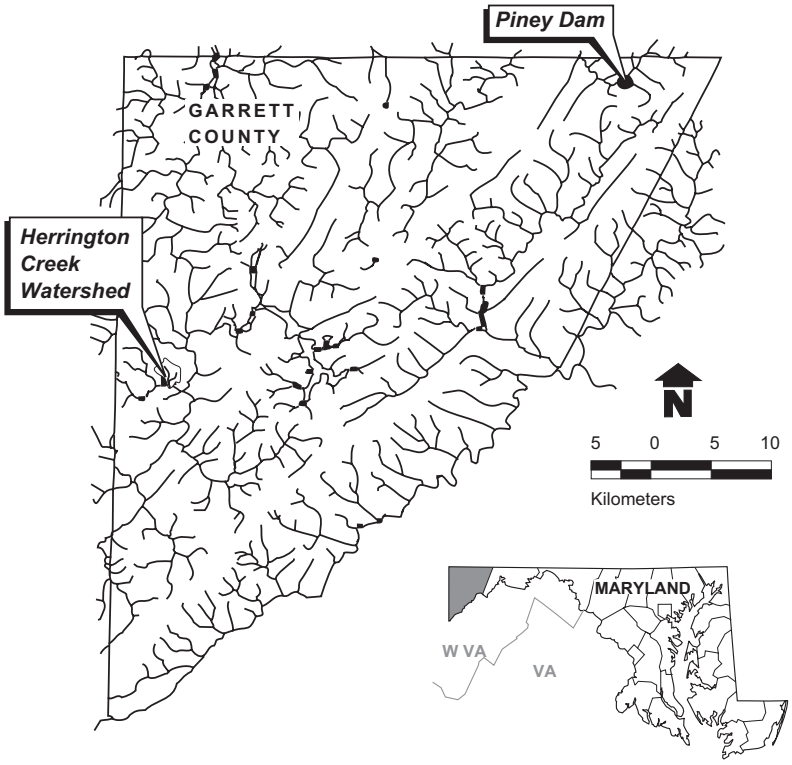
PPRP continues to use the CALPUFF model in assessing the impact of NO_x emissions on the Bay. The assessments are being improved based on evaluations against measured data. This work promises to provide important insights into current and future trends in airborne NO_x emissions and their water quality impacts.

Transport and Deposition of Metals

Research conducted by DNR in the early 1990s suggested that an accurate assessment of trace element loadings to the Chesapeake Bay would require data from additional sites throughout the Bay watershed. To obtain some of this critical data, PPRP initiated the Western Maryland Atmospheric Deposition project in the fall of 1996 to extend the spatial coverage of wet deposition data to the western portion of the Bay watershed.

One of the goals of the study was to increase our understanding of the retention and movement of major ions and trace elements in forested watersheds. To accomplish our goal, we measured atmospheric inputs (precipitation and throughfall, which is the amount of material that reaches the ground after passing through the forest canopy) to a watershed, and stream water export from the same watershed of major ions, trace metals, and mercury. Sampling for the study took place in a completely forested watershed in western Maryland from June 1996 through May 1997. Precipitation was measured on a daily basis at the Piney Dam in Garrett County, Maryland (see Figure 5-4). Throughfall and stream water chemistry were measured on a weekly basis at an unnamed tributary to Herrington Creek in the Herrington Creek Watershed. Continuous stream water discharge from the Herrington Creek Watershed was used with our stream chemistry data to estimate major ion, trace metal, and mercury export from the watershed. These data were used to examine regional patterns in wet deposition and canopy-atmosphere interactions, and to compute "input-output" budgets for the Herrington Creek watershed.

Figure 5-4
Location of Piney Dam and Herrington Creek Watershed in Garrett County, Maryland



The results of sampling efforts PPRP conducted as part of this Western Maryland Atmospheric Deposition study suggest the following conclusions about major ions, trace metals, and mercury input the Chesapeake Bay watershed:

- *Wet deposition is an important source of major ions, trace elements, and mercury to the Herrington Creek watershed. Among the major ions, hydrogen, ammonium, sulfates, and nitrates had the highest annual wet deposition rates. This pattern is similar to those reported for other high deposition sites in the northeastern United States. For the trace metals, aluminum, iron, and zinc had the highest wet deposition rates; cadmium and arsenic had the lowest.*
- *The forest canopy had a major effect on most major ions, and on one trace metal (manganese), but little or no effect on most trace metals, including total mercury. Throughfall deposition rates were 30 to 50 percent greater than wet deposition, and were consistent with expected dry deposition rates. Annual throughfall deposition rates for total mercury were about 30 percent greater than wet deposition rates, probably due to the wash-off of dry deposited material.*
- *On an annual basis, the Herrington Creek watershed retained essentially all of the throughfall inputs of hydrogen and ammonia, and was a net source of sulfates and some other ions (chlorine, calcium, magnesium, and sodium). From among the elements studied, lead, arsenic, and selenium are most strongly retained in the watershed, representing a 50 to 90 percent retention of the atmospheric input. For mercury, about 80 percent of the atmospheric input was retained by the watershed.*

Possible Future Mitigation Efforts for Atmospheric Deposition

Now that we have begun to appreciate the potential impacts of emissions of NO_x and toxics from both local and distant sources on nutrient and metals loadings to the Bay watershed, various groups have begun to consider possible mitigation strategies for this effect. For example, the Chesapeake Bay Program, in its December 1999 Chesapeake Bay Basin-wide Monitoring Strategy report, recommends establishing specific atmospheric deposition loading reduction goals for nitrogen. A watershed-wide nitrogen budget would be established, with loading caps assigned to individual tributary basins. Meeting atmospheric deposition reduction goals would require emissions reductions from upwind sources.

In recognition of the atmospheric input issue, PPRP has begun to evaluate nitrogen deposition impacts as part of its review of new power plants proposed for development within the Bay watershed. PPRP is using the CALPUFF model to predict the incremental nitrogen deposition resulting from major new power plants. This information is then used to recommend a mitigation strategy that the developer should implement as part of the power plant project.

The first example of this new deposition evaluation occurred as part of PPRP's review of the Rock Springs power plant project, proposed for development in Cecil County by Old Dominion Electric Cooperative (ODEC). PPRP conducted deposition modeling to calculate nitrogen loading in the vicinity of the proposed site attributable to NO_x emissions from the project. CALPUFF was run with a full year of meteorological data to determine both wet and dry nitrogen fluxes, and total nitrogen deposition. Deposition fluxes were used to estimate the total nitrogen that would be deposited within the Chesapeake Bay watershed over the course of a year. This total was determined to be approximately 12 tons (nitrogen equivalent), and represents the sum of wet and dry deposition. The State recommended that ODEC plant trees on 50 acres of land to at least partially mitigate the potential nitrogen deposition impacts.

Deposition impacts do not trigger any regulatory requirements. PPRP believes, however, that nitrogen deposition impacts should be considered in the context of nutrient loading goals for the Chesapeake Bay as a whole and thus plans to continue considering deposition effects when evaluating new power plants in Maryland.

Smart Growth and Energy

Maryland's Smart Growth initiative, which was begun in 1997, aims to direct growth to areas of the state where it is most environmentally suitable. The three goals of Smart Growth are to:

- *save Maryland's most valuable remaining natural resources,*
- *support existing communities and neighborhoods, and*
- *save taxpayers the unnecessary expense of building the infrastructure required to support sprawl.*

PPRP has initiated two major projects to ensure that energy infrastrucure, such as power plants and transmission lines, help promote Smart Growth in Maryland. These projects are Smart Siting and the more detailed transmission line data base.

SECTION HIGHLIGHTS

Two recent PPRP projects are utilizing GIS technology to compile and display many layers of interrelated information. Smart Siting is designed to promote environmentally responsible siting of new generating facilities on a broad, statewide basis. The higher resolution transmission line data base supports PPRP's work involving impact assessment of transmission lines, route planning, and right-of-way maintenance.

Smart Siting

In the mid-1990s, it was anticipated that with energy industry restructuring, new generating facilities might be constructed throughout the State of Maryland. It was also thought that these new plants might be built by developers, other than local utilities, who have little prior knowledge of Maryland resources and infrastructure, and that new capacity might not be added at existing plants, but instead at dispersed "greenfield" sites around the state. Given that developing dispersed greenfield sites is at odds with Smart Growth, and that restructuring was imminent, PPRP initiated the Smart Siting project in 1996.

To provide information to developers, and to promote siting power plants in an environmentally responsible manner that is compatible with Smart Growth, PPRP developed the Smart Siting geographic information system (GIS) tool. The primary goal of the Smart Siting project is to identify regions that are more favorable for power plant development in Maryland.

The Smart Siting project uses GIS to display statewide information for the environmental and resource factors, referred to as "siting factors," that should be considered when siting a power generating facility. Smart Siting is designed to highlight potential areas for development; the tool is not designed to identify specific sites that are suitable or unsuitable for facility development. Any areas identified as potentially suitable for power plant siting would have to be evaluated further within the appropriate licensing proceeding.

