

# Environmental Impacts of Power Generation

## Air Emissions from Power Plants

The combustion of fossil fuels to generate electricity results in the release of air pollutants that can potentially degrade air quality, both locally and regionally. Since the 1970s, the U.S. Environmental Protection Agency (U.S. EPA) has taken action through provisions of the Clean Air Act (CAA) to monitor and control the effects of air pollutants from power plants and other sources. The first comprehensive CAA was passed in 1970. It has been amended significantly twice since then, once in 1977 and again in 1990.

The State of Maryland, and state and local entities across the United States, develop air quality regulatory programs for power plants and other industrial and mobile sources to address CAA requirements. Individual states can and often do develop regulations that go beyond CAA requirements to address specific state and local air quality issues.

In this section of the report, we examine trends in air emissions from power plants in Maryland and summarize some of the impacts of those emissions on the local and regional environment. There is additional discussion of the air quality impacts of electric power generation in Section 5.

## Key Air Quality Terms

Air pollution is considered to be the release of unwanted particulate (dusts and solid particles), gaseous (vapors or fumes), or aerosol (minute particles) compounds into the atmosphere by either “natural” or “human” sources. In general, pollution attributable to human activities, such as manufacturing and use of automobiles, far outweighs the contribution from natural sources, such as volcanoes, forest fires, and decay of organic compounds.

The U.S. EPA has established National Ambient Air Quality Standards (NAAQS), which are maximum ambient air concentrations of six pollutants known as **criteria pollutants**. These criteria pollutants are carbon monoxide (CO), nitrogen dioxide (NO<sub>2</sub>), lead, particulate matter (PM), sulfur dioxide (SO<sub>2</sub>), and ozone. NAAQS have been established to protect human health (primary standards) and welfare (secondary standards). The current NAAQS are listed in Table 4-1.

The U.S. EPA and state and local agencies routinely monitor concentrations of the criteria pollutants near ground level at various locations across the United States. If monitoring indicates that the concentration of a pollutant exceeds the NAAQS, that area is labeled a **nonattainment area** for that pollutant, meaning that the area is not attaining the ambient standard. Conversely, any area in

### SECTION HIGHLIGHTS

*The principal air emissions of concern from power plants are carbon dioxide, sulfur dioxide, nitrogen oxides, and toxic substances (including such metals as mercury). PPRP is actively working to evaluate the impacts of these emissions on Maryland's environment, and to help develop control strategies.*

**Table 4-1 National Ambient Air Quality Standards (NAAQS)**

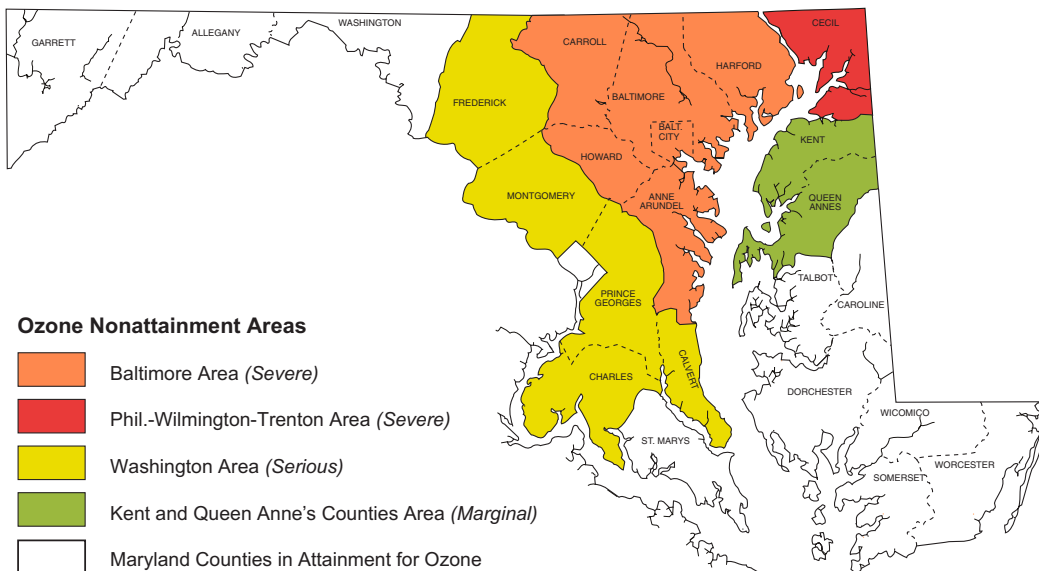
Criteria Pollutant	Averaging Period	Primary NAAQS ( $\mu\text{g}/\text{m}^3$ ) <sup>1</sup>	Secondary NAAQS ( $\mu\text{g}/\text{m}^3$ ) <sup>1</sup>
PM10 (particulate matter <10 microns)	Annual	50	50
	24-hour	150	150
PM2.5 (particulate matter <2.5 microns) <sup>2</sup>	Annual	15	65
	24-hour	15	65
SO <sub>2</sub> (sulfur dioxide)	Annual	80	—
	24-hour	365	—
	3-hour	—	1,300
NO <sub>2</sub> (nitrogen dioxide)	Annual	100	100
Ozone <sup>2</sup>	8-hour	157	157
	1-hour	235	235
CO (carbon monoxide)	8-hour	10,000	10,000
	1-hour	40,000	40,000
Lead	Quarterly	1.5	1.5

Notes:

(1) The NAAQS concentrations in this table are expressed in terms of micrograms per cubic meter ( $\mu\text{g}/\text{m}^3$ ); however, you will sometimes see the NAAQS concentrations expressed in terms of parts per million (ppm).

(2) In July 1997, the U.S. EPA promulgated new NAAQS for PM2.5 and 8-hour ozone in July 1997. However, in May 1999, the U.S. Court of Appeals for the District of Columbia Circuit blocked EPA's authority to implement the new standards. The new standards are not being implemented until the issue is decided in court.

**Figure 4-1  
Ozone Nonattainment Areas in Maryland**



which the monitored concentration of a criteria pollutant is below the NAAQS is labeled an attainment area, indicating that the NAAQS is being met.

The attainment/nonattainment designation is made on a pollutant-by-pollutant basis. Therefore, the air quality in an area of the country may be designated attainment for some pollutants and nonattainment for other pollutants at the same time. For example, the area around a particular power plant may be a nonattainment area for ozone, but an attainment area for the other criteria pollutants. Currently throughout Maryland, measured ambient levels of the criteria pollutants SO<sub>2</sub>, NO<sub>2</sub>, PM, and CO are within the standards set by the U.S. EPA. However, many areas of Maryland are not meeting the NAAQS for ozone (Figure 4-1), making ozone an issue of particular concern in Maryland.

## *Emissions Trends: Traditional Power Plant Air Pollutants*

Power plants are recognized significant sources of “combustion by-product” pollutants including oxides of sulfur and nitrogen (SO<sub>x</sub> and NO<sub>x</sub>), PM, and CO. Mobile sources (cars, trucks, off-road and farm vehicles, etc.) are significant contributors of these pollutants also. The U.S. EPA, State regulatory agencies, PPRP, and others have been tracking emissions of these “traditional” pollutants from power plants for more than 30 years (see, for example, the U.S. EPA’s National Air Pollutant Emission Trends, 1900-1998 report from March 2000 (EPA-454/R-00-002), and CEIRs published by PPRP dating back to the 1970s).

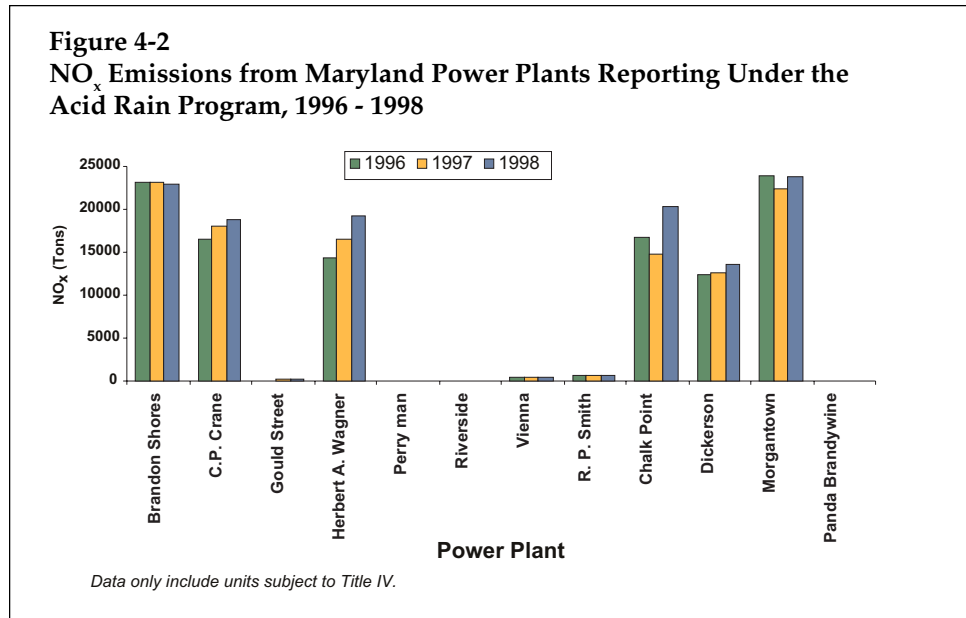
Long-term emissions estimating efforts reported in the U.S. EPA’s Emission Trends report indicate clearly that from 1970 through the end of the 1990s, emissions of SO<sub>2</sub>, volatile organic compounds (VOCs), PM, and lead have decreased, while total fuel consumption has risen by more than 25 percent over the same time period. On the other hand, emissions of NO<sub>x</sub>, CO, and ammonia have either changed little or have increased in recent years.

The majority of SO<sub>2</sub> emissions, and a significant but smaller percentage of NO<sub>x</sub> emissions, arise from the burning of fossil fuels in power plants and other combustion sources. In Maryland, power plant emissions account for 35 to 40 percent of the total NO<sub>x</sub> emissions, by far the largest point source contributor. Maryland power plants are responsible for roughly 85 percent of the total SO<sub>2</sub> emissions in the state.

Until recently, power plant emissions were determined primarily by engineering calculations or “emission factors.” Emission factors for combustion sources

## Criteria Pollutants

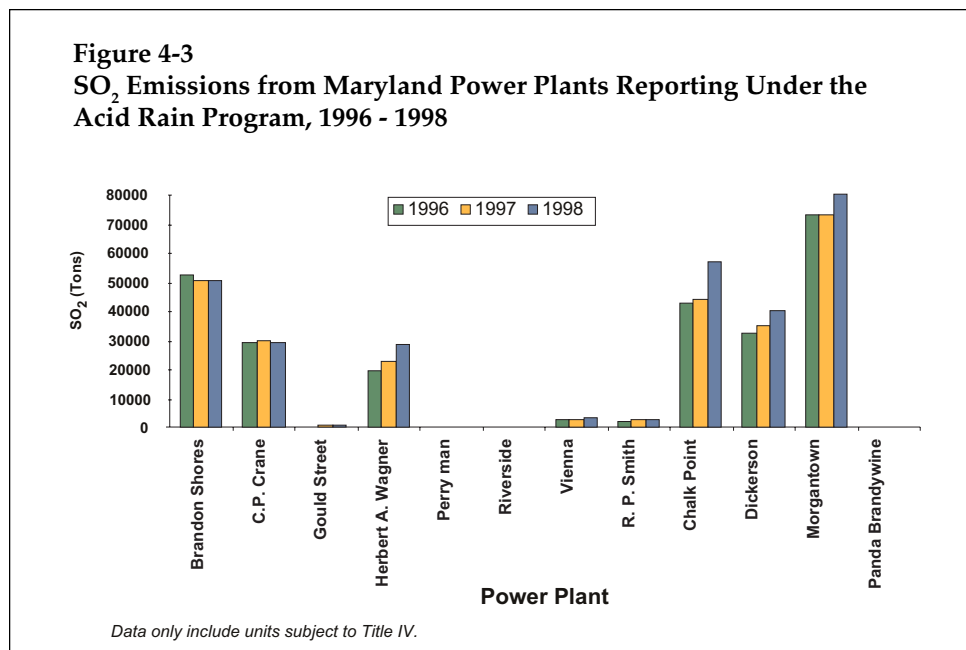
- **Particulate Matter <10 microns in size (PM10)** is composed of solid particles, less than 10 microns in diameter, which are small enough to be inhaled by humans. The particles can be composed of any number of compounds, from road dust to heavy metals, depending on the source.
- **Sulfur dioxide (SO<sub>2</sub>)** is a compound formed both naturally and by the combustion of fossil fuels. Exposure to higher concentrations of SO<sub>2</sub> can cause respiratory problems for some people. When combined with water, SO<sub>2</sub> forms sulfur compounds that are one of the main components of acid rain.
- **Nitrogen dioxide (NO<sub>2</sub>)** is another compound formed by the combustion of fossil fuel which contributes to the formation of both acid rain and smog. NO<sub>2</sub> is one of several nitrogen oxide (NO<sub>x</sub>) compounds present in the atmosphere. The NAAQS is established for NO<sub>2</sub>, but NO<sub>x</sub> is more commonly measured.
- **Ozone** itself is not emitted directly into the air, but rather is formed through a series of complex physical and chemical reactions in the atmosphere. Therefore, discussions about the criteria pollutant ozone often focus on a group of gaseous pollutants known as **volatile organic compounds** or **VOCs**, which are carbon-based, organic compounds that tend to evaporate into the air easily, and NO<sub>x</sub>. Solvents, cleaners and paints are among the hundreds of compounds in use that contain VOCs. In the presence of sunlight, VOCs and other chemical compounds, including NO<sub>x</sub>, react to form ozone.
- **Carbon monoxide (CO)** is a colorless, odorless, and tasteless gas that occurs naturally in the atmosphere and is also formed in the combustion of fossil fuel.
- **Lead (Pb)** is a common metal that is released into the atmosphere from a number of sources, including burning of leaded fuels. Lead has the lowest NAAQS, since exposure to low levels can present health problems.



relate a mass (e.g., pounds) of pollutants emitted to an amount of fuel burned over a period of time. For example, a commonly applied U.S. EPA emission factor for emissions from large, natural gas-fired utility boilers indicates that 84 pounds of CO will be emitted for every million cubic feet of natural gas burned in the boiler.

### Acid Rain Program

With passage of the CAA Amendments of 1990, Congress established a program to reduce emissions from electric utilities that contribute to the formation of acid rain. Electric utilities subject to this Acid Rain program have been required since 1995 to monitor and report hourly emissions of acid rain precursor compounds — SO<sub>2</sub> and NO<sub>x</sub> — and other data to the U.S. EPA on a quarterly basis.



**Table 4-2 SO<sub>2</sub> and NO<sub>x</sub> Emissions from Maryland Power Plants Reporting Under the Acid Rain Program, 1996-1998**

Power Plant	Total SO <sub>2</sub> Emissions (Tons)			Avg. Annual SO <sub>2</sub> Emission Rate for 1998 (lb/MMBtu)	Total NO <sub>x</sub> Emissions (Tons)			Avg. Annual NO <sub>x</sub> Emission Rate for 1998 (lb/MMBtu)
	1996	1997	1998		1996	1997	1998	
Brandon Shores	52,253	50,438	50,343	1.084	23,234	23,344	22,984	0.495
C. P. Crane	28,743	29,790	28,860	2.489	16,570	18,107	18,843	1.675
Gould Street	168	445	428	0.491	79	172	225	0.258
Herbert A. Wagner	19,635	22,584	28,606	1.171	14,339	16,422	19,266	0.789
Perryman	2	5	3	0.004	12	40	58	0.081
Riverside	0	0	0	0	28	27	78	0.273
Vienna	2,582	2,712	2,962	1.864	489	484	460	0.289
R. P. Smith	2,147	2,336	2,379	1.520	651	690	705	0.450
Chalk Point	42,715	43,694	56,453	1.495	16,804	14,847	20,434	0.541
Dickerson	32,538	34,617	40,091	1.950	12,370	12,585	13,604	0.662
Morgantown	72,777	72,991	79,906	2.091	23,919	22,427	23,981	0.627
Panda Brandywine	1	3	4	0.002	16	59	62	0.025

lb/MMBtu = pounds per million Btu

The data are collected by continuous emissions monitoring systems (CEMS). The CEMS database, which is available to the public at <http://www.epa.gov/acidrain>, provides a broad range of emissions and operating information on electric utility generating units never before available to the public.

