# COMPREHENSIVE ANALYSIS OF THE SEDIMENTS RETAINED BEHIND HYDROELECTRIC DAMS OF THE LOWER SUSQUEHANNA RIVER

*Publication 239* *February 28, 2006*

*Prepared by*
*Robert E. Edwards*
*Special Projects Manager*

*Watershed Assessment and Protection Program*
*Susquehanna River Basin Commission*

This report is prepared in cooperation with the Chesapeake Bay Commission and the Pennsylvania Department of Environmental Protection.

# SUSQUEHANNA RIVER BASIN COMMISSION

Paul O. Swartz, Executive Director

Denise M. Sheehan, Acting N.Y. Commissioner
Kenneth P. Lynch, N.Y. Alternate
Scott J. Foti, N.Y. Alternate/Advisor

Kathleen A. McGinty, Pa. Commissioner
Cathleen C. Myers, Pa. Alternate
William A. Gast, Pa. Alternate/Advisor

Kendl Philbrick, Md. Commissioner
Dr. Robert M. Summers, Md. Alternate
Matthew G. Pajerowski, Md. Alternate/Advisor

Brigadier General William T. Grisoli, U.S. Commissioner
Colonel Robert J. Davis, Jr., U.S. Alternate
Colonel Francis X. Kosich, U.S. Alternate
Lloyd Caldwell, U.S. Advisor
Daniel M. Bierly, U.S. Advisor

The Susquehanna River Basin Commission was created as an independent agency by a federal-interstate compact* among the states of Maryland, New York, Commonwealth of Pennsylvania, and the federal government. In creating the Commission, the Congress and state legislatures formally recognized the water resources of the Susquehanna River Basin as a regional asset vested with local, state, and national interests for which all the parties share responsibility. As the single federal-interstate water resources agency with basinwide authority, the Commission's goal is to coordinate the planning, conservation, management, utilization, development and control of basin water resources among the public and private sectors.

**Statutory Citations: Federal - Pub. L. 91-575, 84 Stat. 1509 (December 1970); Maryland - Natural Resources Sec. 8-301 (Michie 1974); New York - ECL Sec. 21-1301 (McKinney 1973); and Pennsylvania - 32 P.S. 820.1 (Supp. 1976).*

This report is available on our website (www.SRBC.net) by selecting Public Information/Technical Reports. For a CD Rom or for a hard copy, contact the Susquehanna River Basin Commission, 1721 N. Front Street, Harrisburg, Pa. 17102-2391, (717) 238-0423, FAX (717) 238-2436, E-mail: srbc@srbc.net.

## TABLE OF CONTENTS

EXECUTIVE SUMMARY ..... 1
Background ..... 1
Introduction ..... 1
Scope of Work ..... 2
Findings ..... 4

## FIGURES

Figure 1. Sediment Core Sites Behind the Hydroelectric Dams on the Lower Susquehanna River and Upper Chesapeake Bay ..... 3

## APPENDICES

Appendix A. Characterization of Bed Sediment Behind the Lower Three Dams on the Susquehanna River

Appendix B. Phosphate Geochemistry and Microbial Activity in Surface Sediments from the Conowingo Reservoir and Susquehanna Flats, Md.: Summary of Findings

Appendix C. Characterization of Bed Sediment Behind the Lower Three Dams on the Susquehanna River: Activities of Anthropogenic Gamma Emitting Isotopes

# EXECUTIVE SUMMARY

## Background

The District of Columbia, State of Maryland, Commonwealths of Pennsylvania and Virginia, Chesapeake Bay Commission (CBC), and U.S. Environmental Protection Agency (USEPA) have agreed to restore and protect the estuarine environment of the Chesapeake Bay (Bay). The Susquehanna River is the largest tributary to the Bay and transports about one-half of the freshwater and a substantial amount of sediment to the Bay. The loads transported by the Susquehanna River to the Bay are significantly affected by the deposition of sediment behind three large hydroelectric dams on the lower Susquehanna River. Currently, the reservoirs trap 50 to 70 percent of the sediment. In 20 to 30 years, when the sediment trapping capacity may be reached, sediment loads to the Bay are expected to substantially increase and produce degraded water quality conditions for the aquatic communities in the Bay.

Nationally, the USEPA has reported that sediment, in its various forms, is the single most-cited reason for streams not meeting their designated use criteria and consequently being placed on the Clean Water Act Section 303(d) list. Sediment is a principal carrier of pesticides, heavy metals, bacteria, viruses, and other contaminants in streams. The data evaluated from bottom sediments collected in reservoirs on the lower Susquehanna River provide information on contaminants and potential toxicity.

