NATIONAL ENERGY TECHNOLOGY LABORATORY

Impacts of TMDLs on Coal-Fired Power Plants

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Disclaimer

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Existing Plants Program

National Energy Technology Laboratory

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Table of Contents

List of Tables

List of Tables (Cont.)

List of Figures

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Chapter 1 – Introduction

The Clean Water Act (CWA) includes as one of its goals restoration and maintenance of the chemical, physical, and biological integrity of the Nation's waters. The CWA established various programs to accomplish that goal. Among the programs is a requirement for states to establish water quality standards that will allow protection of the designated uses assigned to each water body. Once those standards are set, state agencies must sample the water bodies to determine if water quality requirements are being met. For those water bodies that are not achieving the desired water quality, the state agencies are expected to develop total maximum daily loads (TMDLs) that outline the maximum amount of each pollutant that can be discharged to the water body and still maintain acceptable water quality. The total load is then allocated to the existing point and nonpoint sources, with some allocation held in reserve as a margin of safety.

Many states have already developed and implemented TMDLs for individual water bodies or regional areas. New and revised TMDLs are anticipated, however, as federal and state regulators continue their examination of water quality across the United States and the need for new or revised standards.

1.1 Purpose

This report was funded by the U.S. Department of Energy's (DOE's) National Energy Technology Laboratory (NETL) Existing Plants Research Program, which has an energy-water research effort that focuses on water use at power plants. This study complements its overall research effort by evaluating water issues that could impact power plants.

One of the program missions of the DOE's NETL is to develop innovative environmental control technologies that will enable full use of the Nation's vast coal reserves, while at the same time allowing the current fleet of coal-fired power plants to comply with existing and emerging environmental regulations. Some of the parameters for which TMDLs are being developed are components in discharges from coal-fired power plants. If a state establishes a new or revised TMDL for one of these pollutants in a water body where a power plant is located, the next renewal of the power plant's National Pollution Discharge Elimination System (NPDES) permit is likely to include more restrictive limits. Power generators may need to modify existing operational and wastewater treatment technologies or employ new ones as TMDLs are revised or new ones are established. The extent to which coal-fired power plants may be impacted by revised and new TMDL development has not been well established.

NETL asked Argonne to evaluate how current and potential future TMDLs might influence coal-fired power plant operations and discharges. This information can be used to inform future technology research funded by NETL. The scope of investigation was limited to several eastern U.S. river basins rather than providing a detailed national perspective.

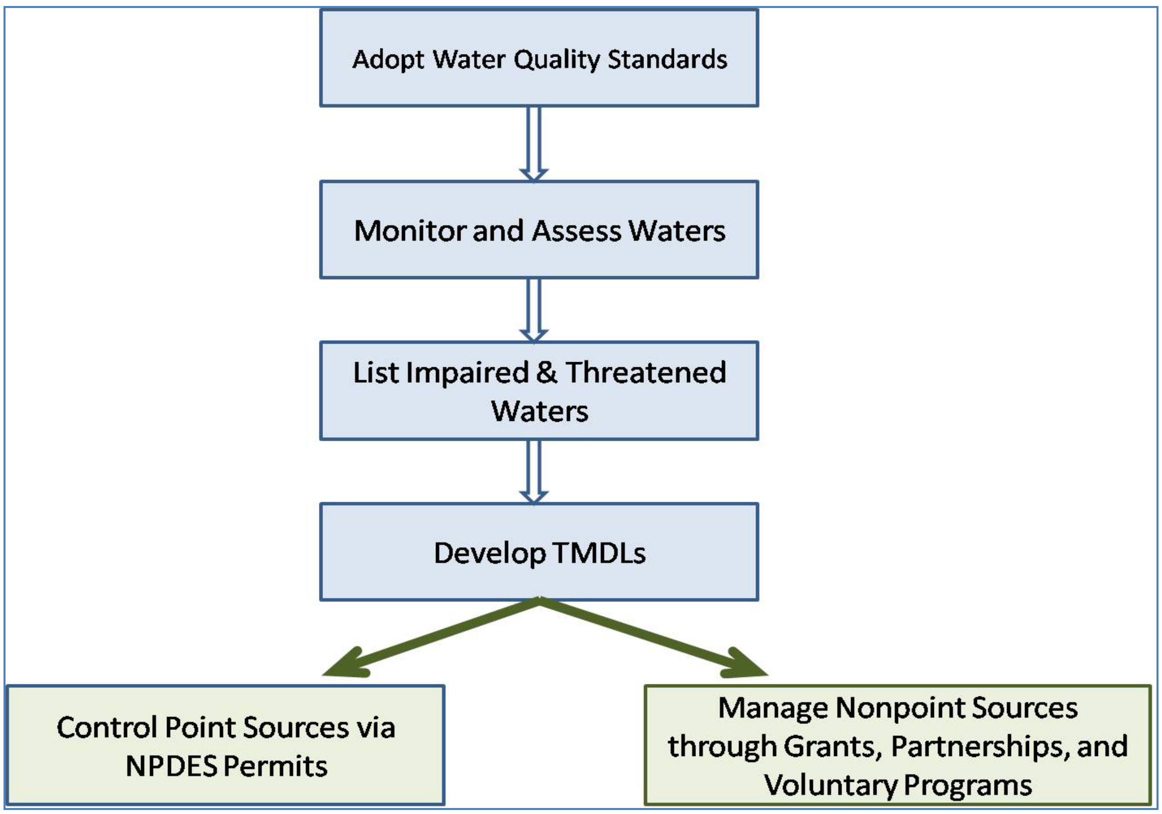
1.2 Report Outline

Chapter 2 describes water quality standards, TMDLs, NPDES permits, and other related water quality regulatory topics. Chapter 3 identifies the three river basins selected for study, why they were chosen, the coal-fired power plants located within the basins, and the types of TMDLs already in place in those basins. Chapter 4 discusses power plant operations and the pollutants involved. Chapter 5 discusses how power plants might become restricted by future TMDLs.

Chapter 2 – Legal Requirements Associated with TMDLs

This chapter describes the federal statutory and regulatory provisions that embody the CWA's water quality-based approach to protecting water. Figure 2-1 shows the steps in the water quality-based approach. First, states must adopt water quality standards for different pollutants or parameters. Second, the states must monitor water quality in the water bodies to determine whether the water quality standards are met. In the third step, the states must compile lists that designate impaired or threatened water quality for those water bodies that do not meet the water quality standards. In the fourth step, the states must develop separate TMDLs for each parameter for which the standards are not being met. In a final step or series of steps, the provisions of the TMDLs are implemented for point sources through NPDES permits, while the TMDL provisions are implemented for nonpoint sources through grants, partnerships, and voluntary programs.

Figure 2-1. The CWA's Water Quality-Based Approach



Source: Based on U.S. Environmental Protection Agency figure at http://www.epa.gov/owow/tmdl/intro.html. (Accessed December 8, 2009.)

The federal requirements for each of these steps are described in the following sections. State requirements should be similar to the federal requirements, but may show some differences. Much has been written on each of these steps. This report provides information at a summary level only. Readers desiring more detail can visit the U.S. Environmental Protection Agency's (EPA's) Office of Water website[1] for more discussion and access to numerous EPA documents.

2.1 Water Quality Standards

Water quality standards consist of three components:

- A description of the designated uses of the water body (e.g., recreation, water supply, aquatic life, cold water fisheries, agriculture).
- Water quality criteria for each parameter that will protect the designated uses. These may be expressed as numeric pollutant concentrations (e.g., maximum concentration of 0.5 mg/L) or as narrative requirements (e.g., shall not produce taste or odor, or change the existing color to produce objectionable color for aesthetic purposes).
- An antidegradation policy that establishes policies for maintaining and protecting existing uses and high quality waters.

In addition to those three components, states typically will develop other general policies that address implementation issues (e.g., what flow values should be used, variances, mixing zones).

2.1.1 CWA Requirements

CWA Section 303(c) requires states to review their water quality standards at least every three years. If necessary, existing standards should be modified or new standards adopted during these reviews. EPA must approve any proposed changes to the state water quality standards. If EPA does not find the proposed state standard to be consistent with the CWA or if EPA believes additional or stricter standards are needed, EPA must propose alternate water quality standards for that state.

2.1.2 EPA Regulations

EPA regulations covering water quality standards are published at Title 40, "Protection of the Environment," of the *Code of Federal Regulations*, Part 131 (40 CFR Part 131).[2] The regulations follow the CWA requirements, but generally provide more clarification, details, and instructions.

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[1] The URL is http://www.epa.gov/water. (Accessed December 8, 2009.)

[2] This is the common way to express regulatory citations. Often additional letters and numbers follow the part number to indicate individual subparts, sections, or paragraphs.

Within Subpart A:

- 131.4 clarifies that states have the lead authority to review, establish, and revise water quality standards.
- 131.5 outlines EPA's role in reviewing state standards and proposing alternate standards, where necessary.
- 131.6 lists the elements that must be included in the state water quality standards.

Subpart B lays out the requirements for establishing standards:

- 131.10 describes how states should designate water body uses. States must consider the standards established for any downstream waters.
- 131.11(a) includes instructions for setting criteria. States must adopt those water quality criteria that protect the designated use. Such criteria must be based on sound scientific rationale and must contain sufficient parameters or constituents to protect the designated use. For waters with multiple use designations, the criteria shall support the most sensitive use.
- 131.11(b) directs states to establish numerical criteria values that are based on EPA-derived water quality criteria[3] either directly or as modified for site-specific use. States may also establish narrative criteria or criteria based upon biomonitoring methods where numerical criteria cannot be established or to supplement numerical criteria.
- 131.12 requires states to develop an antidegradation plan that maintains and protects existing water quality. Further, when existing water quality exceeds the minimum needed to support the basic uses, the plan should protect and maintain the higher level of water quality, except under limited circumstances outlined in the rule.
- 131.13 provides authority to states to develop policies affecting implementation, such as mixing zones and low-flow values, to use when assessing compliance with water quality standards.

Subpart C describes the responsibilities the states have in establishing, reviewing, and updating standards:

- 131.20 directs states to hold public hearings at least every three years to review existing water quality standards and consider development of new standards. States must submit the results of the reviews to EPA, including the scientific rationale behind any revised or new standards.
- 131.21 specifies that EPA must consider the state reviews and determine whether the proposed actions are appropriate. EPA can approve or disapprove the state submittals.

[3] EPA has published water quality criteria for many parameters. The list of EPA's criteria can be viewed at http://www.epa.gov/waterscience/criteria/wqctable/index.html. (Accessed December 9, 2009.) States rely heavily on the EPA criteria when setting numerical state criteria.

- 131.22 instructs EPA to develop water quality standards in cases where EPA has disapproved state proposals and the state does not resubmit an acceptable alternative. EPA standards derived in this manner become enforceable standards for waters in the involved state.

Subpart D lists the EPA-derived criteria described in 40 CFR 131.22 for several states, Puerto Rico, and an Indian reservation.

2.2 Water Body Lists

In the second step of the water quality process, states agencies must monitor and assess the quality of their water bodies. Three different parts of the CWA direct states to evaluate water quality. Section 2.2.1 describes the two sets of CWA requirements. Section 2.2.2 expands the discussion to include the regulatory requirements.

2.2.1 CWA Requirements

Section 305(b) requires states to submit a report to EPA every two years that:

- Describes the water quality of all navigable water bodies in the state and the extent to which the quality of waters provides for the protection and propagation of a balanced population of shellfish, fish, and wildlife and allows recreational activities in and on the water.
- Provides an estimate of the extent to which CWA control programs have improved water quality or will improve water quality and recommendations for future actions necessary and identifications of waters needing action.
- Provides an estimate of the environmental, economic, and social costs and benefits needed to achieve the objectives of the CWA and an estimate of the date of such achievement.
- Provides a description of the nature and extent of nonpoint source pollution and recommendations of programs needed to control each category of nonpoint sources, including an estimate of implementation costs.

Section 303(d) specifies that states must identify any water bodies that do not currently meet water quality standards. States must also identify water bodies that because of thermal discharges do not provide protection and propagation of a balanced indigenous population of shellfish, fish, and wildlife. States must also establish a priority ranking for these water bodies, considering the severity of the contamination and the designated uses of the water bodies. The resulting lists must be submitted to EPA for review.

Section 314(a)(1) requires states to submit to EPA every two years a report on the quality of all publicly owned lakes. The report must include, among other features, an assessment of the status and trends of lake water quality and a list of the lakes that are not meeting water quality standards. Section 314(a)(2) directs states to include the required lake information as part of the 305(b) report.

2.2.2 EPA Regulations

As noted in the previous section, three different portions of the CWA direct states to assess water quality within their boundaries. Although the assessments overlap somewhat, they have different focuses. EPA promulgated separate regulations to govern the assessment of water quality. Those are described below.

EPA's regulations covering 305(b) water quality assessments are published at 40 CFR 130.8. They closely follow the CWA instructions, but include an additional provision:

- 130.8(b)(5) directs states to include an assessment of the water quality of all publicly owned lakes, including the status and trends of such water quality as specified in CWA Section 314(a)(1).

EPA's regulations covering the 303(d) lists are published at 40 CFR 130.7(b) and (d). 130.7(b) gives directions on what must be included in the submittal.

- A list of water quality-limited (impaired and threatened) waters still requiring TMDL(s), pollutants causing the impairment, and a priority ranking for TMDL development (including waters targeted for TMDL development within the next two years).[4]
- A description of the methodology used to develop the list.
- A description of the data and information used to identify waters, including a description of the existing and readily available data and information used.
- A rationale for any decision to not use existing and readily available data and information.
- Any other reasonable information requested by EPA, such as demonstrating good cause for not including a water body or water bodies on the list.

130.7(d) requires states to submit the lists every two years. EPA must review and approve or disapprove the submittal. If EPA disapproves, it must identify those water bodies that are not meeting water quality standards and send the list to the states following public notice.

[4] The list should also include water bodies for which controls on thermal discharges under Section 301 or state or local requirements are not stringent enough to assure protection and propagation of a balanced indigenous population of shellfish, fish, and wildlife.

2.2.3 Additional EPA Guidance

EPA's Office of Water issued guidance to the states to combine the information required for both the 305(b) and 303(d) assessments into a single Integrated Report. An Integrated Report is a biennial state submittal that includes the state's findings on the status of all of its assessed waters, a listing of its impaired waters and the causes of impairment, and the status of actions being taken to restore impaired waters. EPA first issued guidance to the states in 2001, encouraging them to integrate their water quality assessment information into one report. Before the issuance of this guidance, these were separate state 305(b) and 303(d) reports, and in many cases the findings and assessment data in them did not agree. EPA has issued additional guidance on Integrated Reporting in subsequent years.[5] The most current detailed guidance was released by EPA for preparation of the 2006 Integrated Report (EPA 2005).

EPA's water quality assessment website[6] suggests the following interpretations:

- Waters rated by the states as "good" fully support all of their designated uses.
- Waters rated by the states as "threatened" currently support all of their designated uses, but one or more of those uses may become impaired in the future (e.g., water quality may be exhibiting a deteriorating trend) if pollution control actions are not taken.
- Waters rated as "impaired" by the states cannot support one or more of their designated uses.

EPA (2005) recommends that states use the following five reporting categories to classify segments[7] as meeting or not meeting applicable water quality standards:

- Category 1: All designated uses are supported; no use is threatened.
- Category 2: Available data and/or information indicate that some, but not all, of the designated uses are supported.
- Category 3: There is insufficient available data and/or information to make a use support determination.
- Category 4: Available data and/or information indicate that at least one designated use is not being supported or is threatened, but a TMDL is not needed. Within Category 4, EPA offers several options:
    - 4A applies when a TMDL has already been completed,
    - 4B applies when some alternative to a TMDL can be used, and
    - 4C applies when the designated use is not being met, but the cause is not related to pollutant concentrations.

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[5] Guidance relating to Integrated Reports and TMDLs can be found at http://www.epa.gov/owow/tmdl/guidance.html. (Accessed December 9, 2009.)
[6] The URL is http://www.epa.gov/waters/ir/attains_q_and_a.html#11. (Accessed December 9, 2009.)
[7] The term "segment" is used interchangeably with "water body" at various places in this report.

- Category 5: Available data and/or information indicate that at least one designated use is not being supported or is threatened, and a TMDL (or revised TMDL) is needed.

2.3 TMDLs

Following assessment of water bodies and identification of the impaired segments, states are expected to develop TMDLs that will establish a numerical target for improving water quality. A TMDL is specific to a water body segment and a pollutant. Therefore, if one segment fails to meet water quality standards for five pollutants and an adjacent segment fails to meet standards for a single pollutant, a total of six separate TMDLs would need to be prepared.

The steps in developing a TMDL include:

- *Selection of the pollutant(s)*. The assessment of water quality should identify those pollutants that are causing water quality impairment.
- Estimation of the water body's assimilative or loading capacity. This is typically accomplished by some type of modeling work, ranging from simple mass balance calculations to complex water quality simulations. The degree of analysis varies based on a variety of factors including the size and type of water body, the complexity and variability of flow conditions, and the chemical reactions involving the pollutant causing the impairment.
- *Estimation of the pollutant loading from all sources to the water body*. Point source loading can be identified and estimated through two EPA databases related to the NPDES program. The older system, still used by many states, is called the Permit Compliance System (PCS). Nearly half of the states have shifted to a newer and more user-friendly system called Enforcement and Compliance History Online (ECHO). Access to PCS and ECHO is available through the same portal.[8] Nonpoint source loading estimates are far more difficult to develop due to the lack of regular nonpoint source monitoring in most locations. Often nonpoint sources for a particular water body must be extrapolated from studies over larger geographic regions or from areas outside of the immediate water body.
- *Analysis of current pollutant load and determination of needed reductions to meet assimilative capacity*. Once the safe target load is estimated and compared to the current level of discharge, the agency must determine how much reduction is required to assure achievement of water quality standards. The agency takes background sources into account, allows for a margin of safety, and then determines the percentages of the load that will be allocated to the point sources and nonpoint sources.
- *Allocation of the allowable pollutant load by assigning specific numerical shares or allowances to each of the identified contributing sources*. Allocations to point sources are made through waste load allocations (WLAs). Allocations to nonpoint sources are

[8] The URL is http://www.epa-echo.gov/echo/compliance_report_water.html. (Accessed December 9, 2009.)

made through load allocations (LAs). EPA has published various reports and guidance that explain how WLAs and LAs can be calculated.[9] Although not a recent report, EPA (1991) is still cited by other current EPA documents as a good reference for WLAs and LAs.

2.3.1 CWA Requirements

Section 303(d)(1)(C) of the CWA requires state agencies to develop TMDLs on a pollutant-by-pollutant basis where designated stream uses are not being met. Each load should be established at a level necessary to implement the applicable water quality standards with seasonal variations and a margin of safety that takes into account any lack of knowledge concerning the relationship between effluent limitations and water quality.