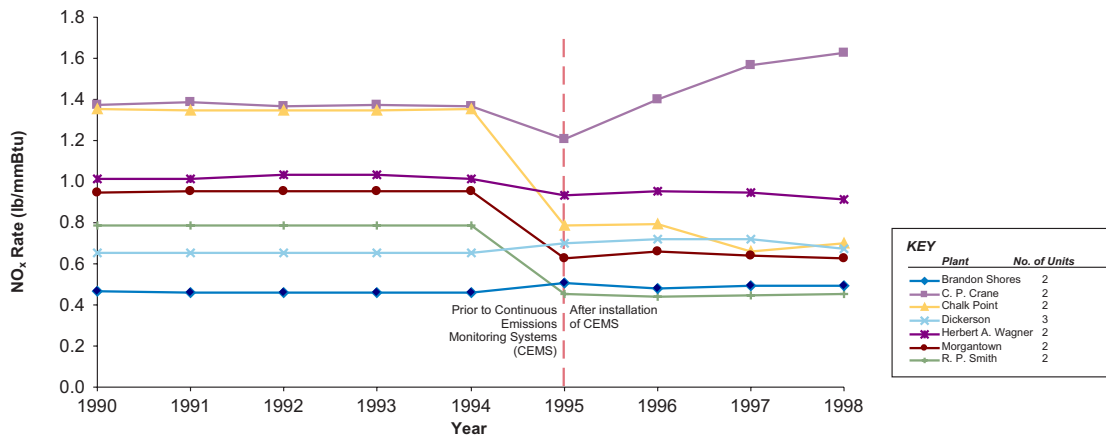
Emissions monitoring under the Acid Rain Program began in 1995. To date, complete years of CEMS data for Acid Rain Program power plants are available for the period from 1995 through 1998.

Figures 4-2 and 4-3 display total NO<sub>x</sub> and SO<sub>2</sub> emitted by those Maryland power plants that reported emissions under the Acid Rain Program for 1996 through 1998; the data are also listed in Table 4-2. Although it is difficult to evaluate trends with only three years of data, it appears that, on a ton-per-year basis, emissions of NO<sub>x</sub> and SO<sub>2</sub> at most power plants in Maryland increased over the period. This is primarily due to increased electrical output, rather than increases in the rate of emissions from a particular generating unit. In fact, the NO<sub>x</sub> emission rate (in pounds of NO<sub>x</sub> per million Btu of fuel burned, or lb/MMBtu) actually decreased somewhat at many plants in Maryland over the period, due to pollution control measures to meet new regulatory demands. Figure 4-4 illustrates the NO<sub>x</sub> emission rates at several coal-fired power plants in Maryland. Note that in 1995, power plants changed the method by which they determined emissions, from engineering calculations to continuous emissions monitoring systems.

Trends in emissions of NO<sub>x</sub> from power plants are important for several reasons, in particular:

- NO<sub>x</sub> emissions from power plants and other sources are significant contributors to the total nitrogen loading to the Chesapeake Bay watershed, and
- NO<sub>x</sub> emissions contribute to ground level ozone (smog) formation.

**Figure 4-4**  
**Average Annual Plantwide NO<sub>x</sub> Emission Rates for Maryland Coal-Fired Power Plants Reporting Under the Acid Rain Program for 1990-1998**



Historical NO<sub>x</sub> emission rates (1990-1994) were developed based on short term NO<sub>x</sub> testing for CEMS or data provided by the utilities, dependent on availability.

Nutrient loadings and ozone pollution have been the subject of substantial investigation and, at least for ozone, significant regulation nationally and in Maryland in recent years. Section 5 of this report provides more detailed information on these NO<sub>x</sub> issues and their implications to power plant licensing.

### Impacts of the Acid Rain Program

PPRP recently completed an investigation of the potential impacts of the Acid Rain Program on emissions and pollutant deposition rates in the region, to determine how much impact regulation of SO<sub>2</sub> and NO<sub>x</sub> may be having on the environment. This recent impact assessment used new types of comprehensive data bases now available from the Acid Rain Program and other initiatives, including:

- Acid rain precursor compound (SO<sub>x</sub> and NO<sub>x</sub>) emissions data now available from the CAA Acid Rain Program’s continuous emissions monitoring reports,
- Sulfate and nitrate particulate concentration monitoring data collected as part of the nationwide IMPROVE (Interagency Monitoring of Protected Visual Environments) monitoring network, and
- Sulfate and nitrate deposition data from the National Atmospheric Deposition Program (NADP) monitoring network.

PPRP’s evaluation indicates that there have been noticeable reductions in SO<sub>2</sub> emissions, resulting in recognizable reductions in sulfate deposition rates in the Northeastern United States since implementation of the Acid Rain Program in 1995. Patterns of NO<sub>x</sub> emissions and resulting nitrate concentrations and deposition rates are less clear, however.

This is not a completely unexpected result. As discussed previously in this chapter, power plants account for the vast majority of SO<sub>2</sub> emissions in Maryland and regionally; therefore, implementation of a nationwide SO<sub>2</sub> control program such as the Acid Rain Program should result in observable reductions in emissions in SO<sub>2</sub> and in the impacts from those emissions. On the other hand, power plants are substantial contributors to NO<sub>x</sub> emissions, but are not the single, dominant source of NO<sub>x</sub> that power plants are for SO<sub>2</sub>. Mobile sources, in particular, affect regional and national NO<sub>x</sub> emissions inventories, especially in areas with high population densities like much of the East Coast. Therefore, although the Acid Rain Program and other power plant NO<sub>x</sub> control initiatives are being implemented, there are still NO<sub>x</sub> impact issues to be addressed.

### *Particulate Matter and the Acid Rain Program*

In July 1997, the U.S. EPA promulgated a new NAAQS for particulate matter, which addresses fine particulate matter less than 2.5 microns in diameter, known as PM<sub>2.5</sub>. In May 1999, the U.S. Court of Appeals for the District of Columbia Circuit blocked EPA's authority to implement the new standards. The new standards are not being implemented until the issue is decided in court; however, U.S. EPA and the states fully expect that the standards will be implemented, and have begun setting up ambient PM<sub>2.5</sub> monitoring networks and conducting other activities anticipating implementation of the new standard.

PM<sub>2.5</sub> is not a chemical compound, but is comprised of various fine particles and aerosols. In fact, the same chemical species-sulfates and nitrates-that contribute to the formation of acid rain also form some of the aerosols that make up PM<sub>2.5</sub>. Therefore, initiatives to control SO<sub>2</sub> and NO<sub>x</sub> should coincidentally reduce PM<sub>2.5</sub> concentrations also.

PPRP investigated this possibility in its recent study of the impacts of the Acid Rain Program. PPRP first looked at existing PM monitoring networks across Maryland. Until the new PM<sub>2.5</sub> NAAQS was promulgated, states and the U.S. EPA monitored PM less than 10 microns (PM<sub>10</sub>). Using the PM<sub>10</sub> data, PPRP then conducted modeling to estimate PM<sub>2.5</sub> ambient concentrations. The estimates were made for a three-year period (1992-1994) prior to implementation of the Acid Rain Program, and a three-year period (1995-1997) after implementation of the Program.

PPRP found that estimated ambient concentrations of PM<sub>2.5</sub> decreased by varying degrees at monitoring locations across the state in the 1995-1997 period relative to the 1992-1994 period. As Figure 4-5 illustrates, in the Baltimore-Washington corridor, estimated PM<sub>2.5</sub> concentrations dropped 8 to 12 percent in the post-Acid Rain Program period; concentrations on the Eastern Shore and at other locations in the state dropped up to 16 percent in the same period. The evaluation indicates that the reductions are attributable to reductions in sulfates and nitrates across the region, which suggests that the Acid Rain Program is having the coincidental benefit of reducing fine particulate levels across the state.



## Combustion Turbines

Even though there is no schedule yet to regulate toxics from utility boilers, the U.S. EPA is moving ahead in developing emissions limitations and control requirements for hazardous air pollutants from combustion turbines. The U.S. EPA is scheduled to propose hazardous air pollutant standards for combustion turbines in early 2001. Formaldehyde emissions are expected to be among the toxics that EPA is targeting in this new regulatory initiative.

## Toxic Release Inventory (TRI) Reporting

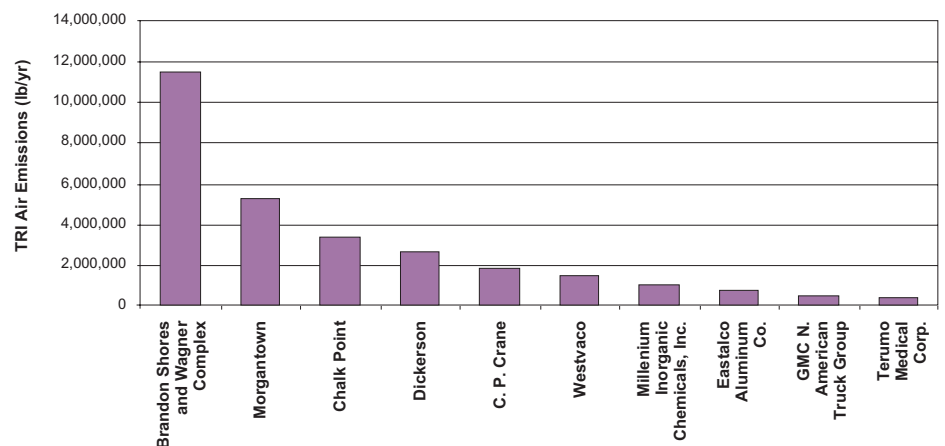
Another federal initiative, Title III of the Superfund Amendments and Reauthorization Act of 1986 (SARA), also known as the Emergency Planning and Community Right-to-Know Act (EPCRA) of 1986, provides a means for informing the public of the existence, quantities, and releases of hazardous substances. This law directs states, communities, and industry to work together to plan for chemical accidents, develop inventories of hazardous substances, track toxic chemical releases, and provide public access to information on hazardous substances.

Most manufacturing industries in the United States have been reporting emissions of toxic chemicals to the environment under an EPCRA program known as the Toxic Release Inventory (TRI) since 1988. Under a modification of the law passed in May 1997, electric utility power plants that handle toxic chemicals above threshold amounts now are also required to report toxic chemical releases to air, water, and land each year. Affected power plants are required to report annual (pound/year) toxic releases of any of the 650 substances on the list of regulated TRI chemicals that the power plant uses, produces, or emits as pollutants in certain minimum quantities.

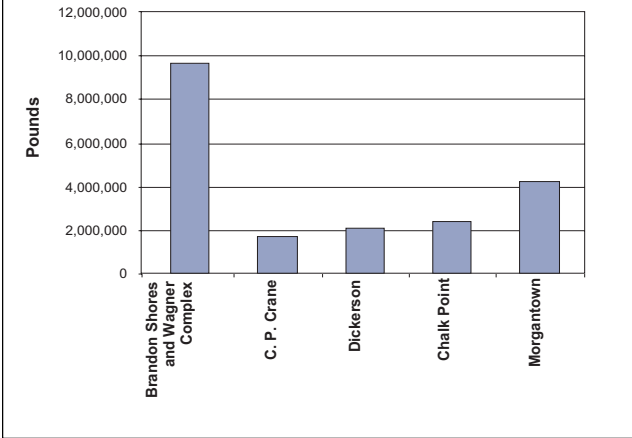
Among the substances on the list of regulated TRI chemicals are several metals, such as mercury, lead, manganese, nickel, arsenic, vanadium, and cadmium, and other compounds, including hydrochloric acid (HCl), that are commonly emitted by coal-fired and oil-fired power plants.

TRI reports are due to federal and state agencies on July 1st of each year and cover the previous calendar year. Power plants in Maryland and across the country made their first TRI reports on 1 July 1999, in which they reported on total toxic releases during calendar year 1998. Figure 4-6 shows the top ten Maryland companies in terms of total (all reported pollutants) TRI releases to air in 1998; the

**Figure 4-6**  
**Maryland's Top Ten Toxic Release Inventory (TRI) Emitters to Air, 1998**



**Figure 4-7  
HCl Emissions for Top Five Emitters in Maryland for 1998**



top five of these are power plants. In past years, before utilities were required to report TRI releases, chemical and other manufacturing facilities typically topped the list of TRI emitters.

The majority of toxic air emissions by mass (pounds of TRI chemical per year) reported by utilities during this first year of TRI reporting is accounted for by releases of HCl. Figure 4-7 shows total HCl emissions to air from the top five TRI power plants in Maryland. Because coal often contains naturally high levels of chlorides and large portions of the chlorides are converted to HCl when the coal is burned, utilities emit relatively large emissions of HCl to the atmosphere.

Even though potential HCl emissions to the air may be large, HCl is highly water soluble and transforms into relatively harmless inorganic salts soon after leaving a power plant smokestack. For this reason, emissions of HCl may not pose a health risk.

## CO<sub>2</sub> and Other Greenhouse Gases

There continues to be a substantial amount of evaluation and discussion of the impacts to global climate resulting from both natural and manmade emissions of carbon dioxide (CO<sub>2</sub>) and other greenhouse gases (GHG). Climate change generally refers to long-term changes in temperature, precipitation, wind, and other components of the Earth’s climate systems.

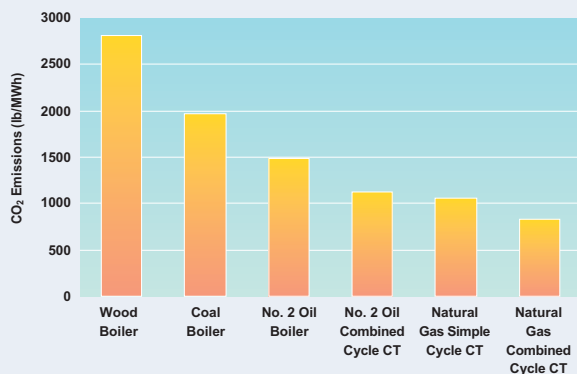
### CO<sub>2</sub> Emissions from Different Type of Generating Technologies and Fuels

There are several gases, known as greenhouse gas (GHGs), that influence global climate change. Of the many GHGs, CO<sub>2</sub> is by far the most significant in terms of tons of gas emitted per

year. The burning of fossil fuels — coal, oil, and natural gas — for energy generation is the primary source of CO<sub>2</sub> globally.

Actual emissions of CO<sub>2</sub> from combustion sources vary depending on the type of fuel, type of generating technology, efficiency of the generating unit, and other factors. The figure below illustrates “typical” CO<sub>2</sub> emission rates that would be expected from various common generating technologies burning coal, oil, or natural gas.

**CO<sub>2</sub> Emissions from Different Technologies and Fuels**  
Pounds of CO<sub>2</sub> generated for each MWh of electricity generated



#### How much CO<sub>2</sub> is this?

*One megawatt-hour (MWh) is about the amount of electricity that a typical household in the U.S. uses in a month. This means that a coal-fired boiler will produce about 2,000 lbs of CO<sub>2</sub> to generate electricity for a household for a month, while a natural gas-fired combined cycle combustion turbine will produce about 850 lbs of CO<sub>2</sub> to generate the same amount of electricity.*

*Keep in mind that these are average emission rates for “typical” generating units. Emissions from any specific power plant can vary significantly from these estimates.*

Among the GHGs under evaluation for impacts to global climate are CO<sub>2</sub>, water vapor, methane (CH<sub>4</sub>), nitrous oxide (N<sub>2</sub>O), and ozone. There are other types of GHGs, primarily manmade compounds, such as classes of compounds known as chlorofluorocarbons and hydrochlorofluorocarbons (CFCs and HCFCs), that are included in evaluations of global climate change research.