PPRP is using GIS for this project because it allows a power plant project team to link a tremendous amount of information on various features (roads, railroads, waterways, transmission lines, etc.) to their locations on a map, and to provide electronic access to all of the data sets. The following siting factors are included in the GIS database:

Air Quality — Criteria Pollutant Attainment Status

Air Quality — Distance to Class I Federal Areas

Air Quality — Large NO_x Emission Sources

Benthic Index of Biotic Integrity

Brownfields
Demographics
Fish Index of Biotic Integrity
Floodplains
Industrial Properties
Landfills
Natural Gas Pipelines
Physical Habitat Index
Power Plants
Previously Identified Power Plant Sites
Priority Funding Areas
Protected Lands
Railroads
Salinity Profile of the Chesapeake Bay
Sensitive Species Project Review Areas
Streams
Surface Water Availability
Taxes/Land Acquisition
Transmission Lines
Wastewater Treatment Plants

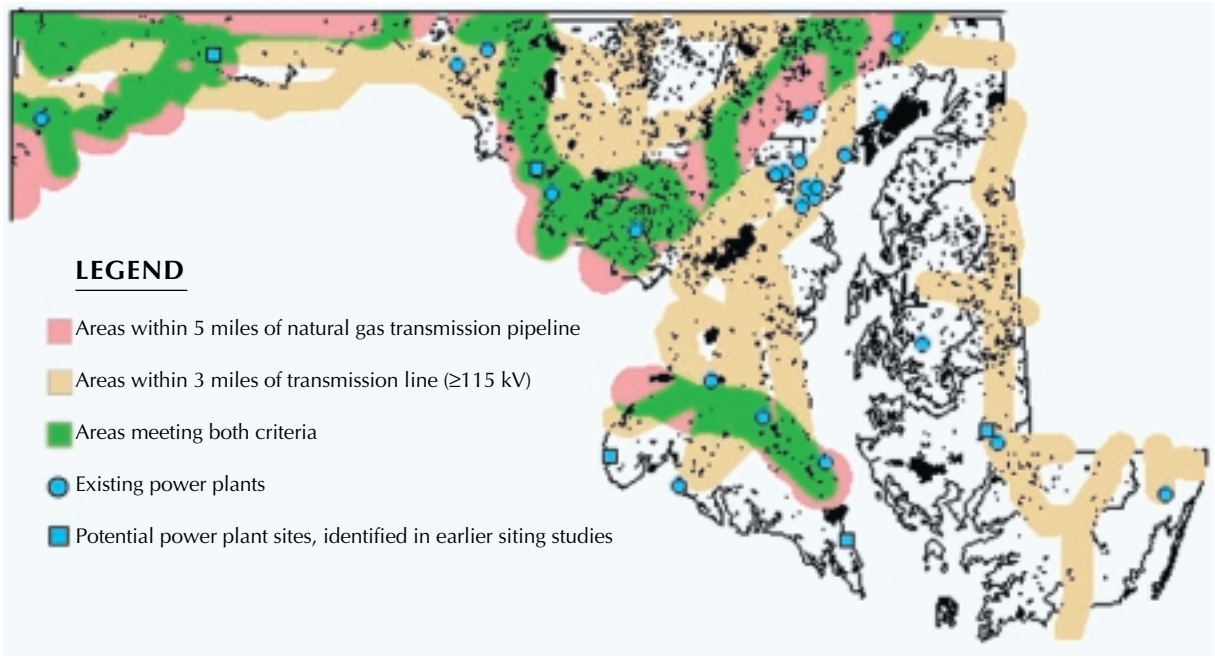
A developer can use the information in the Smart Siting data layers to answer preliminary questions involved in siting a power plant. For example, a developer could use Smart Siting to identify sites within close proximity to both transmission lines and natural gas pipelines, but not near protected lands.

Electronic versions of each data layer, the composite maps, and associated descriptive information are stored on the Smart Siting CD, and are available as part of DNR's Technology Toolbox. To fully operate Smart Siting you must have ArcView® software; however, Smart Siting can be operated on a more limited basis using ArcExplorer®, a free GIS data viewer that can be downloaded from the Internet. PPRP has also published hardcopy and Web-based reports on Smart Siting that describe the project methodology and results.

PPRP expects the Smart Siting GIS tool to be a dynamic, ongoing project that will improve the efficiency and minimize the environmental impact of plant development within Maryland.

Transmission Line Data Base

The electrical power transmission network in Maryland links the generation and distribution facilities of five major utilities, provides interconnections to still other utilities, and is an essential part of the regional power transmission grid (see discussion on page 10). Approximately 3,000 miles of rights-of-way (ROWs) have the potential to impact ecological resources throughout the state. PPRP is responsible for assessing biological and other impacts of existing and proposed lines, and for recommending acceptable routings, permit conditions, and ROW maintenance procedures.



Example of Siting Scenario Results from PPRP Smart Siting Project

One of the siting scenarios examined in the Smart Siting Project resulted in identifying those areas within 5 miles of a natural gas transmission pipeline, and within 3 miles of a transmission line (115 kV or greater). These criteria address the infrastructure that would be needed to support a new simple cycle combustion turbine facility. The green areas in the adjacent map represent those areas of the state meeting both the natural gas pipeline and transmission line criteria. The blackened areas are protected lands, such as federal properties, parks, private conservation lands, and DNR-owned lands, where power plant development would be excluded.

PPRP research frequently addresses routing impacts, best management practices, natural resource planning and enhancement issues, and concerns about the electromagnetic field surrounding transmission lines. To support this research, PPRP has compiled a high-resolution spatial data base of transmission line and substation locations, capacities, and other attributes critical to impact assessment, route planning, and maintenance.

Although long-term needs for additional transmission capacity continue to be identified, the electric power industry has only constructed three transmission lines in Maryland since 1995:

- *BGE added approximately 2,600 feet of 115 kV transmission line at Rutledge in 1995;*
- *Allegheny Power constructed the New Market Loop in 1997, a 230 kV transmission line loop approximately 2.2 miles long;*
- *In 1998, approximately 2.4 miles of 138 kV transmission line were constructed by Allegheny Power at Taneytown.*

Some existing lines are of insufficient capacity, hence they will need to be upgraded and potentially rerouted. Others, supplying growing areas, will

require replacement or supplementation. New power generation capacity may need to be connected to the larger grid, and regional grid stability and reliability may depend upon adding new lines. PPRP's transmission line data base may assist power companies and the regional grid operator, PJM Interconnection, in planning and operating studies as well as power system modeling.

Assessing the adequacy and environmental soundness of Maryland's long-term electric energy supply is also part of PPRP's responsibility. As part of a cooperative effort in support of Maryland's Smart Growth Initiative, PPRP has integrated Smart Growth data (i.e., Priority Funding Areas, Protected Lands, and Rural Legacy Areas) provided by the Maryland Office of Planning and the Growth and Resource Conservation Division of MD/DNR with the transmission line data base. Under the Smart Growth Initiative, future population and economic growth is focused upon targeted areas by allocating State contributions to infrastructure development there, while other areas are designated for preservation as rural or natural areas. When information from PJM about the transmission load (percent of capacity) for each transmission line is integrated with the PPRP transmission line data base, Smart Growth data, and growth projections from the Maryland Office of Planning, it should be possible to assess whether the planned patterns of growth will require additional transmission capacity. It should also be possible to identify areas where the energy supply currently exceeds the energy demand.

PPRP's transmission line data base is a logical foundation for addressing habitat protection and enhancement (in transmission line rights-of-way) from a statewide perspective. Continued development of the data base will broaden its usefulness for PPRP and other State agency projects.

SECTION HIGHLIGHTS

PPRP is working to develop an integrated approach to assessing ecological condition and change. These efforts will be used to address the indirect and cumulative effects of power generation on the State's natural environment, and will support ongoing programs to protect ecosystems throughout the Bay watershed.

Conserving Biodiversity Through Integrated Assessments — Biodiversity Hotspots

PPRP recognizes that, although the State has made great progress in minimizing the impacts of specific power plant activities on individual resources, it has not yet fully addressed the cumulative effects of these activities on Maryland's ecosystems. To do this, we need an integrated approach to the assessment of ecological condition and change, based on watersheds or other ecological regions. This approach will become even more important as the electric utility industry changes into a more decentralized and less structured business. New technologies, such as GIS, will play a central role in integrating assessment information across geographic locations and in developing comprehensive solutions.

This section addresses three PPRP initiatives that support this integrated approach: 1) biodiversity conservation; 2) landscape analysis; and 3) indicator development. GIS plays an important role in this approach by integrating remotely sensed land cover information with ecological measurements from comprehensive field surveys. In addition to addressing the indirect and cumulative impacts of power plants, this approach will further collaborative efforts

on ecosystem protection within DNR (e.g., the Integrated Natural Resource Assessment), with MDE (e.g., watershed-based permitting and biological criteria for water quality standards), and with the U.S. EPA (e.g., regional assessments and priority setting).