Section 303(d)(1)(D) of the CWA requires state agencies to develop total maximum daily thermal loads (TMDTLs) for any water bodies that are not achieving their designated uses as a result of thermal discharges. Although these are not specifically TMDLs, they are closely related. The TMDTLs are mentioned here, given that the focus of this report is the effect of TMDLs on coal-fired power plants, many of which emit heated water (used for cooling) into the water body.

Section 303(d)(2) requires states to submit TMDLs to EPA for review. EPA must approve or disapprove the TMDLs. If EPA disapproves any TMDL, it must develop an alternate TMDL.

2.3.2 EPA Regulations

EPA's regulations covering TMDLs are published at 40 CFR 130.7(c):

- For each of the water quality-limited segments identified in the lists described in Section 2.2 above, states must establish TMDLs with values sufficient to attain and maintain the standards. The TMDLs should consider seasonal variations and include a margin of safety. Determinations of TMDLs shall take into account the critical conditions for stream flow, loading, and water quality parameters, as well as any lack of knowledge concerning the relationship between effluent limitations and water quality.
- TMDLs may be established using a pollutant-by-pollutant or biomonitoring approach. In many cases both techniques may be needed. Site-specific information should be used wherever possible.
- TMDLs shall be established for all pollutants preventing or expected to prevent attainment of water quality standards.

[9] EPA publications relating to water quality modeling and TMDL guidance are listed at http://www.epa.gov/waterscience/models/library/. (Accessed December 10, 2009.)

- States must also develop TMDTLs for those water bodies that are not able to assure protection and propagation of a balanced indigenous population of shellfish, fish, and wildlife. The TMDTLs should take into account the normal water temperatures, flow rates, seasonal variations, existing sources of heat input, and the dissipative capacity of the identified waters or portions thereof. Such estimates shall include a calculation of the maximum heat input that can be made into each portion, and shall also include a margin of safety.

130.7(d) requires states to submit TMDLs, WLAs, and LAs to EPA for review and approval. Schedules for submission of TMDLs are determined by EPA and each state. EPA must review and approve or disapprove the submittal. If EPA disapproves, it must establish alternate TMDLs and send them to the states following public notice.

2.3.3 Additional EPA Guidance

Throughout the 1970s and 1980s, little work was done to develop and implement TMDLs. During the late 1990s, activists sued EPA and states for not moving faster on TMDL development.

EPA provides extensive informational resources on its Impaired Waters and TMDL website.[10] Some of the key features on the website are:

- A national database of impaired water bodies and existing TMDLs. They can be sorted by state or by pollutant.
- Access to TMDL laws, regulations, and guidance documents.
- Other technical documents and resources.
- Example TMDLs for different pollutants.
- Discussion of evolving TMDL issues.

2.3.4 Other Informational Resources

Many other organizations have produced references and reports relating to TMDLs. Of particular relevance to this project is the body of work developed by the Electric Power Research Institute (EPRI). EPRI funded many reports dealing with different aspects of TMDLs. The titles can be found by searching for "TMDL" on EPRI's website.[11] Many of these are available only to EPRI members or for purchase. Other reports are publicly available for free downloading. Several of the publicly available reports are referenced here (EPRI 1998, EPRI 2001, EPRI 2002, EPRI 2006a, EPRI 2006b).

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[10] The URL is http://www.epa.gov/owow/tmdl/. (Accessed December 10, 2009.)
[11] The URL is http://my.epri.com/portal/server.pt?. (Accessed March 29, 2010.)

2.4 Implementation of TMDL

WLAs for point sources can be implemented through the NPDES program. Implementation of LAs is more challenging, because there is no strong CWA mechanism to force nonpoint source controls.

2.4.1 CWA Requirements

Section 402 of the CWA establishes the NPDES program. The details of the NPDES program are beyond the scope of this report. A few highlights are presented below:

- An NPDES permit is required for any point source discharge of pollutants to navigable waters.
- States wanting to administer the NPDES program can petition EPA for delegation of the program. If a state can demonstrate that it has a suitable legal framework and authority, the program can be delegated.
- NPDES permits must reflect the stricter of technology-based limits or water quality-based limits. The TMDL WLAs are considered to be water quality-based limits.
- Stormwater discharges from municipal sewers and industrial sites are subject to NPDES permits.

Section 319 of the CWA requires states to develop nonpoint source management programs. These are generally voluntary programs that are not directly enforceable. Under Section 319, states can receive grant money to support a wide variety of activities including technical assistance, financial assistance, education, training, technology transfer, demonstration projects, and monitoring to assess the success of specific nonpoint source implementation projects.

2.4.2 EPA Regulations

EPA's NPDES regulations are lengthy and span several CFR parts. The main parts are listed below:

- Part 122 provides instructions and guidelines for all phases of the NPDES program, including applications, types of permits, permit conditions, monitoring and reporting, duration of permits, and modification of permits.
- Part 123 outlines the procedures EPA uses to review and authorize state delegation of NPDES authority.
- Part 124 contains the requirements for decision making in several EPA programs. Subpart A covers general requirements, and Subpart D covers NPDES-specific conditions.

- Part 125 provides the criteria and standards to be used to establish technology-based permit limits and to approve several types of NPDES permit variances.
- Parts 405-471 include the effluent limitation guidelines for many industry subcategories.

EPA has not adopted formal regulations for administering the nonpoint source program.

2.4.3 Additional EPA Guidance

The NPDES program is one of the flagship CWA programs. Consequently, EPA has extensive resources and guidance available through its website.[12] The NPDES home page has many links to other web pages and to documents available for downloading.

In part because of the lack of formal nonpoint source regulations, EPA provides a great deal of information relating to nonpoint source management programs on its website.[13] The nonpoint source home page has many links to other web pages and to documents available for downloading.

Those Web pages referred to above cover most contributors to nonpoint source pollution. However, air deposition, either onto land surfaces within a watershed or directly onto the surface of a water body, is not included there. EPA has a separate Web page[14] that provides information resources relating to air deposition.

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[12] The URL is http://cfpub.epa.gov/npdes/. (Accessed December 11, 2009.)
[13] The URL is http://www.epa.gov/owow/nps/. (Accessed December 11, 2009.)
[14] The URL is http://www.epa.gov/owow/airdeposition/index.html. (Accessed December 11, 2009.)

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Chapter 3 – River Systems Selected for Analysis

3.1 Selection Criteria and Process

In the project plan, Argonne agreed to evaluate "several eastern U.S. river basins." In order to choose the river basins that would be included, Argonne considered several decision criteria:

- The rivers should be located in eastern states.
- The watersheds surrounding the river should be home to at least several coal-fired power plants.
- Ideally the river systems should include different types of water bodies flowing through different types of terrain.

Argonne began by examining state energy profiles prepared by DOE's Energy Information Administration (EIA) for the eastern states. Maps of each state, showing the location of power plants of different fuel types, can be viewed at the EIA website.[15] As an example, Figure 3-1 shows the EIA energy map for Pennsylvania. The coal-fired power plants are indicated by black triangles. Although not available in the static image used for Figure 3-1, the original maps on the EIA website allow the user to move the cursor over each symbol to learn the identity of the facility and the plant output in megawatts (MW).

The location of the plants was then compared to a second set of state maps that show the major water bodies in each state. These maps were viewed or downloaded at the Geology.com website.[16] Because of copyright restrictions, the actual map image is not shown here.

Following this review, clusters of coal-fired plants were found along a few river systems. Argonne found five river systems that met the criteria listed above. We selected three of the five for detailed evaluation.

As a southern river, we chose the Roanoke River, its tributaries, and the impoundments/lakes located within the watershed. The Roanoke River flows through Virginia and North Carolina before entering the Albemarle Sound in North Carolina.

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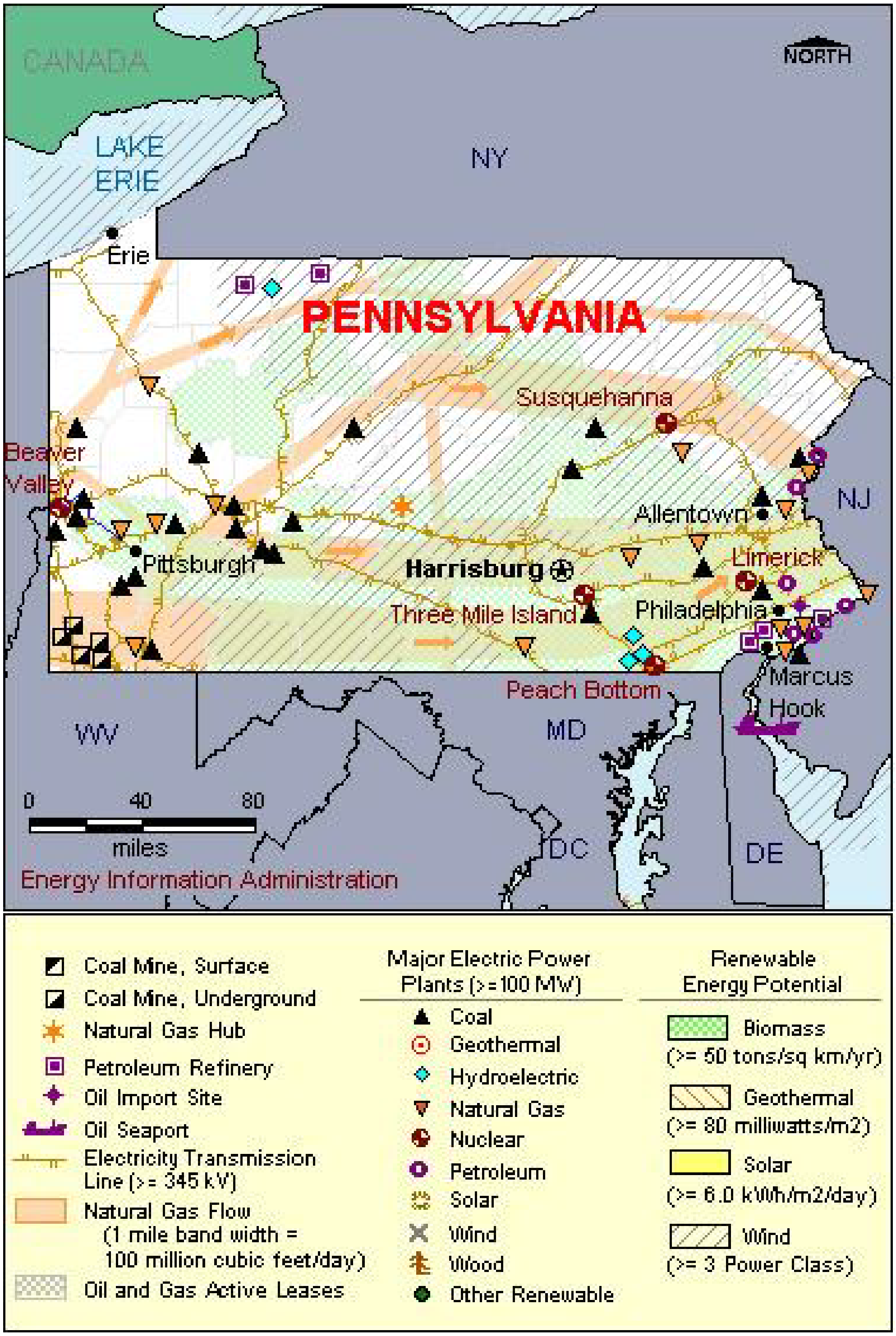
[15] The URL is http://tonto.eia.doe.gov/state/index.cfm. (Accessed December 11, 2009.)

[16] The URL for the Pennsylvania series of maps, including the rivers map is http://geology.com/state-map/pennsylvania.shtml. (Accessed December 11, 2009.) Links to the other states are provided on the margin of that Web page.

Figure 3-1. Energy Map for Pennsylvania



Source: EIA website at http://tonto.eia.doe.gov/state/state_energy_profiles.cfm?sid=PA. (Accessed March 29, 2010.)

The Ohio River is home to numerous coal-fired power plants. However, the Ohio River primarily flows through Midwestern states rather than eastern states. The Ohio River is created in Pittsburgh at the confluence of two smaller river systems – the Allegheny River to the north and the Monongahela River to the south. Both of these rivers have coal-fired power plants within their watersheds. We selected the Monongahela River system because it is home to coal-fired power plants in both Pennsylvania and West Virginia. Selection of the Monongahela will lead to examination of TMDLs and policies in both states.

For the third river system, Argonne looked at two large river systems flowing through Pennsylvania and adjoining states. The Susquehanna River originates in New York and flows southward through eastern and central Pennsylvania. It enters Maryland shortly before becoming the largest source water of the Chesapeake Bay. The Delaware River also originates in New York. It flows southward, forming the boundary between Pennsylvania and New Jersey. Further downstream, it broadens into an estuary forming the boundary between Delaware and New Jersey. It ultimately becomes the primary source water for Delaware Bay.

Although both river systems were home to several coal-fired power plants, we chose the Susquehanna River because of its relationship with the Chesapeake Bay, a hotbed of TMDL interest.

The following sections provide more detail on the three selected river systems.

3.2 Roanoke River System

The Roanoke River flows through large portions of southern Virginia and northern North Carolina. Figure 3-2 shows the entire watershed in pink color.

The following description of the basin is taken from the website of the Roanoke River Basin Association.[17]

> "The Roanoke River Basin extends 9,580 square miles and contains more than 400 miles of rivers, stretching from the foothills of the Blue Ridge Mountains in Virginia in an east-southeast direction to the Albemarle Sound near Plymouth, North Carolina. It includes the Roanoke, Dan, Smith, Staunton, Banister, Hyco, and Cashie Rivers and numerous other rivers and streams.
>
> The basin includes municipalities such as Danville, Martinsville, Bassett, Moneta, Rocky Mount, Brookneal, Altavista, Lawrenceville, Chatham, Roanoke, Salem, Halifax, South Boston, and Clarksville in Virginia and Eden, Mayodan, Reidsville, Yanceyville, Roxboro, Henderson, Warrenton, Gaston, Garysburg, Littleton, Roanoke Rapids,

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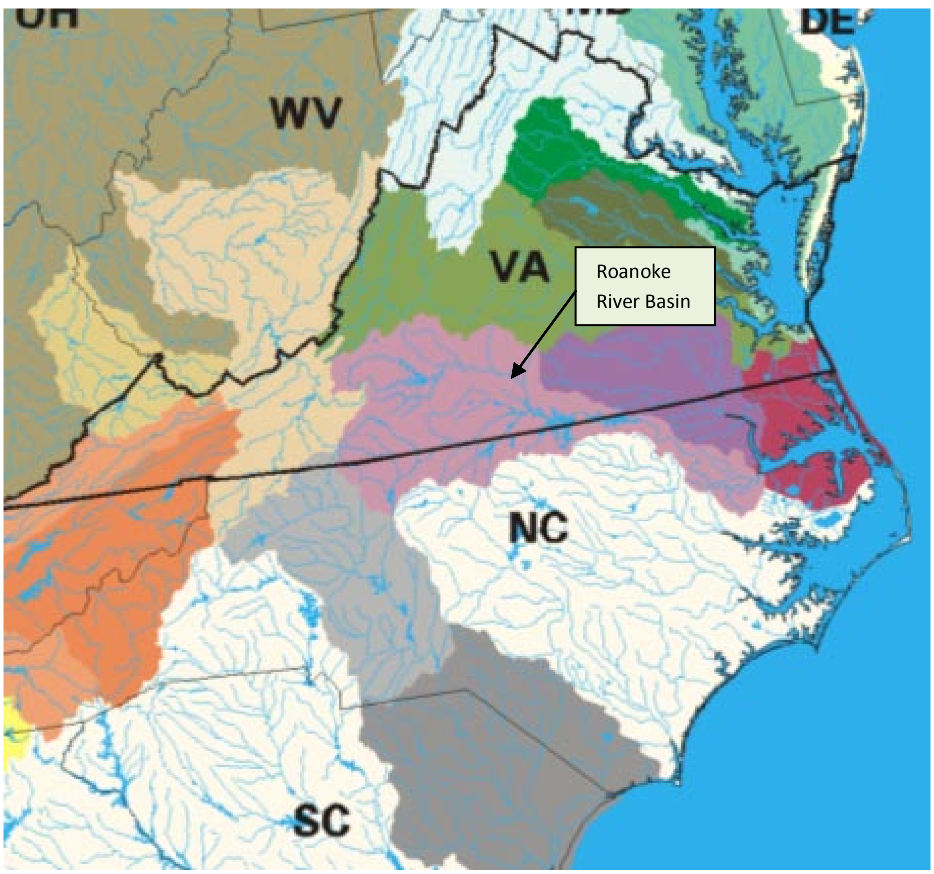
[17] The URL is http://www.rrba.org/. (Accessed December 14, 2009.)

Weldon, Jackson, Rich Square, Scotland Neck, Hamilton, Jamesville, Williamston, Windsor, and Plymouth in North Carolina.

The Roanoke River Basin includes several dams, including: Kerr Dam, Hyco Dam, Mayo Dam, Gaston Dam, Roanoke Rapids Dam, Smith Mountain Lake Dam, Leesville Dam, and Philpott Dam and several other impoundments of water. Kerr Dam Reservoir, constructed in the early 1950s for flood control and hydroelectric power generation, is the largest dam in the Roanoke River Basin system. It, along with upstream Philpott Dam, is operated by the U.S. Army Corps of Engineers (USACE). Hyco Dam and Reservoir is a Carolina Power & Light project. Smith Mountain and Leesville Dams and Reservoirs are operated by American Electric Power Company. Lake Gaston and Roanoke Rapids Dams and Reservoirs are operated by Virginia Electric Power Company. The USACE's operations at Kerr Dam and Reservoir and Dominion's operations at Gaston/Roanoke Rapids Dams and Reservoirs are closely coordinated. The USACE also coordinates its operations at the Kerr and Philpott projects."

Figure 3-2. Map Showing Location of the Roanoke River Basin (the pink basin straddling the state boundary)



Source: Excerpted from a Virginia Department of Conservation & Recreation map titled "Major Drainages Associated with Virginia Waters".