Each of these GHG compounds has a different “global warming potential,” which is based on the compound’s physical and chemical properties. The global warming potential is a relative measure of the ability of a particular GHG to absorb radiation and thus trap heat in the Earth’s atmosphere, influencing global temperatures. The primary GHG by volume emitted by human activities is CO<sub>2</sub>. Because CO<sub>2</sub> emissions outweigh all other GHGs in terms of mass (tons per year), global warming potentials are presented as relative to CO<sub>2</sub>. Similarly, GHG emissions are commonly presented in terms of million metric tons of carbon equivalents (MMTCE).

By far, the largest source of CO<sub>2</sub> and the largest source of total GHG emissions in the United States is fossil fuel combustion. U.S. EPA reports in its document National Air Pollutant Emission Trends, 1900-1998 that fossil fuel combustion accounted for about 81 percent of total CO<sub>2</sub> emissions nationwide in 1997.

### GHG Potentials and Atmospheric Lifetimes of Various Greenhouse Gases (GHGs)\*

Gas	Atmospheric Lifetime (Years)	Global Warming Potential (GWP)
Carbon dioxide	50-200	1
Methane	12±3	21
Nitrous oxide	120	310
HFC-23	264	11,700
HFC-125	32.6	2,800
HFC-134a	14.6	1,300
HFC-143a	48.3	3,800
HFC-152a	1.5	140
HFC-227ea	36.5	2,900
Sulfur hexafluoride	3,200	23,900

\*Source: U.S. EPA (1998). Inventory of U.S. Greenhouse Gas Emissions Sources and Sinks: 1990-1997. U.S. EPA 236-R-99-003.

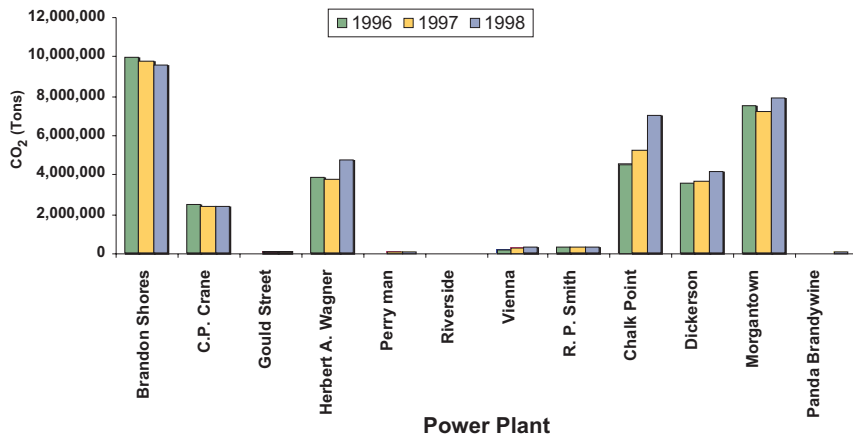
**Table 4-3 CO<sub>2</sub> Emissions from Maryland Power Plants Subject to the Acid Rain Program, 1996-1998**

Power Plant	Total CO <sub>2</sub> Emissions (Tons)			CO <sub>2</sub> Emission Rate for 1998 (lb/MWh)*
	1996	1997	1998	
Brandon Shores	9,952,697	9,769,550	9,530,384	2,295
C. P. Crane	2,428,020	2,368,528	2,379,604	2,385
Gould Street	41,355	85,209	124,178	1,805
Herbert A. Wagner	3,884,974	3,725,208	4,756,740	2,294
Perryman	28,893	73,816	146,974	1,252
Riverside	10,328	11,169	33,959	1,732
Vienna	236,923	248,027	257,258	2,385
R. P. Smith	301,713	315,907	321,128	2,319
Chalk Point	4,547,229	5,190,645	6,983,799	2,178
Dickerson	3,560,889	3,664,773	4,172,497	2,182
Morgantown	7,450,238	7,170,509	7,841,100	2,015
Panda Brandywine	64	33,901	107,200	362

\* Source: E-GRID 2000, Version 1.0.

MWh = megawatt-hour

**Figure 4-8**  
**CO<sub>2</sub> Emissions from Maryland Power Plants Subject to the Acid Rain Program, 1996 - 1998**



Data only include units subject to Title IV.

CO<sub>2</sub> emissions from power plants are directly related to the amount of fuel burned; when electrical generation increases, so do CO<sub>2</sub> emissions. For example, Figure 4-8 presents total CO<sub>2</sub> emissions (1996 to 1998) from power plants in Maryland that have CEMS as required under the Acid Rain Program (CO<sub>2</sub> emissions data are also presented in Table 4-3). For most of the power plants shown, CO<sub>2</sub> increased from 1997 to 1998, because of the increase in electrical output from those plants in recent years.

The U.S. EPA indicates in its Emission Trends report that nationwide GHG emissions are increasing over time. Total GHG emissions in 1997 had increased by about 11 percent from GHG

emissions in 1990. CO<sub>2</sub> emissions from fossil fuel combustion sources contributed substantially to the overall GHG increases. The U.S. EPA attributes this increase in GHG emissions from fossil fuel burning sources primarily to three factors:

- Fuel switching from natural gas to “carbon intensive” coal for fuel price reasons in the mid-1990s,
- Increased consumption of petroleum in the transportation sector, and
- To a lesser extent, an increase in coal consumption by utilities to offset the temporary shut-down of several nuclear power plants in the United States in 1997.

Atmospheric methane is second only to CO<sub>2</sub> as an anthropogenic source of the greenhouse effect. Methane’s overall contribution to global warming is large, in part because it is about 20 times more effective at trapping heat in the atmosphere than CO<sub>2</sub>. Furthermore, methane’s concentration in the atmosphere has more than doubled over the last two centuries. Scientists have concluded that these atmospheric increases are largely due to increasing emissions from anthropogenic sources, such as landfills, agricultural activities, coal mining, fossil fuel combustion, the production and processing of natural gas and oil, and wastewater treatment. In Maryland, power plants do not contribute significantly to methane emissions, according to U.S. EPA data. Significant contributors, as reported for 1990, were landfills (74 percent), manure management (19 percent), and domesticated animals (8 percent).

Section 5 of this report includes further discussion of the influence that power plants have on global climate.

## Water Supply Impacts

This section briefly summarizes the water requirements associated with power plant operation, and describes the most important environmental issues arising from water withdrawals and use at these facilities.

## Water Needs and Sources

Most electricity is produced in Maryland by four broad types of generating technologies - steam generating plants, combustion turbines, combined cycle facilities (a hybrid of steam and combustion turbine units), and hydroelectric facilities. These technologies are briefly described in the sidebar discussion on page 8 of this report. The water needs and uses of these different generating technologies vary significantly. Steam generating power plants, representing about 75 percent of the total installed capacity in Maryland, use combustion heat to produce steam, which then drives steam turbines and generates electricity. Large quantities of water are needed to cool and condense the steam after it passes through the steam turbines, so that it can be recirculated to the boilers and be heated again. While power plants also require water for other purposes, such as the boiler feedwater itself, equipment wash water, and potable supply, these water uses represent insignificant quantities compared with cooling water needs.

Most steam plants in Maryland use once-through cooling, in which cooling water is used then returned to the water body. Four steam plants in Maryland — Chalk Point, Brandon Shores, Vienna, and Panda-Brandywine — use closed-cycle cooling (cooling towers) instead of once-through cooling. (Chalk Point uses both type of cooling systems, with two large steam units on each type of system.) These systems recycle cooling water and require only about one-tenth of the water needed for once-through cooling; however, much of the water is consumed through evaporation, and does not return to the source.

Nuclear plants generate more waste heat than fossil fuel fired plants of the same capacity, and so they need more cooling water, according to data from the U.S. Nuclear Regulatory Commission. Calvert Cliffs' surface water appropriation is about 3 billion gallons per day from the Chesapeake Bay. Calvert Cliffs is the largest single user of water in the state of Maryland; it uses five times more water than the Bethlehem Steel Sparrows Point facility is appropriated (600 million gallons per day), and 12 times more than the municipal supply for the Baltimore City metropolitan area (approximately 250 million gallons per day). Mirant's Morgantown plant has the

### SECTION HIGHLIGHTS

*Large conventional power plants require significant amounts of water for cooling and other purposes. Surface water and ground water withdrawals can affect ecosystems and the availability of ground water for other users.*

### Dry Cooling

Dry cooling towers have been utilized in areas where water is in critically short supply. In dry cooling, large quantities of air are drawn by fans through the tower where sensible (non-evaporative) heat transfer occurs between the steam cycle condenser and the ambient air by direct contact. This arrangement is analogous to a car radiator. Dry cooling does not consume water, it generates no visible plume, and there is no discharge.

Due to the large quantities of air that must be drawn into the towers, large fans are employed. This typically results in a larger tower footprint compared to wet towers designed for similar heat transfer duty. Noise propagation from powerful tower fans must be evaluated on a case by case basis; noise mitigation structures can be employed if necessary.

Parasitic fan power requirements (i.e., the quantity of power generated by the plant that must be consumed to run the tower fans) must also be evaluated with respect to overall project economics. Because they rely only on the sensible transfer of heat to the atmosphere, design efficiencies for dry towers are generally significantly lower than what can be achieved for wet towers, resulting in less net power available on hot days. This is a significant disadvantage because power demand frequently peaks during hot weather.

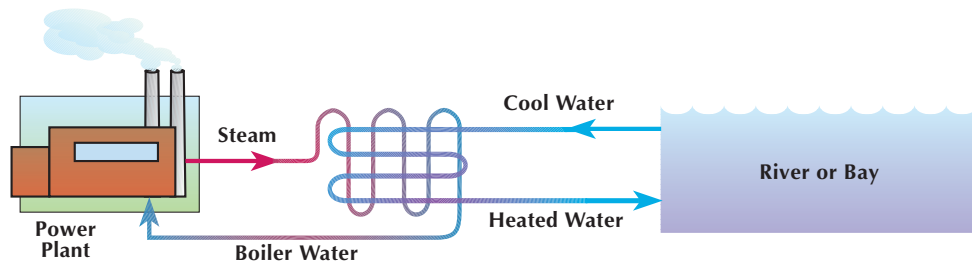
second largest surface water appropriation in the state, at about 1.1 billion gallons per day (twice as much as Bethlehem Steel’s appropriation, and more than 4 times greater than Baltimore City’s municipal supply).

Combined water withdrawal for all steam generating power plants in Maryland is 6 billion gallons per day. By comparison, the Potomac River has a daily flow of about 7 billion gallons, and the Susquehanna about 23 billion gallons. All other (non-power plant) users in the state have a combined appropriation of 3.4 billion gallons per day. Thus, cooling water for electricity generation represents a significant portion — more than 60 percent — of the total surface water appropriations in the state.

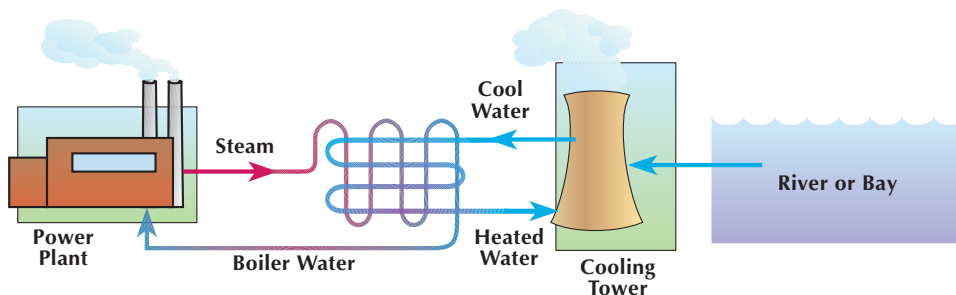
Water requirements for recently constructed power plants are much smaller than those for older facilities. This is due in part to increased concern and awareness of environmental issues related to construction on shorelines and riverbanks, which results in power plants being built farther away from surface water sources. Water supply therefore has become a greater cost factor than it had been previously. Closed-cycle cooling towers have become standard on new steam generating power plants, which reduce water withdrawals substantially compared to once-through cooling systems.

The great majority of power plant cooling water used in Maryland is withdrawn directly from surface water bodies. Power plants that utilize surface water for cooling will have to comply with new regulations that the U.S. EPA is develop-

## Once-Through vs. Closed-Cycle Cooling



In **once-through cooling**, water is drawn continuously from a bay or river to cool the power plant’s condensers (that portion of the plant where steam is condensed to water and recycled to the boiler). Power plants with once-through cooling withdraw very large amounts of water, then return water to the bay or river at elevated temperatures. A small percentage of the water is consumed because the warmer water evaporates more quickly.



In **closed-cycle cooling**, a much smaller amount of water is withdrawn, compared to once-through cooling, and the water is recirculated several times within a cooling tower. But closed-cycle cooling systems consume more water resources than once-through systems by evaporating the water. As much as half of the water withdrawn for cooling tower use is consumed by evaporation.

ing under Section 316(b) of the Clean Water Act. The objective of 316(b) is to minimize the ecological impacts of large surface water withdrawals. In the non-tidal portion of the Potomac River Basin, new consumptive users of water (such as power plants with large cooling water needs) must also comply with Maryland's Consumptive Use Regulations. This program seeks to ensure that upstream users do not withdraw too much water during low-flow periods, and that sufficient water is present downstream to support aquatic life and to provide municipal water supply to the Washington, D.C., metropolitan area. PPRP is evaluating the implications of these consumptive use regulations as part of current power plant licensing cases.

## Cooling Water Intake and Discharge Impacts

In Maryland, most cooling water is drawn from the Chesapeake Bay or one of its tributaries. Although there is ample water available for cooling purposes, adverse environmental effects can result from withdrawing, heating, and discharging large volumes of water. The ways in which power plant operations can impact aquatic organisms include:

- **Entrapment** — accumulation of fish and crabs (brought in with cooling water) in the intake region;
- **Impingement** — trapping of larger organisms on barriers such as intake screens and nets;
- **Entrainment** — drawing in of plankton and larval or juvenile fish through plant cooling systems; and
- **Discharge effects** — adverse impacts of exposure to heated effluents and toxic discharges.

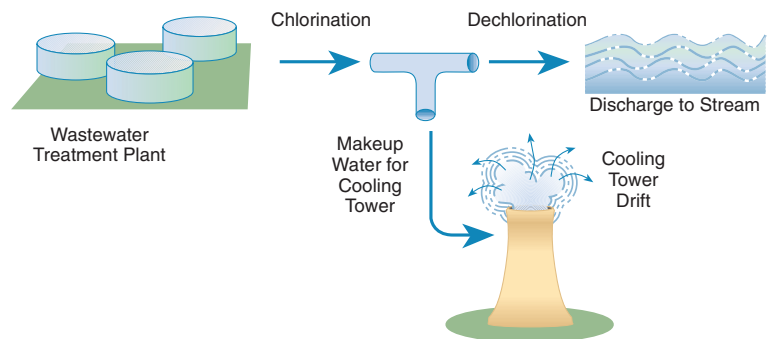
PPRP and Maryland's utilities have evaluated impacts at 12 major power plants in the state over the last two decades, conducting several dozen studies on the nature and extent of entrainment, impingement, and discharge effects. These studies were used to evaluate the relative impacts of power plant operations on the aquatic environment in the state, with special emphasis on the Chesapeake Bay. Some studies were also used as the basis for modifying operating procedures at the plants to reduce impacts and to provide quantitative cost estimates of unavoidable losses in aquatic biota.

