CHESAPEAKE BAY FOUNDATION

Saving a National Treasure

VIA ELECTRONIC MAIL

May 16, 2008

Dominion Virginia City Hybrid Energy Center
c/o Cindy M. Berndt
Department of Environmental Quality
P.O. Box 1105
Richmond, VA 23218
vchec@deq.virginia.gov

Re: Request for Comments by the Department of Environmental Quality on State Air Pollution Board Individual Member Correspondence on the Proposed Virginia City Hybrid Energy Center in Wise County, Virginia

Dear Mrs. Berndt:

The Chesapeake Bay Foundation, Inc. ("CBF") submits the following comments in response the request issued by the Department of Environmental Quality (DEQ) for public comments on the individual correspondence of State Air Pollution Control Board (Board) members concerning the Virginia City Hybrid Energy Center (VCHEC) in Wise County, Virginia. CBF applauds DEQ for providing a public website where comments and documents can be viewed by all interested citizens of the Commonwealth.

After reviewing the questions and issues posed in the correspondence of individual Board members, CBF finds that there are several questions surrounding the emission of hazardous air pollutants and the non- air quality environmental impacts of such emissions during the lifetime of the VCHEC. Accordingly, CBF submits the attached mercury deposition modeling study for the VCHEC performed by Andrew Gray, Ph.D.[1] Gray performed the attached mercury deposition models and analysis in an effort to discover the mercury impact upon waters within the Commonwealth, especially for those waters already impaired for mercury or under a Virginia Department of Health (VDH) fish consumption advisory for mercury. Please note that this study formed the basis of the presentation given by Chesapeake Bay Foundation's Jon Mueller at the Virginia Mercury Symposium. Additionally, it should be noted that Gray's study contains some brief analysis of both sulfur and nitrogen emissions from the VCHEC in addition to his mercury analysis.

In the VCHEC Prevention of Significant Deterioration and Operating Permit (Operating Permit) proposes to allow the VCHEC to emit 71.93 pounds of

---

[1] Curriculum Vitae of Andrew Gray, Ph.D. is attached.

CAPITOL PLACE | 1108 E. MAIN STREET, SUITE 1600 | RICHMOND, VA 23219
804/780-1392 | FAX: 804/648-4011 | WWW.CBF.ORG

mercury per year from the two main boilers. Through the case-by-case Maximum Achievable Control Technology (MACT) Permit DEQ proposes to allow the VCHEC to emit 49.46 pounds of mercury per year. The more stringent MACT permit, however, contains an off ramp in Condition 13 allowing the VCHEC to exceed the 49 pound per year MACT limit whenever VCHEC coal feedstock exceeds an average mercury content of 0.3511 parts per million weight.[2] Given that the VCHEC plans to burn significant amounts of unwashed run of the mill (ROM) coal and waste coal, it appears 71.93 lbs/yr limit will become the de facto limit for the facility. Accordingly, the attached analysis performed by Gray assumes a mercury emissions rate of 71.93 lbs/year for the two main boilers and 2.28 lbs/yr for the auxiliary boiler.

Gray's analysis finds that the VCHEC mercury emissions rate permitted in the VCHEC Operating Permit will have the following cumulative effects over the next 20 years on waters with the Commonwealth which are either already impaired for mercury or under a fish consumption advisory for mercury:

- 29.8 lbs of mercury to the Roanoke River and Kerr Reservoir Basin
- 15.2 lbs of mercury to the North Fork Holston Watershed
- 2.4 lbs of mercury to the Nottoway River Watershed
- 2.2 lbs of mercury to the Pamunkey River Basin
- 0.82 lbs of mercury to the Blackwater Watershed
- 0.14 lbs of mercury to the Great Dismal Swamp
- 0.12 lbs of mercury to the Dragon Run Watershed

Gray's work also finds that the VCHEC may annually deposit 10.2 pounds of mercury within the Commonwealth with 3.4 pounds of mercury deposited within the Chesapeake Bay watershed alone. Again extrapolating these numbers over 20 years, the VCHEC may deposit 204 pounds of mercury with the Commonwealth and 68 pounds of mercury within the Bay watershed.

In closing, CBF notes that CAA §112(d) and 9 VAC 5-80-1410 require the permitting authority to consider "any non-air quality health and environmental impacts" when making a MACT determination. Accordingly, CBF submits the attached air modeling analysis for consideration by the Board. Thank you for the

[2] Condition 13, Footnote (e) on page 6 of the case-by-case MACT permit for the VCHEC states: "The annual mercury emission limit is based on an average of 0.3511 ppmw of mercury in the coal, a higher heating value of 6600 Btu/lb of coal and a 98% control efficiency. ***Deviations from this limit are allowed if***, on a 12-month rolling average basis, the permittee can document through the weekly coal analysis of coal burned in the CFB boilers that the mercury content in the coal averages higher than 0.3511 ppmw and/or the higher heating value of the coal is less than 6600 Btu/lb. (emphasis added).

opportunity to comment on these important aspects of the VCHEC. If you have any questions please feel free to contact me at 804-780-1392.

Sincerely,

Joe Tannery
Virginia Deputy Director
Chesapeake Bay Foundation

cc: Ann Jennings, VA Executive Director

Attachments: Virginia City Power Plant Modeling, Andy Gray, Ph.D.
Curriculum Vitae of Andy Gray, Ph.D.

Virginia City Power Plant Modeling: Mercury Deposition in the Commonwealth of Virginia and Impacts to Impaired Waters

H. Andrew Gray, Ph.D

Virginia City Power Plant Modeling

Mercury pollution has become one of the most important environmental issues of the past decade. Although mercury is a naturally occurring element found in nature, human activities have caused the levels of mercury to rise dramatically in many locations, including in and around the Chesapeake Bay. Large industrial sources and power plants that rely on coal combustion emit significant amounts of mercury into the air. Airborne mercury that deposits on the landscape can be transported by runoff or through groundwater flow into the streams and rivers that run into reservoirs and larger water bodies. Once in the water, mercury becomes methylated, eventually leading to high concentrations of methylmercury in the tissue of fish and other wildlife.

High levels of mercury have been observed in streams and rivers throughout the eastern and northeastern United States. The Virginia Department of Health has issued fish consumption advisories for many of the waterways in Virginia based on unhealthful levels of methylmercury found in fish tissue samples.

To effectively control the hazards of mercury contamination in our waterways, it is essential to understand the pathways by which mercury is transferred from emission sources to contaminated watersheds, or "sensitive receptors." A key element of this process is the atmospheric transport of mercury, whereby directly emitted mercury is mixed with and moved (advected) through the ambient air by meteorological processes until the material is either advected away or deposited to the surface. A recent modeling study was conducted to assess the amounts of airborne mercury deposited at sensitive receptors throughout the Chesapeake Bay Region that can be attributed to specific coal-fired power plants and other emission sources.

The CALPUFF computer modeling system was used to simulate the injection of mercury into the atmosphere from a number of existing or, as in this case, proposed elevated point sources, followed by the meteorological processes affecting the subsequent dispersion of the mercury through the atmosphere. The model was used to simulate an annual cycle of meteorology in order to estimate the long-term effects of emissions from each source. Detailed meteorological data for 1996 were obtained from the Penn State/NCAR Mesoscale Modeling System 5 (MM5), a prognostic model with four dimensional data assimilation. The 36 km MM5 data were augmented by surface meteorological measurements, including winds, temperature, and precipitation data.

The model considered three different species of emitted mercury: gaseous elemental mercury (Hg(0)), reactive gaseous mercury (RGM), and particle-bound mercury (Hg(p)). The lifetime of elemental mercury in the atmosphere is very long (approximately one year), whereas oxidized forms of mercury (RGM and Hg(p)) have a lifetime of only a few days due to higher solubility and particle settling. Hg(0) can be transported over continental distances, whereas RGM and Hg(p) are largely deposited near their source.

The annual wet and dry deposition rates of sulfur, nitrogen, and the three mercury species, as a consequence of the emissions from the proposed Virginia City power plant, were estimated by the model at each of 8,096 locations (spaced every 9 km on a gridded array) within the modeling domain shown in Figure 1.

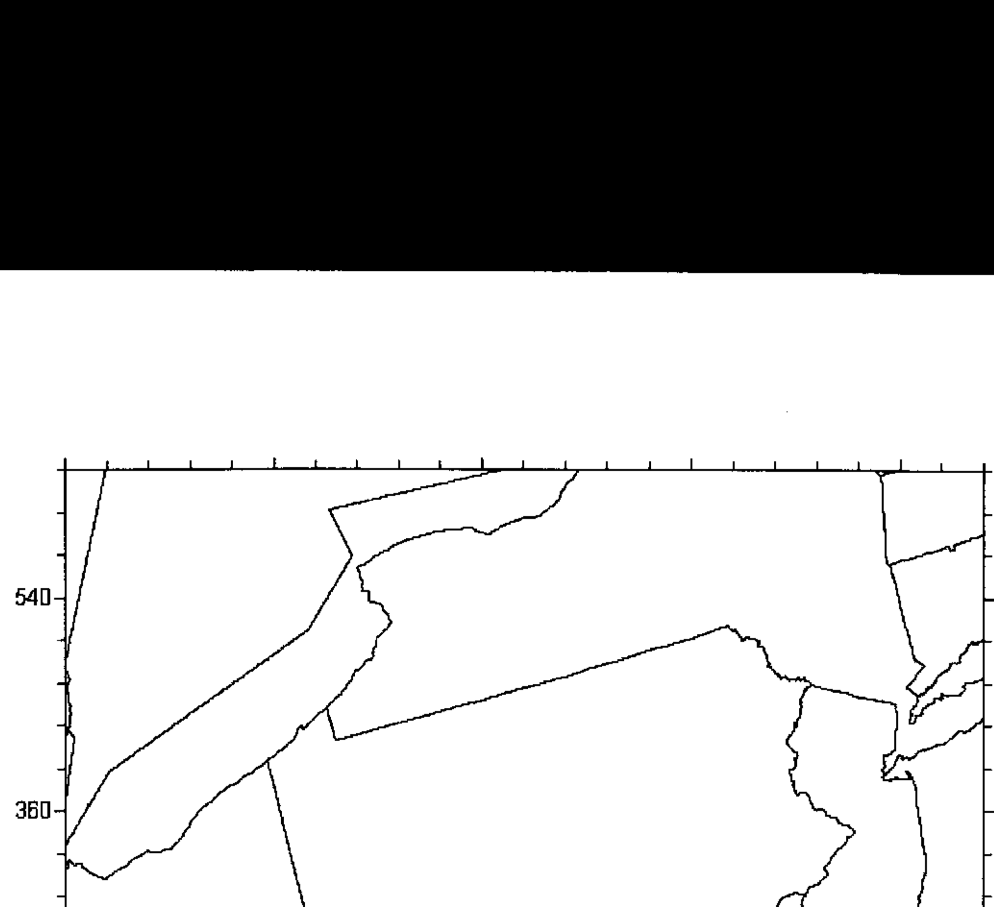
540
360

Table 1. Emissions, lb/hr

	main boiler	auxiliary boiler	total
SO2	751.68	38.39	790.1
NOx (24-hr average)	626.40	22.80	649.2
NOx (30-day average)	438.48	22.80	461.3
CO	939.60	15.20	954.8
CO2	605.73		
PM10	187.92	6.08	194.00
Hg	0.00821	0.00026	0.00847