## Introduction

The Susquehanna River Basin Commission (SRBC), with grant funding provided by the Pennsylvania Delegation of the CBC, convened a multi-agency, multi-disciplinary Sediment Task Force (STF) in July 1999. The STF was formed out of concern for sediment buildup and loss of storage capacity behind the large hydroelectric dams on the lower Susquehanna River. Additional concerns included water quality impacts to the Bay due to increases from delivered sediment and nutrient loads.

The STF evaluated a potential maintenance dredging operation behind one or more of the dams to maintain sediment retention capacity and minimize delivered loads to the Bay. This evaluation was consistent with a major sediment-related water quality goal contained in the Chesapeake 2000 Agreement, which calls for the Chesapeake Bay Program, in cooperation with the SRBC, to “adopt and begin implementing strategies that prevent the loss of the sediment retention capabilities of the Lower Susquehanna River dams” by the year 2003.

Before dredging can be considered an option, occurrence and distribution of toxic substances within the sediments must be evaluated. Previous studies have not focused extensively on sediment quality, and therefore, the data on the subject are limited. In order to prevent environmental damage that may occur from any mitigation efforts, resource managers need a more comprehensive assessment of contaminants in sediment.

## Scope of Work

The scope of work for the study included a physical examination and chemical analyses of the sediments behind three dams on the lower Susquehanna River. This study was undertaken by SRBC with grant funding from the CBC and Pennsylvania Department of Environmental Protection. The sampling and analyses were conducted as part of a multi-disciplinary effort in cooperation with the U.S. Geological Survey (USGS), Maryland Geological Survey (MGS), and University of Maryland Center for Environmental Studies (UMCES).

The USGS collected continuous profiles of sediment cores in 3-inch aluminum irrigation tubes using a boat-mounted vibracore collection system. In deeper areas of the reservoirs, generally greater than 20 feet, a gravity core collection system was deployed. Most of the cores were vibracores, while only the cores closest to the dams were gravity cores. Box core samples were collected to analyze adsorption/desorption properties of phosphorus. Locations of all sites were measured using a global positioning system.

The sediment core samples collected in aluminum irrigation tubes were transported horizontally back to shore. Once on shore, the tubes were cut into approximately 1.5-meter lengths and refrigerated near the collection sites. Cores were later transported to MGS where they were stored at 4 degrees Celsius, X-rayed, split open, described, photographed, and sub-sampled within a week of receipt.

Sediment samples were collected from 34 cores in the reservoirs behind the dams (Figure 1). They were then partitioned into surface, middle, and bottom portions. Shallow box cores, of about 20 centimeters (8 inches), were collected and analyzed for phosphate associations and mobility in and out of the sediments. In addition, an evaluation was made of the antibiotic sensitivity of *in situ* bacteria. The deeper cores were analyzed for particle size (sand-silt-clay and coal fractions), X-rayed for composition of the various layers, tested for metal concentrations, nutrients, organics (polychlorinated byphenyls (PCBs), pesticides, etc.), and selected radionuclides, which can be used as indicators for dating the sediment layers.