Biodiversity Conservation

Biological diversity, or biodiversity, is defined as the "variety of life and its processes," and includes diversity at the levels of genes, species, ecosystems, and landscapes. Scientific and public concern for biodiversity is based on the fact that projections of the loss of species are great (even in the United States) and that environmental degradation continues in the face of attempts to regulate impacts on a resource-by-resource basis. The loss of biodiversity carries with it the diminution of utilitarian values (e.g., medicinal uses of plants, agricultural gene stocks, fisheries as a food source); indirect utilitarian values (e.g., ecosystem services such as air quality, climate amelioration, flood regulation, soil building, waste assimilation, pest control, crop pollination); recreational and aesthetic values; and intrinsic, spiritual, and ethical values. The solution to conserving biodiversity is to preserve and restore natural ecosystems with enough native components to sustain themselves over time.

DNR recognizes that addressing biodiversity is critical to meeting the goals of 1) understanding ecosystem processes and their relationships to Maryland's natural resources; and 2) evaluating the effectiveness of restoration, enhancement, and protection activities for Maryland's natural resources. The DNR Ecosystem Council has embraced the conservation of biodiversity as a key objective.

PPRP is also part of the larger electric industry effort to address this issue. PPRP participated in the first industry conference on biodiversity, sponsored by the Electric Power Research Institute, and is pursuing partnership opportunities so that utilities can better manage their land for biodiversity, avoid biodiversity impacts, and mitigate unavoidable impacts.

PPRP is currently pursuing two primary biodiversity conservation initiatives:

- *Fostering biodiversity and utility partnerships — PPRP is developing new tools for restoration targeting of ROWs within priority biodiversity hot spots and green infrastructure landscapes. Electric utilities are being encouraged to focus their current land management efforts on these targeted ROWs to create habitat for rare, threatened, and endangered species, and to reduce fragmentation in large areas of contiguous habitat. PPRP has worked with other agencies within DNR and other State agencies, as well as local utilities to improve impact evaluation of ROWs and to better target ROWs for ecological restoration and planning. One of the goals of fostering this*

Components of Biological Diversity

Biodiversity exists on many levels, from broad regional patterns down to the variations within individuals of the same species. Assessing impacts to biodiversity requires an understanding of the various levels. In its guidance on incorporating biodiversity considerations into impact analysis, the U.S. Council on Environmental Quality defines four general components of biological diversity:

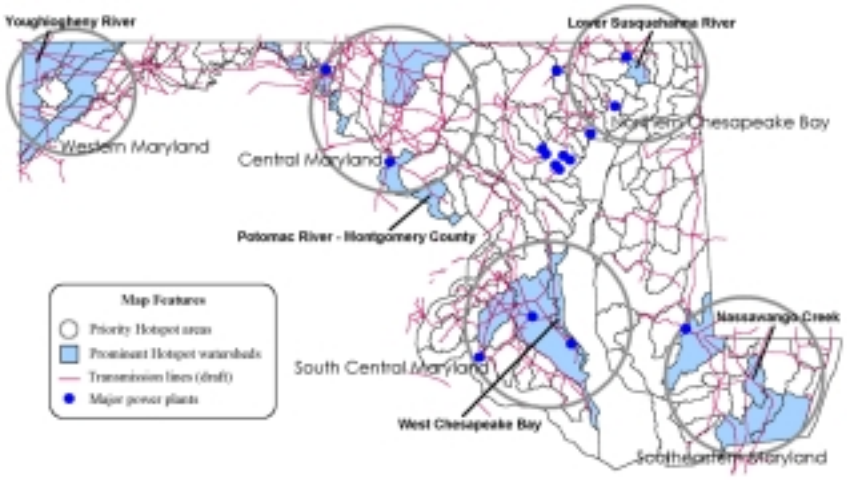
Regional ecosystem diversity — the pattern of local ecosystems across the landscape. Sometimes referred to as "large ecosystem diversity" or "landscape diversity."

Local ecosystem diversity — the diversity of all living and non-living components within a given area and their interrelationships. Ecosystems are the critical biological/ecological operating units in nature. A related term is "community diversity" which refers to the variety of unique assemblages of plants and animals (communities). Individual species and plant communities exist as elements of local ecosystems, linked by processes such as succession and predation.

Species diversity — the variety of individual species, including animals, plants, fungi, and microorganisms.

Genetic diversity — variation within species. Genetic diversity enables species to survive in a variety of different environments, and allows them to evolve in response to changing environmental conditions.

Figure 5-5
Overlay of Transmission Lines and Major Power Plants on Priority Hotspots for Biodiversity Conservation (*Draft*)



interaction is to expedite environmental reviews and build consensus among reviewers by providing standard data in an objective format. Both regulatory review agencies and electric utilities have shown an interest in this format.

- *Mapping biodiversity hotspots — PPRP has undertaken a biodiversity hot spots project to locate and map areas of high species diversity and areas supporting rare species, using existing data from large-scale field surveys. Identification of these biologically rich or unique areas is consistent with the DNR Ecosystem Council recommendations for identifying core and buffer areas for conservation and restoration. Data from the MBSS was used for delineating freshwater fish hotspots, while rare, threatened, and endangered (RTE) species information from the Maryland DNR Heritage and Biodiversity Conservation Programs was used to identify hotspots for 12 major taxonomic and ecological groupings. Results indicate the following:*

  1. *Rare, threatened, and endangered species, especially plants, can be found in all regions of Maryland (only seven of the 138 watersheds in Maryland do not contain RTE species) and therefore provide numerous opportunities for biodiversity conservation for major landowners in the State (e.g. electric utilities with extensive rights-of-way holdings).*

  2. *The pattern of these rare, threatened, and endangered species, taken across all taxonomic and ecological groupings, reveals five hotspot regions (see Figure 5-5) that can form the basis for priority biodiversity conservation efforts. These priority hotspots are restricted to only 15 watersheds or 11 percent of the 138 watersheds in Maryland.*

Landscape Analysis

Although PPRP has considerable information on the volume and variety of potential impacts to Maryland's environment from the construction and operation of electric power plants and transmission systems, a fully integrated assessment of the cumulative effects of these activities on the natural resources of Maryland is needed. It can be difficult, however, to study power plant effects

in the context of effects from other anthropogenic stressors. To assess power plant impacts effectively, PPRP is developing a methodology that focuses on individual resources and whole ecosystems, and on the thresholds of stress beyond which they become degraded. This methodology consists of the following components:

- *Needs assessment for the methodology;*
- *List of cumulative effects issues related to power plants;*
- *GIS with natural airshed, watershed, and ecoregion boundaries at the scales needed to meet the study goals;*
- *Practical land use-based relationship as a surrogate for nonpower-related stresses that can be applied across the state;*
- *More and better indicators of ecological condition using Maryland reference conditions;*
- *Baseline of current ecological condition across the state;*
- *Inventory of power plant activities statewide; and*
- *Basic research on cause-and-effect relationships.*

One of the components listed-practical land use-based surrogate for nonpower-related stresses that can be applied across the state-is a major focus of PPRP activity. PPRP is developing a landscape-ecological condition relationship based on the correlation between land use and integrated indicators of stream condition, the MBSS Indices of Biotic Integrity (IBI) for fish and benthic invertebrates. Using the IBI values derived for MBSS sites, PPRP is determining the best fit of these values with Multi-Resolution Land Characteristics (MRLC) land cover data.

These MRLC data have recently been developed for the mid-Atlantic region as the first step in a national effort by a consortium of federal agencies, including the U.S. EPA and the U.S. Geological Survey, to provide 30-meter resolution land cover/land use data from Landsat imagery.

PPRP's efforts are aimed at determining: 1) the best land cover data and resolution to use; 2) what unit of the landscape should represent the area of influence; and 3) what specific metrics quantifying landscape condition are most useful. Landscape areas of influence that PPRP is considering include the watershed or catchment upstream of each sample site, the riparian corridor upstream of the sample site, and a circular area representing the local land use. Initial results in the Patapsco River basin indicated that such relationships may be useful for inferring the ecological condition of streams where instream measures do not exist. Ongoing work is extending the approach to other river basins and adding data on other power and non-power related stressors. The use of a knowledge-based system to capture a range of stressor relationships is being investigated. Once this surrogate relationship is validated for use in other regions, PPRP will be able to identify areas where additional stresses may cause streams in marginal condition to become degraded, or where restoration may alleviate cumulative adverse effects. This relationship can also be used to determine the incremental contribution of existing and proposed power plants to the cumulative effects on resources of concern.

Integrated Indicators of Ecological Condition

Understanding the status and trends in the condition of natural resources is critical to evaluating the cumulative effects of power generation and transmission. PPRP believes that using environmental indicators is the most cost-effective way of assessing power-related impacts to the environment. Specifically, validated indicators that are based on reference conditions can best determine the status of the resource relative to all other stresses. Integrated indicators that describe the integrity of biological communities are needed to address biodiversity and ecosystem-level impacts.