The same data are shown in Table 2, on an annual basis:

Table 2. Projected Annual Emissions

	main boiler	auxiliary boiler	total
SO2, tpy	3,292.4	168.1	3,460.5
NOx (24-hr average), tpy	1,920.5	99.9	2,020.4
NOx (30-day average), tpy	2,743.6	99.9	2,843.5
CO, tpy	4,115.4	66.6	4,182.0
CO2, tpy	2,653.1		
PM10, tpy	823.1	26.6	849.7
Hg, lb/yr	71.92	2.28	74.20

The emissions of mercury, SO_2, and NO_X from the proposed power plant were modeled using the CALPUFF modeling system. The fraction of gaseous, particulate and reactive mercury emissions were assumed to follow a typical coal-fired power plant profile (Hg(0); 25.7 percent, RGM; 68.2 percent, and Hg(p); 6.1 percent). Emission data that were used for modeling are summarized in Tables 3 and 4.

Table 3. Mercury Emissions Data

Source	Lat (N)	Lon (W)	Base Elev(m)	No. of stacks	Mercury Emissions, (lb/ 1000hr)			
					Hg(total)	Hg(0)	RGM	Hg(p)
Virginia City	36.917	82.340	493.8	2	8.47	2.18	5.78	0.52

Table 4. SO_X and NO_X Emissions Data (tpy)

Source	SO_2	SO_4	NO_X
Virginia City	3,460.5	134.4	2,843.5

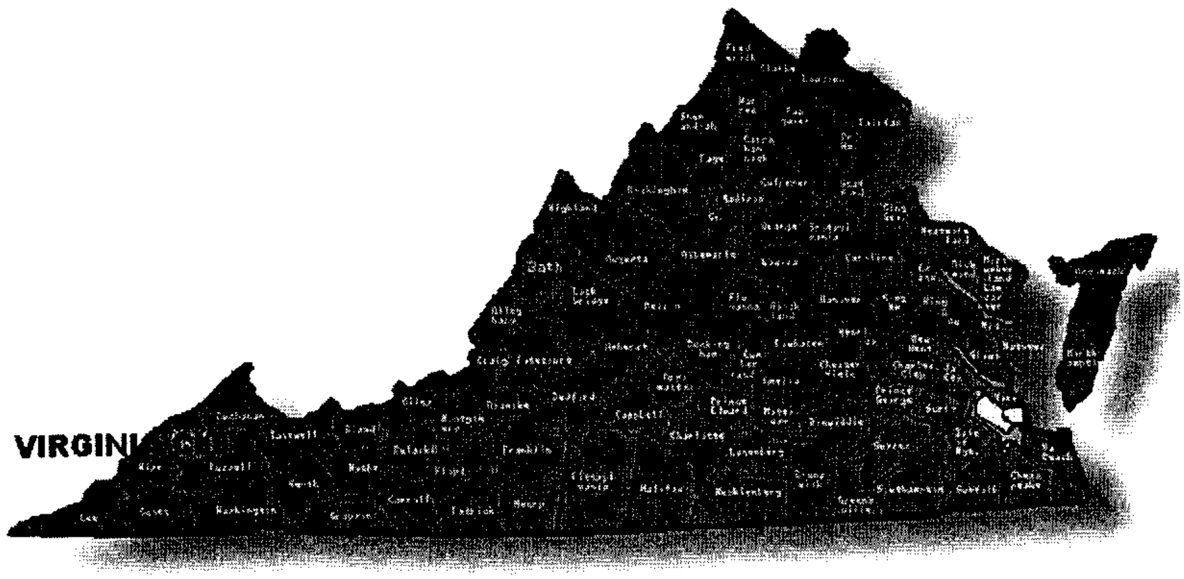

Figure 2. Location of proposed Virginia City power plant

Model Results

The CALPUFF model was used to simulate the atmospheric fate of SO_2, NO_X and mercury emitted from the proposed Virginia City power plant over an annual cycle, as represented by 1996 meteorology. The model accounted for both wet and dry deposition of sulfur, nitrogen and mercury species.

Figures 3 and 4 show the model results for mercury deposition over the modeling domain. The model predicted that the annual mercury deposition due to Virginia City's proposed emissions would be greater than 0.1 g/km^2 over a 16,281 km^2 area within the modeling domain (the yellow area in the lower left of Figure 3). The model estimated that 7.5 lb of mercury, which is over 10 percent of the total mercury emitted from the proposed plant, would be deposited annually within this area that surrounds the source (equivalent to a circular area with a diameter of 144 km).

Deposition to the Chesapeake Bay Watershed

The Chesapeake Bay Watershed includes all the streams and tributaries that ultimately flow into the bay. The watershed extends through six states (and D.C) from Virginia northward into New York, encompassing an area of approximately 170,000 km^2, as shown in Figure 5. A number of major and secondary rivers empty into the Chesapeake Bay, including the James, York, Rappahannock, Potomac, Patuxent, and Patapsco to the west, the Gunpowder, Bush, Susquehanna, Northeast, Elk, and Sassafras to the north, and the Chester, Choptank, Nanticoke, Wicomico, and Pocomoke to the east.

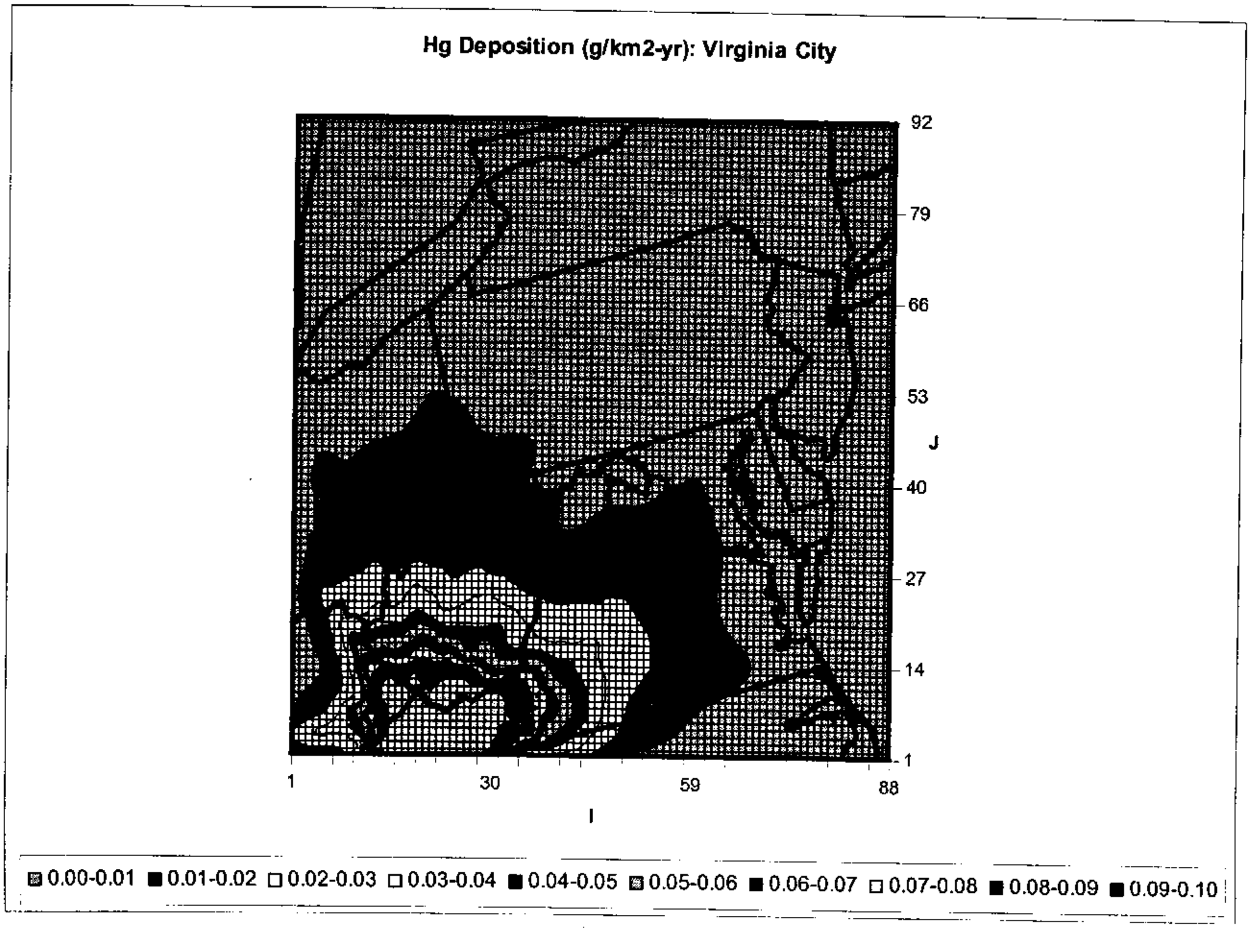

Figure 3. Annual mercury deposition (g/km^2) due to emissions from the proposed Virginia City Power Plant.

The model predicted that over 5 percent of the SO_2 emissions from the proposed Virginia City plant would be deposited within the Chesapeake Bay Watershed, and about 7 percent of the emitted NO_X would be deposited within the watershed. More than 97 tons of sulfur and more than 57 tons of nitrogen would be deposited within the watershed each year due to emissions from the proposed power plant.

The annual deposition of mercury to the Chesapeake Bay Watershed was estimated to be 3.4 lbs (1.56 kg), which is about 5 percent of the total mercury emissions from the proposed plant. As expected, the RGM emissions account for the majority of the mercury deposition. Table 5 shows the annual total sulfur, nitrogen and mercury deposited within the Chesapeake Bay Watershed, deposited to the Chesapeake Bay surface, and deposited within the Commonwealth of Virginia.