### Reuse of Treated Effluent in Cooling Towers

For steam generating power plants, the availability of water for cooling purposes is a critical requirement. Treated effluent from domestic wastewater treatment plants (WWTPs) is emerging as an economical source of cooling water in some areas of the state where high-quality surface water supplies are limited. Wastewater reuse minimizes the impacts to aquatic resources that can result from large surface water withdrawals. It should be noted, however, that wastewater reuse in cooling towers consumes water that otherwise would return to the river or stream.

The Panda-Brandywine combined cycle power plant in Prince George's County utilizes about 1.5 million gallons per day of treated effluent from the Mattawoman WWTP. The proposed Kelson Ridge power plant is also planning to use Mattawoman WWTP effluent. During the CPCN licensing process for this facility, PPRP closely examined the feasibility and potential impacts of effluent reuse, including the impacts of pollutants dissolved in water vapor emitted from the tower ("cooling tower drift"). With proper disinfection and monitoring procedures, this form of water reclamation poses no significant health risks.

#### Schematic of Treated Effluent Reuse as Cooling Tower Makeup Water



Results of these studies show that while operations of individual power plants impact various ecosystem elements in various ways, those impacts, taken together, have had no identifiable substantive cumulative impact on Maryland's aquatic resources to date. Although large entrainment losses of some types of aquatic organisms have been measured frequently, no consistent depletions in numbers of organisms have been found, or the loss is being mitigated. For example, at Chalk Point, PEPCO has reared and stocked fish in the Patuxent River and provided funding to remove blockages to migratory fish as mitigation for mortalities of bay anchovy populations in the river. At Constellation Energy's Wagner plant (located in Baltimore's outer harbor), data from field studies revealed that actual entrainment impacts are substantially less than projected by computer screening models, and PPRP recommended that mitigative measures at this facility are not warranted.

Intake technologies and modifications to operating practices have been developed to reduce entrainment or impingement impacts at steam electric power plants. However, few can reduce both entrainment and impingement impacts. PPRP has investigated the applicability of several intake technologies to Maryland's power plants and ecosystems and found the following:

- *Physical barriers, such as screens or nets, are the most successful and economical for reducing both entrainment and impingement. **Wedge-wire screens** keep entrainment low and essentially eliminate impingement. Such screens are likely to be included in the design of any new proposed facilities that would use Bay water for cooling.*
- *Collecting and releasing organisms after impingement is only partially effective at reducing impingement losses. Some of the collected organisms, particularly those in early life stages and juveniles, are sensitive to handling and abrasion. If they are returned to the receiving water body near the intake structure, they may be susceptible to re-impingement. As a result, Morgantown power plant redesigned its system to return fish to either side of the intake structure depending on the direction of the tide. Similarly, the fish return system installed at the Wagner power plant places impinged fish into a channel leading away from the intake screens.*

Modification of plant operations is also a cost-effective approach for reducing many aquatic impacts. Two operating practices previously evaluated by PPRP were modifying intake screen wash cycles and discontinuing the use of auxiliary tempering pumps. Intake screens at Maryland power plants are rotated on a frequency of anywhere from once per day to continuously. Increasing the frequency of rotation does not alter the rate of impingement, but it can reduce the time organisms are exposed to scavengers and conditions leading to suffocation. Auxiliary tempering pumps withdraw surface water to mix with the plant's discharge and reduce thermal impacts. However, studies by PEPCO and PPRP showed that discontinuing their use would reduce entrainment and impingement and not significantly increase downstream mortalities.

Sometimes an adverse environmental effect cannot be minimized or eliminated through procedural or engineering modifications. In such cases it may be appropriate to employ other types of mitigation to offset certain impacts from power plants. Although mitigation with resources similar to those lost is most desirable (in-kind mitigation), situations arise where mitigation using different resources (out-of-kind mitigation) is the only possible or practical alternative. In-kind mitigation means providing or managing substitute resources that are

physically and biologically similar to those lost due to plant construction or operation. Out-of-kind mitigation means providing or managing substitute resources that are physically and biologically different from those lost. Both in-kind and out-of-kind mitigation have been applied at the Chalk Point power plant and have been included as a license condition to the Dorchester power plant near the Nanticoke River.

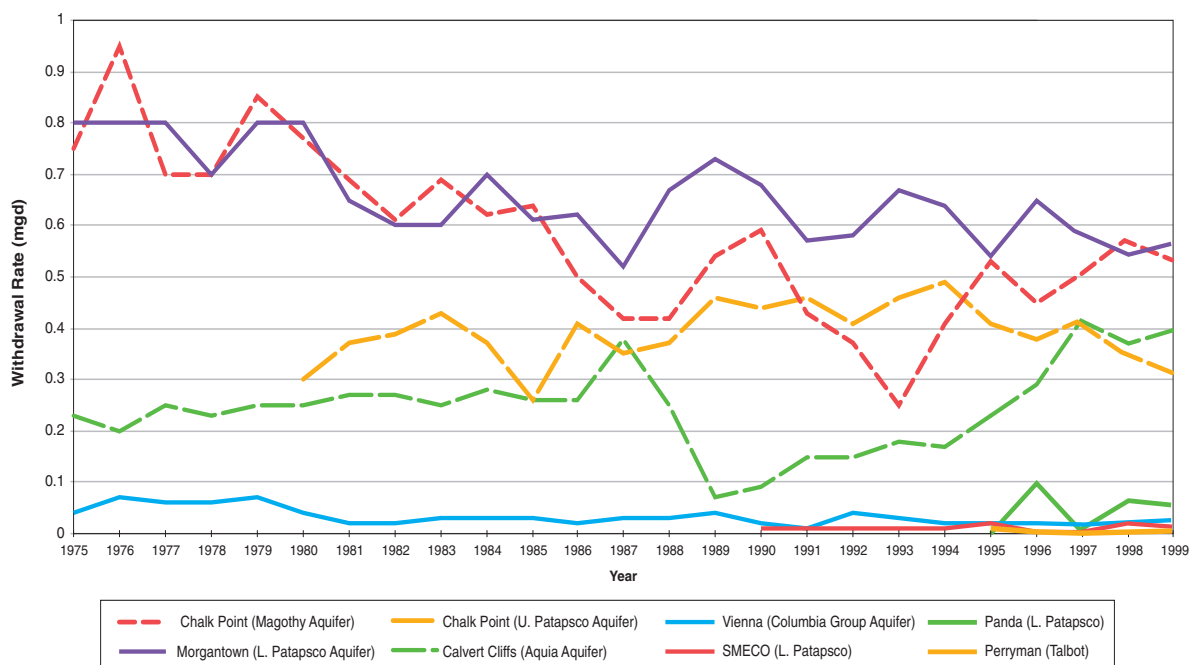
## Ground Water Use and Impacts

Although surface water withdrawals for cooling purposes represent a much larger volume of water usage, Maryland's largest power plants are also significant ground water users. High-quality ground water is needed for boiler feedwater, emissions control, and potable uses.

Large ground water withdrawals have the potential to lower the water level in an aquifer or cause intrusion of salt water into the aquifer. The impact of these withdrawals is a key issue in southern Maryland, where there is a significant reliance on ground water for domestic water supply. Although large volumes of ground water are available in the Coastal Plain aquifers, withdrawals must be managed over the long-term to ensure that adequate ground water supplies are available in the future.

Currently, seven power plants in Maryland use ground water for plant operations. These plants include Constellation's Calvert Cliffs Nuclear Power Plant and Perryman combustion turbine facility, Mirant's Chalk Point and Morgantown power plants, Conectiv's Vienna power plant (being purchased by NRG Energy), SMECO's combustion turbine facility (located at the Chalk Point

**Figure 4-9**  
**Average Daily Ground Water Withdrawal Rates at Maryland Power Plants**



plant), and Panda-Brandywine’s combined cycle power plant. All of these plants are located in the Coastal Plain of Maryland, and with the exception of the Perryman and Vienna facilities, all are located in southern Maryland. The five power plants located in southern Maryland withdraw ground water from three aquifers: the Aquia, the Magothy, and the Patapsco. Three government agencies — the Maryland Geological Survey, the U.S. Geological Survey, and PPRP — jointly operate a ground water monitoring program to measure the water levels in these aquifers to ensure the long-term availability of ground water.

Figure 4-9 shows the ground water withdrawal rates in million gallons per day (mgd) of each of the seven power plants from 1975 to 1999, expressed as daily averages. There are limited data for the Perryman and Panda-Brandywine power plants because they came on line in the past five years. Each of the seven facilities typically withdraws amounts of water well below its appropriated limits. The average withdrawal for all seven power plants in 1999 was 1.9 mgd, compared to a combined daily appropriations limit of 2.8 mgd.

Long-term monitoring indicates a steady decline in water levels in the Aquia, Magothy, and Patapsco aquifers. Although the power plants have contributed to the decline in the water levels in these aquifers, increased withdrawals from municipal well fields in southern Maryland have caused most of the recent declines. The measured water level declines are considered negligible compared to the amount of water available in the aquifers. The amount of water available is expressed as the aquifer’s “available drawdown,” which is defined in MDE Water Management Administration regulations as 80 percent of the historic pre-pumping level in the aquifer. Water quantity impacts to each of the three aquifers are summarized below.

- ***Aquia Aquifer at Calvert Cliffs*** — *Water levels in the Aquia Aquifer at Calvert Cliffs have declined 60 feet over the period 1982 to 1999, with most of the decline occurring since 1990. This acceleration in water level declines is due to the withdrawal from municipal well fields at Lexington Park in St. Mary’s County and Solomons Island in Calvert County. The water levels at Lexington Park and Solomons Island have declined nearly 10 feet since 1997 and approximately 40 feet since 1990. The impacts from the water level declines are considered negligible compared to the 315 feet of available drawdown currently estimated in the Aquia Aquifer at Calvert Cliffs.*
- ***Magothy Aquifer at Chalk Point*** — *Water levels in the Magothy Aquifer at Chalk Point have declined by about 35 feet from 1975 to 1999. Beginning around 1990, MDE Water Management Administration has required industrial users of the Magothy Aquifer to use deeper aquifers like the Patapsco to allay concerns over water level declines in the Magothy. As a result, Chalk Point’s withdrawal rate from the Magothy Aquifer between 1990 and 1999 has decreased by almost 40 percent compared to the period before 1980. The rate of decline in the aquifer water level has been slower since 1990 due to PEPCO’s decreased long-term withdrawal; however, water levels continue to decline due to withdrawals from other users in the Annapolis and Waldorf areas.*
- ***Upper Patapsco Aquifer at Chalk Point*** — *The water level surface in the Upper Patapsco Aquifer declined 12 feet at Chalk Point from 1990 to 1999. These declines will not impact the approximately 740 feet of water available in the Upper Patapsco Aquifer.*

- **Lower Patapsco Aquifer at Morgantown** — *The water level surface of the Lower Patapsco Aquifer in the vicinity of the Morgantown power plant remained stable between 1982 and 1995. Although recent data indicate that the water level declined 24 feet during the period 1990 to 1999, since 1997 water levels in the vicinity of the Morgantown power plant have increased as much as 13 feet. By comparison, water levels in the Waldorf and La Plata area have risen 30 to 40 feet since 1990, with at least a seven-foot rise since 1997.*

## Biological Impacts

Nearly all modes of electric power generation may cause or contribute to adverse effects on biological resources. These include potential impacts to aquatic, wetland, and terrestrial environments. For example, hydroelectric power plants require that water be impounded by damming to create the hydraulic capacity to generate electricity. Impacts of damming include the inundation of riverine habitats, blockage of rivers to movement of aquatic biota, and changes in surface water quality both upstream and downstream from these facilities.

Power plant construction and operation can also adversely affect nontidal and tidal wetlands. In the 1780s, Maryland included about 1,650,000 acres of wetlands (24.4 percent of its surface area); as of 1989, Maryland included only about 440,000 acres of wetlands (6.5 percent of its surface area). These figures represent a 73 percent loss of wetlands in the state. The State is concerned with such losses, and now protects these resources. Through regulations developed under Maryland's 1991 Nontidal Wetlands Protection Act, many activities in nontidal wetlands are regulated under a policy of no net loss. Similarly, activities in tidal wetlands in Maryland are regulated under the 1994 Tidal Wetlands Regulations. Compared with residential and commercial construction, power plant construction has caused minimal direct wetlands impacts since the implementation of Maryland's nontidal wetlands law. Relatively small losses of wetlands were associated with recently licensed Perryman and Panda-Brandywine facilities. Wetlands losses were minimized through the CPCN process, requirements of the Nontidal Wetlands Protection Act, and cooperation from the utilities. To compensate for wetland losses and to meet the state's no net loss goal, mitigation is being required for these projects. Wetlands mitigation is also underway at Mirant's Dickerson site in Montgomery County.

Vegetated, natural terrestrial ecosystems in Maryland include forests, grasslands, and other habitats. Agricultural land, residential development, and commercial development have replaced some of Maryland's natural terrestrial ecosystems. A variety of wildlife inhabit Maryland's terrestrial ecosystems. Construction and operation of power plants and their related linear facilities (transmission line rights-of-way, pipelines, access roads, etc.) can affect terrestrial resources and the wildlife they support in a variety of ways, including: 1) physical change or elimination of existing habitats; 2) disturbance and displacement of wildlife; 3) deposition of particulate matter or gaseous emissions to the atmosphere; and 4) inadvertent spills and permitted release of toxic materials. Forest resources are protected under the 1991 Forest Conservation Act (FCA). Under the FCA, tree conservation, replanting, and other environmental param-

### SECTION HIGHLIGHTS

*Power generation can affect biological communities in several ways, and PPRP is at the forefront of assessment and mitigation efforts. For instance, PPRP continues to be very involved in tracking the impacts of hydroelectric facilities on stream ecosystems and facilitating efforts to mitigate those impacts. DNR's Maryland Biological Stream Survey, to which PPRP has been a key contributor, represents an important data gathering effort that allows us to quantify the health of stream ecosystems and to identify stressors.*

## Mitigating Nitrogen Deposition through Forestry Efforts

The principal impact of the proposed power plant project and right-of-way construction at Rock Springs in Cecil County would be the loss of approximately 20 acres of forest. The majority of the forest that would be removed for construction of the power plant project consists of mature trees such as oaks, which provide hard nuts that many species of wildlife forage upon. Hardwood forests of this type take many years to mature and the substantial ecological benefits they provide are becoming less common in this region. The forest currently provides food, shelter, and other habitat requisites for ubiquitous wildlife such as gray squirrel and white-tailed deer, and for less common forest interior-dwelling birds such as the hairy and red-bellied woodpeckers (all observed at the site). Therefore, PPRP concluded that substantial adverse impacts to terrestrial resources would result from power plant construction and operation at Rock Springs.



Reforestation is the preferred form of mitigation for forest loss. Constraints on the Rock Springs site prevent on-site reforestation. Off-site mitigation options that would provide substantial ecological benefits are:

- (1) reforestation of forest gaps to provide greater contiguous forest area (benefitting forest-interior birds and other area-sensitive species) and
- (2) reforestation of riparian areas bordering nearby streams (reducing runoff and nutrient loads within the watershed and ultimately the Chesapeake Bay).

In the case of Rock Springs, the best opportunities for mitigating the loss of forests and wildlife lie in reforestation near existing parks, preserves or wildlife management areas. Because reforestation cannot replace the ecological values of a mature forest, PPRP recommended 50 acres of reforestation to compensate for the loss of 20 acres of forest habitat and associated wildlife, and to partially compensate for the additional nitrogen deposition that would result from the power plant. (See further discussion of nitrogen deposition in Section 5.)

eters must be considered before any development disturbs forest resources. An exemption for rights-of-way and land for construction of electric generating facilities can be given if a CPCN is issued. A project may lose its exemption status if the developer of a site or its linear facilities cannot demonstrate that cutting or clearing of forest will be minimized. In the current licensing procedure for the Rock Springs power plant, the State is recommending that the loss of 20 acres of forest be mitigated by establishing forest along unbuffered streams or in gaps of fragmented forest that support sensitive species.