Indicators can assess either the condition of the resource or its exposure to stressors. They can both evaluate current baseline conditions and detect trends over time. Proper calibration is needed, using reference conditions as a yardstick to measure the degree of impact at specific sites while also accounting for natural variation in ecological conditions. The use of standard indicators and appropriate reference conditions provides an accurate and scientifically defensible means of evaluating impacts. Such indicators can serve as the basis for evaluating power-related impacts, such as acidic deposition or mine drainage, in the context of other cumulative effects. They are useful diagnostic tools for comparing the relative influence of other, multiple stressors, including physical habitat degradation and urban development. Integrated indicators of ecological condition will make possible comprehensive, integrative assessments of the relationships between environmental stressors and a broad range of resources.

PPRP is currently investigating many kinds of indicators for addressing power-related impacts, including physical indicators, chemical indicators, biological indicators, and landscape indicators using GIS. At the same time, PPRP is working with other agencies and organizations to develop indicators through programs such as DNR's MBSS and Integrated Natural Resources Assessment. Recent program accomplishments include the refinement and validation of the Index of Biotic Integrity (IBI), a reference-based indicator that has undergone rigorous testing and calibration for use in Maryland streams. A third ecological indicator, the physical habitat index (PHI), has also been developed to help determine the deviation from natural stream condition. A fourth potential indicator based on amphibian and reptile communities is being investigated. Preliminary results indicate that stream salamanders show promise as a vertebrate indicator for small streams where there are few or no fish communities. A pilot study comparing the utility of three stream salamander monitoring methods is currently underway.

All three ecological indicators — fish IBI, benthic IBI, and PHI — have been integrated into a statewide assessment of stream conditions. Ongoing work includes investigation of natural variability of the fish and benthic IBIs as MDE considers their use as biological criteria to support State water quality standards. Additional sampling of targeted streams is underway to further IBI development of special habitats, such as cold water trout streams, and to refine reference conditions. As described in the Landscape Analysis section above, GIS-based landscape indicators are also being developed to represent the cumulative impacts of human activities on a watershed scale. PPRP continues to review current state and federal initiatives in indicator development to identify the best indicators and techniques for evaluating the effects of power generation and transmission.

Ozone and NO_x Issues

Ozone pollution, commonly referred to as smog, is the periodic increase in the concentration of ozone in the ambient air near the ground. Ground-level ozone pollution is mainly a daytime problem during the summer months because sunlight plays a primary role in its formation. The ozone formation process starts with emissions of NO_x and volatile organic compounds (VOCs), which are known as the chief "precursors" of ozone, or compounds that react in the presence of sunlight to produce ozone. These gaseous compounds mix like a thin soup in the ambient air, and under certain conditions when they interact with sunlight, form ozone.

Mobile sources are the largest single source of VOCs in our region, accounting for about 55 percent of the regional VOC emissions. Power plants are responsible for less than 1 percent of the total VOC emissions. On the other hand, power plants are significant emitters of NO_x, which is formed mainly by high-temperature chemical reactions during the combustion of fuels. These emissions consist primarily of nitric oxide (NO). Some of the NO converts to nitrogen dioxide (NO_2) in the atmosphere. NO_x refers to the combined amounts of NO and NO_2 in the atmosphere.

Power plants are the largest point source contributor of NO_x in Maryland. Power plant emissions account for 35 to 40 percent of the total NO_x emissions in Maryland, depending on the particular area of the state; however, mobile sources (automobiles, trucks, construction and farm equipment, etc.) account for as much or more of the NO_x in Maryland.

SECTION HIGHLIGHTS

Ground-level ozone is a serious air pollution concern in Maryland, and has been one of the most difficult problems to solve because ozone formation is a complex process. Nitrogen oxides and volatile organic compounds react in the presence of sunlight to produce ozone, sometimes hundreds of miles away from the sources that emitted the compounds in the first place. While transportation sources are the most significant contributor of these compounds in our region, power plants emit large quantities of nitrogen oxides. The State is involved in ongoing research to evaluate power plants' influence on regional ozone.

New Ozone NAAQS

In July 1997, the U.S. EPA promulgated a new National Ambient Air Quality Standard (NAAQS) for ground-level ozone, the primary constituent of smog. This was the first revision of the standard in 18 years. The U.S. EPA revised the standard from a 1-hour average of 0.12 parts per million (ppm), measured as ozone in the air near the ground, to an 8-hour average of 0.08 ppm. The new, more stringent standard was developed following a lengthy scientific review process. The U.S. EPA determined that the new ozone standard, based on 8-hour ozone readings, would better protect health and the environment than the 1-hour standard.

For areas that already were in compliance with the 1-hour ozone standard (nearly 3,000 counties), the U.S. EPA subsequently revoked the 1-hour standard beginning in June 1998. Lawsuits ensued, as various stakeholders questioned the scientific basis for the new standards, as well as EPA's authority under the Clean Air Act to promulgate the standards. On May 14, 1999, the U.S. Court of Appeals for the District of

Ozone Forecasts

When temperatures are high and the mixing of the air currents is limited (that is, little or no wind), ozone can accumulate to unhealthful levels. Meteorologists can predict when these conditions are likely to occur. For the Baltimore and Washington metropolitan areas, a team of meteorologists from the University of Maryland and MDE provides ozone forecasts so that actions can be initiated to help reduce emissions of air contaminants. During the ozone season, which runs from May through October each year, the daily ozone forecast for sites in Maryland can be found on the Internet at www.mde.state.md.us/arma. You can also call the Air Quality Hotline in Maryland at 410-631-3247 or in Washington, D.C. at 202-962-3299 to check air quality daily.

NO_x Budget Program: Buying and Selling NO_x

The price of NO_x allowances has decreased steadily over the first two years of broad-scale NO_x allowance trading. In January of 1999, the price for allowances was more than $5,000 per ton; by June 2000, it had dropped to $500 per ton. For many states, the 1999 ozone season (May-October 1999) was the first trading season under the new NO_x Budget regulations, which require utilities and other large NO_x sources to decrease NO_x emissions during the ozone season to target levels, or buy NO_x allowances on the open market to comply. In Maryland, disputes between the regulated electric utility community and MDE over the timing of the implementation of the NO_x Budget regulations caused a one-year delay in the program.

Some speculate that the dramatic drop in the price of NO_x allowances seen near the end of the 1999 ozone season was influenced by the fact that Maryland utilities were not subject to NO_x Budget regulations during 1999, which contributed to a NO_x allowance surplus during the first ozone season.

Columbia Circuit blocked the Agency's authority to implement the new 8-hour ozone standard. The Department of Justice and the U.S. EPA have appealed the court's decision and are seeking to have it overturned. Pending resolution of this issue, the Agency has reinstated the 1-hour ozone standard to ensure that there is a federal public health standard in place for ozone.

NO_x Regulations Affecting Maryland Power Plants

One of the main goals of the CAA is to bring areas that are not attaining the NAAQS into attainment with the standard. In the past, ozone reduction strategies focused on controlling emissions of certain hydrocarbons, such as VOCs. However, recent studies indicate the need to control both VOC and NO_x emissions to attain the ozone NAAQS.

The CAA Amendments of 1990 address the ozone problem by requiring reductions in emissions of ozone precursors. The CAA requires all states, including Maryland, to submit plans (State Implementation Plans or SIPs) to the U.S. EPA for meeting the ozone NAAQS. Beginning in mid-1995, these plans had to include both VOC and NO_x emissions control and reduction strategies for existing power plants and other large combustion sources. The state plans must outline specific controls or emission limits, representing a level of pollution control known as Reasonably Available Control Technology (RACT), to reduce NO_x and VOC emissions from existing facilities.

After implementing RACT in the mid-1990s, the ozone problem throughout the Northeastern United States persisted. Therefore, the U.S. EPA and states recently implemented more stringent and comprehensive NO_x emissions control programs, including the "NO_x Budget" and "NO_x SIP Call" programs. Both programs involve NO_x "cap and trade" programs. In a cap and trade program, the state sets a cap on total, statewide NO_x emissions to be allowed during the ozone season (May to October) each year — this is the NO_x budget for the state. Each power plant and other large stationary NO_x source is then assigned a certain number of allowable NO_x emissions, referred to as "allowances" for that year under the budget. To meet the budget, power plants can reduce NO_x by switching to "cleaner" fuels such as natural gas, or can install add-on pollution control systems such as low-NO_x burners or selective catalytic reduction (SCR) to reduce NO_x emissions. Alternatively, power plants can purchase NO_x allowances on the open market, as a potentially cost-effective compliance strategy, similar to the Acid Rain Program's SO_2 allowance trading program.

Under its NO_x Budget program, MDE must ensure that the State obtains a 65 percent reduction from statewide 1990 baseline NO_x emissions level from "budget sources" during the ozone season. All but one of the budget sources in Maryland affected by the regulation are power plants.