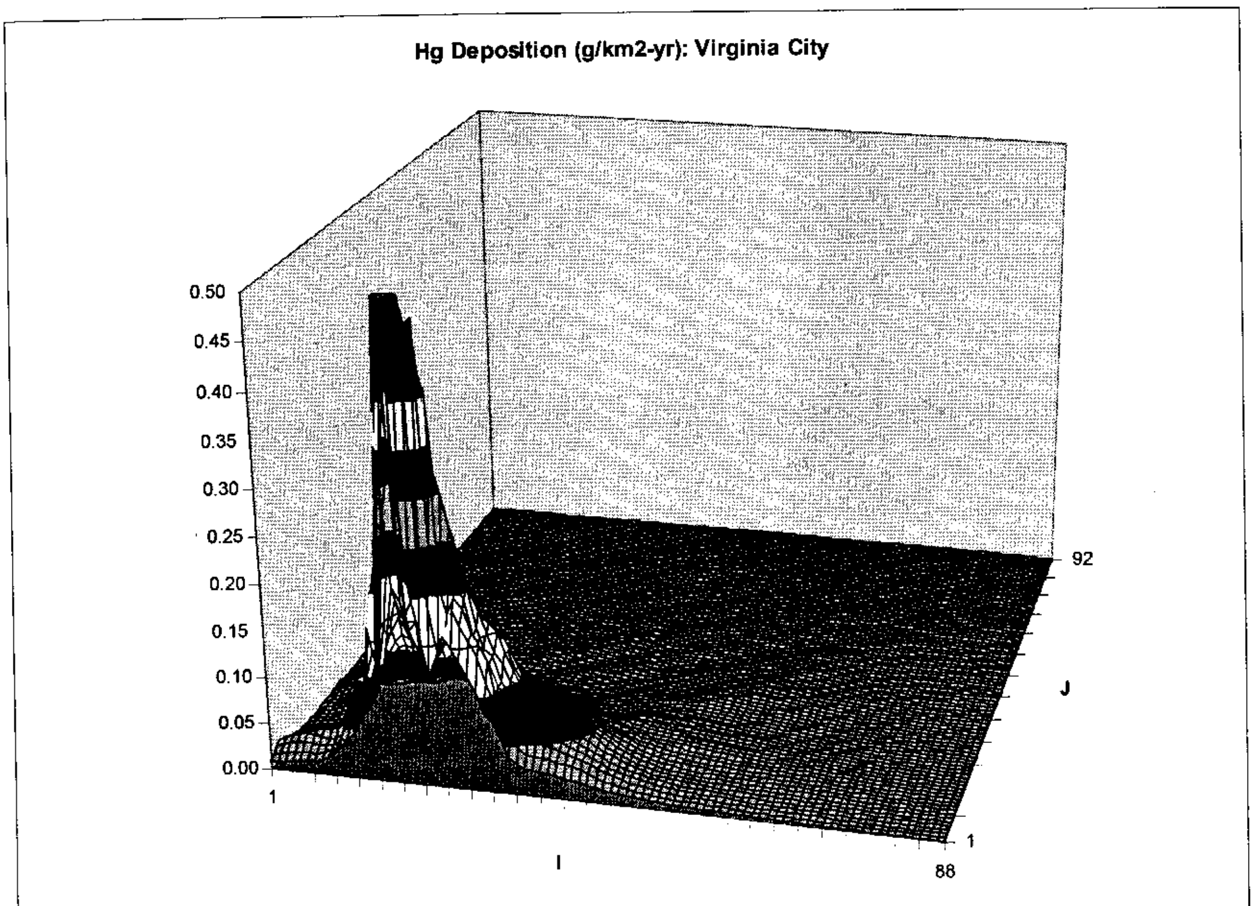

Figure 4. Annual mercury deposition (g/km^2) due to emissions from the proposed Virginia City Power Plant.

Table 5. Total Annual Deposition due to Emissions from Proposed Virginia City Power Plant

	WATERSHED	BAY	VIRGINIA
SULFUR, kg	88,214	2,584	218,610
NITROGEN, kg	52,271	1,639	95,886
MERCURY, lb	3.44	0.094	10.25
Hg_ELEM, lb	0.08	0.002	0.18
RGM. lb	3.05	0.082	9.48
Hg_PM, lb	0.30	0.010	0.59

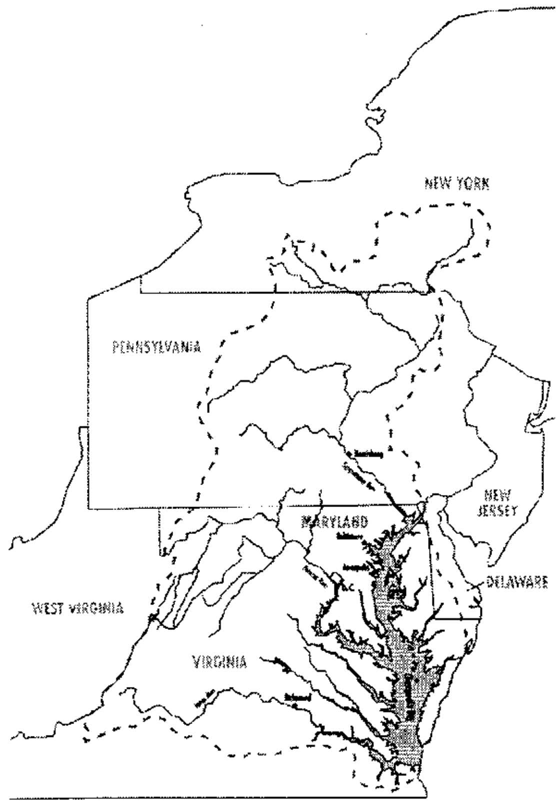

Figure 5. Chesapeake Bay Watershed

Deposition to the Chesapeake Bay

The Chesapeake Bay is the largest estuary in the United States, with an approximate area of 11,600 km^2. The bay and its shoreline (total shoreline: 18,800 km) are home to a diverse ecosystem of vegetation, fish, and other wildlife. The bay is quite shallow in many places; about one quarter of the area of the bay is less than 2m in depth. Fish consumption advisories have been issued in and around the Chesapeake Bay due to high levels of mercury measured in fish tissue.

The CALPUFF model was used to estimate the deposition of airborne sulfur, nitrogen and mercury onto the surface of the Chesapeake Bay that would originate from the proposed Virginia City power plant. The model estimated that over 2.8 tons of sulfur, more than 1.8 tons of nitrogen, and 0.094 lbs (43 grams) of mercury would be deposited directly to the surface of the Chesapeake Bay each year as a result of the proposed plant's emissions.

Deposition within the Commonwealth of Virginia

The model was also used to estimate the deposition of mercury within the borders of the Commonwealth of Virginia. The modeled area was 100,861 km^2, accounting for almost the entire state. The model predicted that between 12 and 14 percent of the plant's emissions of sulfur, nitrogen and mercury would be deposited within the Commonwealth of Virginia, accounting for almost 241 tons of deposited sulfur; 106 tons of deposited nitrogen; and 10.2 lb (4.65 kg) of deposited mercury annually.

Deposition to Other Sensitive Receptors

Many waterways in the Chesapeake Bay region have been contaminated with mercury. The Commonwealth of Virginia has issued fish consumption advisories due to measured unhealthful levels of mercury for a number of waterways, including the Pamunkey River, Dragon Run Swamp, and the Great Dismal Swamp Canal. The locations of these three sensitive receptors are shown on the gridded modeling domain in Figure 6.

Fish consumption advisories have recently been added or modified due to mercury contamination at a number of additional water bodies in Virginia, including the Roanoke River which drains into the Kerr Reservoir, the Blackwater River and Nottoway River Watersheds within the Albemarle-Chowan coastal drainage region, and the North Fork Holston River Watershed in the Upper Tennessee River Basin.

Results of the CALPUFF dispersion model were used to estimate the amount of pollutants emitted by the proposed Virginia City facility that would be deposited in each of the seven "sensitive receptors" that have been found to be contaminated with mercury. Tables 6a and 6b show the estimated annual deposition of Virginia City emissions within each of the sensitive receptor areas.

Table 6a. Total Annual Deposition to Sensitive Receptors

	PAMUNKEY	DRAGON RUN	DISMAL SWAMP
SULFUR, kg	2,853	163	178
NITROGEN, kg	1,605	98	105
MERCURY, lb	0.111	0.0060	0.0069
Hg_ELEM, lb	0.003	0.0002	0.0001
RGM, lb	0.100	0.0054	0.0061
Hg_PM, lb	0.009	0.0005	0.0006

Table 6b. Total Annual Deposition to Sensitive Receptors

	ROANOKE	N. FORK HOLSTON	BLACKWATER	NOTTOWAY
SULFUR, kg	34,594	14,631	1,073	3,052
NITROGEN, kg	16,007	5,463	630	1,620
MERCURY, lb	1.490	0.760	0.041	0.121
Hg_ELEM, lb	0.027	0.013	0.001	0.003
RGM, lb	1.358	0.719	0.037	0.110
Hg_PM, lb	0.105	0.029	0.003	0.008