The remainder of this section focuses on biological impact concerns associated with hydroelectric facilities and with transmission line and pipeline rights of way. The efforts of the Maryland Biological Stream Survey (MBSS) are also presented and discussed. The MBSS is a long-term monitoring program to assess the cumulative impacts of power plant impacts and other stresses on Maryland watersheds. A separate section on conserving biodiversity through integrated assessments draws on MBSS data and is included as a natural resource issue in Section 5 (see page 88).

## Hydroelectric Facilities

Eight hydroelectric projects are operating in Maryland. The largest facility is the Conowingo Hydroelectric Station, with a capacity of 512 MW. The second largest is Deep Creek Station, with a capacity of 19.2 MW. Six smaller projects

around the state have a combined capacity of 3 MW. The Federal Energy Regulatory Commission (FERC) is the federal agency that licenses hydroelectric facilities throughout the country (with the exception of Deep Creek, as discussed later in this section). In Maryland, PPRP is the lead State agency with regard to FERC licensing of hydroelectric facilities. The case studies presented in this section illustrate PPRP's significant involvement in addressing licensing and impact evaluation issues.

Development and operation of hydroelectric facilities can cause three types of impacts:

**Alterations of water quality** — Impoundments created by the construction of hydroelectric dams and modifications of river flow implemented for the purpose of generating electricity can result in changes in natural water clarity, dissolved oxygen concentration, and water temperature upstream and downstream of the dam.

**Fluctuations in water level and flow** — Operating hydroelectric facilities in a peaking mode (that is, not continually but in response to peak demand for electricity) produces unnatural, and frequently extreme, water level fluctuations in impoundments and in aquatic habitats downstream of dams. Small-scale hydroelectric projects may also divert some streamflow away from the natural streambed. Fluctuations in water level and flow may reduce fish abundances and the abundance of food important to fish growth and survival.

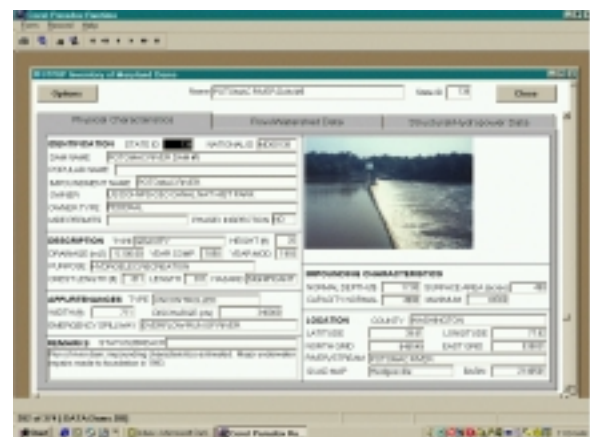
**Direct adverse effects on fish populations** — Dams constructed for electricity generation may prevent the natural upstream and downstream movement of both resident and anadromous (migrating) fish species. Entrainment of fish attempting to move downstream past the dam may result in mortality in the turbines. The type of turbine, the proportion of flow that is diverted through the turbine, and the size of fish have an effect on fish mortality. Each of these modes of impact has been found to be significant at hydroelectric facilities in Maryland. The following discussion presents three case studies, describing the impacts caused by these facilities and the manner in which these impacts have been mitigated through the cooperative efforts of PPRP, other state and federal agencies, and the facility operators.

## The PPRP Inventory of Maryland Dams on CD-ROM

The PPRP Inventory of Maryland Dams is a unique, informational data base covering more than 370 dams throughout the state. First published in 1985, the original hardcopy version, *Inventory of Maryland Dams and Hydropower Resources*, presented information on the size, ownership, and functions of each lake in the state that has hydropower or flooding safety implications. The current inventory, available on CD-ROM, has recently been updated and can be searched for information such as a dam's physical characteristics, flow data, watershed data, and hydropower or other uses of the dam. Information in the data base was provided by MDE's Dam Safety Division and PPRP.

State agencies have used the Dam Inventory extensively as a source document and assessment tool. It has been used to assess hydropower potential based on environmental suitability attributes as part of a U.S. Department of Energy project. It has been a key reference source in the preparation of documents such as Maryland's Water Quality Inventory Reports (305b), which must include information on publicly owned lakes in Maryland. The Dam Inventory has also successfully supported State applications for funding from the Federal Clean Lakes Program for lake assessment and restoration projects. The update of information and conversion to a searchable digital format on CD have increased the usefulness of the inventory, and reviews of the new CD have been extremely positive.

The CD-ROM is available upon request; contact PPRP at the email address or phone number listed at the back of this report.



Example of a display page from the PPRP Inventory of Maryland Dams. Information pertaining to each site is made available according to topic heading provided by display tabs. Illustrated above is information associated with the "physical characteristics" tab.

## *Case Study — Anadromous Fish Passage on the Susquehanna River*

Historically, the Susquehanna River supported large spawning runs of anadromous species such as American shad, river herring, and striped bass. However, the massive anadromous fish runs that generated migrations extending as far upstream as Cooperstown, New York, were eliminated with the construction of four major hydroelectric facilities on the lower Susquehanna River in the early 1900s (Maryland's Conowingo Dam, and the Holtwood, Safe Harbor, and York Haven dams in Pennsylvania).

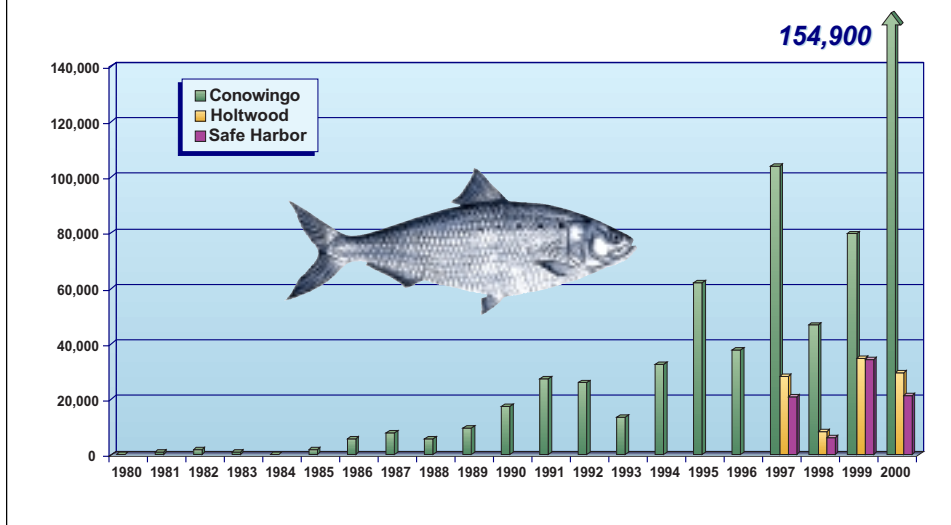
When the FERC licenses for the four Susquehanna River hydroelectric facilities were being considered for renewal in the early 1970s, a major issue that arose was restoration of anadromous fish to the Susquehanna. Participants in the FERC license proceedings have included PPRP, on behalf of the State of Maryland; the State of Pennsylvania; the State of New York; the U.S. Fish and Wildlife Service; and several non-governmental organizations (NGOs). The ultimate goal of the resource agencies and NGOs is the restoration of anadromous fish populations to the entire Susquehanna River drainage system. The primary means for achieving this goal include the installation of fish passage facilities at all four dams, the implementation of an active restoration program involving trapping and transport upstream of adult fish, and hatchery production of young fish for stocking. (PPRP and several other of these parties have also worked toward change in operational protocols at hydroelectric facilities to better mimic natural river flows and to avoid flow cutoffs. These efforts are discussed in the case study on the next page.)

Construction of a small fish lift to support research efforts at Conowingo Dam in the early 1970s provided an opportunity to evaluate the potential effectiveness of lift facilities for restoring American shad and other species and for gathering extensive information on fish populations and passage behavior. The following stock restoration activities began at about the same time: 1) transporting adults from other east coast rivers and releasing them into the Susquehanna River; 2) trapping adults at Conowingo, trucking, and releasing them upstream of the dams; and 3) using shad eggs from many different shad stocks to propagate larvae and juveniles, and releasing them into the Susquehanna River and its tributaries. These different approaches were monitored for their effectiveness, and the findings from the monitoring were used to modify existing programs and develop new programs.

The restoration goal established for Susquehanna River shad is to achieve a combined annual spawning population of two million American shad and hickory shad above the York Haven Dam. To achieve that goal, a restoration target for total shad passage at Conowingo Dam of three million fish has been established. In a significant step toward achieving this goal, the State of Maryland, the U.S. Fish and Wildlife Service, the Pennsylvania Fish and Boat Commission, NGOs, Safe Harbor Water Power Corporation, and Pennsylvania Power and Light (which owns Holtwood) reached an agreement in October 1992 on construction and operation of fish passage facilities at Holtwood and Safe Harbor by 1997.

Growth of the Susquehanna River shad stock in response to the restoration efforts and fish passage construction to date has been dramatic, culminating in

**Figure 4-10**  
**American Shad Passed at Susquehanna River Dams,**  
**1980 - 2000**



the year 2000 in the largest number of American shad to ever be passed over Conowingo Dam, 154,897 (Figure 4-10). Numbers of shad passed at Holtwood and Safe Harbor in 2000 were 29,000 and 21,000 respectively.

GPU, which operates the York Haven Dam upstream of Safe Harbor, constructed a passage facility that was operational in the year 2000 and passed 4,675 American shad in its first season of operation. With its completion, the entire Susquehanna River is now open to migratory fish for the first time since the dams were constructed, creating the potential for shad and other species to move as far upstream as New York State, well over 400 miles of new habitat.

### *Case Study — Water Quality and Flow Regulation at Conowingo Hydroelectric Station*

For more than 20 years, PPRP has devoted substantial effort to addressing the impacts that the Conowingo Hydroelectric Station might have on the water quality and aquatic habitat in the downstream portion of the Susquehanna River. Operation of the Conowingo facility involves the control of water levels and flows to downstream aquatic habitats, thereby affecting fish abundance as well as the amount and type of food organisms available for fish. During peak electricity demand periods in the summer, river water upstream of the dam, if released unchanged, often has low dissolved oxygen (DO), which can cause poor water quality downstream of the dam. These issues were addressed together with fish restoration in the negotiations and litigation discussed above for fish passage. In the 1988 agreement, the State of Maryland and Conowingo operator Susquehanna Electric Company (SECO) resolved most water quality and flow issues through implementation of the following actions:

**Water Quality** — During the 1960s, large fish kills occurred downstream of Conowingo Dam as a result of daily cutoffs of all flows and of fish being exposed to water that contained very low levels of DO. From the early 1970s through the 1980s, SECO evaluated several different means of improving the DO levels in water released from Conowingo generating turbines. Studies

conducted by PPRP in cooperation with SECO led to the adoption of turbine venting, a procedure in which an intake is constructed that allows air to be entrained into the water passing through a turbine to increase the oxygen content of the water. To date, venting has proven effective in providing water below Conowingo Dam that meets Maryland's DO standard.

*Water Flow and Downstream Habitat* — Another issue addressed in the 1988 settlement agreement was the level of minimum flow that should be released from the Conowingo Dam throughout the year to protect and enhance aquatic biota. The flow releases specified in the agreement are seasonal, varying from a high of 10,000 cubic feet per second (cfs) in the spring to as low as 3,500 cfs in the winter. As a result of additional coordinated studies over the winters of 1988 through 1993, it was found that an intermittent flow regime, allowing SECO to shut off the 3,500 cfs flow for up to six hours at a time, did not harm aquatic invertebrate communities during these winter periods. The FERC license was therefore modified to permit an intermittent flow regime during the winter.

The extensive studies and monitoring work performed by PPRP in cooperation with SECO, its contractors, and other agencies have significantly enhanced water quality and aquatic habitat below Conowingo Dam relative to conditions that existed following construction of the dam.

### *Case Study — Water Quality and Recreational Use Conflicts at the Deep Creek Hydroelectric Project*

The 3,900-acre Deep Creek Lake was formed in 1925 by construction of a rock-wall dam across Deep Creek, a tributary of the Youghiogheny River. The Deep Creek Hydroelectric Project includes two turbines that have a combined generating capacity of about 19 MW. When both turbines are operating, the hydroelectric project discharges water to the Youghiogheny at a rate of 630 cfs. The generation of power has the potential to affect lakeside recreation through changes in the lake's water level. Discharge from the hydroelectric project also has the potential to affect downstream environments of the Youghiogheny River — Maryland's only designated "wild" river. The Youghiogheny supports a developing trout fishery and one of the most challenging kayaking and rafting runs in the country.

Penelec, then owner-operator of Deep Creek Station, received an operating license for the Deep Creek Hydroelectric Project from FERC in the 1960s. In 1988, Penelec initiated the operating license renewal process with FERC. PPRP participated in the FERC relicensing process as the lead agency for the State of Maryland. The State sought to ensure that the operation of the hydroelectric plant minimized potential impacts to Maryland's natural and recreational resources while still allowing for the economical generation of electricity.

Subsequent to working with Penelec on the conditions for the FERC license, the Deep Creek Hydroelectric Project was found to be outside of FERC's jurisdiction. Penelec and the State agreed to integrate the conditions that had been negotiated as part of the FERC relicensing effort into a water appropriations permit for Maryland that is administered by MDE.

The conditions attached to the water appropriations permit, issued to Penelec in 1994, were designed to achieve two objectives: 1) provide a reliable and eco-

nomical source of electricity; and 2) enhance Deep Creek Lake's and the Youghiogheny River's natural and recreational resources. Because the interests of various users of Deep Creek Lake's resources are often conflicting, it was a difficult task to develop an operational plan to balance the following complex environmental and recreational issues with economical operation of the plant.

**Lake Levels** — Recreational lake users wanted minimal and consistent draw-down of the lake during summer, and a higher than historic level in the autumn to extend the boating season. Historically, Penelec lowered the water level in the fall and winter to prevent ice damage to the spillway, resulting in an annual water level change of about 9 feet. To help evaluate possible alternative operating strategies, a computer model of historical lake inflow, storage, and generation was developed. Using the results from the model, Penelec and PPRP developed monthly operating rules for the Deep Creek Hydroelectric Project that balanced providing reliable electricity with enhancing lake and river resources.

**River Fisheries** — High water temperatures in the Youghiogheny River and low DO levels in the hydropower project's discharge historically limited the trout habitat. The discharge from the hydroelectric project is cooler than the river because it draws cold water from the bottom of the lake. The timing and volume of cool water discharges from the hydroelectric project could be manipulated during periods of high temperatures in the Youghiogheny to improve trout habitat and assure that the growing trout population would not be subjected to lethal temperature extremes. PPRP developed a protocol for the Deep Creek Hydroelectric Project operators that predicts maximum daily river temperature during the summer. The protocol uses river flow and temperature changes, and available predictions of maximum air temperature and cloud cover for the region. During low flow conditions in the late summer, plant operators follow the protocol in the morning and afternoon to predict river temperature. The goal is to make sure the river temperature never exceeds 25°C. Based on the temperature predictions, the operators decide whether to make a release to cool the river and thus enhance temperature habitat for trout. Penelec also installed structures to provide a continuous minimum flow to the Youghiogheny River and aerate discharge water to alleviate the low DO problem.