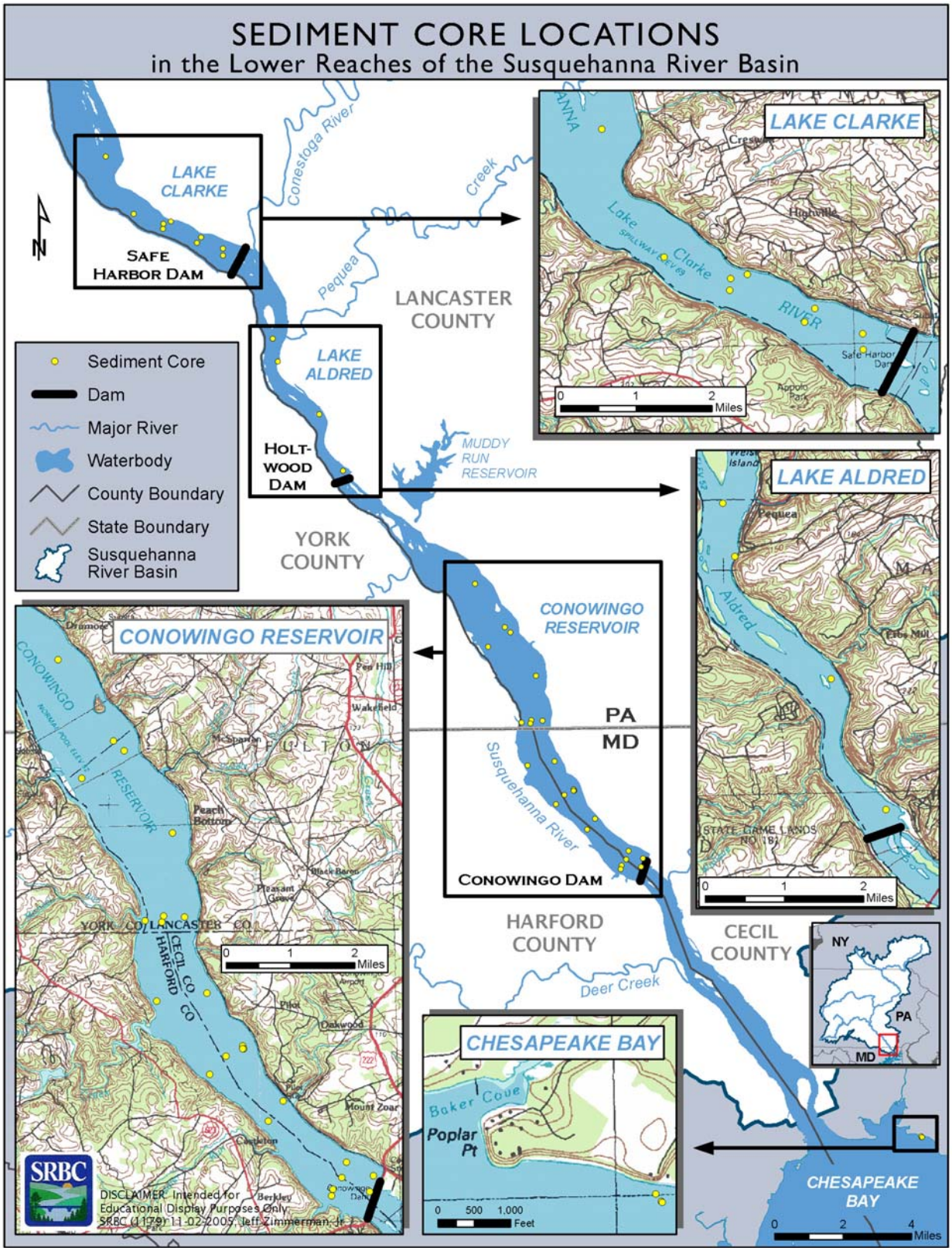


*Figure 1.* ***Sediment Core Sites Behind the Hydroelectric Dams on the Lower Susquehanna River and Upper Chesapeake Bay***

## Findings

The results of the detailed investigations are located in Appendixes A, B, and C. Brief summaries and major findings for each report are listed below.

### Characterization of Bed Sediment Behind the Lower Three Dams on the Susquehanna River

*James M. Hill and Geoffrey Wikel, Maryland Geological Survey, Baltimore, Md.*
*Rob Mason, Joel Baker, Debby Connell, and Dan Liebert, University of Maryland Center for Environmental Studies Chesapeake Biological Laboratory*

The growing concern that the dams on the Susquehanna River are reaching their sediment storage capacity has spurred the need for detailed information concerning the sediment trapped behind the dams. Characterization of these sediments is the foundation for choosing management strategies to address the decreasing storage capacity. In order to characterize the sediment, cores (vibracores and gravity cores) were taken from 34 sites distributed behind the three lower dams on the Susquehanna River, and two sites in the Susquehanna Flats in the upper Bay. Sub-samples of these cores were divided among several laboratories as part of a coordinated effort to analyze the sediments. The MGS laboratories were responsible for taking X-rays of the cores for physical structures, determining water content and grain size, and performing analyses of total - carbon (C), nitrogen (N), sulfur (S), phosphorus (P), cadmium (Cd), chromium (Cr), copper (Cu), iron (Fe), manganese (Mn), nickel (Ni), lead (Pb), and zinc (Zn).

The UMCES Chesapeake Biological Laboratory (CBL) was responsible for analyzing metals and metalloids, including silver (Ag), arsenic (As), cadmium (Cd), mercury (Hg), lead (Pb), and selenium (Se). CBL also analyzed sediments for polycyclic aromatic hydrocarbons (PAHs), PCBs, and pesticides.