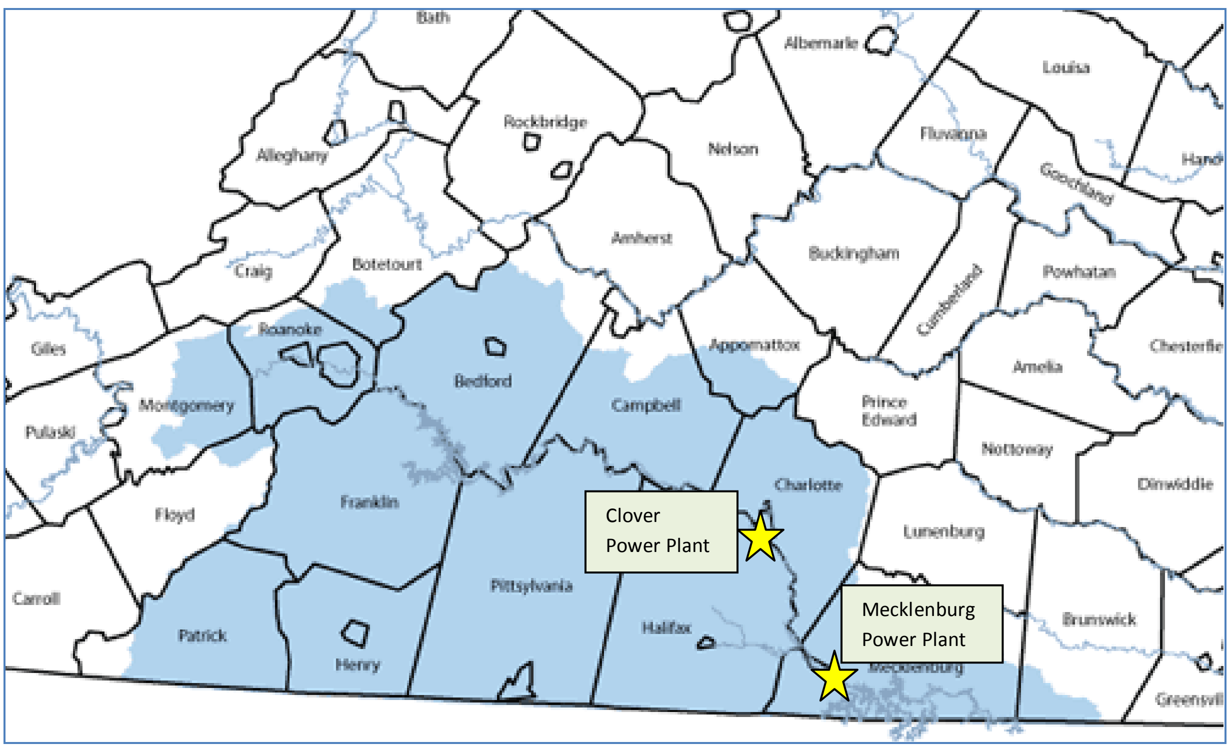
The U.S. Geological Survey (USGS) operates stream gages at 30 Virginia locations[18] and 18 North Carolina locations[19] within the Roanoke watershed. The data complied on the websites allow for long-term information and trends on stream flows.

3.2.1 Coal-Fired Power Plants in the Roanoke River Watershed

The locations of the coal-fired power plants in the Roanoke River watershed are shown in Figures 3-3, 3-4, and 3-5. Figure 3-3 shows the Virginia portion of the watershed with two coal-fired plants. Figures 3-4 and 3-5 show the western and eastern portions, respectively, of the Roanoke River watershed in North Carolina. Four coal-fired plants are located in the western portion, and one plant is located in the eastern portion.

These plants are identified on each map. They are described further in Table 3-1. Four of the coal-fired plants are located on the shores of lakes or reservoirs to take advantage of the water supplies for cooling. The other three plants are located on the free-flowing portions of the Roanoke River.

Figure 3-3. Roanoke River Basin in Virginia



Source: Virginia Department of Conservation & Recreation – plant locations added by the author.

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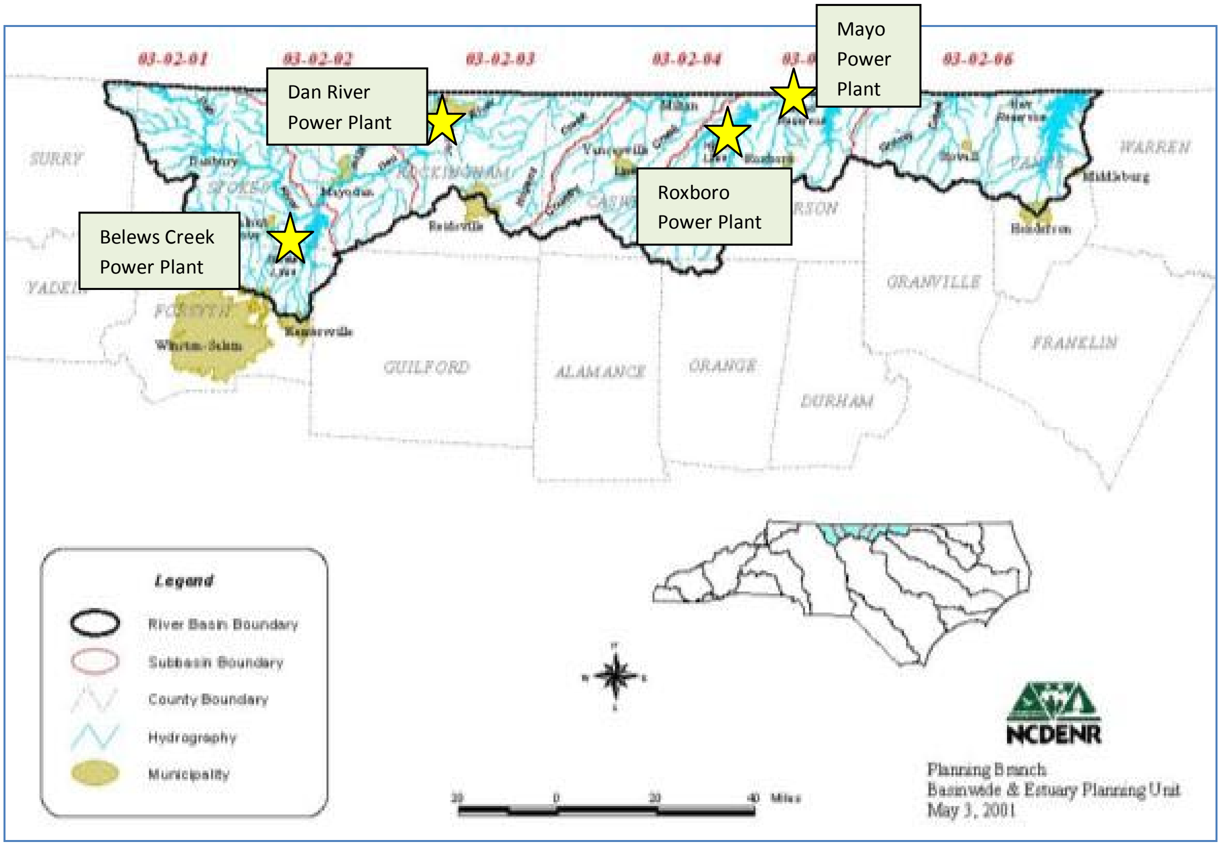
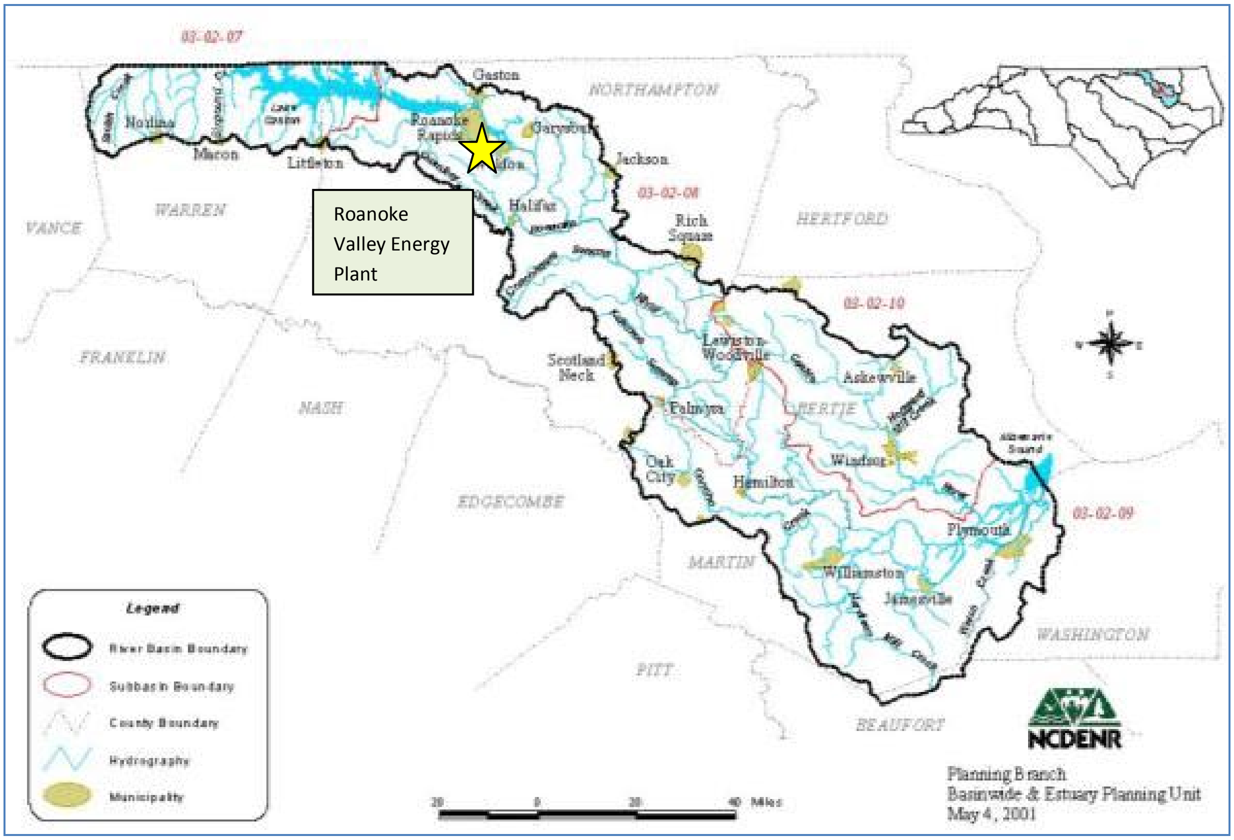
[18] The URL is http://va.water.usgs.gov/duration_plots/dp_map_roanoke.htm. (Accessed December 15, 2009.)
[19] The URL is http://nc.water.usgs.gov/realtime/real_time_roanoke.html. (Accessed December 15, 2009.)

Figure 3-4. Western Portion of Roanoke River Basin in North Carolina



Source: North Carolina Department of Environment and Natural Resources, Water Quality Division website at http://h2o.enr.state.nc.us/basinwide/whichbasinroanoke.htm (Accessed April 1, 2010.) - plant locations added by the author.

Figure 3-5. Eastern Portion of Roanoke River Basin in North Carolina



Source: North Carolina Department of Environment and Natural Resources, Water Quality Division website at http://h2o.enr.state.nc.us/basinwide/whichbasinroanoke.htm (Accessed April 1, 2010.) - plant locations added by the author.

Table 3-1. Coal-Fired Power Plants Located in the Roanoke River Watershed

Plant Name	Operating Company	Town	State	Nameplate Generating Capacity (MW)	Water Body Receiving the Discharge
Belews Creek	Duke Energy	Walnut Cove	NC	2,160	Belews Lake
Clover	Virginia Electric & Power	Clover	VA	848	Roanoke River
Dan River	Duke Energy	Eden	NC	290	Dan River
Mayo	Progress Energy	Roxboro	NC	736	Mayo Lake
Mecklenburg	DPS Mecklenburg	Clarksville	VA	140	Kerr Reservoir
Roanoake Valley I	Westmoreland Partners	Weldon	NC	182	Roanoke River
Roxboro	Progress Energy	Semora	NC	2,558	Lake Hyco

Source: EIA website at http://www.eia.doe.gov/cneaf/electricity/page/eia906_920.html. (Accessed March 30, 2010.)

3.2.2 Impaired Waters and TMDLs in the Roanoke River Watershed

3.2.2.1 Virginia Portion of the Watershed

The Virginia Department of Environmental Quality (VDEQ) prepares a 303(d) list every two years for review and approval by EPA. Different versions of the list of impaired water bodies can be found on the VDEQ and EPA websites. The VDEQ website provides access to the 2004 list of impaired waters within the Roanoke/Yadkin River Basins;[20] the list contains 124 entries. This list shows the specific water body name, county, stream segment ID number, and the pollutant causing the impairment. However, two newer surveys have been conducted since the 2004 survey, and the VDEQ data available on the website do not reflect the newer information.

The second source of impaired water information is the EPA Watershed Assessment, Tracking & Environmental Results (WATERS) website.[21] WATERS collects impaired water body data from each state and consolidates them for the entire country. The data are available from the most recent Virginia 303(d) report – the 2008 edition. The data include the specific water body name, the stream segment ID number, and which pollutant is responsible for the impairment.

Argonne elected to use the more current 2008 data found on the WATERS website. In this set of data, 296 impaired water body/pollutant pairs are identified. The number of times the impairment is caused by specific pollutants is shown Table 3-2.

Table 3-2. Cause of Impairment for Roanoke River Watershed in Virginia

Pollutant Causing Impairment	Number of Water Bodies Listed for This Pollutant
Escherichia coli (*E. coli*)	132
Polychlorinated biphenyls (in fish tissue)	71
Mercury (in fish tissue)	30
Fecal coliform	25
Temperature	16
Dissolved oxygen	12
pH	6
DDT	2
DDE	2

The VDEQ website[22] lists 25 TMDLs for the Roanoke River watershed that were approved by EPA in 2004. All of the TMDLs were written for sediment or some form of bacteria (*E. coli*, fecal coliform, or just bacteria). One of the sediment TMDL reports also included a TMDL for

[20] The URL is http://gisweb.deq.state.va.us/303d/srch303d.cfm. (Accessed December 15, 2009.)
[21] The URL is http://iaspub.epa.gov/waters10/attains_index.control?p_area=VA. (Accessed December 15, 2009.)
[22] The URL is https://www.deq.virginia.gov/TMDLDataSearch/ReportSearch.jspx. (Accessed December 16, 2009.)

phosphorous (Tetra Tech 2004). That particular TMDL was approved in 2004. The 2008 303(d) list no longer includes any Roanoke watershed segments impaired for phosphorus, perhaps indicating that the previous phosphorus impairment had been rectified.

The VDEQ developed a draft TMDL for polychlorinated biphenyls (PCBs) in the Roanoke River in 2009 (Tetra Tech 2009a). The TMDL study drainage area is approximately 2,379 square miles and includes two sections of the Roanoke River watershed – from its headwaters downstream to Niagra Dam (upper Roanoke) and from Leesville Dam downstream to its confluence with the Dan River (lower Roanoke). As of the date of this report, the draft TMDL for PCBs has not been finalized.

3.2.2.2 North Carolina Portion of the Watershed

The North Carolina Department of Environment and Natural Resources (NCDENR) prepares a 303(d) list every two years for review and approval by EPA. The NCDENR website[23] provides copies of the 2006 303(d) list and the draft 2008 list. The website notes that EPA has not yet approved the 2008 list, that other water bodies may be added to the final list, but that no water bodies are likely to be dropped from the list. The list is provided in Adobe Acrobat pdf format, making it impractical to sort the data for analysis. The EPA WATERS website provides the data from the 2006 list in a form that can be moved into an Excel spreadsheet for sorting and analysis.

Argonne started with the 2006 list from the WATERS website. That list included 21 impaired water body/pollutant pairs. These data were compared to the draft 2008 list from the NCDENR website; new entries were manually added to the 2006 list. Several additional impaired water bodies were added, and in other cases, one long stream segment was subdivided into two or more sub-segments.

The final tally for the North Carolina portion of the Roanoke River watershed includes the 2006 list and any new entries included in the draft 2008 list. In this set of data, 44 impaired water body/pollutant pairs are identified. The number of times the impairment is caused by specific pollutants is shown Table 3-3.

[23] The URL is http://h2o.enr.state.nc.us/tmdl/. (Accessed December 16, 2009.)

Table 3-3. Cause of Impairment for Roanoke River Watershed in North Carolina

Pollutant Causing Impairment	Number of Water Bodies Listed for This Pollutant
Mercury (in fish tissue)	17
Lack of ecological and biological integrity	10
Fecal coliform	8
Turbidity	4
Dissolved oxygen	4
Dioxin	1

The NCDENR website[24] lists 7 completed TMDLs for the North Carolina portion of the Roanoke River watershed. These were written for fecal coliform, aquatic weeds, turbidity, dissolved oxygen, and dioxin.

3.3 Monongahela River System

The Monongahela River drains about 7,340 square miles of Pennsylvania and West Virginia and a small corner of Maryland. The Monongahela River begins in West Virginia at the confluence of the West Fork River and Tygart Valley River and flows northward to Pittsburgh, where it joins with the Allegheny River to form the Ohio River. Major tributaries of the Monongahela River generally flow northward and include the Cheat River, Youghiogheny River, Tygart Valley River, and West Fork River. Figure 3-6 shows the location of the watershed. Note that the tributaries in the upper right corner of the map flow into the Allegheny River, not into the Monongahela River.