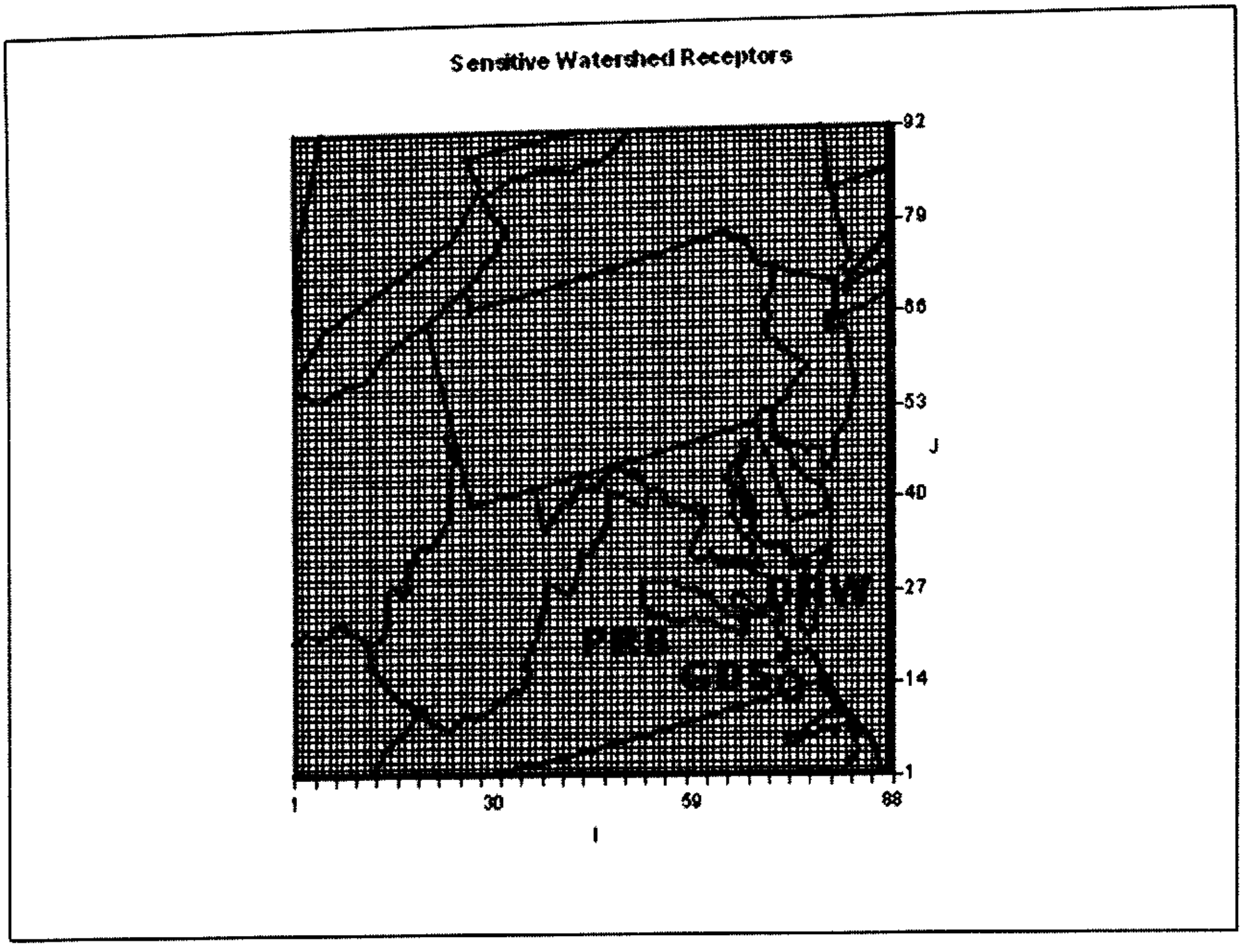

Figure 6. Sensitive Receptors; Pamunkey River Basin (PRB), Dragon Run Watershed (DRW), and Great Dismal Swamp NWR (GDS)

Pamunkey River Basin. The Pamunkey River is a tributary of the York River. The Pamunkey River drains the North Anna, South Anna and Little Rivers in Louisa and Hanover Counties, flowing past the Pamunkey Indian Reservation to the town of West Point, where it meets the Mattaponi River to form the York River. The total area of the Pamunkey River Basin is 3,818 km^2, or about 3.4 percent of Virginia. The Pamunkey River Basin represents about 2 percent of the total Chesapeake Bay Watershed. Fish consumption advisories were established for the Pamunkey and Mattaponi Rivers in 2004 due to high levels of mercury in largemouth bass and blue catfish.

The model estimated that emissions from the proposed Virginia City power plant would contribute 0.11 lbs (50 grams) of mercury annually to the Pamunkey River Basin. The proposed source would also deposit over 3 tons of sulfur and 1.8 tons of nitrogen to the Pamunkey River Basin each year.

Figure 7. Sweet Hall Marsh, located on the lower Pamunkey River

Dragon Run Watershed. The Dragon Run is a forty-mile brackish water stream, located at the headwaters of the Piankatank River, characterized by extensive non-tidal and tidal cypress swamp. The stream flows through the Virginia Middle Peninsula counties of Essex, King and Queen, Middlesex, and Gloucester. Fed by underground springs, surface runoff and numerous feeder swamps, the Dragon Run twists and turns, meandering through the four-county area, eventually emptying at the headwaters of the Piankatank River. The Dragon Run is recognized by the Smithsonian Institute as Virginia's most pristine water body to empty into the Chesapeake Bay. The Dragon Run Watershed, shown on the map in Figure 8, consists of 363 km^2, of which 10 percent are wetlands.

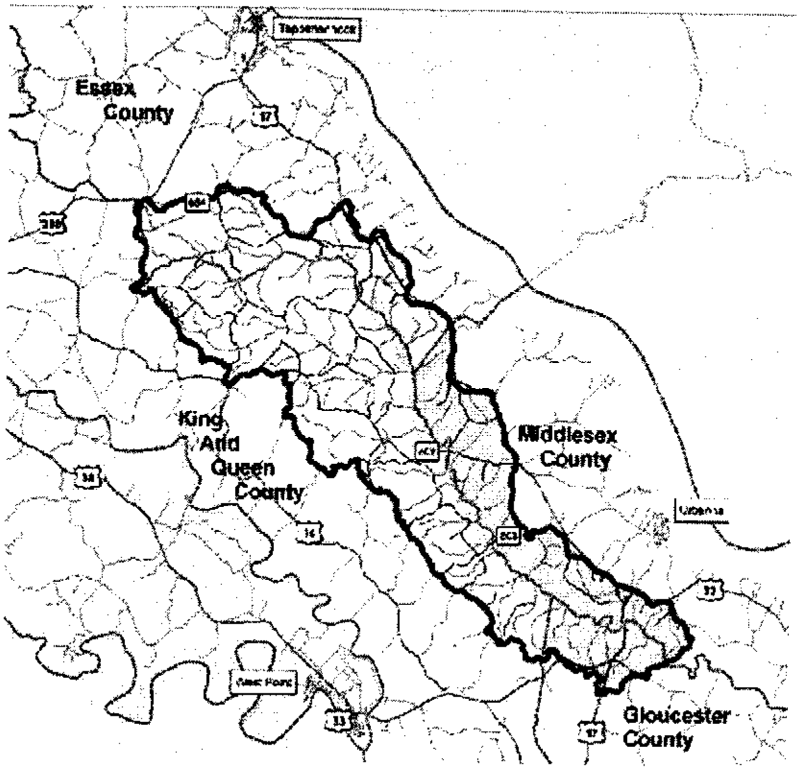

Figure 8. Dragon Run Watershed

The Dragon Run, along with the surrounding Dragon Run Swamp, is almost entirely undeveloped, forming an ecologically unique system with excellent water quality and numerous and diverse species of flora and fauna. The watershed is characterized by dense stands of hardwoods with occasional upland ridges extending to the stream's edge. The Dragon Run supports both recreational fishing and excellent game and non-game wildlife. There is very little evidence of man's presence, essentially maintaining a primitive character throughout the entire watershed.

Figure 9. Dragon Run

The model estimated that the proposed Virginia City power plant would be responsible for 163 kg of sulfur, 98 kg of nitrogen and 0.006 lb (2.7 grams) of mercury deposition annually within the Dragon Run Watershed.

Great Dismal Swamp. The Great Dismal Swamp National Wildlife Refuge (NWR) is a largely inaccessible marshy region located in southeastern Virginia and northeastern North Carolina. The refuge consists of 444 km^2 of forested wetlands, including the Dismal Swamp Canal and Lake Drummond, a 13 km^2 lake located in the heart of the swamp (the larger of only two natural freshwater lakes in Virginia). The waters of Lake Drummond and the Great Dismal Swamp naturally flow southward into North Carolina, emptying into the Pasquotank River and Albemarle Sound. However, the Feeder Ditch and the Dismal Swamp Canal connect the lake (and Albemarle Sound) with the Elizabeth River which empties into the Chesapeake Bay, via the Deep Creek Locks, to the north. A fish consumption advisory was issued for the Great Dismal Swamp Canal in 2003 due to high levels of mercury found in bowfin and chain pickerel.

The model predicted that emissions from the proposed Virginia City power plant will cause an additional 178 kg of sulfur, 105 kg of nitrogen, and 0.007 lb (3.1 grams) of mercury deposition within the Great Dismal Swamp NWR each year.

Figure 10. Lake Drummond, Great Dismal Swamp NWR

Kerr Reservoir/Roanoke River. The Kerr Reservoir is located along the Virginia – North Carolina border, in Mecklenburg County, VA, Vance County, NC, Granville County, NC, and Warren County, NC. The John H. Kerr Dam was constructed in 1952 just upstream of Buggs Island on the Roanoke River (also called the Staunton River) for flood control and for hydropower generation. The resulting 50,000 acre reservoir has over 850 miles of shoreline, where popular recreational activities include boating, camping, swimming, picnicking, hiking, and hunting. The reservoir provides habitat for many game fish species. The Kerr Reservoir is widely known for its large-mouth bass and striped bass fishing. In August 2007, fish consumption advisories were issued for the Kerr Reservoir, the Dan River and a portion of the Roanoke River due to high levels of mercury found in largemouth bass, white bass, and striped bass.

The Roanoke River flows from the foothills of Virginia's Blue Ridge Mountains to North Carolina's northern coast before emptying into the Albemarle Sound. Spanning close to 400 miles, the Roanoke carries more water than any other river in North Carolina, supplying over half of Albemarle Sound's fresh water. As it flows from the Appalachian foothills to the flat coastal plains of North Carolina, the river changes from narrow and lively to broad and slow. In the coastal lands, its swampy floodplains are sometimes five miles wide. With its springtime tendency to overflow, the river nourishes the basin with a rich blanket of organic sediment. The Roanoke River Basin and the John H. Kerr Dam are shown on the map in Figure 11.