There are a number of issues, in addition to the cost and availability of allowances, that will affect how individual power plants elect to meet the NO_x Budget

requirements. Among the more complex issue is the fact that reductions required by the NO_x Budget program are independent of NO_x reductions that utilities in Maryland will likely have to implement to meet future ozone pollution-driven NO_x requirements in the coming years. The uncertainty in the ultimate level of NO_x control influences how and when a utility chooses to install add-on pollution control systems, versus implementing less costly control technology in combination with allowance purchases.

The NO_x RACT, NO_x Budget, and NO_x SIP Call programs affect existing power plants in the state. Proposed new power plants in Maryland and much of the East Coast also face stringent NO_x requirements under the Nonattainment Area New Source Review (NA-NSR) permitting program. Among other requirements, new power plants subject to NA-NSR must demonstrate that emissions will meet the most stringent type of pollutant control technology available-Lowest Achievable Emission Rate or LAER-to ensure that NO_x emissions are as low as possible.

Even after ensuring LAER, large new combustion sources subject to NA-NSR must actually show a net reduction in NO_x emissions after installing a new power plant. These net reductions are achieved by new plants through purchases of NO_x "offsets." Offsets, similar to NO_x allowances, are generated when a source reduces NO_x emissions from an existing power plant or other source and "banks" these pollutant reductions. New power plants subject to NA-NSR must purchase offsets at some ratio greater than 1 to 1, to achieve the net reduction in NO_x. The actual ratio depends on how severe the ozone pollution is in the vicinity of the new power plant. For example, in the Baltimore metropolitan area, where ozone pollution is severe, new sources subject to NA-NSR must obtain offsets at a ratio of 1.3 to 1.

Ozone has and continues to be a persistent summertime problem in much of the East Coast and in urban areas across the United States. Ozone related NO_x control issues will undoubtedly continue to affect the fossil fuel-fired energy sector for years to come.

Recent Ozone Issue Studies

Each state must demonstrate to the U.S. EPA that the ozone NAAQS will be attained by the deadlines mandated in the CAA. These demonstrations of attainment are made through the use of computer modeling that predicts smog levels based on projected future emissions, photochemistry, and meteorology. The U.S. EPA has developed such a computer model for the entire northeast region of the United States, including Maryland. Current studies for this region suggest that additional NO_x and VOC emissions reductions from existing sources are needed throughout the region to attain the ozone standard.

Concurrently, some states, including Maryland, are using a more detailed model to study smog formation. The goal of the state studies is to identify specific areas where NO_x and VOC reductions will help achieve the ozone standard. MDE is currently conducting additional regional ozone modeling studies with assistance from PPRP and the University of Maryland. These results will be critical for designing appropriate control plans for the various

source categories, including power plants, and for determining areas where NO_x emissions control would help in attaining the ozone NAAQS.

PPRP's Recent Ozone Climatology Projects

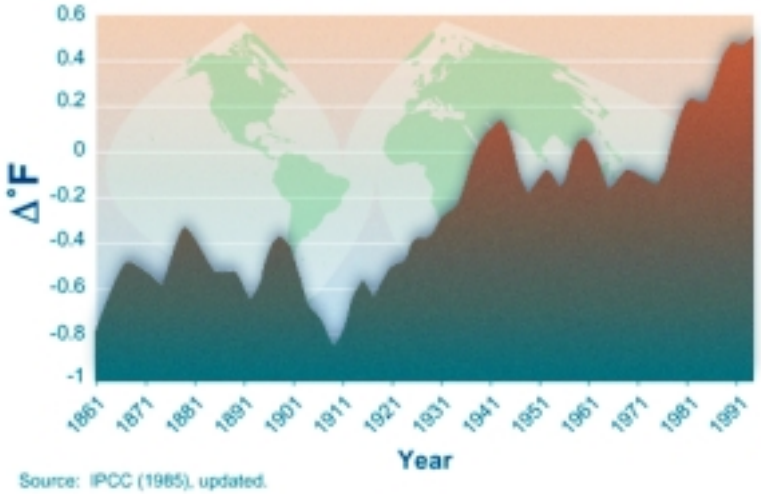
PPRP has conducted several studies since 1996 to assist in the evaluation of the influence that power plants have on regional ozone issues. Two of PPRP's most recent ozone assessments were statistical studies of "ozone climatologies" in the Baltimore-Washington, D.C. area. The goal of these projects was to review ozone monitoring data collected from monitoring stations in the Maryland and Virginia area and evaluate the climatological behavior of ozone in the area. This climatological analysis provides insights into the possible effectiveness of the application of NO_x control strategies during different times of the year and into what degree of reduction in ozone concentrations at different time scales will be effective in reducing the occurrence of high ozone episodes in the summertime.

For many pollutants, such as SO_2 or particulate matter, computer air dispersion models are run daily to evaluate the potential impacts that stack emissions from a power plant or other source might have on air quality. However, because ozone formation is such a complex process, the models to predict ozone are themselves quite complex, and historically have been so labor- and computer-resource intensive that only state and federal agencies routinely ran the models. The understanding of the mechanisms of ozone formation that PPRP is developing through statistical and other analyses is crucial to developing and applying "simplified" ozone prediction models. When such "simplified" ozone prediction models are up and running, they can be used to conduct screening-level assessments of the effect of NO_x and VOC emissions control strategies on ground-level ozone.

Regional Ozone Assessment Using the Ozone Screening Tool "SIPM"

In response to the need for a practical ozone screening modeling tool, PPRP has been evaluating and enhancing the Simplified Ozone Modeling System (SOMS) since 1996. SOMS was originally developed by the Electric Power Research Institute (EPRI), with the majority of the development work being performed by researchers at the University of California at Riverside. PPRP recognized the potential usefulness of this model in the development of long-term (15-year) time series of ozone predictions, which can be used to assess the impact of NO_x control strategies or emissions trading scenarios on long-term ozone trends. The analysis of long-term trends is generally absent in the current State Implementation Plan modeling, which typically focuses on ozone episodes lasting no more than a

Figure 5-6
Global Temperature Changes (1861 - 1996)



few days. The effect of control strategies on long-term trends is anticipated to be useful in developing ozone attainment demonstrations.

PPRP is nearing completion of a major enhancement and upgrade of the modeling system, now called SIPM (for the Semi-empirical Integrated Pollutant Model). SIPM incorporates some improvements from the original SOMS model for ozone screening modeling, and adds a method to predict particulate matter in a screening capacity.

Power Plants and Climate Change

Impacts to Global Climate

In addition to affecting acid rain, deposition, and ozone, power plants and combustion can affect global climate by emitting large quantities of greenhouse gases (GHGs). Atmospheric GHGs (water vapor, CO_2, methane, etc.) trap some of the energy from the sun, creating a natural "greenhouse effect." Without this effect, ground level air temperatures would be too low to support life as it is we know it. However, it is believed that this naturally occurring and beneficial greenhouse effect is enhanced by excessive amounts of human-generated emissions of GHGs, including CO_2 from combustion sources. The enhanced greenhouse effect is projected to contribute to changes in global climate patterns, which result in such problems such as increases in global atmospheric temperatures and changes in precipitation, soil moisture, and sea level. Figure 5-6 shows global temperature changes from 1861 to 1996.

As discussed previously in Section 4, the burning of fossil fuels — coal, oil, and natural gas — for energy is the primary source of GHG emissions globally. These emissions associated with fossil fuel combustion can be attributed to the source — power generation — or to the "end-use sectors," which are the industrial, residential, commercial, and transportation entities that use the electricity and steam generated by fossil fuel-fired power plants. These end-use sectors are estimated by the U.S. EPA to be responsible for about 80 percent of global CO_2 emissions. In the United States, burning fossil fuels accounts for about one-third of the nation's CO_2 emissions.

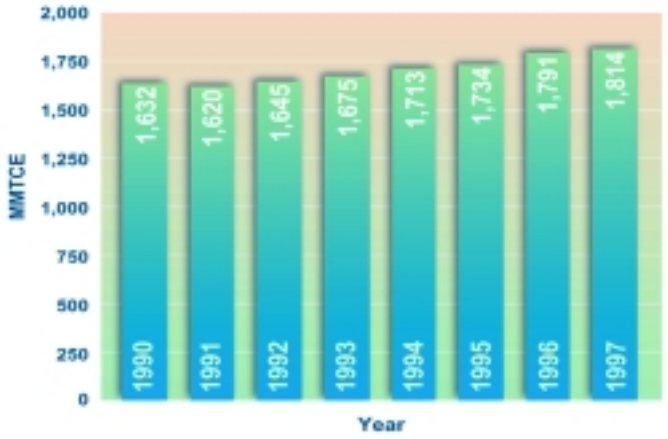
As illustrated in Figure 5-7, the U.S. EPA estimated total 1990 emissions of all greenhouse gases, including CO_2, to be about 1,632 million metric tons carbon equivalent (MMTCE). The U.S. EPA's calculations compiled in 1997 show total greenhouse gas levels to be roughly 1,814 MMTCE, which is 11 percent higher than the 1990 baseline levels. Of that 1,814 MMTCE, about 1,344 MMTCE was contributed by CO_2 emissions.