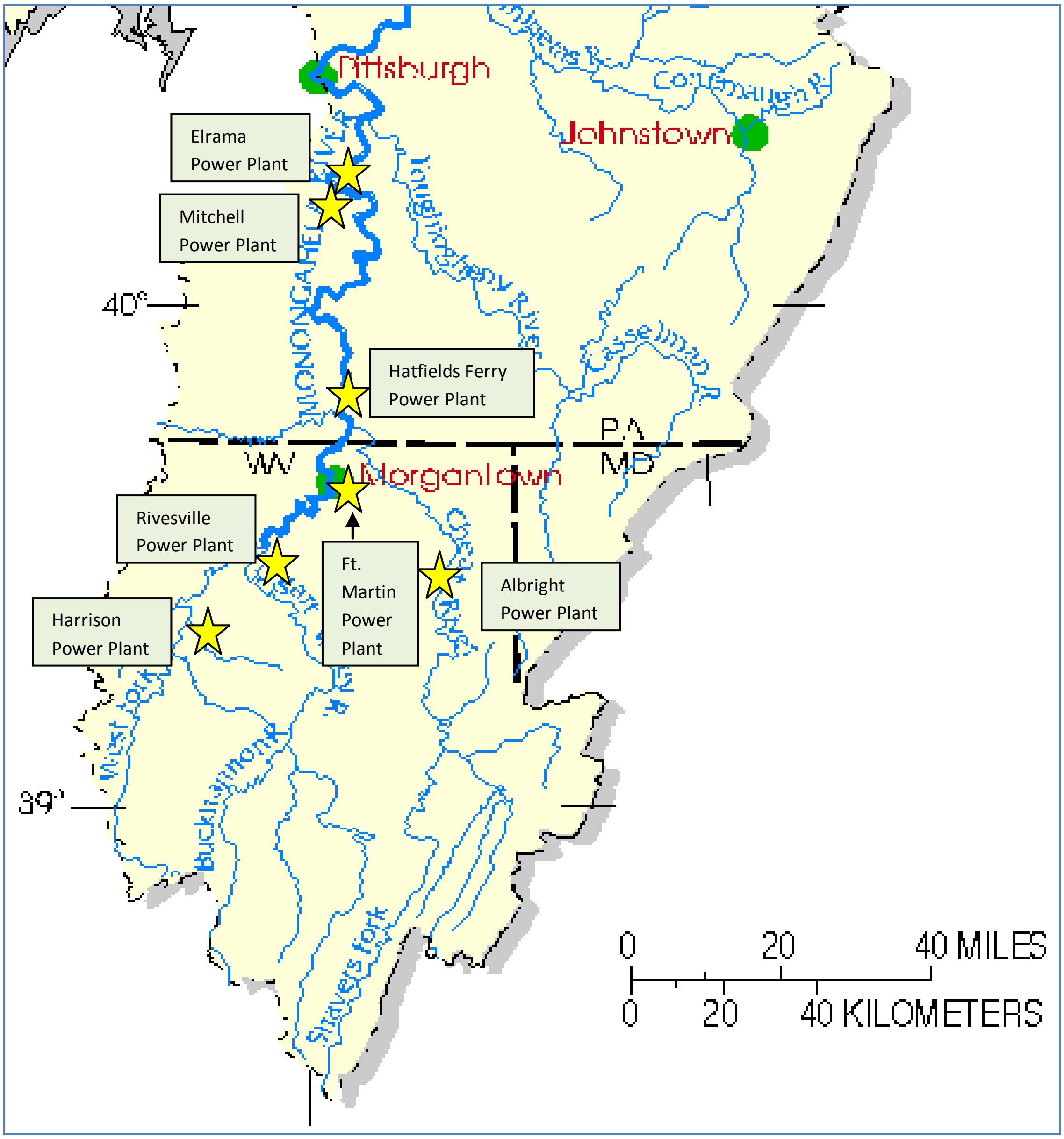
Stream flow in much of the river is controlled by dams and reservoirs. Most of the reservoirs are used for flood control, and some are used for recreation and water supply, as well as for control of water quality and navigation during low flows. A series of locks and dams permits navigation over about 100 miles of the Monongahela River.

3.3.1 Coal-Fired Power Plants in the Monongahela River Watershed

The locations of the coal-fired power plants in the Monongahela River watershed are shown in Figure 3-6. Four coal-fired plants are located in the West Virginia portion, three plants are located in the Pennsylvania portion, and none are located in the Maryland portion. These plants are described further in Table 3-4.

[24] The URL is http://h2o.enr.state.nc.us/tmdl/TMDL_list.htm#Interstate_TMDLs. (Accessed December 16, 2009.)

Figure 3-6. Map of the Monongahela River System



Source: USGS report at http://pa.water.usgs.gov/projects/amd/almn_nawqa.html (Accessed April 1, 2010.) – plant locations added by the author.

Table 3-4. Coal-Fired Power Plants Located in the Monongahela River Watershed

Plant Name	Operating Company	Town	State	Nameplate Generating Capacity (MW)	Water Body Receiving the Discharge
Albright	Monongahela Power	Albright	WV	278	Cheat River
Elrama	Orion Power Midwest	Elrama	PA	510	Monongahela River
Ft. Martin	Monongahela Power	Maidsville	WV	1,152	Monongahela River
Harrison	Monongahela Power	Haywood	WV	2,052	West Fork River
Hatfields Ferry	Allegheny Energy Supply	Masontown	PA	1,728	Monongahela River
Mitchell	Allegheny Energy Supply	Courtney	PA	651	Monongahela River
Rivesville	Monongahela Power	Rivesville	WV	110	Monongahela River

Source: EIA website at http://www.eia.doe.gov/cneaf/electricity/page/eia906_920.html. (Accessed March 30, 2010.)

3.3.2 Impaired Waters and TMDLs in the Monongahela River Watershed

3.3.2.1 West Virginia Portion of the Watershed

The West Virginia Department of Environmental Protection (WVDEP) prepares a 303(d) list every two years for review and approval by EPA. The draft 2008 303(d) list is available on the WVDEP website,[25] but the EPA WATERS website shows the final 2008 list. The WVDEP organizes the main watersheds into sub-watersheds; six sub-watersheds make up the West Virginia portion of the Monongahela watershed. Impaired water listings for those six sub-watersheds were combined to make up the 2008 West Virginia Monongahela watershed list.

In this set of data, 605 impaired water body/pollutant pairs are identified. The number of times the impairment is caused by specific pollutants is shown Table 3-5.

[25] The URL is http://www.wvdep.org/item.cfm?ssid=11&ss1id=720. (Accessed December 18, 2009.)

Table 3-5. Cause of Impairment for the Monongahela River Watershed in West Virginia

Pollutant Causing Impairment	Number of Water Bodies Listed for This Pollutant
Aluminum	69
Benthic bioassessments	124
Chloride	3
Dissolved oxygen	1
Fecal coliform	76
Iron	111
Lead	1
Manganese	72
Mercury	8
pH	130
PCBs	8
Zinc	2

The WVDEP website[26] lists 11 completed TMDLs for four of the six sub-watersheds within the West Virginia portion of the Monongahela River watershed. Most of them were written for contaminants associated with acid mine drainage (aluminum, iron, manganese, and pH). One addressed zinc, and another addressed dissolved oxygen. Whereas the 303(d) list includes numerous individual stream segments, the completed TMDLs cover groups of stream segments or tributaries to a main water body. The most recent of these was completed in 2002.

Two more current TMDLs address the other two sub-watersheds within the Monongahela watershed. A 2009 TMDL for the Dunkard Creek sub-watershed (Tetra Tech 2009b) lists iron TMDLs for 41 stream segments, fecal coliform TMDLs for 25 stream segments, and chloride TMDLs for 3 stream segments. Another 2009 TMDL for the Youghiogheny River sub-watershed (Tetra Tech 2009c) lists iron TMDLs for 4 stream segments, fecal coliform TMDLs for 8 stream segments, pH TMDLs for 3 stream segments, and an aluminum TMDL for 1 stream segment.

The WVDEP website notes that the department is undertaking a major water quality sampling program for the Cheat River sub-watershed during 2009. Nearly 100 locations were sampled. As of the date of this report, a TMDL has not been established.

3.3.2.2 Pennsylvania Portion of the Watershed

The Pennsylvania Department of Environmental Protection (PADEP) prepares a 303(d) list every two years for review and approval by EPA. The final 2008 303(d) list is available on the

[26] The URL is http://www.wvdep.org/item.cfm?ssid=11&ss1id=930. (Accessed December 18, 2009.)

PADEP website[27]; however, it is in Adobe Acrobat pdf format and cannot be readily sorted. For Pennsylvania, the EPA WATERS website does not show the 2008 list. Therefore, Argonne used excerpts from the PADEP list and manually tallied the impaired water bodies.

In this set of data, 1,658 impaired water body/pollutant pairs were identified. The number of times the impairment was caused by specific pollutants is shown Table 3-6.

Table 3-6. Cause of Impairment for the Monongahela River Watershed in Pennsylvania

Pollutant Causing Impairment	Number of Water Bodies Listed for This Pollutant
Excessive algal growth	1
Mercury	5
Metals	433
Nonpriority organics	2
Nutrients	38
Oil and grease	11
Organic enrichment/low dissolved oxygen	267
Pathogens	2
pH	175
Priority organics	1
Salinity/total dissolved solids/chlorides	12
Siltation	686
Suspended solids	15
Taste and odor	1
Turbidity	7
Unionized ammonia	2

PADEP has developed numerous TMDLs for the water bodies within the Monongahela watershed. The TMDL page on the PADEP website[28] allows searching by stream code number. Thirty-eight TMDL reports have been developed for the Monongahela watershed. It is difficult to determine how many actual water body/pollutant pairs are included in those reports. Most of the TMDL reports list the cause of impairment as metals and pH. However, when the actual reports are examined, they contain TMDLs for aluminum, iron, manganese, and acidity. In addition to the TMDLs focusing on those parameters, several TMDLs cover siltation, suspended solids, salinity/TDS/chlorides, chlordane, PCBs, nutrients, and pesticides.

[27] The URL is http://www.depweb.state.pa.us/watersupply/cwp/view.asp?a=1261&q=535678. (Accessed December 18, 2009.)
[28] The URL is http://www.dep.state.pa.us/watermanagement_apps/TMDL/. (Accessed December 21, 2009.)

3.3.2.3 Maryland Portion of the Watershed

The Maryland Department of the Environmental (MDE) prepares a 303(d) list every two years for review and approval by EPA. The 2008 303(d) list is available on the MDE website.[29] MDE lists 7 impaired water body/pollutant pairs for the small portion of the Monongahela watershed located in Maryland. Four of the listings report impairment related to benthic and fish bioassessments. Two are impaired by fecal coliform, while one is impaired by phosphorus.

MDE has prepared 8 TMDLs for the Monongahela watershed in Maryland. Two of the TMDLs cover sediment, two cover pH, while the others are for fecal coliform, mercury, carbonaceous biochemical oxygen demand (BOD), and nitrogenous BOD.

3.4 Susquehanna River System

The Susquehanna River watershed drains 27,510 square miles, covering half the land area of Pennsylvania and portions of New York and Maryland. The watershed includes all or portions of 67 counties. There is a need to coordinate the efforts of three states and the agencies of the federal government, as well as a need to establish a management system to oversee the use of the water and related natural resources of the Susquehanna. As a result, the U.S. Congress, along with state legislatures in New York, Pennsylvania, and Maryland, signed the Susquehanna River Compact in 1970. The Compact established the Susquehanna River Basin Commission (SRBC), which serves to enhance public welfare through comprehensive planning, water supply allocation, and management of the water resources of the Susquehanna River Basin.

The statistics in the previous paragraph and the following paragraphs come from the SRBC website.[30]

The Susquehanna River Basin, with more than 49,000 miles of stream segments, makes up 43 percent of the Chesapeake Bay's drainage area. The watershed contains six major sub-watersheds (see Figure 3-6). The basin is home to a population of nearly 4 million residents.

The main stem of the Susquehanna River flows 444 miles from its headwaters at Otsego Lake in Cooperstown, NY, to Havre de Grace, MD, where the river meets the Chesapeake Bay. It is the largest tributary of the Chesapeake Bay, providing 50 percent of its fresh water flows. The Susquehanna is the largest river lying entirely within the United States that drains into the Atlantic Ocean. It has a normal flow of about 18 million gallons per minute at Havre de Grace, MD.

The lower Susquehanna River is home to four hydroelectric dams. York Haven, Safe Harbor, and Holtwood are in Pennsylvania, and Conowingo is in Maryland.

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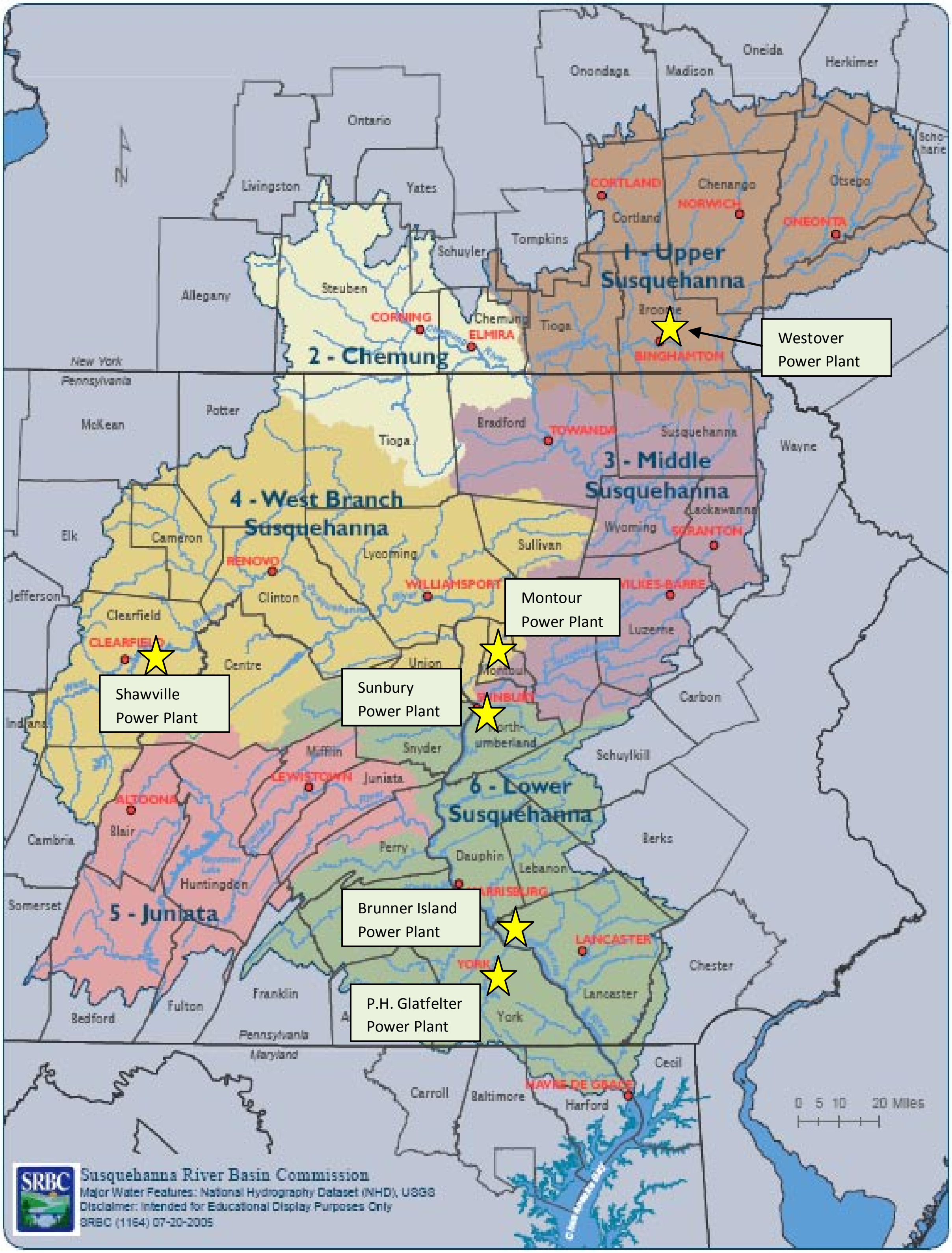
[29] The URL is http://www.mde.state.md.us/Programs/WaterPrograms/TMDL/index.asp. (Accessed December 21, 2009.)
[30] The URL is http://www.srbc.net/index.htm. (Accessed December 23, 2009.)

3.4.1 Coal-Fired Power Plants in the Susquehanna River Watershed

The locations of the coal-fired power plants in the Susquehanna River watershed are shown in Figure 3-7. One coal-fired plant is located in the New York portion, five plants are located in the Pennsylvania portion, and none are located in the Maryland portion. These plants are described further in Table 3-7.

Figure 3-7. Map of Susquehanna River Watershed Showing Subbasins



Source: SRBC website – plant locations added by the author.

Table 3-7. Coal-Fired Power Plants Located in the Susquehanna River Watershed

Plant Name	Operating Company	Town	State	Nameplate Generating Capacity (MW)	Water Body Receiving the Discharge
Brunner Island	PPL	York Haven	PA	1,558	Susquehanna River
Montour	PPL	Washingtonville	PA	1,642	Susquehanna River
P.H. Glatfelter	P.H. Glatfelter Co.	Spring Grove	PA	97	North Codorus Creek
Shawville	Reliant Energy Midatlantic	Clearfield	PA	125	Susquehanna River
Sunbury	WPS Energy Services	Shamokin Dam	PA	425	Susquehanna River
Westover	AEP Westover	Johnson City	NY	119	Susquehanna River

Source: EIA website at http://www.eia.doe.gov/cneaf/electricity/page/eia906_920.html. (Accessed March 30, 2010.)

3.4.2 Impaired Waters and TMDLs in the Susquehanna River Watershed

3.4.2.1 New York Portion of the Watershed

The New York Department of Environmental Conservation (NYDEC) prepares a 303(d) list every two years for review and approval by EPA. The 2008 303(d) list is available on the WVDEP website,[31] but the EPA WATERS website shows the final 2008 list. Only six water bodies in the New York portion of the Susquehanna watershed were listed. Three lakes were listed for phosphorus, with another lake was listed for PCBs. Two rivers were listed for pathogens.

Only one water-body-specific TMDL was identified for the Susquehanna watershed in New York. It sets a load for phosphorus in a lake. In addition, New York joined the other northeastern states in developing the Northeast Regional Mercury Total Maximum Daily Load (Connecticut DEP et al. 2007), which outlines a strategy for reducing mercury concentrations in fish in Northeast fresh waterbodies so that water quality standards can be met.

3.4.2.2 Pennsylvania Portion of the Watershed

As described in Section 3.3.2.2, Argonne used excerpts from the 2008 PADEP 303(d) list and manually tallied the impaired water bodies.

In this set of data, 3,647 impaired water body/pollutant pairs were identified. The number of times the impairment was caused by specific pollutants is shown Table 3-8.

[31] The URL is http://www.dec.ny.gov/chemical/31290.html. (Accessed December 23, 2009.)

Table 3-8. Cause of Impairment for the Susquehanna River Watershed in Pennsylvania

Pollutant Causing Impairment	Number of Water Bodies Listed for This Pollutant
Chlorine	4
Excessive algal growth	3
Mercury	23
Metals	276
Nutrients	526
Oil and grease	1
Organic enrichment/low dissolved oxygen	185
Pathogens	24
PCBs	1
pH	417
Priority organics	2
Salinity/total dissolved solids/chlorides	3
Siltation	2,145
Suspended solids	21
Thermal modifications	15
Unionized ammonia	1

PADEP has developed 86 TMDLs for the water bodies within the Susquehanna watershed. It is difficult to compare the pollutants limited in the TMDL reports based on the cause of impairment. For example, many water bodies reported impairment from metals and pH. However, the individual TMDL reports for these segments typically set loadings for aluminum (75 times), iron (75 times), manganese (75 times), and acidity (76 times). Other reports listed the cause of impairment as nutrients, organic enrichment, etc. These typically set loading for phosphorus (25 times) and sediment (22 times). The only way to determine which pollutants were limited in the TMDLs was to download and review the individual TMDL reports.

One TMDL, reportedly approved by EPA in 1999, was identified for Bald Eagle Creek. The cause of water body impairment was listed as thermal modification. However, unlike nearly all of the other PADEP TMDLs, the TMDL report for Bald Eagle Creek was not available for downloading through the PADEP website. Therefore, Argonne was unable to determine what pollutant was limited in the TMDL report.