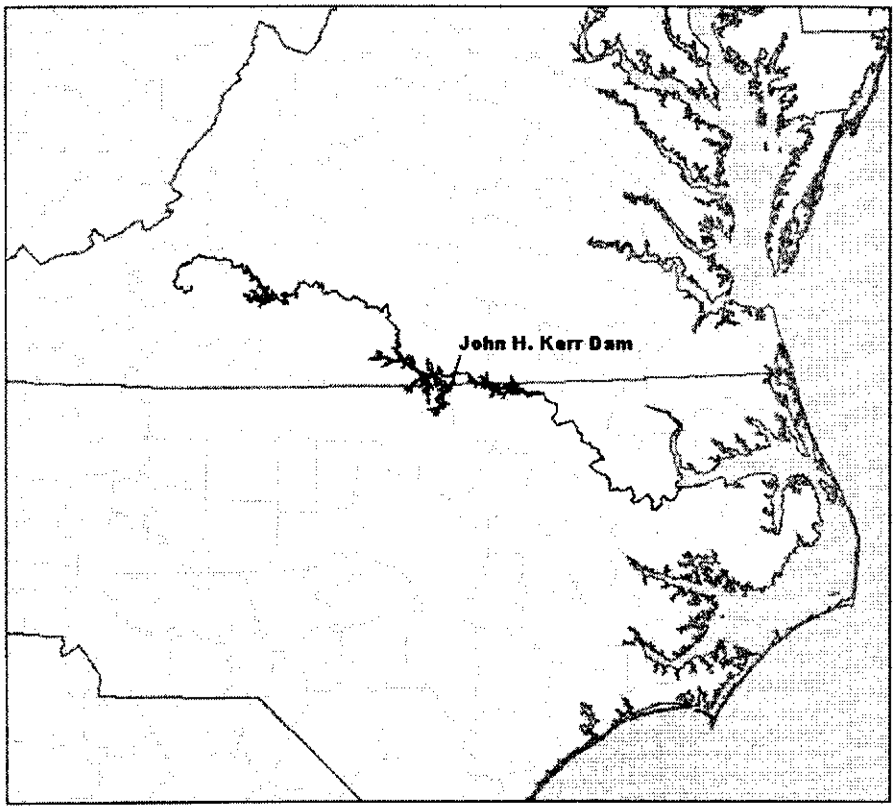

Figure 11. Roanoke River Basin

The dam, at about 300 ft elevation, is the terminus point for the Middle Roanoke River Watershed, which is downstream of four other tributary watersheds. These five watersheds make up the upper portion of the Roanoke River Basin (USGS watershed accounting unit: 030101), as shown in Figure 12. A combined watershed was defined for this analysis, consisting of the Kerr Reservoir and all its tributaries. The Middle Roanoke Watershed (03010102) is fed by the Upper Roanoke (03010101), Upper Dan River (03010103), Lower Dan River (03010104), and the Bannister River (03010105).

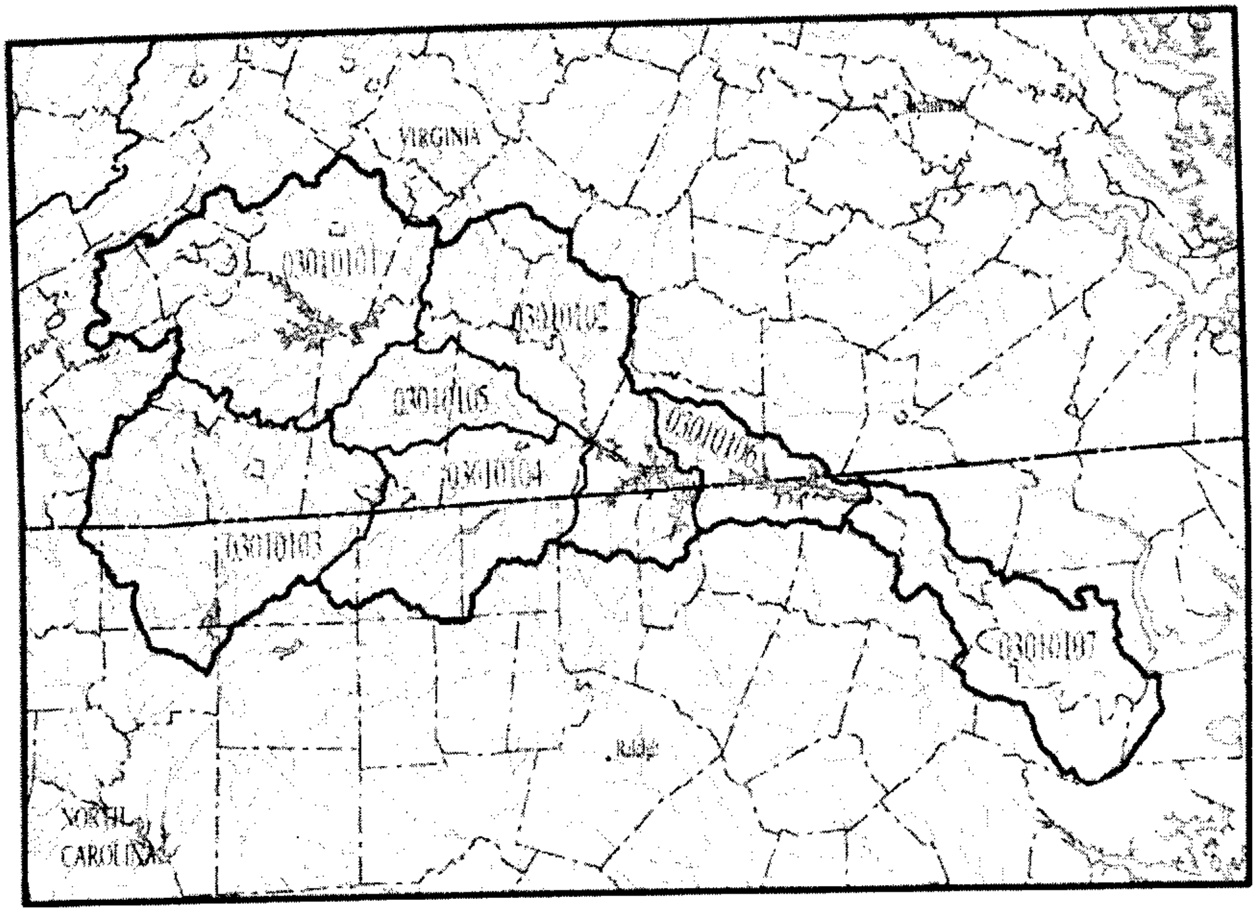

Figure 12. Roanoke River Basin (with USGS cataloguing units)

The amount of pollutant deposition within the combined five-watershed receptor area (the Kerr Reservoir and all its tributaries; area: 20,202 km^2) due to emissions from the proposed Virginia City power plant was estimated by the CALPUFF model. The model estimated that the power plant would deposit more than 38 tons of sulfur and almost 18 tons of nitrogen onto the Kerr Reservoir and its tributaries each year. The power plant would also cause the deposition of 1.49 lb (676 grams) of mercury annually to the combined watershed. (Note: Less than 4 percent of the combined watershed area is outside the modeling domain; the estimated deposition totals are for deposition within the modeling domain only; the modeled "on-grid" area is 19,467 km^2.)

<u>North Fork Holston Watershed</u>. The Holston River is a major river system of southwestern Virginia and East Tennessee. The three major forks of the Holston (its North, Middle and South Forks) rise in southwestern Virginia and have their confluence near Kingsport, Tennessee, as shown in Figure 14. The North Fork Holston River begins in Bland County near the community of Ceres and drains portions of six Virginia

Figure 13. John H. Kerr Dam and Reservoir

counties (Bland, Tazewell, Smyth, Washington, Russell and Scott) before it joins the Holston River and eventually the Tennessee River in Tennessee. The North Fork Holston River Watershed (USGS watershed 06010101), shown in Figure 15, encompasses 1,834 km^2. The river is known for exceptional fishing from the town of Saltville downstream, although, under the current health advisory due to mercury contamination, fish are prohibited from being consumed (all species).

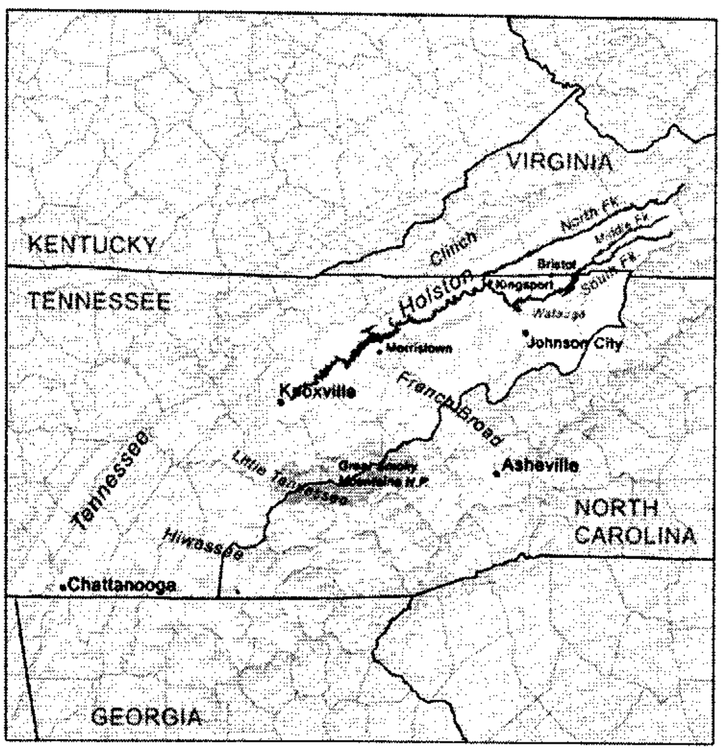

Figure 14. Holston River

The CALPUFF model was used to estimate the amount of pollutant deposition that would occur in the North Fork Holston Watershed as a result of emissions from the proposed Virginia City power plant. About two-thirds of the watershed (1,190 km^2) is in the modeling domain. The model estimated that the power plant would annually deposit more than 16 tons of sulfur and 6 tons of nitrogen onto the portion of the watershed within the modeling domain. The model also estimated that mercury deposition in the modeled portion of the watershed would increase by 0.76 lb (345 grams).

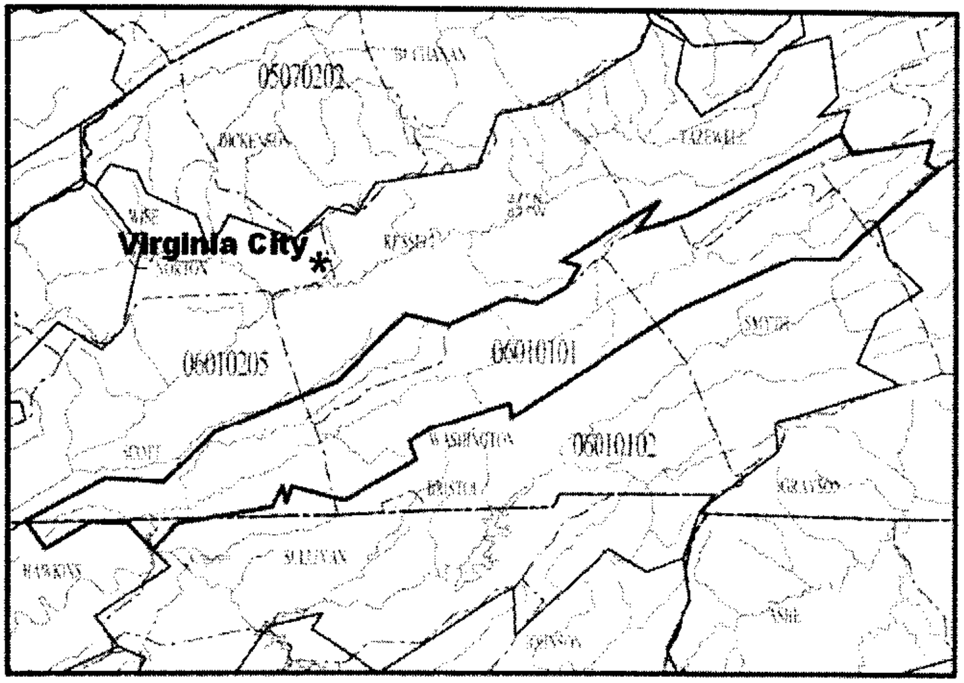

Figure 15. North Fork Holston Watershed (showing location of proposed source)

The North Fork Holston Watershed is closer in proximity to the proposed Virginia City power plant than the other sensitive receptors examined in this report. As a consequence, a larger relative amount of the power plant's emissions would be deposited in a given area of this watershed (see Table 7). The average annual rate of mercury deposition across the modeled portion of the North Fork Holston Watershed was estimated to be 0.29 g/km^2.