***Findings from the Maryland Geological Survey and University of Maryland Chesapeake Biological Laboratory include the following:***

- Coal is a major component of the system. Of the 34 cores, 23 had distinct layers where coal was clearly the major constituent. Of these 23 cores, the average total length of the coal bearing layers was 24 centimeters for 100 centimeters of sediment depth. All samples analyzed to date contain coal whether visible on inspection or not. The average coal content of the sediment, excluding the visible coal layers, is approximately 11 percent.

- Sulfur content of the Susquehanna River sediments is approximately one-fourth to one-half the concentration of the lowest levels found in the Bay. The lower levels of sulfur indicate a lower potential for acid formation due to oxidation of the sulfur.

- Bed sediments behind the dams closely resemble the sediment in the northernmost reaches of the Bay, except for the high coal content and the lower levels of S and Mn (enriched in the northern Bay).

- The concentrations of metals analyzed in the Susquehanna River sediment cores were similar to concentrations found in the mainstem northern Bay. This is based on concentration ranges in the northern Bay, crustal abundance levels (using enrichment factors employing Fe concentrations to normalize the data), and baseline northern Bay metals behavior - As a result, the level of biological influence and expected toxicological effects of the metals would be similar to that found in the northern Bay sediments. The handling of Susquehanna sediments would be expected to be the same as the northern Bay sediments in this regard.

- Metal concentrations and geochemistry varied site to site. Specific locations and samples at greater depths had elevated metal concentrations. These variations in metal content are significant and must be addressed when deciding upon management options. For management options that result in sediment removal, one must evaluate the specific site and the depth to which sediment may be disturbed in order to assess any potential problems with sediment associated metals toxicity.

- High silver concentrations were found at depth, which suggests that in the past silver may have come from pollution sources within the river basin.

- Overall organic contaminant concentrations were comparable to those found in the upper Bay. However, the Susquehanna River appears to be the main source of PCBs to the upper Bay while pesticides and PAHs appear to be trapped behind the dams.

## Phosphate Geochemistry and Microbial Activity in Surface Sediments from the Conowingo Reservoir and Susquehanna Flats, Md.: Summary of Findings

*N. S. Simon, U.S. Geological Survey, Reston, Va.*
*Jenefir Isbister, George Mason University, Fairfax, Va. 22030*

The transport of phosphate is directly related to the transport of sediment. As part of a preliminary evaluation of the feasibility of dredging Conowingo Reservoir on the Susquehanna River, Pa., a characterization study was initiated that included a description of phosphorus biogeochemistry in the reservoir. Analyses included determination of total phosphorus and interstitial water phosphate concentrations, and phase association of phosphate from sequential extraction data. In addition, an evaluation was made of the antibiotic sensitivity of *in situ* bacteria.

Three box cores were collected in the reservoirs on the lower Susquehanna River in May 2000. To provide data for comparison of the characteristics of sediment that has been transported beyond the dam with the characteristics of sediment retained behind the dam, a fourth box core was collected at the mouth of the Susquehanna River, near Havre de Grace, Md.,

in August 2000. The box corer collected surface material to a depth of 20 cm (8-inches) without compaction of the sediment.

***Findings from the U.S. Geological Survey include the following:***

- Methane gas is escaping from the bottom sediments of the Conowingo Reservoir.

- Phosphate concentrations in the bottom sediments vary with location and with the amount of granular coal in the bottom sediment.

- Interstitial water contains small concentrations of phosphate with no increase in phosphate concentrations with depth from the sediment-water interface. Thus, the release of phosphate from bottom sediments does not occur by diffusion.

- The ranges in percent of total phosphorus for the geochemical phases are 2 to 4 percent exchangeable phosphate, 2 to 20 percent calcium-bound phosphate, 30 to 60 percent phosphate sorbed to iron oxides, and 30 to 70 percent organic phosphorus.

- The environmental conditions under which phosphorus could be released depend upon the geochemical phase of phosphorus. The exchangeable phosphate can be released to water if replaced by another anion. If calcium-bound phosphate is soluble, a slow release of phosphate can occur. Calcium-bound phosphate can be transported with suspended solids or formed in bottom sediment. Iron oxides could release phosphate under three conditions: (1) if oxidized iron is reduced ($Fe^{3+}$ to $Fe^{2+}$); (2) if hydrogen sulfide produced by bacterial sulfate reduction precipitates iron; or (3) if sediment is exposed to acidic conditions. Organic phosphorus would be available when microbes degrade organic matter.

- The largest concentrations of organic phosphorus found in samples were those in bottom sediments from the channel of Conowingo Reservoir.