3.4.2.3 Maryland Portion of the Watershed

The Maryland Department of the Environmental (MDE) prepares a 303(d) list every two years for review and approval by EPA. MDE lists 5 impaired water body/pollutant pairs for the small portion of the Susquehanna River watershed located in Maryland. Two of the listings report impairment by PCBs, and another listing is related to benthic and fish bioassessments. One is impaired by total suspended solids, while one is impaired by phosphorus.

MDE has not prepared any TMDLs for the Susquehanna watershed in Maryland. However, as noted in the opening paragraphs of Section 3.4, the Susquehanna River is the largest tributary flowing into the Chesapeake Bay. Although this current study is limited to the Susquehanna River watershed, which ends as the river enters the Chesapeake Bay, it is worth noting the large amount of attention presently being given to Chesapeake Bay water quality. TMDLs developed for the northern portions of the Chesapeake Bay mainstem are likely to institute loadings that could in turn affect the loadings from the tributaries themselves.

Chapter 4 – Power Plant Operations and Discharges

This chapter describes the operations that take place within a coal-fired power plant and reviews the pollutants likely to be generated and potentially discharged.

4.1 The Steam Electric Power Industry

EPA released a detailed evaluation of power plant operations and wastewater streams in October 2009 (EPA 2009). That report is used as a current source for much of the information presented in this section. EPA's descriptions are restricted to those facilities that are covered under the EPA effluent limitations guidelines (ELGs) for the steam electric power industry. The following facilities are excluded from the steam electric power ELGs:

- Industrial non-utilities that generate power for their own internal use rather than selling it externally.
- Power generating facilities that employ methods other than steam processes or combined cycle processes.
- Plants using fuels sources other than fossil fuels or nuclear power.
- Plants that produce only steam as their externally distributed product.

EPA (2009) compiled data from 2005 EIA records to characterize the fuel types used for steam electric power production in the United States. The information is shown in Table 4-1. More than half of the steam electric generating capacity and nearly half of the generating units use coal as the fuel source.

4.2 Steam Electric Power Processes

Three basic processes are used to generate power in a fossil-fueled steam electric power plant:

- Combusting fuel in a boiler to make steam,
- Passing steam through a turbine attached to a generator, and
- Condensing the steam.

Each of those major processes is accomplished through many other steps and processes that all contribute to a complex operation. Figure 4-1 shows a flow diagram of the process steps at a steam electric power plant. The following discussion links the many processes shown in Figure 4-1 to the three basic process steps listed above. Discussion of the wastes and wastewater types are included for each process step.

Table 4-1. Type of Fuel Used in U.S. Steam Electric Power Plants

Fuel Type	Number of Plants	Number of Electric Generating Units	Total Steam Turbine Capacity (MW)
Coal:	488 (41%)	1,181 (46%)	329,211 (51%)
Anthracite coal, Bituminous coal	280	697	175,271
Sub-bituminous coal	173	411	130,300
Lignite coal	17	29	14,643
Coal synfuel	10	22	6,960
Waste/other coal	20	22	2,037
Petroleum coke	11 (0.9%)	12 (0.5%)	778 (0.1%)
Oil:	75 (6.3%)	147 (5.7%)	32,219 (5.0%)
Residual fuel oil	60	127	30,983
Distillate fuel oil	14	19	1,216
Waste oil	1	1	20
Gas:	619 (52%)	1,113 (44%)	175,455 (27%)
Natural gas	613	1,104	175,186
Blast furnace gas	2	5	152
Other Gas	4	4	117
Nuclear	66 (5.6%)	104 (4.1%)	105,585 (16%)
Total	1,187 (100%)	2,557 (100%)	643,249 (100%)

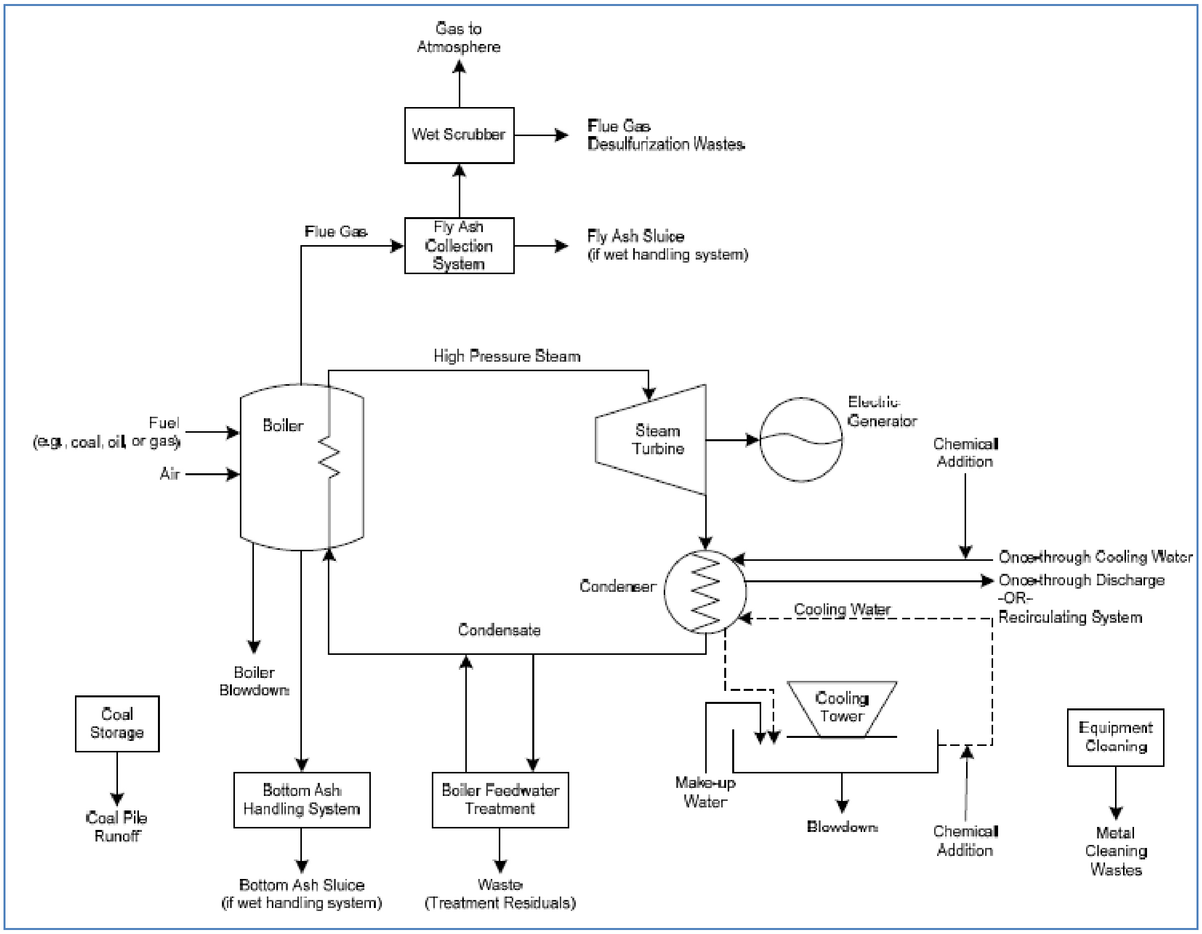
Source: EPA (2009).

4.2.1 Steam Generation

In order to generate steam in the boiler, a fuel source, air, and purified water must be provided. Oil and natural gas fuels are generally stored onsite in large tanks. These activities do not generate much wastewater other than stormwater that collects in the fuel storage areas. Coal is generally stored onsite in large outdoor piles. Stormwater that falls in the coal storage area (coal pile runoff) does become contaminated and should be treated before discharge.

The boiler feed water must be highly purified to prevent scaling and other operational problems. The plant's regular water supply generally receives additional treatment to demineralize the water. The residues from the treatment steps may be in liquid or solid form. They require proper management. Specialty chemicals such as biocides, oxygen scavengers, and corrosion inhibitors are often added to the boiler feed water. To avoid build up of contaminants, a small portion of the boiler water/steam flow is periodically removed from the recirculating system. This is known as boiler blowdown.

Figure 4-1. Flow Diagram of Steam Electric Power Plant



Source: EPA (2009).

After the fuel is combusted, the resulting solid residues become ash. The heavier particles are removed from the boiler as bottom ash, while the smaller and lighter fly ash particles are carried into the exhaust stream. The fly ash or bottom ash, or both, may be handled in a wet or dry fashion. If handled wet, the fly ash and bottom ash may be stored in a common ash pond or in separate impoundments. Coal-fired power plants typically generate large quantities of both fly ash and bottom ash. Oil-fired plants produce less ash than coal-fired plants, and most of the ash produced is fly ash. Natural gas-fired plants do not produce ash. The characteristics of ash depend to some degree on the type of fuel combusted, how it is prepared prior to combustion, and the operating conditions of the boiler. Fly ash and bottom ash transport waters typically contain heavy metals, including priority pollutants (EPA 2009). Ash storage ponds or lagoons contain contaminated water that requires treatment before discharge, to meet water quality requirements.

In addition to management of ash, the power companies often employ other equipment, like wet scrubbers or flue gas desulfurization (FGD) technologies, to remove various air pollution contaminants from the exhaust stream. The water used in these processes contributes to other wastewater streams. The solids removed by the treatment processes must also be managed.

4.2.2 Power Generation

The high-pressure steam created in the boiler is sent to a turbine, where the steam expands and pushes against the fins on the turbine, causing it to spin rapidly. The turbine shaft is connected to a generator that produces electricity. Other than small volumes of water used for periodic cleaning, the power generation stage does not create much wastewater or solid waste.

Two different generating stages are employed in a combined-cycle plant. In the first stage, fuel (typically natural gas) is combusted, with the hot exhaust gases spinning a combustion turbine to generate electricity. The gases exiting the combustion turbine are used to heat a boiler that then operates a steam electric stage.

4.2.3 Cooling Steam in the Condenser

After leaving the turbines, the steam passes through a condenser that has multiple tubes and a large surface area. A large volume of cool water circulates through the tubes, absorbing heat from the steam. The temperature of the cooling water rises as the steam cools and condenses. The condensed steam then returns to the boiler to be reheated.

Most power plants use either once-through cooling or closed-cycle cooling. Once-through cooling systems withdraw large volumes of water – typically in the range of tens of millions to billions of gallons per day from a river, lake, estuary, or ocean. The water is pumped through the condenser and finally returned to the same or a nearby water body. Plants using once-through cooling discharge heated wastewater. Often chlorine or some other type of biofouling control chemical is added to avoid growth on the condenser tubes that would restrict heat exchange.

Closed-cycle cooling systems receive their cooling water from and return it to a cooling tower and basin, cooling pond, or cooling lake. Since some water evaporates in this process, the concentrations of certain constituents increase in closed-cycle systems. To maintain proper concentrations, a portion of the recirculated water is discharged as cooling tower blowdown, and fresh water is added. Because evaporation and planned cooling tower blowdown remove cooling water from the evaporative system, regular additions of “makeup” cooling water are needed. Makeup volumes are much lower than daily once-through volumes, and may range from hundreds of thousands to millions of gallons per day. Biocides, corrosion and scale inhibitors, and other chemicals are typically added to the recirculating cooling water.

Cooling tower blowdown can be hot, and contains elevated concentrations of constituents present in the cooling water supply plus the chemical additives.

The previous paragraphs describe cooling using water as the heat exchange medium. This is by far the most common approach. However, in some parts of the world, including a few examples in the United States, power companies are opting to use dry cooling systems that use either no water or minimal water. These are not discussed further here since they are not yet common in the United States. None of the plants examined in this study employ these technologies.

4.2.4 Other Plant Processes

Several other processes that produce wastewater are part of the operations at a coal-fired power plant. First, any construction activity at the site can contribute to sediment loads and contaminated runoff. Proper stormwater management practices can minimize the impacts of construction-related runoff.

Power plant operations require numerous employees to be onsite throughout the day. These employees generate wastewater through showering, bathrooms, and general cleaning. Most power plants operate onsite sewage treatment facilities.

Some of the equipment at the plant is periodically cleaned using acids and other chemicals during plant outages. The resulting wastewater often contains metals, and is often treated before discharge to meet water quality requirements.

Operators of some coal-fired power plants are contemplating adding carbon capture equipment to their plants. The processes currently available require substantial quantities of water to capture carbon dioxide. As of the end of 2009, carbon capture technology has been used only in pilot tests. However, it is likely that carbon capture will be installed at full-scale operating units over the next decade. The carbon capture processes will generate some wastewater.

Some coal-fired power plants are designed to convert coal into synthetic gas (syngas) then combust the gas. These are known as integrated gasification combined cycle (IGCC) plants. The syngas is cleaned of particulates, sulfur, and other contaminants and is then combusted in a high-efficiency combustion gas turbine/generator. Heat from the combustion turbine exhaust is then extracted in a heat recovery steam generator to produce steam and drive a steam turbine/generator. IGCC plants use various processes not found at a conventional coal-fired plant. Therefore, they are likely to generate new wastewater streams that contain different groups of pollutants. EPA (2009) describes the syngas processing steps used at the Wabash River IGCC generating facility in Indiana.

4.3 EPA ELGs for Steam Electric Power Plants

The Steam Electric Power industry ELGs were originally adopted by EPA in 1974, with revisions in 1977 and 1982 at 40 CFR Part 423. The ELGs provide minimum national technology-based discharge standards for existing and new power plants. The existing power plants must meet both best conventional pollutant control technology (BCT) and best available technology economically achievable (BAT). New plants must meet new source performance standards (NSPS). The discharge standards for both existing and new facilities are summarized in Table 4-2.

Table 4-2. Summary of EPA ELGs for Existing and New Plants

Wastewater Stream	Existing Plants	New Plants
All wastewater streams	pH: 6–9 PCBs: zero discharge	pH: 6–9 PCBs: zero discharge
Low-volume wastes[a]	TSS[b]: 100 mg/L; 30 mg/L[c] Oil and grease: 20 mg/L; 15 mg/L	TSS: 100 mg/L; 30 mg/L Oil and grease: 20 mg/L; 15 mg/L
Fly ash transport	TSS: 100 mg/L; 30 mg/L Oil and grease: 20 mg/L; 15 mg/L	Zero discharge
Bottom ash transport	TSS: 100 mg/L; 30 mg/L Oil and grease: 20 mg/L; 15 mg/L	TSS: 100 mg/L; 30 mg/L Oil and grease: 20 mg/L; 15 mg/L
Once-through cooling	Total residual chlorine (TRC): If >25 MW: 0.20 mg/L instantaneous maximum; ff <25 MW, free available chlorine: 0.5 mg/L; 0.2 mg/L. TRC discharge is limited to 2 hours/day/unit.	TRC: If >25 MW: 0.20 mg/L instantaneous maximum; if <25 MW, free available chlorine: 0.5 mg/L; 0.2 mg/L. TRC discharge is limited to 2 hours/day/unit.
Cooling tower blowdown	Free available chlorine: 0.5 mg/L; 0.2 mg/L 126 priority pollutants: zero discharge, except: – Chromium: 0.2 mg/L; 0.2 mg/L – Zinc: 1.0 mg/L; 1.0 mg/L	Free available chlorine: 0.5 mg/L; 0.2 mg/L 126 priority pollutants: zero discharge, except: – Chromium: 0.2 mg/L; 0.2 mg/L – Zinc: 1.0 mg/L; 1.0 mg/L
Coal pile runoff	TSS: 50 mg/L instantaneous maximum, when flow is <10-year, 24-hour rainfall event.	TSS: 50 mg/L instantaneous maximum, when flow is <10-year, 24-hour rainfall event.
Chemical metal cleaning wastes	TSS: 100 mg/L; 30 mg/L Oil and grease: 20 mg/L; 15 mg/L Copper: 1.0 mg/L; 1.0 mg/L Iron: 1.0 mg/L; 1.0 mg/L	TSS: 100 mg/L; 30 mg/L Oil and grease: 20 mg/L; 15 mg/L Copper: 1.0 mg/L; 1.0 mg/L Iron: 1.0 mg/L; 1.0 mg/L

[a] Low-volume wastes include but are not limited to wastewaters from wet scrubber air pollution control systems, ion exchange water treatment systems, water treatment evaporator blowdown, laboratory and sampling streams, boiler blowdown, floor drains, cooling tower basin cleaning wastes, and recirculating house service water systems (sanitary and air-conditioning wastes are not included).

[b] TSS is total suspended solids.

[c] Where two numbers are shown separated by a semicolon, the first number is the maximum limit and the second number is the average limit.

Source: 40 CFR Part 423.

EPA (2009) is the final report of a multi-year evaluation of the steam electric power industry to determine if new or revised ELGs are appropriate. In 2009, EPA announced that it would begin formal efforts to update the steam electric power industry ELGs. EPA's decision to revise the current ELGs is largely driven by the high level of toxic-weighted pollutant discharges from coal-fired power plants and the expectation that these discharges will increase significantly in the next few years as new air pollution controls are installed. In addition to focusing on new wastewater sources not currently covered by the ELGs, EPA may reconsider discharge standards for the waste streams currently included in the ELGs.

4.4 Coal-Fired Power Plant Wastewater

4.4.1 Coal Combustion Wastewater

EPA visited 34 coal-fired plants in 14 states as part of its information-collection activities for the EPA (2009) report. Five of those plants are located within the watersheds described in this Argonne report: Roxboro, Belews Creek, and Clover plants in the Roanoke watershed and the Mitchell and Harrison plants in the Monongahela watershed. EPA conducted detailed water sampling at six of the visited plants, including the Belews Creek and Harrison plants. The sampling was conducted on coal combustion wastewater (i.e., FGD wastewater and ash handling water).

The results of EPA's detailed sampling for several power plant wastewater streams are shown in Appendices A and B. The major coal combustion wastewater streams are described in the following sections.

4.4.1.1 FGD

Appendix A shows the FGD concentrations of many constituents from five different power plants. Many of the metals are present in the range of tenths to tens of mg/L. Total dissolved solids (TDS), total suspended solids (TSS), BOD, sulfate, and chlorides are found in the thousands of mg/L range.

The pollutant concentrations in FGD scrubber purge vary from plant to plant depending on the coal type, the sorbent used, the materials of construction in the FGD system, FGD system operation, and the air pollution control systems operated upstream of the FGD system. The coal is the source of the majority of the pollutants that are present in the FGD wastewater (i.e., the pollutants present in the coal are likely to be present in the FGD wastewater). The sorbent used in the FGD system can also introduce pollutants into the FGD wastewater, and therefore the type and source of the sorbent used affect the pollutant concentrations in the FGD wastewater. (EPA 2009)

4.4.1.2 Ash Handling Water

Coal-fired power plants generate large amounts of fly ash and lesser amounts of bottom ash. Many older units employ wet ash handling systems and transport ash to settling ponds. Newer units installed or upgraded since 1982 can no longer use wet fly ash handling systems, based on the NSPS requirements in the ELGs.