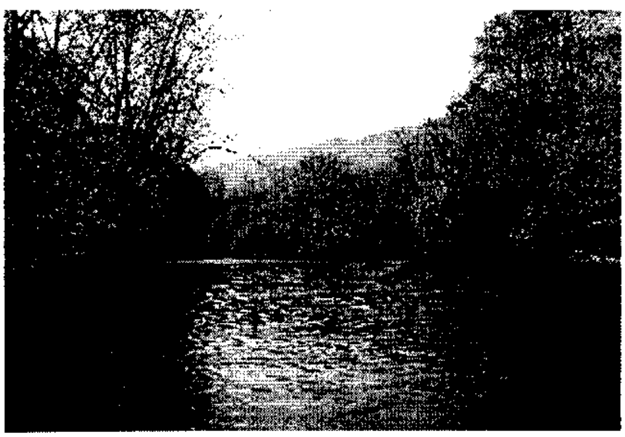

Figure 16. North Fork Holston River

Blackwater and Nottoway River Watersheds. The Chowan River flows into the Albemarle Sound in North Carolina. Major tributaries of the Chowan include the Blackwater and the Nottoway, which join to form the Chowan at the Virginia – North Carolina state line (see Figure 17). Fish advisories have been established for both the Blackwater and Nottoway Rivers due to high levels of mercury found in many fish species, including largemouth and smallmouth bass, sunfish, bowfin, and chain pickerel.

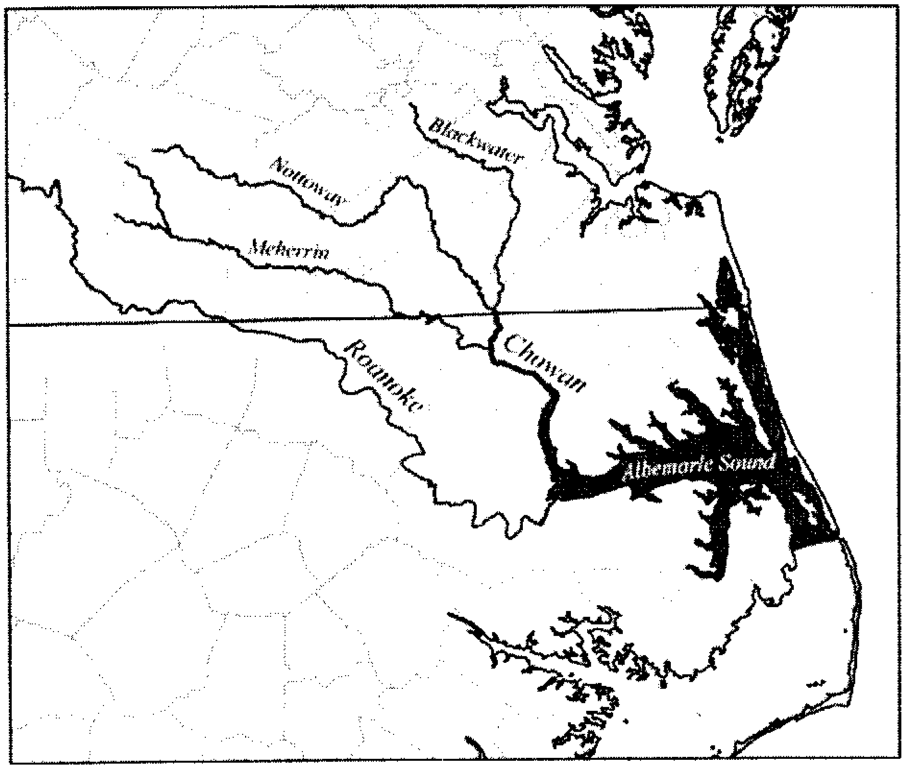

Figure 17. Chowan River Basin

The Blackwater originates as a coastal plain swamp in Prince George County. It flows east through braided channels of bald cypress and tupelo in Surry County. The river then turns south along the Southampton County line where several boat ramps are accessible for anglers, hunters and boaters. The Nottoway is a scenic river, with a minimum of development that also maintains a diverse fishery. It begins in Nottoway County, turns northeast in Surry County, then heads southward through Southampton County until it forms the Chowan River in North Carolina at its confluence with the Blackwater River. The Blackwater River Watershed (USGS watershed 03010202; area: 1,927 km^2) and the adjacent (to the west) Nottoway River Watershed (03010201; area: 4,403 km^2) are shown in Figure 18.

Results of the CALPUFF modeling were used to estimate the impact of the proposed Virginia City power plant's emissions on pollutant deposition rates within the Blackwater and Nottoway watersheds. The model estimated that the proposed power plant would add 1,073 kg (1.2 tons) of sulfur and 630 kg (0.7 tons) of nitrogen to the Blackwater River Watershed each year. Emissions from the proposed power plant would also increase the annual deposition in the Notttoway River Watershed by 3,052 kg (3.4 tons) of sulfur and 1,620 kg (1.8 tons) of nitrogen.

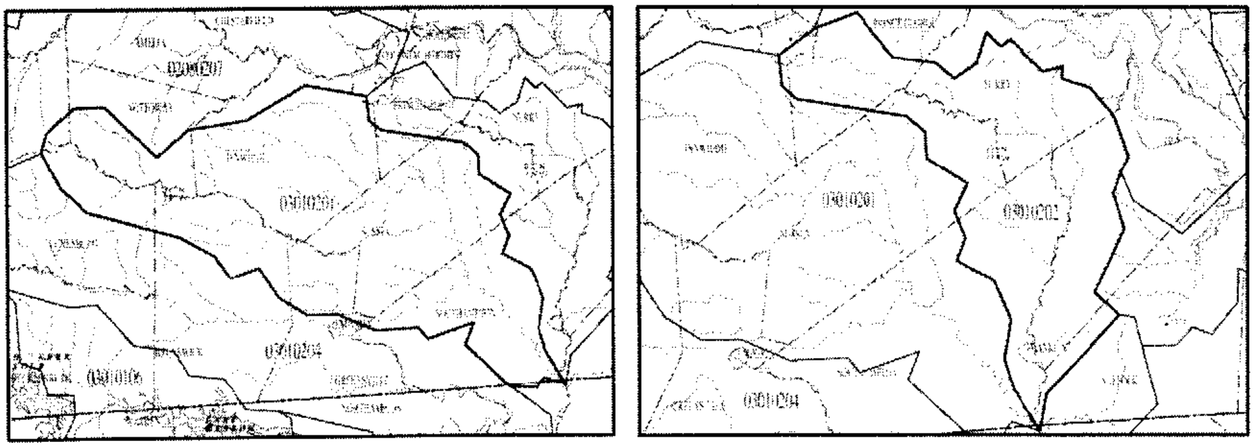

Figure 18. Blackwater River Watershed (03010202), right, and Nottoway River Watershed (03010201), left

The model estimated that the proposed power plant would increase the level of mercury deposition in the Blackwater River Watershed by 0.041 lb (19 grams) per year, and would result in the deposition of 0.12 lb (55 grams) of mercury each year within the Nottoway River Watershed.

Figure 19. Nottoway River

Average Rate of Mercury Deposition to Each Sensitive Receptor

Dividing the total mass of mercury that would be deposited within each receptor by the total (modeled) area of the receptor provides a comparison of the relative deposition rates between receptors. Not surprisingly, the receptor area that includes the proposed source (Virginia), or the receptors that are close to the source (e.g., N. Fork Holston Watershed, Kerr/Roanoke Watershed), exhibit much higher relative rates of deposition. The spatial average rates of mercury deposition due to the proposed Virginia City power plant are shown in Table 7.

Table 7. Average Spatial Rates of Mercury Deposition

RECEPTOR	ANNUAL MERCURY DEPOSITION (grams)	AREA (km^2)	AVERAGE MERCURY DEPOSITION RATE (g/km^2)
Chesapeake Bay Watershed	1,560	170,000	0.009
Chesapeake Bay	42.7	11,600	0.004
Virginia	4,649	100,861	**0.046**
Pamunkey River Basin	50.4	3,818	0.013
Dragon Run Watershed	2.74	363	0.008
Great Dismal Swamp	3.11	444	0.007
Kerr/Roanoke River	676	19,467	**0.035**
N. Fork Holston Watershed	345	1,190	**0.290**
Blackwater River Watershed	18.7	1,927	0.010
Nottoway River Watershed	54.8	4,403	0.012

Long-term Deposition Rates

The model results can be used to estimate the long-term impacts at each of the sensitive receptor areas due to the proposed Virginia City power plant. The lifetime of a coal-fired power plant is typically greater than 20 years, so one can safely assume that the proposed power plant would operate for at least twenty years. Table 8 shows the total amount of mercury that would be deposited in each of the receptor areas over a 20 year period.

The model estimates that, over a 20 year period, emissions from the proposed power plant would deposit almost 70 lb of mercury into the Chesapeake Bay Watershed. During the same time period, over 200 lb of mercury would be deposited within the Commonwealth of Virginia. The Kerr Reservoir and its tributary watersheds would collect almost 30 lb of mercury as a result of this plant's emissions. Mercury deposition due to the proposed power plant would exceed 15 lb in the nearby North Fork Holston Watershed over the lifetime of the power plant.