Currently, there is no federal program to limit greenhouse emissions. However, there is growing consensus among businesses and government leaders that ultimately some action to reduce greenhouse gas emissions will be required. Some research groups have suggested emissions trading programs generally modeled on the successful CAA Acid Rain Program, which would allow businesses and utilities flexibility to choose their compliance methods and to buy and sell the right to emit.

SECTION HIGHLIGHTS

Carbon dioxide emissions have increased in the United States during the 1990s. Many business and government leaders, as well as research organizations, believe that ultimately some action to reduce emissions of carbon dioxide and other greenhouse gases will be necessary. There is still considerable debate over the severity of global climate change, and to what extent greenhouse gases influence global climate. The potential for sea level rise is of particular concern in Maryland because of the effects it could have on the state's extensive shoreline, among other factors.

Figure 5-7
Total U.S. Greenhouse Gas Emissions



CO_2 Control

There are few proven post-combustion pollution technologies or systems available to control CO_2 emissions. However, as discussed previously, GHG emissions, and CO_2 in particular, are directly related to the amount of fuel burned in (or electricity generated by) fossil-fuel fired combustion units. CO_2 mitigation is achieved by either improving energy efficiency (reducing amount of fuel burned) or by "sequestering" and then disposing of or reusing the CO_2 elsewhere.

The potential for reuse of captured CO_2 is limited. Estimates indicate that industrial reuse applications of captured CO_2, such as in beverage production, fire extinguishers, wastewater treatment systems, and oil extraction systems for example, are able to use only approximately 2 percent of total emissions of CO_2 generated by power plants in the United States in a year.

Other options that would help to stabilize the increasing concentration of GHGs in the atmosphere deal primarily with developing " CO_2 sinks". The largest, most effective CO_2 sinks are forests. Significant investment in research is being spent to evaluate the effect that improved forest management will have on global warming, and also what effects increased atmospheric GHG concentrations will have on forests.

Maryland and Climate Change

There is great debate among scientists, policymakers, and others about the extent of influence on global climate from increasing emissions of GHGs. However, there is general agreement that temperature and other climate factors have been, and will continue to be, affected by enhanced greenhouse effect. Using complex global circulation models and other tools, researchers try to predict the types and magnitudes of climate changes attributable to GHG emissions. Among the many effects that might occur are:

- *Temperature — average overall global temperatures may rise, and perhaps more importantly, the frequency and duration of extreme hot days in different areas could increase.*
- *Precipitation — there may be increases in the total amount of precipitation, but more importantly, the frequency and distribution of precipitation patterns could change significantly; there could be more frequent heavy intensive rainfall in some areas in different seasons.*

In turn, these changes in temperature and precipitation can affect other climate variables, and can affect them differently in different parts of the world. Among the parameters that might be affected in different parts of the world are: magnitude and rate of change of sea level rise; length of the growing season; incidence of flooding due to changes in precipitation patterns; and patterns of winter storms.

Although GHGs and climate change are global issues, the U.S. EPA has conducted some investigations into how changes in climate might affect resources in each of the 50 states, based on projections made by the Intergovernmental Panel on Climate Change and from climate modeling conducted at the United Kingdom Hadley Center. For example, according to information from the "State Impacts" section of the U.S. EPA's Global Warming Web site, the following types of climate changes could theoretically occur in Maryland over the next century:

- *Temperatures in Maryland could increase by about 3˚F in spring and 4˚F in other seasons;*
- *There could be an increase in the frequency and intensity of heat waves in the summertime, which could increase the number of heat-related illnesses and death, particularly in urban areas;*
- *Longer stretches of higher temperatures and strong sunlight could exacerbate ozone smog problems, again, particularly in urban areas of Maryland and metropolitan Washington, D.C.;*
- *Precipitation could increase by about 20 percent over the year, and the patterns of precipitation could change; and*
- *Sea level rise could lead to flooding of coastal areas, loss of coastal wetlands, erosion of beaches, and changes in salinity profiles and other aspects of the Chesapeake Bay.*

Given Maryland's diverse coastal environment, impacts of sea level rise will vary from region to region; however, shoreline erosion and coastal flooding pose the most significant threat to Maryland. Approximately 31 percent of Maryland's coastline is already experiencing some degree of erosion. Although sea level rise itself is not the driving force behind erosion, it makes Maryland's coastline more vulnerable to erosion. Also, elevated sea levels will exacerbate coastal flooding associated with tropical storms and hurricanes that impact Maryland's coast.

Some studies have predicted sea level rise of 2 to 3 feet by the year 2100. The Maryland DNR Coastal Zone Management Program is researching the impact of rising sea levels to better understand the potential impact along Maryland's coastline and to develop response strategies.

Carbon Sequestration

PPRP is currently using a computational model to quantify the amount of carbon that can be sequestered under various forestry and wood product management option. The ultimate purpose of these investigations is to develop optimal scenarios that utilities or the State of Maryland could implement to reduce the total atmospheric load of carbon dioxide.

The carbon model is a compartment model for accounting for the flow of carbon between natural and manmade storage pools. The model is designed to be able to represent a wide range of decision alternatives and physical variables characteristic of the management of forest and agricultural lands and the production and use of biomass products.

A scenario was constructed with parameter values that are suitable for the Maryland region. This scenario was first run as a "natural" case in which no harvesting takes place. Alternative management cases were: harvesting every 100 years; harvesting every 50 years; and harvesting every 25 years. The harvesting cases yield a much higher total carbon storage at the end of 400 years.

The most interesting of the "management" parameters is the harvesting rotation period. There is a narrow range that is optimal; outside of the range, the longer the harvesting period the less gain in carbon storage. There is an optimum (maximum amount stored) between 20 and 50 years. The choice of harvesting period has a major effect on the cumulative storage amount.

GHG Action Plans and Mitigation Efforts

Numerous government and private agencies and groups have established plans, programs, and initiatives to address various aspects of GHG emissions and climate change. Much of the activity to date has been in research efforts to better characterize the extent of the risks from and impacts of GHG emissions. Internationally, many countries have agreed to strategies and targets established during the Kyoto Conference of 1998. Many countries, including the United States, are working under the international Framework Convention on Global Climate Change to coordinate GHG and global climate efforts.

In the United States, the U.S. Global Change Research Program (USGCRP) coordinates one of the largest research efforts on climate change in operation today. Additionally, the Clinton Administration has been encouraging participation from the private sector, states, and local agencies and groups in developing cost-effective ways to address climate change issues.

U.S. efforts on global climate issues rely in part on participation by individual states to develop programs and policies on reducing GHG. As of November 1999, 34 states and Puerto Rico had become partners in the U.S. EPA's State and Local Climate Change Program, which provides financial and technical resources to state officials. Most efforts to date have been focused on improving GHG emissions inventories, providing educational programs, and conducting demonstration projects. Maryland is not yet among the 25 states and Puerto Rico which have developed specific State Action plans; however, the State continues to investigate GHG and global climate impacts.

Section Highlights

PPRP has undertaken a long-term program to promote the utilization of coal combustion products (CCPs) — predominantly fly ash produced in coal-fired power plants — which would otherwise be placed in a landfill. For instance, CCPs can be used as structural fill in road construction projects. PPRP is conducting field studies at completed road construction projects to assess the potential for ground water quality impacts from this type of beneficial use. Extensive field work is also underway in Western Maryland, where PPRP, MDE, and a consortium of private and public sector partners are examining the feasibility of using CCPs to prevent acid mine drainage from abandoned underground mines.

Coal Combustion Product Management

Maryland coal-fired power plants generate significant quantities of coal combustion products (CCPs) annually. With the addition of the 180 MW coal-fired AES Warrior Run facility, in May 2000, producing 400,000 tons of CCPs per year, Maryland's CCP generation rate is now about 1.6 million tons per year.

In 2000, about 40 percent of the total volume of CCPs generated in Maryland will be placed in landfills. Construction of landfills consume valuable, undeveloped terrestrial resources and is inconsistent with the State's initiatives to limit greenfield development. Furthermore, these landfills have the potential to adversely impact Maryland's terrestrial and aquatic resources if not designed and managed properly.

PPRP, electricity generators, potential CCP users, and State regulators are actively engaged in researching and developing beneficial uses of CCPs as alternatives to landfilling. The term beneficial use, as it pertains to CCP utilization, applies to an environmentally friendly alternative to a material that would otherwise be placed in a landfill. Currently, 60 percent of the CCPs generated in Maryland are beneficially used. Recent examples of beneficial use in Maryland include the use of CCPs as components of concrete, in construction of highway embankments (i.e., replacing structural fill), as surface mine reclamation material, in cinder block manufacturing, and as components of flowable grout. Maryland's 60 percent CCP utilization rate is relatively high compared to other states and the national average.