**Whitewater Recreation** — The Youghiogheny River is an exceptional whitewater recreation resource that is almost totally dependent upon releases from the Deep Creek Project to provide adequate flow volume in most summer months. Whitewater boaters need timed, dependable releases from the hydroelectric facility to plan trips in advance. The "Upper Yough," which runs from Sang Run to Friendsville, is the key section of the river for whitewater boating that is affected by the Deep Creek Project. During dry periods, the Upper Yough may be the only whitewater resource in the area available to boaters. Under the negotiated permit conditions for the hydroelectric project, Penelec now schedules generation of electricity to provide: 1) whitewater boating whenever possible; 2) at least three-hour periods of release particularly during low river flow conditions during the whitewater boating season (April 15 through October 15); 3) suitable flow for boating at fixed times on all Fridays and Mondays during the whitewater recreation season, except when lake levels are too low; and 4) suitable boating flow on at least one Saturday per month and during other special events on a prearranged schedule.

Deep Creek Station was purchased by Sithe Energies in 1998, and the company subsequently sold the facility to Reliant Energy. The water appropriations permit was transferred without modification to Reliant Energy in 2000, and it expires in 2006. The State will review the license conditions when the appropriations permit comes up for renewal, with the goal of continuing to promote optimal use and protection of Deep Creek Lake.

## *Transmission Line and Pipeline Rights-of-Way*

Electric transmission line and pipeline rights-of-way are located throughout the state. Both temporary and permanent impacts can arise from transmission line and pipeline corridor construction and maintenance. Forested communities are particularly prone to impacts from construction of rights-of-way, especially where fragmentation of large parcels occurs. To construct these corridors, land must be cleared of vegetation, and sometimes graded. Once the linear facilities have been installed, the rights-of-way are typically maintained in herbaceous or shrubby vegetation, resulting in permanent impacts to forest, wildlife, and wetlands resources.

With appropriate planning and construction techniques under ideal conditions, nontidal wetlands (excluding forested systems) can recover from linear facilities construction in as little as two years. Recent investigation by PPRP has shown that construction of electric transmission line rights-of-way has had relatively little impact on nontidal wetlands in Maryland. Transmission line construction accounted for only 1 of the 92 wetlands permits and about 7 of the 682 Letters of Authorization approved by DNR from January 1991 (when State nontidal wetlands permitting activities began) to May 1994. In the same period, the construction of new transmission line rights-of-way has permanently impacted only about one acre of nontidal wetlands and temporarily impacted about eight acres. Many of these impacts represent conversion of one type of vegetation to another; for example, forest is converted to a scrub/shrub habitat. To put these numbers into context, permanent nontidal wetlands impacts for all projects in Maryland authorized from January 1991 through December 1993 totaled 76.9 acres. Temporary impacts authorized during that time totaled 93.6 acres.

Under Maryland's nontidal wetlands regulations, permanent impacts to nontidal wetlands must be mitigated (i.e., new wetlands created, other disturbed wetlands restored, or payment made to the Wetlands Compensation Fund) at various ratios depending on the type of wetlands affected. A ratio of 3:1 is applied to scrub/shrub and forested wetlands of special state concern, a 2:1 ratio to scrub/shrub and forested wetlands and to herbaceous wetlands of special state concern, and 1:1 for emergent wetlands. Mitigation ratio requirements are similar for state tidal wetlands. Temporary impacts and impacts to wetlands buffers do not usually have to be mitigated.

When transmission line corridors go through forested areas, individual trees are lost, and the natural forest community is often fragmented. Fragmentation of forest habitats may affect biodiversity. Forest-dwelling species that require large tracts of intact forest—such as migratory songbirds—may be eliminated through predation or parasitism by edge species that invade the corridor. While

the total number of species in the local area may increase as a result of the invasion of common species with an affinity for brushy or oldfield habitats, the regional diversity will usually decrease as rarer forest-interior species are eliminated.

PPRP recognizes the importance of reducing forest fragmentation caused by transmission line corridors and is working with utilities on several tasks to encourage management practices that reduce edge effects. One on-going PPRP research task involves compiling information on innovative rights-of-way management practices that work to reduce fragmentation effects, such as the selective application of herbicides to control tall growing woody vegetation. This method, which involves spraying individual trees that are or have the potential to be taller than clearance requirements allow, arrests ecological succession and promotes a low-growing, scrub/shrub plant community. Such communities will help provide a more natural system in which the type and height of vegetation gradually transitions from a low, managed plant community in the rights-of-way to a taller, more natural adjacent plant community. It is also hoped that such low-growing communities will help prevent colonization of rights-of-way by invasive species.

Another recently initiated PPRP research effort on fragmentation is directed towards identifying locations where transmission line rights-of-way sever wildlife corridors that are of state-wide importance to Maryland's Green Infrastructure. Once these locations have been identified and prioritized, PPRP can work with utility companies and others to implement management practices designed to reduce fragmentation effects associated with the rights-of-way. Section 5 of this report describes in more detail additional methods PPRP is developing to evaluate and promote biodiversity.

PPRP is also developing a siting model for new transmission lines that takes into account the need to preserve large tracts of intact forest. This model uses GIS map overlay techniques to "grade" points on the landscape as to their suitability for construction of power facilities. Sensitive resources (including intact forest) at each location combine to produce higher avoidance scores, while existing infrastructures produce favorable siting scores. Following the appropriate algorithm, multiple transmission line routes can be drawn and evaluated. This model will provide an effective tool to assist siting decisions, once the model is validated and economic factors are included.

## *Rights-of-Way Maintenance*

Growth of woody vegetation on transmission line and other rights-of-way (such as natural gas pipelines) can present public safety hazards. Trees or branches that grow too close to power lines (danger trees) could fall on the conductors, while deep roots jeopardize the integrity of underground utilities. Utilities manage vegetation through a combination of mechanical and chemical treatments. State regulations permit the utilities to use only U.S. EPA-approved herbicides. These herbicides pose little danger to the terrestrial environment if properly applied.

The herbicides most commonly used by Maryland utilities, those with glyphosate as the active ingredient, persist in the environment for less than two

## Natural Resource Damage Assessment — Chalk Point Oil Spill

Following the recent significant oil spill on Swanson Creek adjacent to the PEPCO Chalk Point power plant, Maryland DNR has been assigned the role of Natural Resource Damage Assessment Trustee. PPRP is directing the development of long-term monitoring of resource recovery in the spill area. PPRP has also provided technical support for specific damage assessment activities, such as characterizing the affected tidal wetlands and contributing to damage assessment surveys.

Baseline information about marsh vegetation and other features within the area of the oil spill were derived from a scaled, low-altitude, color aerial photograph from 1998 that was supplied by DNR. This photograph of Swanson Creek marsh was laminated and brought into the field. The entire area depicted in the photograph was traversed on foot. Boundaries describing discrete vegetation associations were drawn directly upon the laminated photograph and general notations were made about the presence and the type of oil product within the marsh.

Information derived from the aerial photograph and the field survey was digitized, thus enabling the graphic representation and quantification of marsh vegetation types. At least some vegetation within all of the vegetation types (that were mapped) exhibited apparent negative physical effects. The long-term consequences of these apparent effects are uncertain at this time. Such long-term effects, however, could include re-colonization by species other than the currently predominant vegetation, increased erosion in non-vegetated parts of the marsh, and loss of wildlife habitat.

Benthic invertebrate surveys have been initiated within the Patuxent River in the vicinity of Chalk Point and in Swanson Creek. These surveys should provide information about the magnitude of impact from the Chalk Point oil spill upon important ecological resources.



*Containment boom placed at the mouth of Swanson Creek to control the migration of spilled oil into the Patuxent River. Chalk Point Power Plant is in the left background.*

months and are generally not toxic to wildlife when applied appropriately. Improper use of chemical herbicides, however, can result in excessive amounts being carried by runoff or wind transport into areas outside the right-of-way, and may damage untargeted vegetation and wildlife.

Several of Maryland's electric utilities have initiated maintenance programs to improve wildlife habitats in rights-of-way. Under these programs, stable oldfield (i.e., weedy, shrubby) habitats are established with tree species that do not have the potential for becoming danger trees. This is typically accomplished by spot treating potentially undesirable trees with glyphosate herbicide every three to five years, instead of annual mowing or broadcast spraying of herbicides. Results provided by the utilities indicate that such selective programs have created better, more stable habitats for wildlife, and have saved thousands of dollars in annual maintenance costs.

Mechanical cutting of vegetation in rights-of-way is not necessarily benign; it can disturb and kill wildlife, and has the potential for polluting soils and surface waters with petroleum products (i.e., chainsaw bar oil, grease, etc.), depending on the type of equipment used. Right-of-way management, whether it is accomplished by mowing or by herbicides, often affects wildlife by altering the original vegetative community. Most Maryland utilities indicate that they use a combination of selective herbicide application and mechanical cutting, rather than exclusively one or the other.

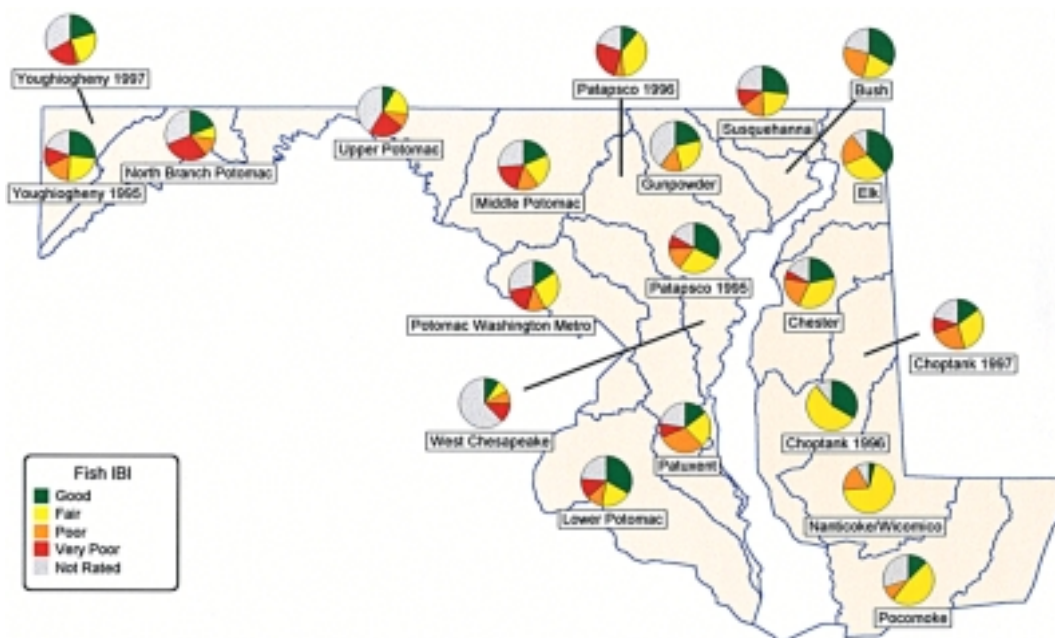
As stated in the previous section, PPRP is compiling information on innovative rights-of-way management practices that work to reduce fragmentation and other effects on local wildlife and plant communities. For example, management techniques for grasslands including strip mowing (alternate strips are mowed), "feathered" or soft edges to ease transitions between habitat types, rotational mowing schedules (e.g., annual, winter, summer), and the promotion of native grasses. In wetlands, management practices can include methods such as maintaining vegetative buffers and native wetland vegetation, creating snags by topping trees and girdling trunks, and "lop and drop" (where trees are topped and cuttings are left where they fall). In scrub/shrub habitats, the selective removal of tall growing tree species (greater than 10-12 feet in height) can be used to halt plant succession and promote a lower growing plant community in the rights-of-way.

PPRP has also been collaborating with Maryland utility companies to improve utility tree trimming and maintenance programs within utility rights-of-way through a series of meetings. These meetings, called the Tree Trimming Working Group, began when the PSC ordered utility companies to meet with the DNR as a result of major storm-related power outages during 1999 (PSC Case No. 8826). Upon completion of the investigation and submission of recommendations to the PSC, the Tree Trimming Working Group evolved into the Maryland Electric Reliability Tree Trimming Council, which continues to meet quarterly and provides a forum for discussion and continued dialogue on tree trimming issues along utility rights-of-way.

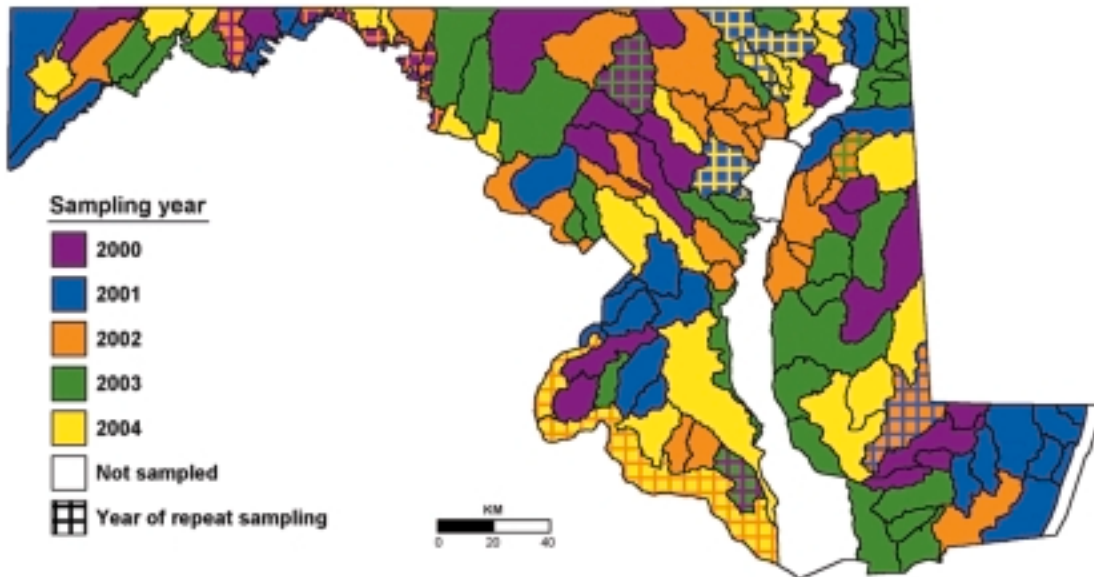
## Maryland Biological Stream Survey (MBSS)

PPRP has a long history of addressing the impacts of power plant operations on natural resources. One focus of ongoing research since the 1980s has been establishment of baseline measures of stream condition against which changes in response to regulatory measures can be evaluated. To address this need, DNR has designed and implemented the Maryland Biological Stream Survey (MBSS) to assess the biological status of Maryland's nontidal streams. The results of Round One of the MBSS (1995-1997) have gone a long way toward confirming the impact of acidic deposition on biota and to establishing a scientifically defensible baseline for future assessments. These results are also being used to support State water quality standards and as a model for stream monitoring by other jurisdictions.

**Figure 4-11**  
1995 - 1997 Maryland Biological Stream Survey Fish Index of Biotic Integrity Scores by Basin, as the Percentage of Stream Miles in each category (good, fair, poor, very poor)



**Figure 4-12**  
**Watershed Sampling Schedule for the 2000 - 2004 Maryland Biological Stream Survey**



The MBSS collects information on aquatic biota (including fish and benthic macro invertebrates), physical habitat, and water quality to assess the fishability and biological integrity of Maryland streams. Three characteristics of the Survey differentiate it from previous stream monitoring efforts in Maryland. Sampling is probability-based, allowing accurate and robust population estimates of variables such as abundances of particular species of fish and the number of stream miles with degraded habitat. The design also permits estimation of sampling variance, so that estimates of status can be made with quantifiable confidence. Second, MBSS monitoring and assessments focus on biological responses to stress. Metrics for characterizing pollutant stress and habitat condition are measured simultaneously to provide a context for interpreting biological response. Third, the scale of the Survey is basinwide and statewide, rather than local. However, MBSS data can be used to assess stream condition at a county level and even for some smaller watersheds.