Table 8. Lifetime Mercury Deposition Rates Due to Proposed Power Plant

RECEPTOR	LIFETIME (20-yr) MERCURY DEPOSITION RATE (lb)
Chesapeake Bay Watershed	68.8
Chesapeake Bay	1.88
Virginia	205.0
Pamunkey River Basin	2.22
Dragon Run Watershed	0.121
Great Dismal Swamp	0.137
Kerr/Roanoke River	29.8
N. Fork Holston Watershed	15.2
Blackwater River Watershed	0.83
Nottoway River Watershed	2.42

H. ANDREW GRAY

EDUCATION

Ph.D. environmental engineering science, California Institute of Technology, Pasadena, California, 1986

M.S. environmental engineering science, California Institute of Technology, Pasadena, California, 1980

B.S. civil engineering/engineering and public policy, Carnegie-Mellon University, Pittsburgh, Pennsylvania, 1979

EXPERIENCE

Dr. H. Andrew Gray has been performing research in air pollution for 30 years, within academic, governmental, and consulting environments. He has made significant contributions in the areas of airborne particles and visibility, including the development and application of computer-based air quality models. His areas of expertise are air pollution control strategy design and evaluation, computer modeling of the atmosphere, characterization of ambient air quality and air pollutant source emissions, aerosol monitoring and modeling, visibility analysis, receptor modeling, statistical data analysis, mathematical programming, numerical methods, and analysis of environmental public policy. Dr. Gray is currently an independent contractor focusing on particulate matter and visibility related research issues. Previous Gray Sky Solutions projects include assessment of Clean Air Act and other regulations on visibility in Class I (park and wilderness) areas, development of air pollution control plans and emission inventories for tribal lands, review and development of guidelines for modeling long-range transport impacts using the CALPUFF model, evaluation of particulate air quality impacts associated with diesel exhaust emissions, air quality management plan modeling protocol review, a critical review of Clean Air Mercury Rule (CAMR) documents, and assessment of the regional air quality impacts of power plant emissions. Most recently, Dr. Gray has been carrying out dispersion modeling studies to determine the impacts associated with mercury emissions in the Chesapeake Bay region.

Before starting Gray Sky Solutions, Dr. Gray was the manager of the PM_{10} and Visibility Program at Systems Applications International (SAI / ICF Inc.). At SAI, Dr. Gray conducted and managed a number of varied air pollution research projects. In the early 1990s, Dr. Gray directed a large (over $1 million) air-quality modeling program to determine the impact of SO_2 emissions from a large coal-fired power plant on Grand Canyon sulfate and visibility levels. He managed projects to develop carbon particle emission data for the Denver area, designed a PM_{10} monitoring and modeling program for the El Paso area, determined the appropriate tradeoffs between direct PM_{10} emissions and emissions of PM_{10} precursors, estimated the visibility effects in federal Class I areas due to the 1990 Clean Air Act Amendments (results of which were incorporated into EPA's 1993 Report to Congress on the expected visibility consequences of the 1990 Clean Air Act Amendments), and provided assistance to EPA Region VIII's tribal air programs. Other projects include emission inventory development for Sacramento and carbon monoxide modeling of Phoenix, Arizona to support federal and regional implementation plans in those regions, systematic evaluation of the Interagency Workgroup on Air Quality Modeling (IWAQM) recommendations for the use of MESOPUFF II, a critical assessment of exposures to particulate diesel exhaust in California, and an evaluation of $PM_{2.5}$ and PM_{10} air quality data in support of EPA's review of the federal particulate matter air quality standards. Later projects included a study of micrometeorology and modeling of low wind speed stable conditions in the San Joaquin Valley (CA), an assessment of the reductions in nationwide ambient particulate nitrate exposures due to mobile source NO_x emission reductions, an evaluation of visibility conditions in the Southern Appalachian Mountains region, a review of cotton ginning emission factors, and a critical review and assessment of the PM_{10} Attainment Demonstration Plan for the San Joaquin Valley. Dr. Gray was a member of the modeling subcommittee of the technical committee of the Grand Canyon Visibility Transport Commission.

Previous to his tenure at SAI, Dr. Gray was responsible for the PM_{10} and visibility programs at the South Coast Air Quality Management District which involved directing monitoring, analysis, and modeling efforts to support the design of air pollution control strategies for the South Coast Air Basin of California. He developed and applied the methodologies for assessing PM_{10} concentrations that have continued to be used by the District through numerous subsequent air quality management plan revisions. Dr. Gray authored portions of the 1989 Air Quality Management Plan issued by the District that describe the results of modeling and data analyses used to evaluate particulate matter control strategies. Dr. Gray was instrumental in promoting the development and application of state-of-science models for predicting particulate matter concentrations. His responsibilities included direction and oversight of numerous aerosol-related contracts, including development of the SEQUILIB and SAFER models, construction of an ammonia emission database, and development of sulfate, nitrate and organic chemical mechanisms. In addition, Dr. Gray was responsible for initiating the District's visibility control program.

In research performed at the California Institute of Technology, Dr. Gray studied control of atmospheric fine primary carbon particle concentrations and performed computer programming tasks for acquisition and analysis of real-time experimental data. He designed, constructed, and operated the first long-term fine particle monitoring network in Southern California in the early 1980s. He also developed and applied deterministic models to predict source contributions to fine primary carbon particle concentrations and constructed objective optimization procedures for control strategy design. In research carried out for the Department of Mechanical Engineering at Carnegie-Mellon University, Dr. Gray developed fuel use data for input to an emission simulation model for the northeastern United States.

Specialized Professional Competence

- Air pollution control strategy design
- Atmospheric air quality characterization
- Aerosols and visibility
- Computer modeling and data analysis
- Dispersion modeling for particulate matter and visibility
- Receptor modeling including Chemical Mass Balance (CMB) and factor analysis
- Analysis of environmental public policy

Professional Experience

- Systems Applications International (SAI)—PM_{10} and visibility program manager—participated in and managed numerous air quality modeling and analysis projects for public and private sector clients, with emphasis on particulate matter and visibility research
- South Coast Air Quality Management District, El Monte, California—air quality specialist—developed and applied air quality modeling analyses to support air pollution control strategy design for the South Coast Air Basin of California
- California Institute of Technology, Pasadena, California—research assistant—Ph.D. candidate in environmental engineering science. Thesis: Control of atmospheric fine primary carbon particle concentrations
- California Institute of Technology, Pasadena, California—laboratory assistant—performed computer programming tasks for acquisition and analysis of real-time experimental data
- Department of Mechanical Engineering, Carnegie-Mellon University, Pittsburgh, Pennsylvania—research assistant—developed fuel use data for an emissions simulation model for the northeastern United States. Grant from the U.S. Department of Energy for evaluation of national energy policy
- Department of Civil Engineering, Carnegie-Mellon University, Pittsburgh, Pennsylvania—consultant—analyzed structural retrofit design for Ferrari Dino import automobile for United States five mph crash test

HONORS AND AWARDS

Harold Allen Thomas Scholarship Award, Carnegie-Mellon University

University Honors, Carnegie-Mellon University

PROFESSIONAL AFFILIATIONS

Air and Waste Management Association

American Association for Aerosol Research

SELECTED PUBLICATIONS AND PRESENTATIONS

"Source Contributions to Atmospheric Fine Carbon Particle Concentrations" (with G.R. Cass), *Atmospheric Environment*, 32:3805-3825 (1998)

"Monitoring and Analysis of the Surface Layer at Low Wind Speeds in Stable PBL's in the Southern San Joaquin Valley of California" (with others), presented at the American Meteorological Society's 12th Symposium on Boundary Layers and Turbulence, Vancouver, British Columbia (July 1997)

"Estimation of Current and Future Year NOx to Nitrate Conversion for Various Regions of the United States" (with A. Kuklin), presented at the 90th Meeting of the Air and Waste Management Association, Toronto, Ontario (June 1997)

Integrated Monitoring Study (IMS) 1995: Characterization of Micrometeorological Phenomena: Mixing and Diffusion in Low Wind Speed Stable Conditions: Study Design and Preliminary Results (with others), in *Measurement of Toxic and Related Air Pollutants*, Air and Waste Management Association, Pittsburgh, Pennsylvania, pp. 484-500 (1996)

Regional Emissions and Atmospheric Concentrations of Diesel Engine Particulate Matter: Los Angeles as a Case Study (with G.R. Cass), in *Diesel Exhaust: A Critical Analysis of Emissions, Exposure, and Health Effects*, Health Effects Institute, Cambridge, Massachusetts, pp. 125-137 (1995)

"Assessment of the Effects of the 1990 Clean Air Act Amendments on Visibility in Class I Areas", presented at the 86th Annual Meeting & Exhibition of the Air and Waste Management Association, Denver, Colorado (June 1993)

"Source Contributions to Atmospheric Carbon Particle Concentrations" (with others), presented at the Southern California Air Quality Study Data Analysis Conference, Los Angeles, California (July 1992)

"Modeling Wintertime Sulfate Production in the Southwestern United States" (with M. Ligocki), presented at the AWMA/EPA International Specialty Conference on PM10 Standards and Nontraditional Particulate Source Controls, Scottsdale, Arizona (January 1992)

"Deterministic Modeling for the Navajo Generating Station Visibility Impairment Study: An Overview," presented at the 84th Meeting of the Air and Waste Management Association, Vancouver, British Columbia (June 1991)

"Receptor and Dispersion Modeling of Aluminum Smelter Contributions to Elevated PM10 Concentrations" (with R. G. Ireson and A. B. Hudischewskyj), presented at the 84th Meeting of the Air and Waste Management Association, Vancouver, British Columbia (June 1991)

Visibility and PM-10 in the South Coast Air Basin of California (with J.C. Marlia), in *Visibility and Fine Particles*, Air and Waste Management Association, Pittsburgh, Pennsylvania, pp. 468-477 (1990)

Chemical characteristics of PM10 aerosols collected in the Los Angeles area (with others), *J. Air Pollut. Control Assoc.*, 39:154-163 (1989)

Atmospheric carbon particles and the Los Angeles visibility problem (with others), *Aerosol Sci. Technol.*, 10:118-130 (1989)

Receptor modeling for PM10 source apportionment in the South Coast Air Basin of California (with others), in *PM-10: Implementation of Standards*, Air Pollution Control Association, Pittsburgh, Pennsylvania, pp. 399-418 (1988)

Optimization of PM10 control strategy in the South Coast Air Basin (with others), in *PM-10: Implementation of Standards*, Air Pollution Control Association, Pittsburgh, Pennsylvania, pp. 589-600 (1988)

Quantitative high-resolution gas chromatography and high-resolution gas chromatography/mass spectrometry analyses of carbonaceous fine aerosol particles (with others), *Int. J. Environ. Anal. Chem.*, 29:119-139 (1987)

"Development of an Objective Ozone Forecast Model for the South Coast Air Basin" (with others), presented at the 80th Meeting of the Air Pollution Control Association, New York (June 1987)