An impediment to increasing the beneficial use of CCPs in Maryland has been the unfamiliarity of regulators and potential users with the technical and economic benefits associated with replacing costly raw materials with CCPs. Similarly, regulators and end users are generally unfamiliar with the environmental implications associated with the beneficial use of CCPs.

PPRP has undertaken a CCP program to promote the beneficial use in Maryland and address these institutional barriers. The goal of PPRP's CCP program is to increase beneficial use of CCPs as a means of protecting Maryland's natural

resources, as well as controlling growth by avoiding the expansion or construction of landfills for CCP disposal. This program has been underway since 1996, and has garnered the support and assistance of Maryland's coal-fired electric generating facilities, other State agencies, and private stakeholders (e.g., Maryland coal companies).

The scope of activities being conducted by PPRP to achieve this goal falls into three broad categories (see locations in Figure 5-8):

- *Field projects designed to determine the environmental effects of high volume uses of CCPs in Maryland;*
- *Outreach efforts to disseminate information on the availability, quality, quantity, and potential environmental effects of CCPs generated in Maryland; and*
- *Implementation of the Western Maryland Coal Combustion By-product/Acid Mine Drainage (AMD) Initiative, which is intended to develop large volume uses of CCPs to reduce acid mine drainage in Maryland's abandoned, underground coal mines.*

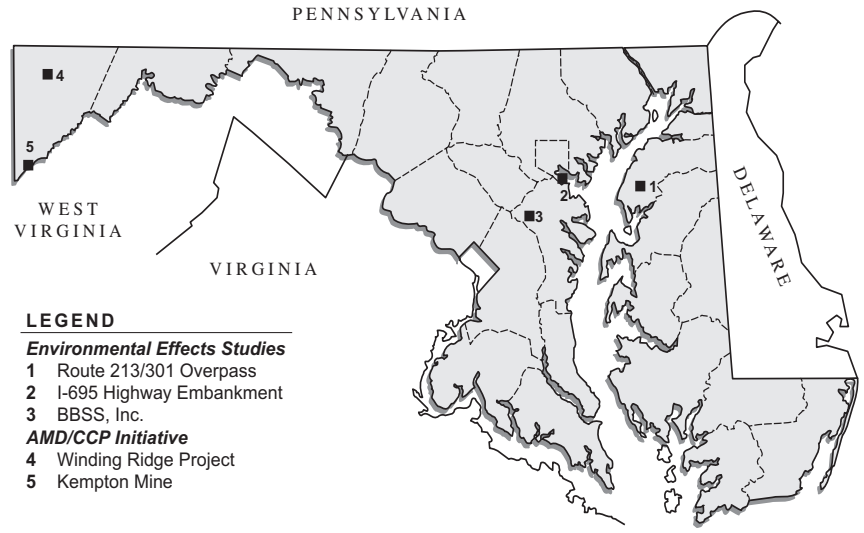
Environmental Effects Analysis

Recent projects conducted by the private sector indicate that the use of CCPs in structural fill is a high volume use that is technically and economically feasible for implementation in Maryland. Future road construction projects in Maryland provide potential opportunities for the use of large quantities of CCPs as structural fill. However, potential users, regulators, and the public have expressed concern about the potential for CCPs to degrade ground water quality.

In response to this uncertainty, PPRP is conducting the three field projects described below to evaluate the environmental effects of CCPs on ground water quality.

- ***Highway Embankments Studies.*** *PPRP is conducting two studies designed to evaluate potential environmental impacts that could occur from the beneficial use of CCPs as highway embankment material.*
  - ***Routes 213/301 Overpass Site.*** *The first project is located at the 213/301 overpass on Maryland's Eastern Shore where 60,000 tons of CCPs were used to construct the embankments for the overpass. The study, which commenced in 1999, is a cooperative effort with the Maryland State Highway Administration (SHA). As part of this project, lysimeters were placed above, within, and below the embankments to collect and assess pore water quality (Figure 5-9). Ground water monitoring wells were also installed in the water table upgradient and downgradient of the site. The results to date show that Class F fly ash can be used for highway embankments while adequately protecting ground water quality. Monitoring will continue through 2000.*
  - ***I-695 Overpass.*** *The other highway embankment study is the I-695 overpass project, which is located on highway I-695 in Sparrow Point. Between 1996 and 1998, BGE provided about 320,000 tons of CCPs to the Maryland Transportation Authority (MTA) for beneficial use to construct three highway embankments for the new approach to the Key Bridge. Lysimeters, moisture probes and monitoring wells have recently been installed in three locations to collect pore water and ground water samples for laboratory analyses. Site monitoring will be completed*

Figure 5-8
Location of CCP Study Sites



in fall 2000 to determine whether constituents are being attenuated in soil or are impacting ground water.

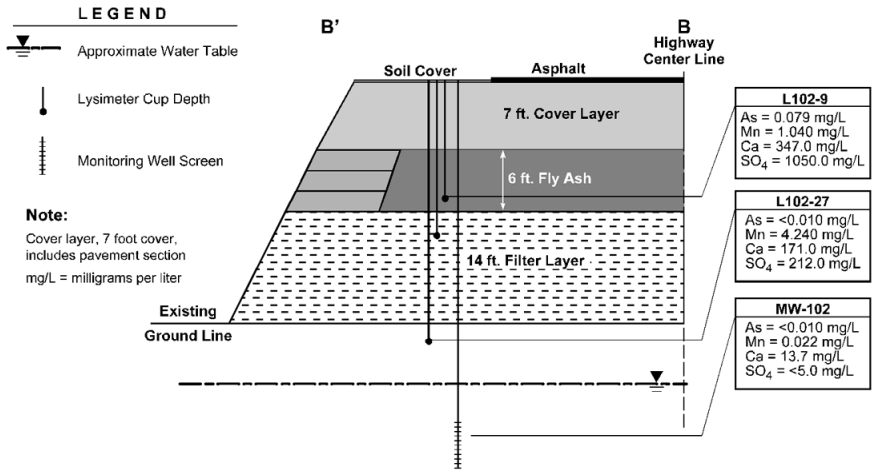
- ***BBSS Mine Reclamation.*** *The third study is an assessment of ground water quality conditions beneath the BBSS aggregate mine site in Anne Arundel County. From 1995 through 1999, BGE (now Constellation) used over one million tons of CCPs to reclaim the mine, and plans to place another two million tons in the mine over the next few years. The large-scale use of CCPs for this mine reclamation project has provided PPRP the opportunity to assess current and potential surface water and ground water quality impacts that may result from placement of CCPs. To date, the study shows that sulfate is present in the ground water beneath that portion of the site reclaimed with CCPs. In 2000, PPRP will continue to evaluate updated water quality data collected by Constellation and to assess potential long-term surface water and ground water quality effects from the placement of CCPs at the site.*

Outreach Efforts

Studies by PPRP, Maryland utilities, and other researchers have shown that it is unlikely that properly managed CCP beneficial uses would result in significant water quality impacts. Nonetheless, uncertainty among the public and regulatory community regarding the technical and environmental aspects of CCP use creates an institutional barrier to expanding the beneficial use of CCPs. In response to this uncertainty, PPRP has conducted outreach projects to promote the beneficial use of CCPs.

One of the barriers to increasing CCP use is the uncertainty users may have regarding the State's regulatory approval process. Therefore, one of the outreach projects involved a comparison and evaluation of the regulatory frameworks for CCP management in Maryland and neighboring states to identify

Figure 5-9
Schematic Half-section of Route 213/301 Overpass



potential regulatory approaches to encourage CCP use. Based on the survey, PPRP believes that Maryland would benefit from the development of a uniform regulatory approach for CCP beneficial use that is mutually recognized by the State, CCP generators, and CCP users. This approach should identify a uniform set of procedures for State review of CCP use projects, and provide a list of pre-approved CCP uses.

Another outreach project undertaken by PPRP to promote CCP use is to provide information to potential users regarding the availability, quality, and environmental effects of CCPs. PPRP prepared a technical report to describe the status of CCP generation, disposition, and beneficial use in Maryland for the purpose of assisting potential users in evaluating the viability of CCPs use. The report documents the source, type, amount, chemical and physical properties, and potential environmental effects of CCPs generated in Maryland, and was prepared with assistance from two of the state's largest CCP generators, BGE and PEPCO.

AMD/CCP Initiative

In 1995, PPRP and MDE Bureau of Mines (BOM) undertook the Western Maryland CCP/AMD Initiative to develop large volume uses of CCPs to reduce acid mine drainage in Maryland's abandoned underground coal mines. The Initiative started in 1995 with the Winding Ridge project, which involved the injection of a CCP grout into a small abandoned coal mine to reduce acid formation. The experimental application in the Frazee Mine on Winding Ridge was very successful in reducing acid production in the mine and suggested that CCP grout would also be highly effective in mine applications to restore ground water flow patterns, restore surface drainage affected by subsidence, stabilize subsidence areas, and prevent further subsidence. Building upon the success of the Winding Ridge Project, PPRP is performing ongoing research and development of the beneficial use of CCPs to reduce acid formation and facilitate other

restoration measures in the Kempton Mine Complex, which is Maryland's largest source of AMD. A demonstration of managing mine water movement is also under investigation for the Ezra Micheal Mine.