Because dry fly ash handling practices do not generate wastewater streams, converting to a dry system eliminates the discharge of fly ash transport water and the pollutants typically present in the wastewater (e.g., arsenic, mercury, and selenium). In addition, it reduces the amount of water used by the plant and eliminates the need for the fly ash pond. However, if ash is disposed of in landfills or ash monofills, there is the possibility of leachate collecting in underdrains. The leachate may be discharged to nearby water bodies after treatment.

EPA (2009) reports on the ash handling practices at 97 power plants the agency has surveyed. The results are shown in Tables 4-3 and 4-4 below. About one-third of the plants and the generating capacity use wet handling for fly ash. Because bottom ash is not subject to the same ELG restriction, and the larger size of bottom ash particles allows easier settling, a larger proportion of plants (about 90 percent) employ wet handling for bottom ash. Note that the percentages in the “Number of Plants” columns do not add up to 100 percent. This is because some plants have multiple generating units that employ different ash handling methods.

Table 4-3. Fly Ash Handling Methods at 97 Power Plants

Fly Ash Handling	Number of Plants	Number of Electric Generating Units	Capacity (MW)
Wet-sluiced	34 (35%)	95 (40%)	38,300 (33%)
Handled dry or removed in scrubber	63 (65%)	128 (54%)	73,600 (63%)
Other – most ash handled dry or unknown	7 (7%)	14 (6%)	4,950 (4%)
Total	97	237	117,000

Source: EPA (2009).

Table 4-4. Bottom Ash Handling Methods at 97 Power Plants

Fly Ash Handling	Number of Plants	Number of Electric Generating Units	Capacity (MW)
Wet-sluiced	85 (88%)	214 (90%)	106,000 (91%)
Handled dry or removed in scrubber	13 (13%)	22 (9%)	10,200 (9%)
Other – most ash handled dry or unknown	1 (1%)	2 (1%)	600 (<1%)
Total	97	238	117,000

Source: EPA (2009).

Appendix B shows the ash pond influent wastewater concentrations of many constituents from two different power plants. One of the plants combines both fly ash and bottom ash in the ash pond. The second plant places only the fly ash in the pond. Several of the metals are present in concentrations above 10 mg/L (aluminum, calcium, iron, magnesium, sodium). TSS and sulfate concentrations exceed 1,000 mg/L.

4.4.1.3 Summary of Coal Combustion Wastewater Pollutants

EPA (2009) lists those pollutants found in coal combustions wastewater that have been associated with documented environmental impacts or could have the potential to cause environmental impacts based on the loads and concentrations present in the wastewater. The list includes:

- Arsenic,
- BOD,
- Boron,
- Cadmium,
- Chlorides,
- Copper,
- Chromium,
- Iron,
- Lead,
- Manganese,
- Mercury,
- Nitrogen,
- pH,
- Phosphorus,
- Selenium,
- TDS, and
- Zinc.

4.4.2 Pollutants from Other Wastewater Streams

The detailed analytical data provided by EPA (2009) is limited to several coal combustion wastewater streams. To assess the pollutants present in other coal-fired power plant wastewater streams, several other reference sources are available, as noted in the following sections.

4.4.2.1 EPA Development Document

Normally when EPA develops ELGs, it prepares a series of reports. One of these is called a Development Document. The last detailed EPA report on discharges from the steam electric power industry was a 1982 Development Document (EPA 1982) that provides the data, assumptions, and analysis used to develop the 1982 steam electric ELGs. EPA's 2009 report represents the culmination of EPA's study to determine if new ELGs are warranted for the steam electric power industry. It is not a Development Document, but the information included in the 2009 report will help to steer EPA's ELG investigations. EPA will prepare a new Development Document as part of its new ELG effort. Although the Development Document contains a great deal of data, the information is spread out over many pages for individual plants without consolidating it into summary tables.

One table from EPA (1982) is reproduced below as Table 4-5. It summarizes data supplied to EPA by the power companies as part of the "308 survey." The responses from more than 150 plants show how frequently each of the 53 listed priority pollutants were found or suspected to be present in six different waste streams.

Different waste streams contained different groups of priority pollutants. For example, the ash transport waste streams frequently contained metals. Water treatment wastes were occasionally reported to contain arsenic, copper, mercury, and nickel. Cooling system wastewater showed very little occurrence of any pollutants except for chromium and zinc. The other three waste streams showed unique combinations of pollutants.

Arsenic, chromium, copper, lead, nickel, phenol, and zinc were reported for all six waste streams. Cadmium, mercury, and EDTA were reported in five of the six waste stream categories.

Table 4-5. Number of Plants Reporting Priority Pollutants in Waste Streams

Priority Pollutant	Ash Transport Wastes	Water Treatment Wastes	Cooling System Wastes	Maintenance Wastes	Construction Wastes	Other Wastes
Acenaphthene	9	0	0	0	0	0
Acrolein	0	0	0	0	0	0
Acrylonitrile	0	1	0	0	0	0
Aldrin-dieldrin	0	0	0	0	0	0
Antimony and compounds	108	0	3	0	0	15
Arsenic and compounds	155	13	2	2	11	36
Asbestos	5	0	0	32	9	4
Benzene	0	0	0	2	0	19
Benzidine	0	0	0	0	0	0
Beryllium and compounds	96	0	0	1	0	15
Cadmium and compounds	124	1	3	0	8	25
Carbon tetrachloride	0	0	0	0	0	9
Chlordane	0	0	0	1	0	0
Chlorinated benzenes	1	0	0	1	0	0
Chlorinated ethanes	1	0	0	20	0	2
Chlorinated phenols	0	0	7	1	0	1
Chloroalkyl ethers	0	0	0	0	0	0
Chloroform	0	0	1	0	0	19
Chromium and compounds	145	4	40	3	43	45
Copper and compounds	132	38	8	9	76	69
Cyanides	18	0	0	0	0	12
DDT and metabolites	0	0	0	0	0	0
Dichlorobenzenes	0	0	0	0	0	0
Dichloroethylenes	0	0	0	0	0	0
Diphenylhydrazine	0	1	0	0	0	0
EDTA	2	7	6	6	0	39
Fluoranthene	0	0	0	0	0	0
Haloethers	0	0	0	0	0	0
Halomethanes	0	0	0	0	0	0
Heptachlor and metabolites	0	0	0	0	0	0
Isophorone	1	0	0	0	0	0
Lead and compounds	132	9	3	12	8	37
Mercury and compounds	137	11	2	13	0	43
Naphthalene	0	0	0	0	0	14
Nickel and compounds	137	14	3	3	65	48

Table 4-5. (Cont.)

Priority Pollutant	Ash Transport Wastes	Water Treatment Wastes	Cooling System Wastes	Maintenance Wastes	Construction Wastes	Other Wastes
Nitrosamines	6	0	0	0	0	0
PCBS	4	0	0	2	0	0
Pentachlorophenol	1	0	9	0	0	1
Phenol	5	6	2	1	2	19
Phthalate esters	0	0	0	0	0	1
Polynuclear aromatic hydrocarbons	1	0	0	0	0	0
Selenium and compounds	120	0	2	0	1	20
Silver and compounds	83	3	2	0	0	26
Tetrachloroethylene	0	0	0	1	0	0
Thallium and compounds	34	0	2	0	0	2
Toluene	0	0	0	0	0	18
Trichloroethylene	0	0	0	5	0	0
Vanadium	94	0	2	0	0	6
Vinyl chloride	0	0	0	0	1	0
Zinc and compounds	142	7	22	9	59	49
2-chlorophenol	0	0	0	0	0	0
2,4 Dichlorophenol	0	0	0	0	0	0
2,4 Dimethylphenol	0	0	0	1	0	7

Source: EPA (1982).

4.4.4.2 NPDES Permit Program Records

EPA maintains several large online databases that can be used to extract information related to discharges at individual facilities, including power plants. This section describes the two databases that store NPDES discharge monitoring reports (DMRs). The NPDES permits specify which pollutants must be monitored, where the monitoring is to take place, and how often monitoring must be done. The DMRs are submitted to state and EPA permitting agencies monthly or at some other frequency.

EPA has operated the online Permit Compliance System (PCS) database of NPDES information for many years. In recent years, EPA developed a more advanced and flexible database called Enforcement and Compliance History Online (ECHO). An EPA water data Web page indicates which states use PCS and which use ECHO.[32] It provides links to the query screens for each system. With some practice, a user can obtain all of the DMR results for the past several years

[32] The URL is http://www.epa-echo.gov/echo/compliance_report_water.html. (Accessed December 29, 2009.)

for each permitted discharge point at a facility. The data provide a month-by-month picture of pollutant concentrations for any pollutants limited by the NPDES permit.

To view an example of the type of information that can be gleaned from ECHO records, readers can go to the ECHO data screen[33] associated with the PPL Brunner Island plant; this is one of the coal-fired plants within the Susquehanna River watershed. Then click on the green box marked "Download." The final output is displayed in an Excel spreadsheet. The data are displayed across many columns, making it impractical to reproduce the actual data here. However, by using the tools within Excel, the data can be evaluated statistically to give averages, maxima, and other information.

One drawback is that the DMRs report only those pollutants limited in the permits. They offer no information about other pollutants that may or may not be present. However, the NPDES system does have an alternate way to obtain more detailed results for individual facilities. The NPDES permit application, submitted every five years when the permit must be renewed, requires sampling for a large list of pollutants. Although each state may use a somewhat different application form for different groups of permits, large industrial dischargers must provide some analytical data describing their discharges on Application Form 2C.[34] Form 2C lists nine pages of pollutants. Depending on the nature of the specific discharge, analyses must be provided for some or all of the pollutants through each point of discharge.

Typically, permit applications are not readily available online; often they exist in files only in their original paper format. The NPDES permitting agencies must be contacted to obtain access to the files and applications.

4.4.4.3 Toxics Release Inventory Records

EPA operates a completely separate national program known as the Toxics Release Inventory (TRI). Begun in 1988 through the Emergency Planning and Community Right-to-Know Act (EPCRA), the TRI contains information on releases of nearly 650 chemicals and chemical categories from industries, including manufacturing, metal and coal mining, electric utilities, and commercial hazardous waste treatment, among others. Facilities must report releases and other waste management information if they:

- Have 10 or more full-time employees or the equivalent;
- Are in a covered North American Industry Classification System (NAICS) code; and

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[33] The URL is http://www.epa-echo.gov/cgi-bin/effluents.cgi?permit=PA0008281&charts=viols&monlocn=all&outt=all. (Accessed December 30, 2009.)

[34] A blank copy of Form 2C can be found on EPA's Web site at: http://www.epa.gov/npdes/pubs/3510-2C.pdf. (Accessed December 29, 2009.)

- Exceed any one threshold for manufacturing (including importing), processing, or otherwise using a toxic chemical listed in 40 CFR 372.65. (Additional information can be found in 40 CFR 372.22.)

Each year, industries within the scope of the TRI must report releases of the listed chemicals to different environmental media, such as air, surface water, ground water via underground injection, land via land treatment, impoundments, or other mechanisms. EPA makes the TRI data readily available through its TRI Explorer tool.[35] Users can extract data from different geographic regions for subsets of the chemicals or for different industry sectors.

It is possible to get annual pound loads of certain chemicals on the TRL list for individual facilities. However, the load represents a composite of all discharges and waste streams. For example, it does not allow for differentiating between ash handling water and cooling tower blowdown.

Figure 4-2 shows the type of information that can be gleaned from TRI records, again using the PPL Brunner Island plant as an example. Although the print in Figure 4-2 is small, readers can see the types of data that can be reported through the TRI program. In this case, the plant reported no releases of any of the TRI chemicals to surface water in quantities above the reporting threshold. The plant did have some reportable releases to the air during the year.

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[35] The URL is http://www.epa.gov/triexplorer/facility.htm. (Accessed December 29, 2009.)

Figure 4-2. 2008 TRI Data for PPL Brunner Island Power Plant

	Other On-site Disposal or Other Releases									
Facility and Chemical	Fugitive Air Emissions	Point Source Air Emissions	Surface Water Discharges	Underground Injection Class II-V Wells	Land Treatment	RCRA Subtitle C Surface Impoundments	Other Surface Impoundments	Other Land Disposal	Sub Total	Total On- and Off-site Disposal or Other Releases
BRUNNER ISLAND STEAM ELECTRIC STATION, WAGO RD PPL BRUNNER ISLAND SES, YORK HAVEN	**45**	**5,259,238**	**0**	**0**	**0**	**0**	**0**	**0**	**5,259,283**	**5,259,321**
ARSENIC COMPOUNDS	5	1,461	0	0	0	0	0	0	1,466	1,466
BARIUM COMPOUNDS	5	5	0	0	0	0	0	0	10	10
CHROMIUM COMPOUNDS(EXCEPT CHROMITE ORE MINED IN THE TRANSVAAL REGION)	5	950	0	0	0	0	0	0	955	993
COBALT COMPOUNDS	5	376	0	0	0	0	0	0	381	381
COPPER COMPOUNDS	5	5	0	0	0	0	0	0	10	10
DIOXIN AND DIOXIN-LIKE COMPOUNDS	0	**	0	0	0	0	0	0	**	**
HYDROCHLORIC ACID (1995 AND AFTER "ACID AEROSOLS" ONLY)	0	4,171,700	0	0	0	0	0	0	4,171,700	4,171,700
HYDROGEN FLUORIDE	0	521,463	0	0	0	0	0	0	521,463	521,463
LEAD COMPOUNDS	0	1,426	0	0	0	0	0	0	1,426	1,426
MANGANESE COMPOUNDS	5	1,693	0	0	0	0	0	0	1,698	1,698
MERCURY COMPOUNDS	0	293	0	0	0	0	0	0	293	293
NICKEL COMPOUNDS	5	1,013	0	0	0	0	0	0	1,018	1,018
SELENIUM COMPOUNDS	5	4,519	0	0	0	0	0	0	4,524	4,524
SULFURIC ACID (1994 AND AFTER "ACID AEROSOLS" ONLY)	0	552,902	0	0	0	0	0	0	552,902	552,902
ZINC COMPOUNDS	5	1,432	0	0	0	0	0	0	1,437	1,437
Total	**45**	**5,259,238**	**0**	**0**	**0**	**0**	**0**	**0**	**5,259,283**	**5,259,321**

Source: EPA TRI Explorer website.

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Chapter 5 – Potential for Power Plants to Be Impacted by TMDLs

The previous chapters have provided background information on the regulatory requirements related to evaluating water quality, how TMDLs are developed, the three river systems included in this report, the actual TMDLs developed by states for water body segments within those river systems, and the operations and waste streams associated with coal-fired power plants. In Chapter 5, this information is brought together in a discussion of the potential for power plant discharges and other non-discharge operations such as air emissions to become restricted through future TMDLs.

5.1 Key Pollutants

EPRI (2009a) suggests a short list of pollutants of particular concern to the power industry:

- Mercury,
- Nitrogen,
- Heat and temperature,
- Metals other than mercury,
- PCBs,
- Phosphorus, and
- Stormwater sediment.

These pollutants were identified by polling members of EPRI's TMDL Program Advisory Committee. Each of these is discussed in the following sections.

5.2 Mercury

One of the leading sources of mercury in the atmosphere is coal combustion. Air emissions are transported through the atmosphere until they fall to the ground as dry fall or rainfall.

Mercury has been identified as a cause of impairment for each of the river systems studied in this report. Some of the states associated with those river systems have already developed TMDLs for mercury, while others have mercury on their lists for upcoming TMDL development.

EPRI (2009a) offers the following reasons why mercury is an important TMDL pollutant for the power industry:

- Air regulations are likely to become stricter over time. This could potentially increase mercury concentrations in wastewater discharges.
- Mercury analytical methods may be developed with lower detection limits, resulting in more mercury TMDLs.

- EPA and state water quality criteria are already set at very low concentrations. New water quality standards could be developed for mercury at even lower levels.
- Although point source contributions of mercury can be measured to very low and precise levels, it is and will be difficult to quantify nonpoint sources and contributions of mercury.
- It is challenging to model the behavior of mercury in the aquatic environment.

Another important impact of mercury, not included in the list above, is its contribution to nonpoint source pollution, often hundreds of miles down-drift from the exhaust source. EPA and states are wrestling with how to control nonpoint source mercury in one jurisdiction when it originates in one or more different jurisdictions. One approach being used is development of regional TMDLs. Regional TMDLs can be established on different geographic scales. EPRI (2009b) identifies three existing regional mercury TMDLs as of March 2009 and one other under development:

- The smallest regional mercury TMDL covers the Ochlockonee watershed in Georgia (EPA 2002).
- The Minnesota Statewide Mercury TMDL (MPCA 2007) divides the state into two regions.
- The Florida Mercury TMDL (FLDEP 2007, under development) covers the entire state.
- The Northeast Regional Mercury TMDL (Connecticut DEP et al. 2007, previously mentioned in Section 3.4.2.1) covers seven states collectively as a region.

EPA developed guidance for mercury TMDLs where atmospheric contributions are the predominant source of mercury loading (EPA 2008). The document identifies the elements of TMDLs and other considerations for developing mercury TMDLs at different geographic scales in a checklist format. A few key recommendations from the checklist are shown below:

- The TMDL should include information on the geographic distribution of air deposition (i.e., whether deposition is uniform across the state or region, or whether there are any areas with local sources and significantly higher local deposition.
- Where water bodies are grouped into regions, the TMDLs should include a calculation of the total nonpoint source load (air deposition load) for each region or group of water bodies. In a multi-state approach, the TMDL should indicate the geographic distribution of sources across multiple states and identify any state or local differences, and how the TMDL accounts for such differences. For example, the northeastern states regional mercury TMDL set its allocations based on the different fish tissue criteria in each state.
- The TMDL or TMDLs may include a single gross load allocation for a group of water bodies or area within the state where data shows that loadings (e.g., air deposition) are relatively uniform over that region or area, or areas of higher deposition compared to other areas may need to be addressed with a separate TMDL calculation and allocation.

- A state may choose to, but is not required to, identify in-state and out-of-state contributions to the load allocation (or out-of-region, in the case of a multi-state approach).
- States may wish to use adaptive implementation, which involves an iterative implementation process that makes progress toward achieving water quality goals as new data and information become available. Mercury TMDLs have also used a staged implementation approach in which implementation is staged over a period of time, with reduction goals to be met in several phases.

5.3 Nitrogen

Nitrogen enters the environment from many sources, including agricultural runoff, sewage discharges, and atmospheric sources. Of particular concern to the power industry is the formation of nitrogen oxide (NO_x) compounds during the coal combustion process. Historically, power plant emissions contributed large amounts of nitrogen to the atmosphere. Through various Clean Air Act programs, power plant emissions have been greatly reduced. However, the treatment technologies used to remove nitrogen from air emissions result in the nitrogen entering wastewater or solid waste streams. If those streams are not properly managed, they can contribute to nitrogen releases to the environment. In addition to the air pollution control equipment, other plant activities, such as sewage treatment plant effluent, contribute nitrogen to surface waters.