"PM10 Modeling in the South Coast Air Basin of California" (with others), presented at the 79th Annual Meeting of the Air Pollution Control Association, Minneapolis, Minnesota (1986)

Characteristics of atmospheric organic and elemental carbon particle concentrations in Los Angeles (with others), *Environ. Sci. Technol.*, 20:580-589 (1986)

"Chemical Speciation of Extractable Organic Matter in the Fine Aerosol Fraction" (with others), presented at the 1984 International Chemical Congress of Pacific Basin Societies, Honolulu, Hawaii (1984)

"Source Contributions to Atmospheric Carbon Particle Concentrations" (with others), presented at the First International Aerosol Conference, Minneapolis, Minnesota (1984)

Elemental and organic carbon particle concentrations: A long term perspective (with others), *Sci. Total Environ.*, 36:17-25 (1984)

"Meteorological and Chemical Potential for Oxidant Formation" (with others), presented at the Conference on Air Quality Trends in the South Coast Air Basin, California Institute of Technology, Pasadena, California (1980)

Containing recombinant DNA: How to reduce the risk of escape (with others), *Nature*, 281:421-423 (1979)

OTHER PUBLICATIONS

"Air Quality Modeling and Visibility Impacts Associated with Sammis Power Plant Emissions," prepared on behalf of the United States of America, Washington, D.C. (2003)

"Air Quality Modeling and Visibility Impacts Associated with Baldwin Power Plant Emissions," prepared on behalf of the United States of America, Washington, D.C. (2002)

"Assessment of the Impacts of Clean Air Act and Other Provisions on Visibility in Class I Areas" (with others), prepared for American Petroleum Institute, Washington, D.C. (1998)

"California Regional PM10 Air Quality Study: *1995 Integrated Monitoring Study Data Analysis: Time and Length Scales for Mixing Secondary Aerosols During Stagnation Periods"* (with others), prepared for California Air Resources Board, Sacramento (1997)

"San Joaquin Valley Regional PM10 Study: *Characterizing Micrometeorological Phenomena: Mixing and Diffusion in Low Wind Speed Conditions Phase III: Monitoring and Data Analysis"* (with others), prepared for California Air Resources Board, Sacramento (1997)

"Cotton Gin Particulate Emission Factors," prepared for U.S. Environmental Protection Agency, Region VIII, San Francisco, California (1997)

"Benefits of Mobile Source NOx Related Particulate Matter Reductions" (with A. Kuklin), SYSAPP-96/61, prepared for Office of Mobile Sources, U.S. Environmental Protection Agency, Ann Arbor, Michigan (1996)

"Evaluation of Existing Information on the Effects of Air Pollutants on Visibility in the Southern Appalachians" (with D. Kleinhesselink), SYSAPP-96-95/060, prepared for Southern Appalachian Mountains Initiative, Asheville, North Carolina (1996)

"Statistical Support for the Particulate Matter NAAQS" (with others), SYSAPP-96-95/039, prepared for Office of Air Quality Planning and Standards, U.S. Environmental Protection Agency, Research Triangle Park, North Carolina (1996)

"San Joaquin Valley Regional PM10 Study Support Study 5A: *Characterizing Micrometeorological Phenomena: Mixing and Diffusion in Low Wind Speed Conditions Phase II: Detailed Recommendations for Experimental Plans*" (with others), prepared for California Air Resources Board, Sacramento (1995)

"San Joaquin Valley Regional PM10 Study Support Study 5A: *Characterizing Micrometeorological Phenomena: Mixing and Diffusion in Low Wind Speed Conditions Phase I: Literature Review and Draft Program Recommendations*" (with others), prepared for California Air Resources Board, Sacramento (1995)

"Class I Grouping for Subsequent Assessment of Regional Haze Rules" (with others), SYSAPP-94/129, prepared for Air Quality Strategies and Standards Division, Office of Air Quality Planning and Standards, U.S. Environmental Protection Agency, Research Triangle Park, North Carolina (1994)

"Retrospective Analysis of the Impact of the Clean Air Act on Urban Visibility in the Southwestern United States" (with C. Emery and T.E. Stoeckenius), SYSAPP-94/108, prepared for Office of Policy Analysis and Review, Office of Air and Radiation, U.S. Environmental Protection Agency, Washington, D.C. (1994)

"Evaluation of Ambient Species Profiles, Ambient Versus Modeled NMHC:NO_x and CO:NO_x Ratios, and Source-Receptor Analyses" (with G. Yarwood, M. Ligocki, and G. Whitten), SYSAPP-94/081, prepared for Office of Mobile Sources, U.S. Environmental Protection Agency, Ann Arbor, Michigan (1994)

"Diesel Particulate Matter in California: Exposure Assessment" (with M. Ligocki and A. Rosenbaum), SYSAPP-94/077, prepared for Engine Manufacturers Association, Chicago, Illinois (1994)

"Interagency Workgroup on Air Quality Modeling (IWAQM): Assessment of Phase I Recommendations Regarding the Use of MESOPUFF II" (with M. Ligocki and C. Emery), SYSAPP-94/030, prepared for Source Receptor and Analysis Branch, Technical Services Division, Office of Air Quality Planning and Standards, U.S. Environmental Protection Agency, Research Triangle Park, North Carolina (1994)

"Analysis of the 1991-1992 Pine Bend Monitoring Data" (with others), SYSAPP-94/007, prepared for Minnesota Pollution Control Agency, St. Paul, Minnesota (1994)

"Assessment of the Effects of the 1990 Clean Air Act Amendments on Visibility in Class I Areas" (with others), SYSAPP-93/162, prepared for Ambient Standards Branch, Office of Air Quality Planning and Standards, U.S. Environmental Protection Agency, Research Triangle Park, North Carolina (1994)

"Revised Base Case and Demonstration of Attainment for Carbon Monoxide for Maricopa County, Arizona" (with others), SYSAPP-94-93/156s, prepared for Maricopa Association of Governments, Phoenix, Arizona (1994)

"Sacramento FIP 2005 Modeling Inventory" (with others), SYSAPP-93/237, prepared for Pacific Environmental Services, North Carolina, and U.S. Environmental Protection Agency, Region IX, San Francisco, California (1993)

"Carbon Monoxide Modeling in Support of the 1993 State Implementation Plan for Maricopa County, Arizona" (with others), SYSAPP-93/156, prepared for Maricopa Association of Governments, Phoenix, Arizona (1993)

"Air Quality Modeling of Carbon Monoxide Concentrations in Support of the Federal Implementation Plan for Phoenix, Arizona" (with others), SYSAPP-93/039, prepared for Pacific Environmental Services, North Carolina, and U.S. Environmental Protection Agency, Region IX, San Francisco, California (1993)

"Base Case Carbon Monoxide Emission Inventory Development for Maricopa County, Arizona" (with others), SYSAPP-93/077, prepared for Maricopa Association of Governments, Phoenix, Arizona (1993)

"Sacramento FIP Modeling 3: Future Emissions Inventory" (with others), SYSAPP-93/036, prepared for Pacific Environmental Services, Inc., North Carolina and U.S. Environmental Protection Agency, San Francisco (1993)

"Emissions Inventory Development for the Tribal Air Program" (with M. Causley and S. Reid), SYSAPP-92/146, prepared for U.S. Environmental Protection Agency, Region VIII, Denver, Colorado (1992)

"Carbon Particle Emissions Inventory for Denver Brown Cloud II: Development and Assessment" (with S. B. Reid and L. R. Chinkin), prepared for Colorado Department of Health, Denver, Colorado (1992)

"Analysis to Determine the Appropriate Trade-off Ratios Between NO_x, SO_x, and PM10 Emissions for the Shell Martinez Refinery" (with M. Ligocki), SYSAPP-92/006, prepared for Shell Oil Co., Martinez, California (1992)

"Modeling Program for PM-10 State Implementation Plan Development for the El Paso/Ciudad Juarez Airshed" (with C. Emery and M. Ligocki), SYSAPP-91/134, prepared for U.S. Environmental Protection Agency, Dallas Texas (1991)

"Deterministic Modeling for Navajo Generating Station Visibility Study. Volume I. Technical Report" (with others), SYSAPP-91/045a, prepared for Salt River Project, Phoenix, Arizona (1991)

"Deterministic Modeling in the Navajo Generating Station Visibility Study" (with others), SYSAPP-91/004, prepared for Salt River Project, Phoenix, Arizona (1991)

"Analysis of Contributions to PM10 Concentrations During Episodic Conditions" (with A. B. Hudischewskyj and R. G. Ireson), SYSAPP-90/072, prepared for Kaiser Aluminum and Chemical Corporation (1990)

"Preparation of Elemental and Organic Carbon Particle Emission Inventories for the Denver Area: Work Plan" (with L. R. Chinkin), SYSAPP-90/068, prepared for Colorado Department of Health (1990)

"Evaluation of Control Strategies for PM10 Concentrations in the South Coast Air Basin," Air Quality Management Plan: 1988 Revision, Appendix V-O. South Coast Air Quality Management District, El Monte, California (1988)

"Annual PM10 Dispersion Model Development and Application in the South Coast Air Basin," Air Quality Management Plan: 1988 Revision, Appendix V-L. South Coast Air Quality Management District, El Monte, California (1988)

"PM10 Modeling Approach" (with others), 1987 AQMP Revision Working Paper No. 2, South Coast Air Quality Management District, El Monte, California (1986)

"Workplan for Air Quality Modeling and Analysis," 1987 AQMP Revision Working Paper No. 5, Planning Division, South Coast Air Quality Management District, El Monte, California (1986)

"Control of Atmospheric Fine Primary Carbon Particle Concentrations," (EQL report No. 23), Ph.D. thesis, California Institute of Technology, Pasadena, California (1986)

"Policy on Recombinant DNA Activities: Relaxing Guidelines While Increasing Safety," project report, Department of Engineering and Public Policy, Carnegie-Mellon University, Pittsburgh, Pennsylvania (1978)

"Air Pollution Control Analyses for State Implementation Plan Revisions in Allegheny County," project report, Department of Engineering and Public Policy, Carnegie-Mellon University, Pittsburgh, Pennsylvania (1978)

EMPLOYMENT HISTORY

Systems Applications International	Manager, PM-10 and Visibility Program	1989–1997
South Coast Air Quality Management District	Air Quality Specialist	1985–1989
California Institute of Technology, Pasadena, California	Research Assistant Laboratory Assistant	1979–1985 1979
Carnegie-Mellon University, Dept. of Mechanical Engineering Pittsburgh, Pennsylvania	Research Assistant	1978–1979