Round One of the MBSS provided a comprehensive statewide assessment of the extent to which acidic deposition is affecting critical biological resources within streams of the state. Statewide, about 28 percent of stream miles were acidic or acid-sensitive. Acidic deposition was the predominant source of acidification in 18 percent of stream miles. Acid mine drainage (AMD), agriculture, and natural organic sources has contributed to acidification with substantial AMD effects occurring in western Maryland basins. The abundance and diversity of fish species decreased dramatically in acid-sensitive streams, with species composition shifting in favor of acid-tolerant species. In general, acid neutralizing capacity values for the 1995-1997 MBSS were slightly higher than those in the 1987 Maryland Synoptic Stream Chemistry Survey (MSSCS), indicating an improvement in acid-base chemistry of streams over time.

The survey uses the Index of Biotic Integrity (IBI) approach to characterize stream health. This approach uses information on water quality, physical habitat, land uses, and watershed area in interpreting biological data. In statewide and basin-specific assessments, the IBI was a useful tool for assessing the impacts of acidic deposition, particularly in the context of other cumulative impacts such as AMD, urban development, and physical habitat degradation. Fish and benthic macro invertebrate IBI ratings showed a marked decline in streams most susceptible to acidification, a pattern paralleled by other biological characteristics including fish species richness, abundance, and biomass.

The fish and benthic IBI results were used to quantify the extent and severity of stream degradation and identify associations with key stressors. Statewide, 29 percent of stream miles were rated as poor to very poor by the fish IBI. Perhaps more sensitive to degradation, the benthic IBI showed 51 percent of stream miles in poor to very poor condition. Both IBIs were significantly correlated with the recently developed Physical Habitat Index, confirming that habitat quality plays an important role in the health of fish and benthic macro invertebrate communities. Strong relationships were noted between urban land use and biotic integrity, highlighting the importance of landscape context in assessing multiple, cumulative impacts to streams. Figure 4-11 shows the MBSS for fish IBI scores by basin, as the percentage of stream miles in each category.

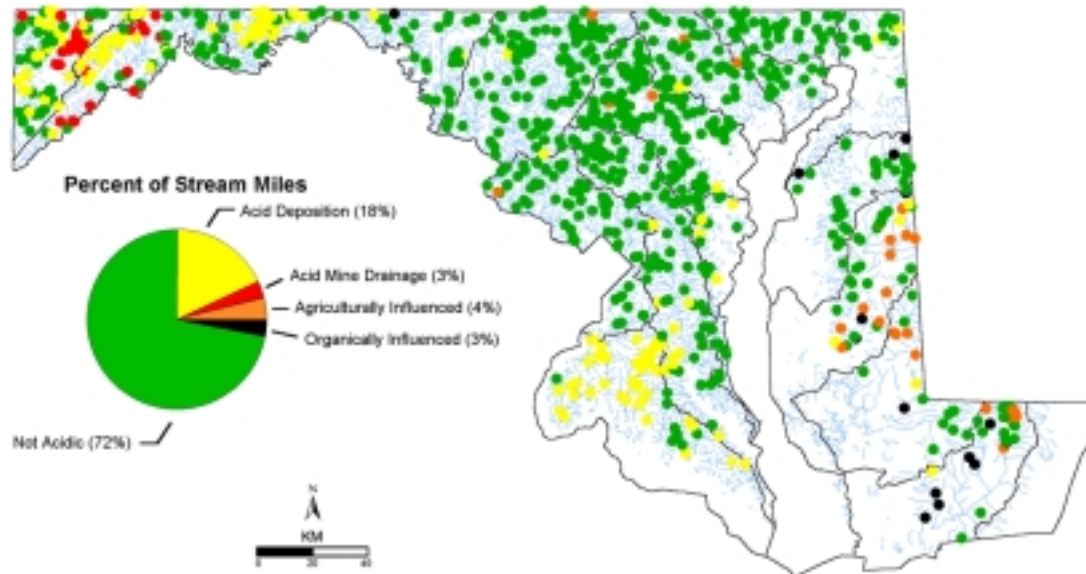
The MBSS provides a critical baseline for conducting future monitoring to address short-term and long-term trends. Already, the survey has shown that the extent of acid-sensitive streams in Maryland has declined slightly since the 1987 MSSCS. This result has important implications for assessing the effectiveness of further controls instituted as a result of the 1990 Amendments to the Clean Air Act. Future trends detection using the MBSS baseline monitoring data will likely prove invaluable for addressing continued population growth (supporting the Governor's Smart Growth initiative) and climate change.

Following the 1995-1997 MBSS, the survey is evolving as a long-term stream monitoring program expected to meet an even broader set of goals and objectives. While continuing to support the assessment of cumulative power plant impacts such as acidic deposition, the MBSS is now expected to be the central pillar of nontidal stream monitoring in the state. To meet emerging natural resource management needs, Round Two of the MBSS features an updated sample design focused on finer-scale watersheds (Maryland 8-digit watersheds) and a more detailed stream base map (1:100,000 scale). The second round of sampling began in Spring 2000 and will continue through 2004. Figure 4-12 shows the 2000 to 2004 watershed sampling schedule. Building on the success of the survey to date, Round Two will provide additional data for detecting trends, better characterizing existing and new stressors, and refining and further developing ecological indicators.

## *Deposition Impacts*

PPRP has conducted a substantial amount of research over the past 20 years on the generation and effects of acid deposition in Maryland. PPRP designed these projects to complement deposition research conducted at the national level by focusing on resources unique to Maryland or on topics that are not being studied elsewhere.

**Figure 4-13**  
**Locations of Acidic and Acid-sensitive Streams, by Dominant Sources of Acidification, 1995 - 1997,**  
**Maryland Biological Stream Survey**



Studies have shown that the deposition of acidified materials can affect aquatic and terrestrial resources. The magnitude and type of impact of the acid deposition, however, depends on a variety of complex factors. These factors include the amount of materials deposited, the relative ability of the water body or soils to buffer the effects of the acidity, the sensitivity of organisms to pH changes, and the types and amount of vegetation. The goal of much of Maryland's acid rain research is to generate information needed for effective management, including mitigation, of the acid deposition problem in Maryland.

The results of the 1995-1997 MBSS showed that acidification remains a significant issue affecting the State's stream resources. Figure 4-13 shows the locations of acidic and acid-sensitive streams, by dominant sources of acidification. Statewide, more than one-quarter of all stream miles were acidic or acid-sensitive. Consistent with earlier findings, deposition effects were most evident in western and southern Maryland. Although some improvement was suggested by comparisons with the 1987 Maryland Synoptic Stream Chemistry Survey, only continued monitoring will provide a clear picture of long-term trends in stream chemistry. Currently, however, effects on stream biota remain a concern.

Reductions in acidic deposition have the potential to improve the condition of Maryland surface waters, particularly in small streams most susceptible to acidification. The 1990 Clean Air Act Amendments (CAAA) introduced new controls on emissions of SO<sub>2</sub> and NO<sub>x</sub>, the primary precursors of acid deposition. Under Title IV of the 1990 CAAA, SO<sub>2</sub> emissions are to be reduced by 10 million tons per year from 1980 emissions. Implementation of Phase I began in 1995.

To evaluate changes in stream chemistry associated with Phase I implementation of the CAAA, PPRP recently conducted a study comparing deposition patterns determined from a regional wet deposition model to critical load estimates. Wet deposition of acidifying compounds to Maryland and the Chesapeake region for the periods before and after 1995 were compared. The deposition model incorporated precipitation chemistry data from National Atmospheric Deposition Program (NADP) monitoring stations, combined with regional climatological patterns. Critical loads — the rate of sulfur and nitrogen deposition that results in stream pH less than the critical pH values for target fish species — had been mapped in a previous PPRP study. Geographic overlays of wet deposition on the critical loads map suggested that critical loads continue to be exceeded in some areas of the state, despite 1995 reductions in sulfate deposition. MBSS stream chemistry results for 1995-1997 confirmed the persistence of low acid neutralizing capacity in these areas. Although Phase I results are encouraging, it is unlikely that full implementation of Title IV will eliminate acidification problems in Maryland streams.

Although acidic deposition is the most widely acknowledged form of atmospheric deposition, with well-known effects on lakes, streams, and forests, the effects of nutrients and toxic contaminant deposition have received added attention in recent years. Atmospheric contributions of nitrogen are recognized as a source of excessive nutrients entering the Chesapeake Bay. Nutrient deposition contributes to eutrophication, which in the Chesapeake Bay results in such adverse effects as reduced oxygen levels, nuisance algal blooms, dieback of submerged aquatic vegetation, and reduced populations of fish and shellfish. The Chesapeake Bay Program has determined that the loss of submerged aquatic vegetation as a result of over enrichment of nutrients is a principle stressor on the living resources in the Bay. Deposition of both trace elements (e.g., arsenic, cadmium, chromium, copper, mercury, molybdenum, nickel, lead, selenium, vanadium, and zinc) and organic contaminants can be directly toxic to organisms or pose health risks to humans and other organisms consuming contaminated individuals. For many aquatic ecosystems, atmospheric inputs are now the dominant source of mercury, either via direct input or runoff from the watershed receiving atmospherically deposited mercury. Bioaccumulation and biomagnification processes concentrate the amount of toxic substances in plants and animals. Mercury bioaccumulation in fish tissue is one example of direct concern to Maryland residents.

To investigate the impacts of toxic deposition on aquatic resources, PPRP has initiated several projects to improve understanding of the fate, transport, and transformation of trace elements in aquatic ecosystems. Analysis of biota and water chemistry will provide critical information on the ecological effects of deposition to the state's streams, reservoirs, and the Chesapeake Bay. Greater information is required on both the deposition of materials to aquatic ecosystems and their subsequent transfer through ecological systems and biota.

Nationwide, there is increased interest in mercury issues, particularly related to health hazards posed by the consumption of fish with elevated mercury levels. Based on a pilot study suggesting the presence of elevated mercury in some freshwater gamefish populations, PPRP is embarking on a new effort to evaluate concentrations of mercury in fish tissue, primarily in the state's largest

freshwater reservoirs. In partnership with Maryland Department of the Environment, PPRP will use results to evaluate whether fish consumption advisories might be warranted.

PPRP also continues to investigate processes and factors affecting mercury bioaccumulation. Specifically, PPRP has conducted studies using aquatic invertebrates as indicators of mercury and other trace element bioaccumulation in Western Maryland streams to improve the understanding of trace element uptake in aquatic food webs at different trophic levels and under different water chemistry regimes. Other ongoing investigations of mercury concentrations in stream fish include evaluating bioaccumulation in ecosystems with different acid neutralizing capacity and dissolved organic carbon levels. Also, in conjunction with precipitation sampling near the Dickerson power generation facility, PPRP is undertaking further investigations of mercury cycling within the freshwater ponds in the vicinity of the plant. The objective is to augment existing information on bioaccumulation processes by determining how mercury is partitioned among the water column, pond sediments, and aquatic biota

## SECTION HIGHLIGHTS

*Noise from power generation can be a significant issue for plant neighbors. Sound levels are made up of many components at different frequencies or pitch, and these levels steadily decrease with distance. PPRP evaluates noise data as part of plant licensing cases to predict potential impacts and to recommend mitigation if needed.*

## Noise Impacts

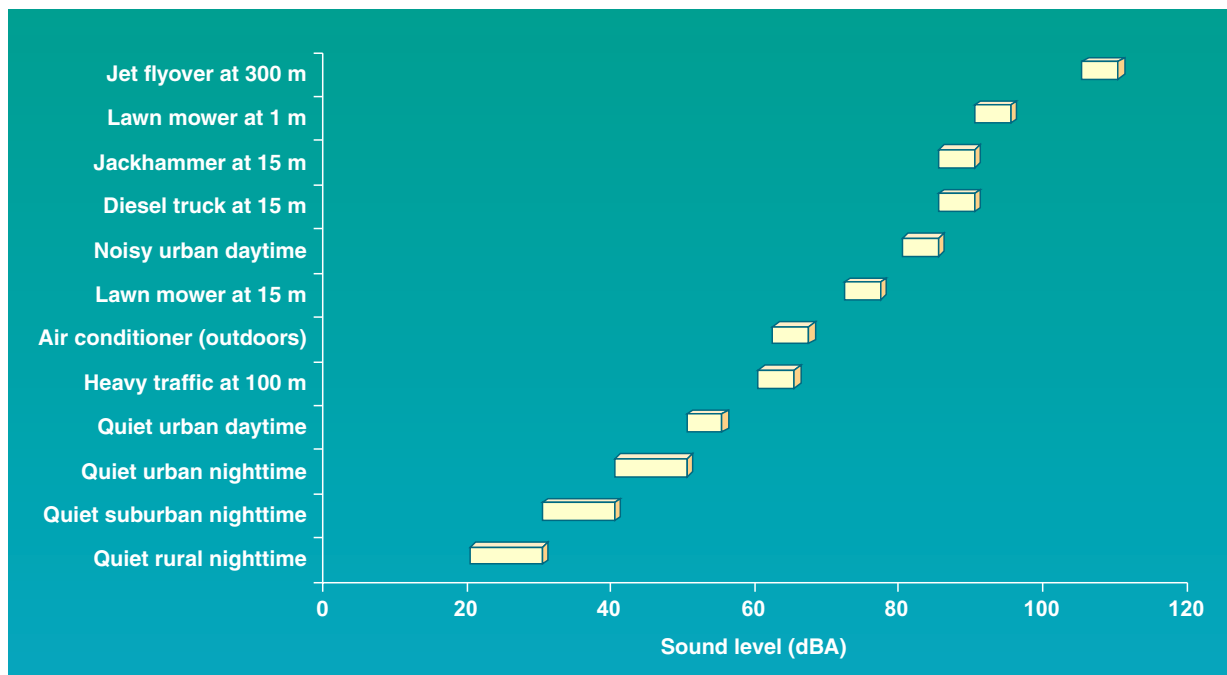
The noise created by power plants is unlike other environmental impacts in that it does not involve emissions of physical substances such as air pollutants or wastewater. Rather, noise consists of vibrations in the air that gradually decrease, or attenuate, the farther they travel. For people who live or work near a power plant, the noise impacts, along with visual and traffic impacts, can be the most significant type of effect caused by the facility.

Noise is made up of many components of different frequency (pitch) and loudness. The decibel (dB) is a measure of sound energy; one decibel is approximately the smallest change in sound intensity that can be detected by the human ear. A tenfold increase in the intensity of sound is expressed by an additional 10 units on the decibel scale, and is perceived subjectively as a doubling of the loudness. A 100-fold increase in sound intensity equates to an additional 20 units on the decibel scale, and sounds like a quadrupling of loudness.

The sensitivity of the human ear varies according to the frequency of sound; consequently, a weighted noise scale is used when discussing noise impacts. This A-weighted decibel (dBA) scale weights the various components of noise based on the response of the human ear. For example, the ear perceives middle frequencies better than low or high frequencies; therefore, noise composed predominantly of the middle frequencies is assigned a higher loudness value on the dBA scale.

The sound level measured at a particular location cannot be determined by directly adding all the individual noise sources. Rather, the total noise is primarily a result of the source of highest intensity. Two sources of 50 dBA each will together emit 53 dBA; a source of 65 dBA combined with a source of 85 dBA will result in a noise level of 85.1 dBA. As the intensity difference between two noise sources increases, the effects of the lower sound source becomes negligible.

## Typical Range of Common Sounds



Structures such as berms and walls may be constructed solely to provide noise control, and have been used in transportation applications for many years. Vegetative buffers may be used in conjunction with these structures for additional noise abatement. Sound waves decrease in strength as they travel, and each doubling of distance from a noise source results in a decrease of 6 dBA in the measured sound level.