Winding Ridge Project

The Winding Ridge Project was the Initiative's first project that demonstrated the beneficial use of CCPs to reduce acid formation in an underground coal mine. The Frazee Mine, which is a small, abandoned underground coal mine in Western Maryland, was selected for this demonstration project.

The CCPs used for this project consisted of fluidized bed combustion (FBC) ash from the Morgantown Energy Associates power plant, and Class F fly ash and flue gas desulfurization (FGD) product from the Mt. Storm power plant. In 1996, 5,600 cubic yards of CCP grout were injected into the Frazee Mine. The grout consisted of 60 percent conditioned FBC ash (commingled bottom and fly ash with a free lime content of about 5 percent), 20 percent Class F fly ash, and 20 percent FGD product, mixed with mine water.

Post-injection monitoring has shown that the grout retained its strength and low permeability as it cured in the mine environment. Post-injection monitoring has also shown that there have not been any significant increases in AMD-related parameters or trace elements in the mine water other than short-term or transient water quality changes immediately after injection. About one year after grout injection, iron, aluminum, total acidity and trace element concentrations and loadings dropped to levels below pre-injection conditions (Figures 5-10). Heavy metals of frequent concern cuch as copper, zinc, and nickel have not been detected in the remaining Frazee Mine effluent since 1998. Figure 5-10 also illustrates that there have been favorable trends in all AMD parameters since the transition period that followed the grout injection. Acid production in the mine has been reduced by at least 75 percent. Post-injection monitoring will continue to track the continuing improvement in water quality from the mine and develop the case for regulatory acceptance of mine applications of CCP grouts.

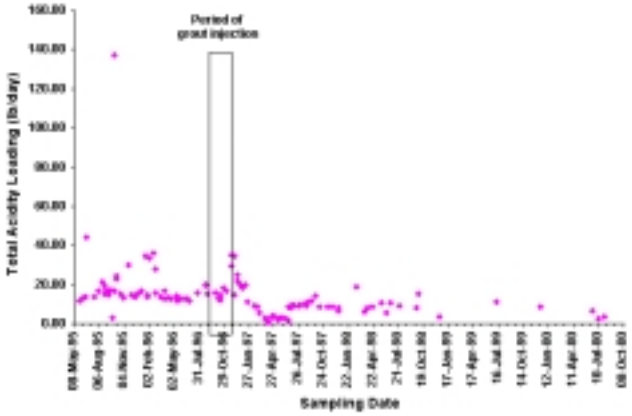
Kempton Mine Complex

The Kempton Mine Complex provides an opportunity to demonstrate several restoration measures in abandoned mines that will favorably impact surface and ground water movement in mined areas and reduce acid production. The restoration efforts are further designed to prevent additional land subsidence, which allows good quality water to continue flowing into acidic mine pools and perpetuates further acid production by exposing fresh sulfur-bearing materials. PPRP has been successful in obtaining Federal support to implement CCP grout injection demontration projects at the Kempton Complex because of the broad applicability of the technology being developed to three problem areas:

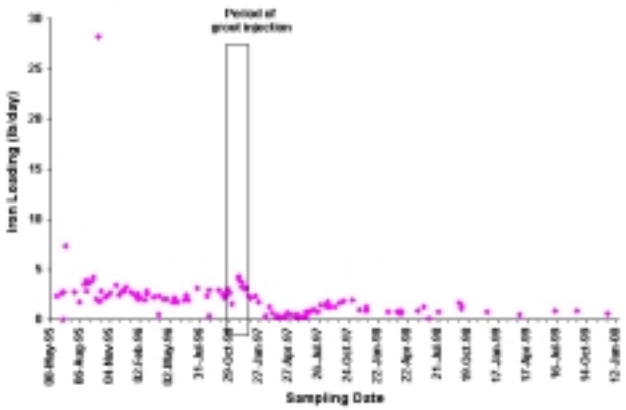
- *Loss of good quality surface water to the acidic mine pools via subsidence fracture zones under stream beds;*
- *Loss of good quality ground water to the acidic mine pools via subsidence fracture zones, abandoned boreholes, abandoned mine shafts, and other similar abandoned mine features; and*

Figure 5-10
Loadings of Key AMD Parameters in Lower Seep at Mine Opening No. 2, Winding Ridge Project

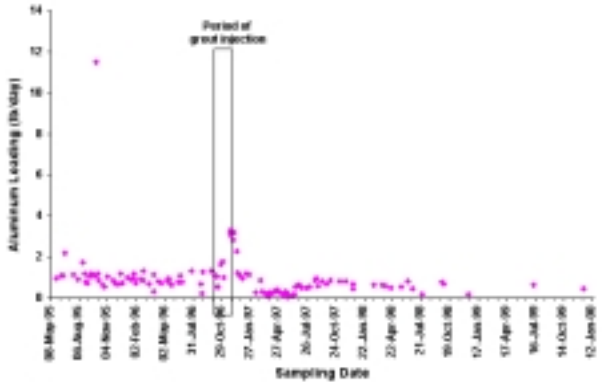
Total Acidity



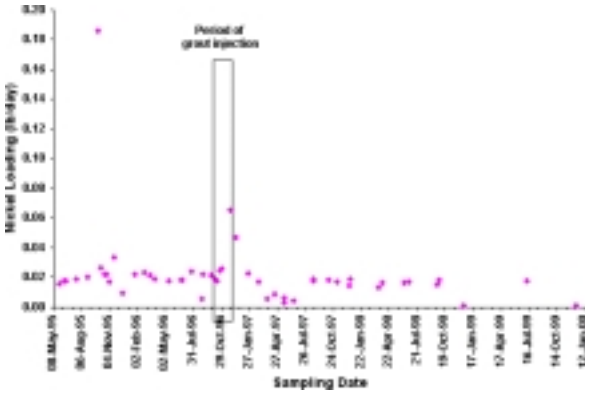
Iron Loading



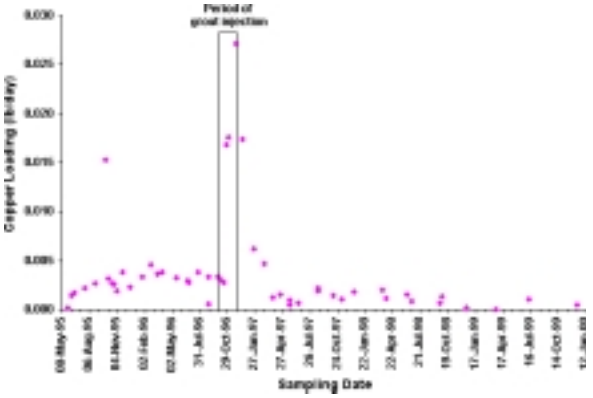
Aluminum Loading



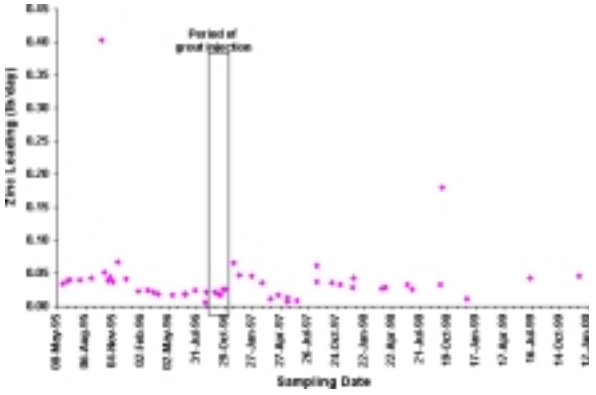
Nickel Loading



Copper Loading



Zinc Loading



- *Suspected high acid production from sulfurous material exposed in areas of mines that are not flooded.*

The Kempton Mine Complex is Maryland's largest source of AMD, currently discharging an average of 3.5 mgd of low pH water into Laurel Run. The complex consists of nine interconnected mines that involve about 12 square miles of underground works. After operating for about 70 years, the mines were closed in 1950. The immense scope of the Kempton Complex provides an opportunity for beneficially using millions of tons of CCPs if these demonstration projects are deemed successful. The opportunity to restore an important segment of Maryland's terrestrial and aquatic resources is similarily great. Site characterization, baseline monitoring, and the planning and engineering for the demonstration projects at Kempton have involved Frostburg State University, Garrett Community College, the University of Maryland at College Park, the Maryland Bureau of Mines, the Western Maryland Resource Conservation and Development Council, three Federal agencies, several support contractors, and Western Maryland industry partners. The State is working to further develop public and private partnerships to make full restoration of the Kempton Mine Complex and other abandoned underground mines a reality.