Nitrogen, or its various forms (e.g., nitrate, nitrite, ammonia) can cause water quality impairment primarily through nutrient enrichment of water bodies. Nitrogen and/or phosphorus serve as food sources for microorganisms and algae. When those organisms overpopulate and die off, decomposition of their biomass leads to oxygen depletion, eutrophication, and degradation of a healthy aquatic ecosystem. In addition, ammonia can have toxic impacts when present at high enough concentrations. EPA has developed national water quality criteria for ammonia; many states have also adopted ammonia water quality criteria.

All three of the river systems studied in this report have water bodies impaired by low dissolved oxygen. Some states also list excessive algal growth, unionized ammonia, benthic or fish bioassessments, ecological integrity, nutrients, and nitrogenous BOD as other causes of impairment. Nitrogen discharges can contribute to all of these.

As described previously for mercury, in some situations, regional TMDLs for nitrogen or related pollutants may be developed. These are discussed in more detail in EPRI (2009b). The first regional TMDL associated with nitrogen was jointly developed for Long Island Sound by New York and Connecticut (NYDEC and Connecticut DEP 2000). The goal of the TMDL is to reduce nitrogen inputs to the Long Island Sound so that water quality standards can be achieved for dissolved oxygen.

EPA's Chesapeake Bay Program Office has been working on a Chesapeake Bay watershed TMDL for nutrients for several years. EPA plans to complete its work in December 2010. The most recent draft estimate of allowable loads is presented in a November 3, 2009, letter from EPA to each of the bay states. The actual letter sent to Virginia[36] is available on the EPA Chesapeake Bay TMDL website.[37] It shows annual loads of nitrogen and phosphorus for each major tributary, and sums them for the entire watershed. Of relevance to this report, the letter sets a proposed nitrogen target load for the Susquehanna River Basin of 80.18 million lb/year. Separate allocations are given for New York, Pennsylvania, Maryland, West Virginia, Delaware, and the District of Columbia.

5.4 Heat and Temperature

Coal-fired power plants produce a very large amount of heat that must be dissipated. Most plants employ water as the cooling medium. Many of the nation's plants that use once-through cooling systems are operating under thermal variances authorized through Section 316(a) of the CWA. The 316(a) variances allow alternative thermal limits if the discharger can demonstrate that the otherwise applicable thermal effluent limits are more stringent than necessary to protect the organisms in and on the receiving water body, and that other, less stringent effluent limitations would protect those organisms. The variance does not eliminate the need to meet any applicable water quality-based limits for constituents of cooling water other than heat or temperature.

316(a) variances must be reviewed during each permit renewal cycle (nominally five years). In the past, most 316(a) variances were routinely renewed. However, with today's greater emphasis on water body impairment, the potential exists for TMDLs to drive stricter thermal discharge loads, primarily in situations in which other dischargers are adding heat to a water body or land use conditions in a water body lead to a change in thermal impacts. During future power plant NPDES permit renewals, the permitting agencies may give more scrutiny to thermal discharge impacts.

In addition to the direct impacts of discharging heated water on aquatic organisms, warmer temperatures in the water bodies can compound other impairments. For example, bacteria grow more rapidly in warmer water. If a stream is impaired or nearly impaired by *E. coli* or fecal coliform, warmer conditions could exacerbate the bacterial loads. The ability of water to hold dissolved oxygen declines as water temperature increases. Warmer in-stream water could contribute to a low dissolved oxygen condition.

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[36] The URL is http://www.epa.gov/reg3wapd/pdf/pdf_chesbay/Bay_TMDL_Loads_Letter.pdf. (Accessed December 31, 2009.)

[37] The URL is http://www.epa.gov/reg3wapd/tmdl/ChesapeakeBay/index.html. (Accessed December 31, 2009.)

Drought conditions can lead to warmer in-stream temperatures. Power plants using once-through cooling are designed for a fixed delta-T (fixed increase in temperature from intake to discharge). If the water temperature at the intake rises because of drought conditions, discharge temperatures may rise, too. Conceivably, this could lead to exceedances in the plant's NPDES permit. Kimmell and Veil (2009) note that a few plants have been forced to shut down operations when drought conditions create unacceptably high discharge temperatures.

Water bodies within the Roanoke and Susquehanna River watersheds have identified temperature and thermal modification as causes of impairment.

5.5 Metals Other Than Mercury

The EPRI TMDL Program Advisory Committee members elected to list all other metals collectively (EPRI 2009a). However, that report does mention arsenic, boron, cadmium, chromium, copper, lead, manganese, nickel, selenium, and zinc as pollutants of concern. Metals are present in coal as impurities. When coal is combusted, much of the metals end up in the fly ash. When ash is managed in wet handling systems, some of the metals can dissolve into the wastewater.

EPRI (2009a) raises two specific concerns about metals:

- As air quality standards get stricter, there may be more metals that end up in the fly ash waste stream. Management of the ash handling wastewater and solid wastes will become more of a challenge.
- The state water quality standards for metals are frequently expressed as the dissolved form of the metal. Regulators may conservatively assume that 100 percent of the effluent metals are dissolved, and set the limit in terms of total metals. This can bias metals TMDLs toward excessive proposed load reductions.

Another consideration is the newly initiated EPA effort to update the ELGs for the steam electric power industry. EPA's data collection thus far has focused on the coal combustion waste streams. The results from the sampled plants indicate the presence of metals in the untreated wastewater at relatively high levels. This is likely to draw attention from the regulatory community to examine the levels of metals in the treated and discharged wastewater.

While not specifically discussed in EPRI (2009a), metals associated with acid mine drainage can impact water bodies. Portions of the Monongahela and Susquehanna watersheds are located in areas that have historically supported extensive coal mining. Many local water bodies are impaired by acid mine drainage from old mining activities. Pennsylvania and West Virginia have developed many TMDLs for control of acid mine drainage. Typically the TMDLs set limits on aluminum, iron, manganese, and acidity. To the extent that coal-fired power plants are located in water bodies subject to these TMDLs, plant operations could potentially be impacted.

EPRI (1998; 2001; 2006a) developed a TMDL modeling tool called the Watershed Analysis Risk Management Framework (WARMF) to assist in evaluating water quality across watersheds. WARMF has been adapted for use in different environments and for different pollutants. Herr and Chen (2000) demonstrate how WARMF can be modified to assist in calculating TMDLs for acid mine drainage in the Cheat River, a tributary to the Monongahela River.

5.6 PCBs

PCBs are man-made chemicals that were used in hundreds of industrial and commercial applications including electrical, heat transfer, and hydraulic equipment; as plasticizers in paints, plastics, and rubber products (including caulk); and in many other industrial applications. They were often found in electrical transformers. Manufacturing of PCBs was banned in 1979 due to concerns about their persistence, bioaccumulation, and potential for adverse effects on human health and the environment.

The ELGs for the steam electric power industry prohibit the discharge of PCBs, but power plants typically do not have limits on PCBs in their NPDES permits because most plants have modified operations to avoid PCB discharges. Therefore, little PCB monitoring is undertaken in power plant effluents. All three of the river systems studied in this report have water bodies impaired by PCBs.

EPRI (2009a) raises several issues about PCBs that could result in concerns for electric utilities:

- PCB impairment is typically based on fish consumption advisories rather than on direct water quality measurements. As a result, calculation of TMDL targets can be complicated and often involves a translation between fish tissue to water column using limited data.
- It is difficult to quantify sources of PCBs from various potential sources (e.g., air deposition, legacy sediments, nonpoint sources). Reductions in point source discharges are often instituted as the primary means of complying with the TMDL, even though impacts from nonpoint sources such as legacy sediment contamination typically have much greater impacts.
- Advancement in analytical chemistry now allows for lower detection limits than were historically possible.

These concerns and others suggest that power plants may be faced with new PCB monitoring requirements in the future.

5.7 Phosphorus

Like nitrogen, phosphorus is an important nutrient. When present in excessive amounts, phosphorus can trigger eutrophication, low dissolved oxygen, and reduced ecological health.

Although power plants are not typically significant dischargers of phosphorus, many water bodies in the three river systems studied in this report were listed as having impairment caused nutrients, organic enrichment, etc. In Pennsylvania, many of the resulting TMDLs set loading limits for phosphorus.

EPRI (2009a) discusses several potential concerns about phosphorus for power plants:

- If a phosphorus reduction is needed for an impaired water body, TMDLs may target any point source discharges first, rather than implementing nonpoint source reductions, which are less enforceable.
- A coal-fired power plant may not even discharge phosphorus, but could still be considered a responsible party for TMDL action simply by impounding water and creating the environment for nutrient enrichment and dissolved oxygen problems to occur.

As noted in Section 5.2, EPA's Chesapeake Bay Program Office is developing a Chesapeake Bay watershed TMDL for nutrients. The most recent draft estimate of allowable loads is presented in a November 3, 2009, letter from EPA to each of the bay states. It shows annual loads of nitrogen and phosphorus for each major tributary, and sums them for the entire watershed. Of relevance to this report, the letter sets a proposed phosphorus target load for the Susquehanna River Basin of 3.29 million lb/year. Separate allocations are given for New York, Pennsylvania, Maryland, West Virginia, Delaware, and the District of Columbia.

5.8 Stormwater Sediment

The last pollutant listed by the EPRI TMDL Program Advisory Committee in EPRI (2009a) is stormwater sediment (their choice of terminology, not Argonne's). Sediment is ubiquitous. In addition to creating conditions unhealthy for aquatic organisms, sediment can carry other contaminants attached to soil particles.

By far the most common cause of impairment listed for the three river systems studied in this report is siltation, along with the other related causes (total suspended solids, sediments, and turbidity). In some cases, when the cause of water body impairment was listed as nutrients, organic enrichment, or low dissolved oxygen, the resulting TMDLs were written with loadings established for sediment.

Power plants typically occupy large tracts of land. When sections of the plant property are disturbed for construction activities, power plants can contribute sediment to water bodies. In addition to stormwater runoff, coal-fired power plants discharge other wastewater streams that contain suspended solids (e.g., coal pile runoff, cooling tower blowdown, low-volume wastewater streams, treated sewage).

5.9 Other Key Pollutants Not Listed by the Industry Committee

The EPRI TMDL Program Advisory Committee identified and listed the 7 pollutants it felt were most likely to affect the power industry. All of the selected pollutants are good choices. There may be a few other pollutants that justify mentioning in this chapter.

Section 5.4 notes that many water bodies within the Monongahela and Susquehanna watersheds are listed as impaired because of metals and pH. The resulting TMDLs typically are written with loads for aluminum, iron, manganese, and acidity. If coal-fired plants are located on streams with TMDLs for these pollutants, it is possible that plant NPDES permits could be modified.

Some of the water bodies are listed as impaired by salinity, total dissolved solids, or chlorides. The data shown in Appendix A indicate that FGD wastewater is very high in chlorides and total dissolved solids. In another related topic, large portions of the Monongahela and Susquehanna watersheds carry high TDS loads from legacy abandoned mine activities and are underlain by the Marcellus Shale formation that is being rapidly developed for natural gas production. In the past few years, gas exploration and production in Pennsylvania and West Virginia has increased dramatically. New York State is moving forward more slowly with gas wells. Part of the well preparation process involves hydraulic fracturing, in which several million gallons of fresh water, sand, and various chemicals are injected into a newly drilled well at very high pressure. The pressure creates fractures or cracks in the rock. When the pressure is released a few hours later, the sand remains in the cracks to prop them open, while much of the water is returned to the surface. During its time in the formation, the water picks up high concentrations of total dissolved solids. Disposal of this “flowback water” presents challenges for gas operators because of the high total dissolved solids. Until recently, gas operators hauled the flowback water to sewage treatment plants in the region. The plants blended the flowback water with its other wastewater and ran it through the plant.

Any organic components of the flowback water could be treated in the plant, but the plants did not have treatment units to reduce the total dissolved solids, which passed through the plant and were discharged. In earlier years, when the number of truck loads of flowback water was small, the incremental load of solids was not important. However, more recently, the volume of flowback water introduced to the plants became much larger such that the river to which the plant discharged showed an elevated total dissolved solids concentration.

In response to this, the PADEP developed draft regulations in November 2009 that would limit new discharges to 500 mg/L total dissolved solids, 250 mg/L total chlorides, and 250 mg/L total sulfate.[38] These limits are discharge limits and not water quality standards. Therefore, they do not necessarily trigger water quality exceedances and TMDL development.

New coal combustion wastewater treatment facilities at power plants in Pennsylvania could potentially be required to meet these strict discharge standards. Further, the enhanced awareness of total dissolved solids and chlorides as pollutants could lead to future TMDLs that could impact power plants. Other nearby states may follow Pennsylvania's lead and adopt regulations targeted at shale gas wastewater.

Other pollutants not discussed in this chapter could impact coal-fired power plants under the right set of circumstances. It is not possible to predict all situations under which power plants may be impacted by new TMDLs.

5.10 Power Industry Awareness and Participation

The process of developing TMDLs is subject to public notice with ample opportunity to comment. It is in the power companies' best interests to pay close attention to the 303(d) lists that are prepared every two years and the TMDLs that are developed as resources allow. Power companies and industry associations like EPRI may be able to assist funding-limited state agencies in developing TMDLs that reflect sound science.

EPRI (2009a) outlines some of the benefits to power companies from participating in the TMDL process:

- Early involvement may help reduce the need to challenge the outcome through costly procedural or legal pathways.
- TMDL involvement may give a power company the opportunity to build relationships with regulators and other stakeholders in the community through meetings, sharing of data, and consensus building. [Note: The author, who worked in a state NPDES program early in his career, can confirm the value of such relationships to enhance communication].
- A TMDL requires the identification of pollutant loads from all potential sources prior to setting acceptable limits. This exercise may help refocus attention to pollution sources other than large and visible point sources, particularly if the agency's preconceived impression is that all or most of the contribution comes from a handful of dischargers, when in reality the science shows that it is mix of point and nonpoint sources causing the impairment.

[38] The URL is http://www.pabulletin.com/secure/data/vol39/39-45/2065.html. (Accessed December 31, 2009.)

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Chapter 6 – Findings and Conclusions

This report provides an overview of and introduction to the process of assessing and improving water quality in surface water bodies. The discussion focuses on three eastern river systems – the Roanoke River, the Monongahela River, and the Susquehanna River. The report evaluates how TMDLs may impact coal-fired power plants, some of which are located within each of the three studied watersheds.

6.1 Findings

- The CWA requires each state to evaluate all of the water bodies within its boundaries every two years. Any water body that is impaired from meeting its designated uses by one or more pollutants must be listed in a formal 303(d) list that is submitted to EPA. When a water body is listed as impaired, the states must develop TMDLs that allocate loadings for the target pollutant to each point source and nonpoint source contributing to the water body. The TMDLs must also include a margin of safety in the calculations.
- For the three river systems studied in this report, the states have listed more than 6,000 impaired water body/pollutant pairs. Many of the impairments are attributed to siltation, sedimentation, metals, pH, bacteria, and nutrients, although other pollutants are listed, too.
- The states targeted in this study have developed more than 175 TMDLs to address the impaired water bodies in the three river systems. This constitutes just a small fraction of the impaired water bodies within the states. However, many of the TMDLs cover a stream and all of its tributaries, whereas the impaired streams list shows each stream segment or tributary separately.
- The pollutants actually limited in the TMDLs are not necessarily the same ones that are listed as the cause of impairment. For example, many water bodies reported impairment from metals and pH. However, the individual TMDL reports for these segments typically set loadings for aluminum, iron, manganese, and acidity. There is a relationship between metals and iron, for example, but the actual substances are different. The determination of impairment and the subsequent development of TMDLs are supposed to be done on a pollutant-by-pollutant basis. For other water bodies, the cause of impairment was listed as nutrients, organic enrichment, etc. The resulting TMDLs typically set loading for phosphorus and sediment. As noted above, the cause of impairment is listed as a generic parameter while the TMDL-limited parameter is a more specific pollutant.
- An EPRI TMDL Program Advisory Committee identified and listed 7 pollutants it felt were most likely to affect the power industry. These are:
    - Mercury,
    - Nitrogen,
    - Heat and temperature,

  - Metals other than mercury (particularly “heavy metals”),
  - PCBs,
  - Phosphorus, and
  - Stormwater sediment.
- Several other pollutants, not on the Committee’s list, are also discussed as having potential for impact on coal-fired power plants. These are the pollutants associated with acid mine drainage (aluminum, iron, manganese, and acidity) and those associated with salinity (total dissolved solids and chlorides).

6.2 Conclusions

- The power industry has historically been implicated as a source of pollution for mercury and nitrogen through air emissions from coal-fired power plants. Because airborne pollutants are transported over long distances before they fall to the ground, the state or region receiving the contamination may be different from the state in which the power plant is located. This creates regulatory challenges that are not yet resolved.
- The steam electric power industry is currently under additional scrutiny related to its wastewater discharges. The EPA is undertaking a multi-year effort to characterize discharges and develop new ELGs (discharge standards). Through the process of collecting much new analytical data on the pollutants present in power industry wastewater, regulatory agencies may add new and/or stricter limits to future NPDES permits. However, any new limits would be based on TMDLs only to the extent that new data indicated that discharges contributed to water quality exceedances.
- With only a relatively small number of existing TMDLs, and considering regulatory scrutiny on water quality in general and the power industry in particular, it is likely that new TMDLs will be developed and existing TMDLs may be revised to be more stringent. New efforts to develop new TMDLs and revise existing TMDLs are already under way.
- The power industry is well advised to keep informed of state and EPA efforts to develop new TMDLs that could affect the water bodies on which their plants are located or on nearby water bodies. Involvement by industry scientists and engineers can help in developing valid TMDLs that place restrictions on the most appropriate sources.