In recent licensing cases where developers are constructing on smaller sites (relative to large utility power plant sites that were typically many hundreds of acres in size), noise impacts to surrounding communities have sometimes been quite controversial. PPRP uses data provided by the developer to conservatively estimate the sound levels that will be experienced once a proposed plant is operating. In the recently licensed Rock Springs power plant, noise levels were of particular concern because the predominantly rural setting has a low background noise level. The developer, ODEC/Reliant, agreed to incorporate additional noise reduction features at the facility, following negotiations with State agencies, local residents, and elected officials. The Rock Springs plant will have to meet a noise limit of 55 dBA at the nearest residential property boundary whenever it is operating, which is significantly quieter than the current State regulatory standard of 65 dBA for residential areas during daytime hours.

**SECTION HIGHLIGHTS**

*PPRP monitors the concentrations of radioactive elements released into the environment from Calvert Cliffs - Maryland's only nuclear power plant - and from Peach Bottom, which is located on the Susquehanna River just upstream from the Maryland-Pennsylvania border. These concentrations are very small compared to naturally occurring background radioactivity, and impacts from these releases are negligible.*

## Radiological Impacts

Production of nuclear power in the United States is licensed, monitored, and regulated by the U.S. Nuclear Regulatory Commission (NRC). Provisions in the operating licenses of each plant allow utilities to discharge low levels of radioactive material to the environment. The kind and quantity of releases are strictly regulated and must fall within limits defined in federal law. The NRC regulates releases from power plants according to the principle that the exposure of the environment and humans to radiation be kept “as low as reasonably achievable.”

Pathways of exposure to radioactive material in the environment are similar to those for other pollutants. An aqueous (water) pathway dose can be received internally or externally by ingesting contaminated water and seafood or by exposure to contaminated sediments and water. An atmospheric pathway dose can result from exposure to or inhalation of radioactive gas or airborne particles or ingestion of radionuclides deposited on or assimilated by terrestrial vegetation and animals.

Nuclear power plants are minor contributors to radiation exposure in the United States. As Figure 4-14 illustrates, natural radiation sources account for more than 80 percent of the average radiation dose to humans. Of the approximately 18 percent of the radiation dose arising from manmade sources, only 1 percent is attributed to commercial nuclear power production.

Figure 4-15 shows the locations of nuclear power plants in and near Maryland. Calvert Cliffs Nuclear Power Plant, in Calvert County, is the only nuclear station in the state. The next closest plant, Peach Bottom Atomic Power Station, is on the Susquehanna River just north of the Pennsylvania/Maryland border. These two facilities both release radionuclides into Maryland’s environment. PPRP, MDE, and the utility operators conduct environmental monitoring

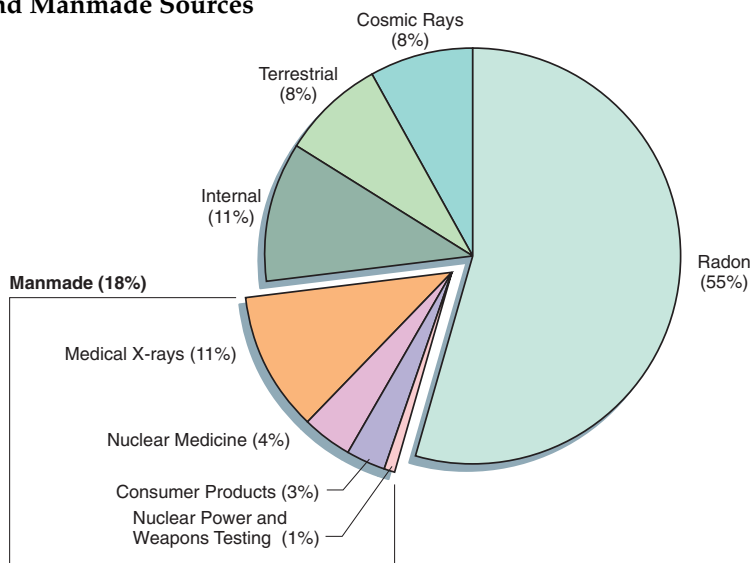
programs near both plants. These monitoring programs are used to assess the radiological effects on the environment attributable to each of the power plants.

## Calvert Cliffs Nuclear Power Plant

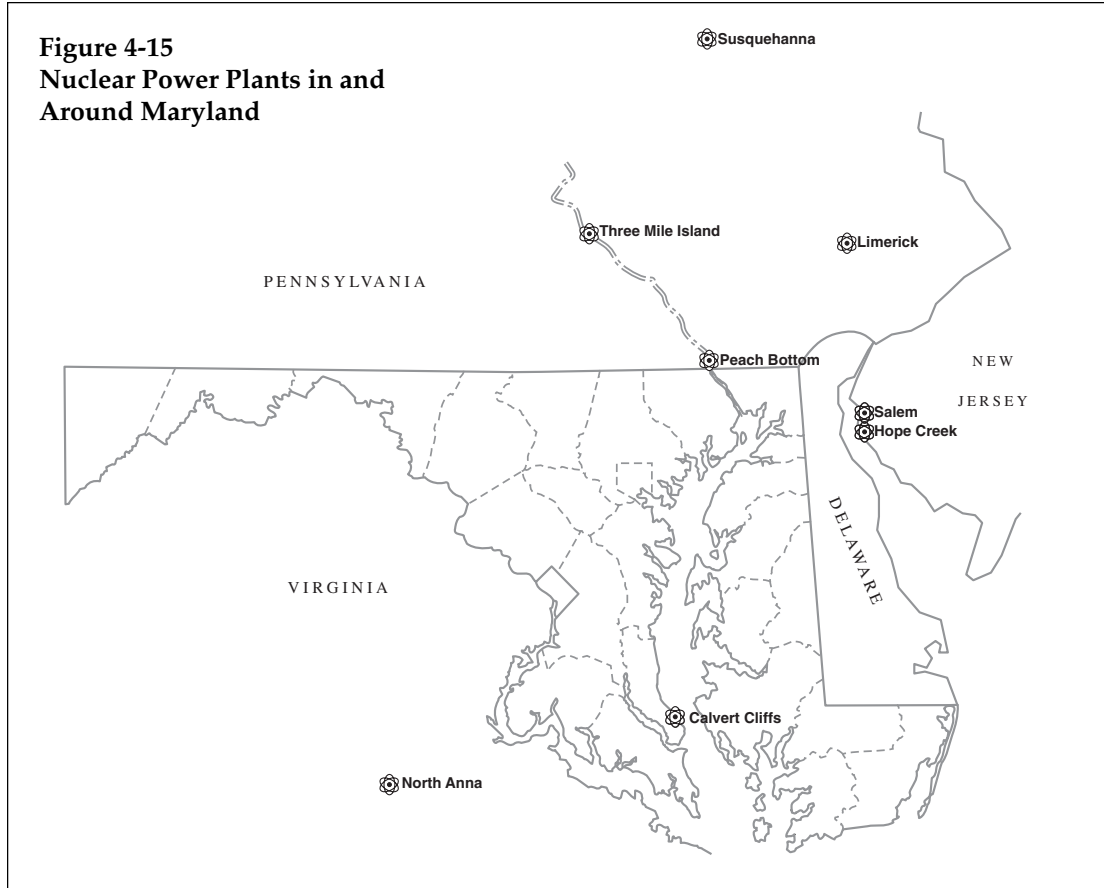
Constellation Nuclear owns and operates the Calvert Cliffs facility, on the western shoreline of the Chesapeake Bay. Each of its two units is a pressurized water reactor with a generating capacity of approximately 860 MW. The units began service in May 1975 and April 1977.

Calvert Cliffs routinely releases low-level gaseous, particulate, and liquid radioactive effluents into the atmo-

**Figure 4-14**  
**Estimated Effective Radiation Dose from Natural and Manmade Sources**



**Figure 4-15**  
**Nuclear Power Plants in and**  
**Around Maryland**



sphere and the Chesapeake Bay. The level of radioactivity of these effluents at any given time depends on many factors, such as plant operating conditions and conditions of the nuclear fuel. Since Calvert Cliffs has been in operation, releases of radioactivity to the environment have been well within the regulatory limits.

Radioactive noble gases, primarily xenon, krypton, and argon, constitute most of the radioactive material released to the atmosphere from Calvert Cliffs. Noble gases are chemically inert, are not readily incorporated into biological tissues, and are not bioconcentrated. They are readily dispersed in the atmosphere, and most have short half-lives decaying rapidly to stable forms. For these reasons, the noble gases do not represent a significant threat to human or ecological health. The most recently compiled results from environmental monitoring (for the years 1996 and 1997) indicate that releases of radioactivity to the atmosphere by the Calvert Cliffs plant were not detectable in air, precipitation, or vegetation.

In the plant's aqueous releases to the Chesapeake Bay, the environmentally significant radionuclides are primarily forms of radioactive iron, cobalt, and tin. These radionuclides are notable because Bay biota, such as oysters, accumulate them readily. They also can be trapped in sediments at the bottom of the Bay. Through the food chain, these radionuclides in sediments may ultimately contribute a radiation dose to human populations. However, the quantities of environmentally significant radionuclides released from Calvert Cliffs and subsequently detected in shellfish and Bay sediments were quite small (approx-

mately 1 percent of all radioactivity detected in sediments, which includes historic nuclear weapons testing fallout and naturally occurring radionuclides).

Bay oysters are ideal indicators of environmental radionuclide concentrations because they do not move and they readily ingest and concentrate metals. Oysters are commercially harvested near Calvert Cliffs, and they have the greatest potential for contributing to a human radiation dose through seafood consumption. PPRP routinely monitors the uptake of radionuclides in test oysters placed on platforms on the Bay floor, in the vicinity of the Calvert Cliffs discharge. The oysters are collected at scheduled time intervals and analyzed for radionuclide content in their tissues. Radiosilver continues to be the principal plant-related radionuclide accumulated by oysters; it has consistently been detected in test oysters as well as oysters on natural beds.

As part of the surveillance program, PPRP estimates doses of radiation to individuals consuming seafood. The doses are calculated based on maximum or worst-case estimates of the amount of plant-related radioactive materials potentially available. Results indicate that radiation doses attributable to operations at Calvert Cliffs are well below federally mandated limits.

Chesapeake Bay sediments are also useful indicators of environmental radionuclide concentrations because they serve as natural sinks for both stable and radioactive metals. PPRP collects sediment samples seasonally from eight transects extending bayward north and south of the Calvert Cliffs plant. Cobalt-60 was the plant-related radionuclide detected almost exclusively in Bay sediments during the 1996-1997 reporting period.

A comparison of radionuclide concentrations in environmental samples collected between 1996 and 1997 with levels detected since 1978 shows the following:

- *The levels of plant-related radionuclides detected during 1996 and 1997 are slightly less than the range of concentrations detected over the previous decade.*
- *Although radionuclide concentrations fluctuate seasonally and annually, no long-term accumulation of plant-related radioactivity in Bay aquatic life and sediments is evident.*
- *The radioactivity introduced into the environment by Calvert Cliffs is very small compared with background radioactivity from natural sources and weapons test fallout.*
- *Atmospheric and aqueous releases and radiation doses to humans are well within regulatory limits.*
- *Environmental, biological, and human health effects of releases of radioactivity from Calvert Cliffs are insignificant.*

## *Calvert Cliffs License Renewal*

The operating licenses for both units at Calvert Cliffs were renewed on March 23, 2000, after a nearly two-year process. The license renewal will allow the reactors to remain operational until 2034 and 2036, respectively. Constellation

decided to pursue relicensing and replacement of the steam generators following an eight-year evaluation of options for safely and competitively maximizing the life of Calvert Cliffs. The utility and NRC carried out the renewal process through a series of more than 30 public meetings, commission meetings, technical reviews, inspections, and document filings. The requested filings included the Generic Environmental Impact Statement (GEIS), Supplemental Environmental Impact Statement (SEIS), and Safety Evaluation Report.

The power generated at the plant makes up a large portion of the electricity used by Maryland residents — in 1996, Calvert Cliffs generated 27 percent of the power produced in the State of Maryland. During the same year, coal-fired generators produced about 62 percent of the power generated in Maryland.

Following the license renewal pioneering effort of Calvert Cliffs, about a dozen other nuclear power plants have filed for renewal or have publicly stated their intention to file for renewal.

## *Peach Bottom Atomic Power Station*

Peach Bottom Atomic Power Station (PBAPS), located on Conowingo Reservoir just north of the Pennsylvania-Maryland border, is owned and operated by Exelon, a company formed in 2000 with the merging of PECO Energy (the former operator of PBAPS) and Unicom. The plant's two operating units are boiling water reactors, each with a currently licensed capacity of approximately 1,150 MW, and have been in service since 1974. The NRC recently approved the transfer of the licenses for both units to Exelon Generation Co.

Exelon has notified the NRC that it intends to pursue license renewal for a 20-year term for both units at PBAPS and expects to formally submit an application in July 2001. PPRP has met with Exelon on numerous occasions to identify environmental issues of interest or concern to Maryland that should be addressed in the environmental review component of the license renewal application. As was the case with Calvert Cliffs, PPRP will coordinate the State's review of the PBAPS application upon its submittal to the NRC.

Like Calvert Cliffs, Peach Bottom routinely releases low-level gaseous, particulate, and liquid radioactive effluents into the atmosphere and the Susquehanna River. Since the plant has been in operation, all liquid and atmospheric releases of radioactivity have been well within regulatory limits.

Information from monitoring programs shows that in recent years radionuclides of xenon and krypton accounted for nearly all of the radioactivity released to the atmosphere by the plant. These particular radionuclides are chemically inert and, therefore, are of little environmental concern. Based on environmental monitoring from 1996 and 1997, no radioactivity attributable to atmospheric releases by Peach Bottom was detected in air samples collected from the plant site and distant locations.

Of the radionuclides released by Peach Bottom to the Susquehanna River in 1996 and 1997, 99 percent was tritium (a radioactive form of hydrogen), which is not bioaccumulated and is of limited environmental concern. Very small quantities of radioactive cobalt, zinc, and manganese accounted for most of the remaining radioactive material released in liquid effluent. These particular

radionuclides are environmentally significant because they can be readily accumulated by aquatic life such as mussels and finfish.

Finfish collected from the Conowingo Reservoir area contained both plant-related and fallout-related radionuclides. Peach Bottom plant-related radioactivity was also detected in sediments collected down-river of the plant, at slightly lower levels than in previous years. Concentrations of radiocobalt and radiocesium were highest in the Conowingo Reservoir area, as they have been in previous years. It is estimated that historically, less than 20 percent of the radioactivity released in Peach Bottom water discharge is found in sediments of the Conowingo Reservoir. The remaining radioactivity is transported downstream to the Chesapeake Bay.

Estimates of radiation doses to individuals consuming fish were calculated using the maximum plant-related radionuclide concentrations, similar to the studies at Calvert Cliffs; however, because the Susquehanna River is a source of drinking water, its ingestion, in addition to fish consumption, may potentially contribute to a human radiation dose. The annual total body doses associated with the consumption of finfish and drinking water are well below federal limits.

Comparing PPRP's radiological monitoring of Peach Bottom-related radioactivity of aquatic life and sediments collected from 1996 to 1997 with monitoring results since 1978 shows the following:

- *The low levels of plant-related radioactive material detected in aquatic life and sediments represent a small portion of the radioactive material in the Susquehanna River-Chesapeake Bay system compared with that from natural sources and weapons test fallout.*
- *No long-term accumulation of plant-related radioactive material in river biota is evident.*
- *Long-term operation of Peach Bottom Atomic Power Station has not caused significant accumulation of radioactive material within the Conowingo Reservoir.*
- *Atmospheric and aqueous releases and radiation doses to humans are well within regulatory limits.*
- *Environmental, biological, and human health effects of releases of radioactivity from Peach Bottom are insignificant.*