- Iron oxide associated phosphorus is the principal geochemical phase in the bottom sediments collected at shoreline sites within Conowingo Reservoir.

- The bottom sediments are not a source of dissolved reactive phosphate to the water column of Conowingo Reservoir.

- Bacteria in the sediment that could be cultured in the laboratory were, in general, antibiotic resistant.

- Bacteria from all sampling sites were resistant to penicillin and ampicillin at normal effective concentrations for inhibition of microbial growth, as well as significantly higher antibiotic concentrations.

- Bacteria in the sediment collected within the Susquehanna Flats were resistant to all five antibiotics: amoxicillin, penicillin, ampicillin, tetracycline, and sulfadimethoxine.

**Characterization of Bed Sediment Behind the Lower Three Dams on the Susquehanna River: Activities of Anthropogenic Gamma Emitting Isotopes**

*Jeffrey C. Cornwell, University of Maryland Center for Environmental Science*
*Horn Point Laboratory, Cambridge, Md. 21613-0775*

The management of sediments trapped behind the lower Susquehanna River dams requires an understanding of the concentrations of pollutants within the sediment bed. Analyses of sediment cores provided new data on the activity (concentration) of the gamma-emitting nuclides (especially cesium-137 ($^{137}$Cs)) and other relevant nuclide data. The sources of anthropogenic radiation in this system included direct atmospheric inputs from the testing of nuclear weapons, erosional inputs of these same inputs, and inputs from two nuclear power generating facilities.

Horn Point Laboratory analyzed nuclides of environmental interest. These nuclides included silver-110 ($^{110}$Ag), cobalt-58 ($^{58}$Co), cobalt-60 ($^{60}$Co), cesium-134 ($^{134}$Cs), $^{137}$Cs, manganese-54 ($^{54}$Mn), zinc-65 ($^{65}$Zn), and zirconium-95 ($^{95}$Zr). In addition, radium-226 ($^{226}$Ra) was used for measurement calibration. While radium-226 ($^{226}$Ra) was not of environmental concern, its relatively constant activity in fine-grained muds provided a secondary check of the instrumentation counting system.

Most of the potential reactor nuclides in this study were not detected. Only $^{137}$Cs with a 30.2-year half-life was routinely detectable. The highest activities found in this study were approximately 42 milli-becquerels per gram (mBq $g^{-1}$), a relatively small amount of radiation. The higher activities found in other studies were of limited geographical extent and generally restricted to narrow sediment horizons. These typical activities were less than 15 mBq $g^{-1}$, with a substantial number of samples with no detectable $^{137}$Cs. Because anthropogenic nuclides have been around half the lifetime of the reservoirs, homogenization during activities such as dredging would result in sediment that would be extremely low in $^{137}$Cs. The likelihood of radiation issues in the placement of Susquehanna reservoir sediment would be very low. Any further work at the time of sediment removal should be restricted to the immediate vicinity of Peach Bottom Atomic Power Station.

***Findings from the University of Maryland Center for Environmental Science Horn Point Laboratory include the following:***

- Activities of $^{110}$Ag, $^{58}$Co, $^{60}$Co, $^{134}$Cs, $^{54}$Mn, $^{65}$Zn, and $^{95}$Zr were below the limit of detection due to the short half-lives of these nuclides.

- The highest activities of $^{137}$Cs were found near the Peach Bottom Atomic Power station. These results are consistent with other studies conducted near the reactor.

- It is unlikely that higher activities near Peach Bottom would have any environmental consequences for sediment placement.

- When compared to measured results in other studies (Donoghue et al.1989; McClean et al. 1991), the activities of $^{137}$Cs found in this investigation of reservoir sediments were

generally lower than activities observed in core data near Peach Bottom and in surficial grab samples.

- The range of $^{226}Ra$ activities of 20-30 mBq $g^{-1}$ were similar to $^{226}Ra$ activities documented in other studies of the Bay.

- Hot spots of high activity were not observed suggesting that radionuclide contamination was not a likely issue with these sediments.

# APPENDIX A

# Characterization of Bed Sediment Behind the Lower Three Dams on the Susquehanna River

# APPENDIX B

## Phosphate Geochemistry and Microbial Activity in Surface Sediments from the Conowingo Reservoir and Susquehanna Flats, Md.: Summary of Findings

# APPENDIX C

## Characterization of Bed Sediment Behind the Lower Three Dams on the Susquehanna River: Activities of Anthropogenic Gamma Emitting Isotopes