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Appendix A – Effluent Concentrations from Flue Gas Desulfurization Systems at Five Plants

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Analyte	Method	Unit	Big Bend – Influent to FGD Wastewater Treatment [a]	Homer City – Influent to FGD Wastewater Treatment [a]	Widows Creek – FGD Scrubber Blowdown [a]	Mitchell – FGD Scrubber Purge [a]	Belews Creek – FGD Scrubber Purge [a]
Routine Total Metals – 200.7							
Aluminum	200.7	µg/L	31,200	289,000	234,000	17,900	33,100 R
Antimony	200.7	µg/L	62.5	86.4	ND (86.9)	28.7	18.1 R
Arsenic	200.7	µg/L	75.5	1,590	523	72.5	236
Barium	200.7	µg/L	1,590	11,900 R	7,200	588	651
Beryllium	200.7	µg/L	12.9	28.8	44.3	8.04	3.60 R
Boron	200.7	µg/L	626,000	224,000	28,900	229,000	307,000 R
Cadmium	200.7	µg/L	224	150	89.2	19.7	ND (0.250)
Calcium	200.7	µg/L	6,690,000	3,220,000	5,990,000	3,030,000	6,070,000
Chromium	200.7	µg/L	757	1,400	1,360	70.7	84.8 R
Cobalt	200.7	µg/L	172	369	ND (217)	68.0	14.7 R
Copper	200.7	µg/L	120	811	653	164	37.6
Iron	200.7	µg/L	23,500	824,000	299,000	60,600	59,100 R
Lead	200.7	µg/L	69.1	340	436	103	31.2 R
Magnesium	200.7	µg/L	4,830,000	2,760,000	321,000	1,470,000	990,000
Manganese	200.7	µg/L	21,900	225,000	2,780	28,800	9,020 R
Mercury	245.1	µg/L	ND (10.0)	243	26.5	67.5	NA
Molybdenum	200.7	µg/L	618	375	1,340	65.0	NA
Nickel	200.7	µg/L	2,090	2,560 R	489	554	1.59 R
Selenium	200.7	µg/L	4,150	4,000 R	652	2,130	2,930 R
Silver	200.7	µg/L	ND (20.0)	ND (40.0)	ND (86.9)	ND (20.0)	10.0
Sodium	200.7	µg/L	2,530,000	1,430,000	104,000	314,000	61,000
Thallium	200.7	µg/L	ND (10.0)	Exclude	ND (43.4)	ND (10.0)	41.2 R
Titanium	200.7	µg/L	420	1,300 R	8,180	377	NA
Vanadium	200.7	µg/L	724	766	1,580	203	77.6
Yttrium	200.7	µg/L	245	586	217	64.9	NA

Analyte	Method	Unit	Big Bend – Influent to FGD Wastewater Treatment [a]	Homer City – Influent to FGD Wastewater Treatment [a]	Widows Creek – FGD Scrubber Blowdown [a]	Mitchell – FGD Scrubber Purge [a]	Belews Creek – FGD Scrubber Purge [a]
Zinc	200.7	µg/L	1,540	1,900	3,140	885	ND (25.0)
Routine Dissolved Metals – 200.7							
Aluminum	200.7	µg/L	ND (50.0)	ND (50.0)	86.6	ND (50.0)	ND (50.0)
Antimony	200.7	µg/L	33.9	ND (20.0)	ND (20.0)	ND (20.0)	ND (4.00)
Arsenic	200.7	µg/L	18.6	ND (10.0)	13.9	ND (10.0)	24.7 R
Barium	200.7	µg/L	1,820	149 R	257	488	489 R
Beryllium	200.7	µg/L	ND (5.00)	10.5	ND (5.00)	6.02	ND (1.00)
Boron	200.7	µg/L	618,000	254,000	24,100	232,000	301,000 R
Cadmium	200.7	µg/L	179	26.2	ND (5.00)	ND (5.00)	ND (0.250)
Calcium	200.7	µg/L	4,470,000	1,990,000	849,000	2,350,000	5,370,000
Chromium	200.7	µg/L	ND (10.0)	ND (10.0)	18.7	ND (10.0)	19.2 R
Hexavalent Chromium	D1687-92	µg/L	24.0	ND (2.00)	ND (2.00)	5.00	4.20
Cobalt	200.7	µg/L	ND (50.0)	201	ND (50.0)	ND (50.0)	8.40 L,R
Copper	200.7	µg/L	27.2	14.5	ND (10.0)	ND (10.0)	ND (2.50)
Iron	200.7	µg/L	ND (100)	ND (100)	ND (100)	ND (100)	ND (25.0)
Lead	200.7	µg/L	ND (50.0)	ND (50.0)	ND (50.0)	ND (50.0)	ND (1.50)
Magnesium	200.7	µg/L	4,110,000	3,100,000	176,000	1,370,000	955,000 R
Manganese	200.7	µg/L	9,610	173,000	583	27,900	8,540
Mercury	245.1	µg/L	ND (10.0)	ND (10.0)	ND (2.00)	ND (10.0)	NA
Molybdenum	200.7	µg/L	581	30.6	876	22.2	NA
Nickel	200.7	µg/L	851	1,350	ND (50.0)	355	105 R
Selenium	200.7	µg/L	3,610	656 R	366	46.9	105 R
Silver	200.7	µg/L	ND (20.0)	ND (20.0)	ND (20.0)	ND (20.0)	7.80
Sodium	200.7	µg/L	1,970,000	1,440,000	76,700	324,000	58,700
Thallium	200.7	µg/L	14.3	61.2	14.3	ND (10.0)	106 R
Titanium	200.7	µg/L	12.5	ND (10.0)	ND (10.0)	ND (10.0)	NA

Analyte	Method	Unit	Big Bend – Influent to FGD Wastewater Treatment [a]	Homer City – Influent to FGD Wastewater Treatment [a]	Widows Creek – FGD Scrubber Blowdown [a]	Mitchell – FGD Scrubber Purge [a]	Belews Creek – FGD Scrubber Purge [a]
Vanadium	200.7	µg/L	108	ND (20.0)	ND (20.0)	ND (20.0)	2.00 R
Yttrium	200.7	µg/L	ND (5.00)	6.28	ND (5.00)	ND (5.00)	NA
Zinc	200.7	µg/L	16.8	ND (10.0)	ND (10.0)	87.8	ND (25.0)
Low-Level Total Metals – 1631E, 1638, HG-AFS							
Antimony	1638	µg/L	24.9	31.1	51.8	9.23	17.6 R
Arsenic	1638	µg/L	165	1,220	617	59.9	1,270
Arsenic	1638 – DRC	µg/L	NA	NA	NA	NA	1,010 R
Arsenic	HG-AFS	µg/L	NA	NA	NA	NA	929
Cadmium	1638	µg/L	238	52.8 R	86.0	5.28	4.84 R
Chromium	1638	µg/L	651 L	1,270	1,380	176 L	256
Chromium	1638 – DRC	µg/L	NA	NA	NA	NA	262 R
Copper	1638	µg/L	103	747	826	139	188 R
Lead	1638	µg/L	69.9	351	545	68.1	193 R
Mercury	1631E	µg/L	16.4	533	24.7	138	85.6
Nickel	1638	µg/L	2,570	2,840	634	650	1,240
Nickel	1638 – DRC	µg/L	NA	NA	NA	NA	396 R
Selenium	1638	µg/L	3,470	3,530	651	1,990	8,660
Selenium	1638 – DRC	µg/L	NA	NA	NA	NA	8,250 R
Selenium	HG-AFS	µg/L	NA	NA	NA	NA	9,100
Thallium	1638	µg/L	39.8	37.3	93.8	6.33	9.51 R
Zinc	1638	µg/L	1,870	2,130	2,720	730	438
Zinc	1638 – DRC	µg/L	NA	NA	NA	NA	526 R
Low-Level Dissolved Metals - 1631E, 1636, 1638, HG-AFS							
Antimony	1638	µg/L	21.9	ND (0.400)	8.90	1.97	3.83
Arsenic	1638	µg/L	137	24.2 R	18.0	20.2	133
Arsenic	1638-DRC	µg/L	NA	NA	NA	NA	17.4 R

Analyte	Method	Unit	Big Bend – Influent to FGD Wastewater Treatment [a]	Homer City – Influent to FGD Wastewater Treatment [a]	Widows Creek – FGD Scrubber Blowdown [a]	Mitchell – FGD Scrubber Purge [a]	Belews Creek – FGD Scrubber Purge [a]
Arsenic	HG-AFS	µg/L	NA	NA	NA	NA	11.4
Cadmium	1638	µg/L	190	24.5	3.16	ND (1.00)	4.47
Chromium	1638	µg/L	ND (160)	ND (16.0)	ND (16.0)	ND (80.0)	19.1
Chromium	1638-DRC	µg/L	NA	NA	NA	NA	ND (5.00)
Copper	1638	µg/L	ND (40.0)	11.3	ND (4.00)	ND (20.0)	ND (5.00)
Lead	1638	µg/L	ND (10.0)	ND (1.00)	ND (1.00)	ND (0.500)	ND (2.00)
Mercury	1631E	µg/L	0.206	0.0809	0.0761	0.0111	0.0844
Nickel	1638	µg/L	1,030	1,450	29.6	433	382
Nickel	1638-DRC	µg/L	NA	NA	NA	NA	316 R
Selenium	1638	µg/L	3,280	584	325	443	468
Selenium	1638-DRC	µg/L	NA	NA	NA	NA	412 R
Selenium	HG-AFS	µg/L	NA	NA	NA	NA	206
Thallium	1638	µg/L	39.4	23.2	22.5	4.47	11.1 R
Zinc	1638	µg/L	ND (100)	34.7	ND (10.0)	160	78.6
Zinc	1638-DRC	µg/L	NA	NA	NA	NA	69.7 R
Classicals							
Ammonia As Nitrogen (NH_3-N)	4500-NH_3F[b]	mg/L	31.5	4.12	2.26	1.89	1.50
Nitrate/Nitrite (NO_3-N + NO_2-N)	353.2	mg/L	NA	54.5	1.00	20.6	14.7
Total Kjeldahl Nitrogen (TKN)	4500-N,C[b]	mg/L	51.6	14.2	22.3	13.3	6.20
Biochemical Oxygen Demand (BOD)	5210B	mg/L	1,370	ND (120)	172	21.0	ND (4.00)
Chemical Oxygen Demand (COD)	5220 C	mg/L	NA	NA	NA	NA	304
Chloride	4500-CL-C[b]	mg/L	24,200	11,800	832	7,200	9,680
Hexane Extractable Material (HEM)	1664A	mg/L	ND (6.00)	ND (5.00)	22.0	11.0	ND (5.00)

Analyte	Method	Unit	Big Bend – Influent to FGD Wastewater Treatment [a]	Homer City – Influent to FGD Wastewater Treatment [a]	Widows Creek – FGD Scrubber Blowdown [a]	Mitchell – FGD Scrubber Purge [a]	Belews Creek – FGD Scrubber Purge [a]
Silica Gel Treated HEM (SGT-HEM)	1664A	mg/L	NA	NA	6.00 E	ND (5.00)	ND (5.00)
Sulfate	D516-90[b]	mg/L	3,590	6,920	11,900	1,640	1,290
Total Dissolved Solids (TDS)	2540 C	mg/L	44,600	23,200	4,740	18,100	34,600
Total Phosphorus	365.3[b]	mg/L	0.990	2.64	10.5	3.57	9.90
Total Suspended Solids (TSS)	2540 D	mg/L	4,970	13,300	25,300 E	7,320	5,200

Source: [ERG, 2008l; ERG, 2008m; ERG, 2008n; ERG, 2008o; ERG, 2009q].
Note: EPA used several analytical methods to analyze for metals during the sampling program. For the purposes of sampling program, EPA designated some of the analytical methods as "routine" and some of them as "low-level." EPA designated all of the methods that require the use of clean hands/dirty hands sample collection techniques (i.e., EPA Method 1669 sample collection techniques) as "low-level" methods. Note that although not required by the analytical method, EPA used clean hands/dirty hands collection techniques for all low-level and routine metals samples.
a – The concentrations presented have been rounded to three significant figures.
b – The method used for the Belews Creek sampling analysis is different than the method presented in the table. See Table 2-3 for details.
DRC – Dynamic reaction cell. For the Belews Creek analysis, a DRC was used in combination with EPA Method 1638 for certain analytes.
E – Sample analyzed outside holding time.
HG-AFS – Hydride generation and atomic fluorescence spectrometry.
L – Sample result between 5x and 10x the blank result.
R – MS/MSD % recovery outside method acceptance criteria.
Exclude – Results were excluded because the MS/MSD samples had a zero percent recovery.
NA – Not analyzed.
ND – Not detected (number in parentheses is the report limit). The sampling episode reports for each of the individual plants contains additional sampling information, including analytical results for analytes measured above the detection limit, but below the reporting limit (i.e., J-values).

Author's note: The ERG references cited at the end of this table were not reviewed, nor were they listed in this report's reference section. Interested readers can review EPA (2009) to learn more about those references.

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Appendix B – Effluent Concentrations from Wet Ash Transport Systems at Two Plants

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Analyte	Method	Unit	Widows Creek – Influent to Combined Ash Pond [a,b]	Cardinal - Influent to Fly Ash Pond [a]
Routine Metals – Total				
Aluminum	200.7	µg/L	94,800	320,000
Antimony	200.7	µg/L	ND (38.0)	ND (81.2)
Arsenic	200.7	µg/L	131	1,520
Barium	200.7	µg/L	6,080	5,060
Beryllium	200.7	µg/L	11.3	71.5
Boron	200.7	µg/L	4,330	2,790
Cadmium	200.7	µg/L	ND (9.50)	39.6
Calcium	200.7	µg/L	103,000	204,000
Chromium	200.7	µg/L	107	1,300
Cobalt	200.7	µg/L	ND (95.0)	381
Copper	200.7	µg/L	188	964
Iron	200.7	µg/L	80,700	298,000
Lead	200.7	µg/L	208	786
Magnesium	200.7	µg/L	25,700	35,100
Manganese	200.7	µg/L	337	1,120
Mercury	245.1	µg/L	2.66	2.31
Molybdenum	200.7	µg/L	65.5	333
Nickel	200.7	µg/L	ND (95.0)	739
Selenium	200.7	µg/L	27.5	ND (20.3)
Sodium	200.7	µg/L	31,200	69,900
Thallium	200.7	µg/L	ND (19.0)	ND (40.6)
Titanium	200.7	µg/L	7,150	24,900
Vanadium	200.7	µg/L	346	2,340
Yttrium	200.7	µg/L	133	521
Zinc	200.7	µg/L	785	1,220
Routine Metals – Dissolved				
Aluminum	200.7	µg/L	663	283
Antimony	200.7	µg/L	ND (20.0)	ND (20.0)
Arsenic	200.7	µg/L	46	86.8
Barium	200.7	µg/L	178	164
Beryllium	200.7	µg/L	ND (5.00)	ND (5.00)
Boron	200.7	µg/L	2,150	1,380
Cadmium	200.7	µg/L	ND (5.00)	ND (5.00)
Calcium	200.7	µg/L	40,300	94,800
Chromium	200.7	µg/L	ND (10.0)	ND (10.0)
Hexavalent Chromium	D1687-92	µg/L	ND (2.00)	5
Cobalt	200.7	µg/L	ND (50.0)	ND (50.0)
Copper	200.7	µg/L	ND (10.0)	ND (10.0)
Iron	200.7	µg/L	ND (100)	ND (100)
Lead	200.7	µg/L	ND (50.0)	ND (50.0)
Magnesium	200.7	µg/L	7,110	15,200
Manganese	200.7	µg/L	ND (15.0)	40.3
Mercury	245.1	µg/L	ND (0.200)	ND (0.200)
Molybdenum	200.7	µg/L	50.1	243

Analyte	Method	Unit	Widows Creek – Influent to Combined Ash Pond [a,b]	Cardinal - Influent to Fly Ash Pond [a]
Nickel	200.7	µg/L	ND (50.0)	ND (50.0)
Selenium	200.7	µg/L	26.8	16.6
Sodium	200.7	µg/L	13,400	64,400
Thallium	200.7	µg/L	ND (10.0)	ND (10.0)
Titanium	200.7	µg/L	ND (10.0)	ND (10.0)
Vanadium	200.7	µg/L	66.8	70.7
Yttrium	200.7	µg/L	ND (5.00)	ND (5.00)
Zinc	200.7	µg/L	ND (10.0)	ND (10.0)
Low-Level Metals – Total				
Antimony	1638	µg/L	13.1	33.1
Arsenic	1638	µg/L	88.9	519
Cadmium	1638	µg/L	ND (20.0)	9.51
Chromium	1638	µg/L	ND (160)	569
Copper	1638	µg/L	114	719
Lead	1638	µg/L	104	260
Mercury	1631E	µg/L	1.02	1.16
Nickel	1638	µg/L	ND (200)	291
Selenium	1638	µg/L	ND (200)	ND (200)
Thallium	1638	µg/L	ND (4.00)	43.6
Zinc	1638	µg/L	198	720
Low-Level Metals – Dissolved				
Antimony	1638	µg/L	8.54	17.4
Arsenic	1638	µg/L	49.5	80.7
Cadmium	1638	µg/L	ND (2.00)	ND (1.00)
Chromium	1638	µg/L	ND (16.0)	ND (80.0)
Hexavalent Chromium	1636	µg/L	NA	NA
Copper	1638	µg/L	ND (4.00)	ND (20.0)
Lead	1638	µg/L	ND (1.00)	ND (0.500)
Mercury	1631E	µg/L	ND (0.000500)	0.00055
Nickel	1638	µg/L	ND (20.0)	ND (100)
Selenium	1638	µg/L	ND (100)	21.2
Thallium	1638	µg/L	ND (0.400)	3.1
Zinc	1638	µg/L	ND (10.0)	ND (50.0)
Classicals				
Ammonia As Nitrogen (NH3-N)	4500-NH3F	g/L	0.4	0.17
Nitrate/Nitrite (NO3-N + NO2-N)	353.2	mg/L	0.36	2.65
Total Kjeldahl Nitrogen (TKN)	4500-N,C	mg/L	7.41	1.01
Biochemical Oxygen Demand (BOD)	5210B	mg/L	53	ND (2.00)
Chloride	4500-CL-C	mg/L	21.4	56.8
Hexane Extractable Material (HEM)	1664A	mg/L	ND (5.00)	7
Silica Gel Treated HEM (SGT-HEM)	1664A	mg/L	NA	6
Sulfate	D516-90	mg/L	58.1	1,110
Total Dissolved Solids (TDS)	2540 C	mg/L	224	662
Total Phosphorus	365.3	mg/L	16.6	4.03
Total Suspended Solids (TSS)	2540 D	mg/L	9,190	23,400

Appendix B Table Footnotes

Source: [ERG, 2008k; ERG, 2008o].
Note: EPA used several analytical methods to analyze for metals during the sampling program. For the purposes of sampling program, EPA designated some of the analytical methods as "routine" and some of them as "low-level." EPA designated all of the methods that require the use of clean hands/dirty hands sample collection techniques (i.e., EPA Method 1669 sample collection techniques) as "low-level" methods. Although not required by the analytical methods, EPA used clean hands/dirty hands collection techniques for all low-level and routine metals samples.
a – The concentrations presented have been rounded to three significant figures.
b – The sample collected from the diked channel influent to the combined ash pond represents only the wastewaters associated with six of the eight generating units. The wastewaters for the other two units enter the combined ash pond at a different point.
NA – Not analyzed.
ND – Not detected (number in parenthesis is the report limit). The sampling episode reports for each of the individual plants contains additional sampling information, including analytical results for analytes measured above the detection limit, but below the reporting limit (i.e., J-values).

Author's note: The ERG references cited at the end of this table were not reviewed, nor were they listed in this report's reference section. Interested readers can review EPA (2009) to learn more about those references.