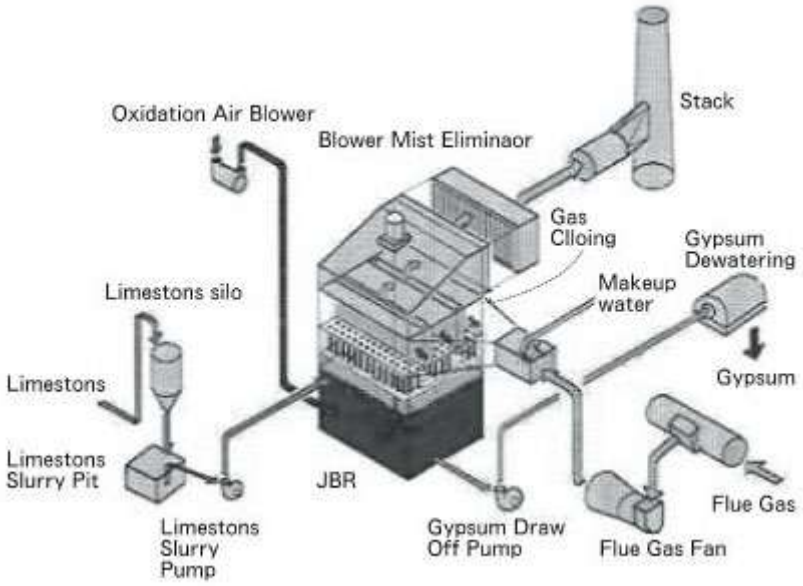
Interim Report of the Division of Air Quality to the

Environmental Management Commission on the

Control of Mercury Emissions from

Coal-Fired Electric Steam Generating Units

In accordance with 15A NCAC 02D.2509 (b)



July 1, 2008

Division of Air Quality

North Carolina Department of Environment and Natural Resources

Preface

The Division of Air Quality presents this report to the North Carolina Environmental Management Commission in accordance with the requirement in 15A NCAC 02D .2509, Periodic Review and Reallocations.

The report provides updated information on the subjects listed under Paragraph 02D .2509(b) where it is available. If the information is not available, a plan is provided to develop the information for the 2012 Report.

The information required includes:
(1) actual emissions from units covered under this Section (15A NCAC 02D .2509) since 2010 and all other principal sources of mercury;
(2) estimates of the amounts of the different species of mercury being emitted;
(3) create a mercury balance for North Carolina, including imported, exported, and in-state mercury emissions and the fate and transport of mercury in the air and waters of the State;
(4) what are the projected mercury emissions for 2015, 2018, 2023, and 2025?;
(5) discuss the amount of new source growth and projected new units growth through 2025;
(6) what is the state of mercury control technology, including technological and economic feasibility?;
(7) assessment of cost and performance of Hg control technology as it may be applied to uncontrolled sources of Hg in North Carolina, including both coal-fired electric steam generating units and other sources that emit Hg, and including an assessment of technology used to satisfy requirements of the Clean Smokestacks Act (CSA) (G.S. 143-215.107D), and other requirements for controlling nitrogen oxide and sulfur dioxide SO_2 emissions;
(8) provide a recommendation of mercury control technology, including the cost and expected reductions in mercury emissions;
(9) results of studies and monitoring on mercury and its species in fish in North Carolina, including an evaluation of the impact of reduced mercury emissions from coal-fired power plants on the levels of mercury observed in fish tissue;
(10) a summary of mercury-related health problems in North Carolina, including accumulation of mercury in humans, toxicity, and mercury exposures from non-air emitting sources;
(11) results of studies on mercury deposition, applying monitoring techniques, back trajectory analysis, source attribution methodology, including other relevant methodologies, to assess the role of coal-fired units in North Carolina deposition;
(12) recommendations, if any, on rule revisions.

1. Actual emissions from units covered under this Section (15A NCAC 02D .2509) since 2010 and all other principal sources of mercury

Definitions:
"Actual" means presently existing in fact and not merely potential or possible. "Emissions" means the amount of airborne, total mercury released in one year. "From units covered under this section" means coal-fired utility electric generating units (EGUs). "All other principal sources of mercury" means industrial, commercial, or institutional point sources with emissions greater than one percent (1%) of total mercury emissions in the most recent annual North Carolina mercury inventory.

ACTUAL MERCURY EMISSION ESTIMATES
Actual emission estimates were developed from emission factors and production levels consistent with annual actual emission inventories, reported by utilities and industries to DAQ and EPA. DAQ used 2006 emission inventory data, the latest year available for this report. Based on a projected statewide mercury emission total of about 2,000 pounds in or about the year 2012, principal sources of mercury were considered those with emissions greater than 20 pounds per year (lbs/yr).

In 2006, approximately 4,150 lbs of mercury were emitted from permitted stationary sources of air pollution in North Carolina. This estimate includes emissions reported by the three local air programs. Table 1 presents the most recent stationary source air emissions inventory of mercury air emission rates for the top 25 principal sources (>20 lbs) in North Carolina. Analysis of the statewide inventory indicates that:

- 76% of the emissions (3,158 lbs/yr) are attributed to coal-fired EGUs from the two primary utility companies: Duke Energy Carolinas, LLC (Duke Energy) and Progress Energy Carolinas, LLC (Progress Energy).
    - Most Duke Energy and Progress Energy coal-fired EGUs emit mercury in the range of 100-700 lbs/yr, with only 3 of their EGU facilities emitting less than 100 lbs/yr.
    - 13 of the top 15 North Carolina mercury emission sources are coal-fired EGUs; scrubbers mandated under the Clean Smokestacks Act (CSA) will be installed on 9 out of those 13 EGUs by 2012, to significantly reduce mercury emissions.
- The remaining 24% of statewide mercury emissions is attributed to various non-EGU industrial coal-fired boilers, steel mills, incinerators, and other sources. Statewide emissions from the remaining sources are distributed as follows:
    - 6% to one fertilizer industry facility
    - 6% to two steel industry facilities
    - 2% to five paper industry facilities
    - 1% to two waste incineration facilities
    - 9% to all other sources statewide.
- Most principal non-EGU facilities emit mercury in the range of 20-40 lbs/yr, with only 2 of the non-EGUs emitting mercury in the range of 200-240 lbs/yr.

- One source, PCS Phosphate fertilizer facility, may actually have lower emissions than reported, since their emission test data pre-dates installation of additional emission control equipment.
- Emissions from the two steel mills in North Carolina are expected to continue to decline from the implementation of the mercury switch removal program. Nucor reported emissions of 679 lbs in 2002 and 205 lbs in 2006; that is a 474 lb reduction over 4 years.
- A few industrial coal boilers have already ceased coal combustion since the 2006 inventory, such as a large boiler at the Domtar Paper Mill in Plymouth. Mercury emissions at the Blue Ridge Paper Mill in Canton, may in fact be higher than reported, as 2006 stack testing revealed much higher emissions than the previous 1993 stack tests.

TABLE 1. 2006 ACTUAL MERCURY AIR EMISSIONS INVENTORY OF NORTH CAROLINA SOURCES

(Emissions rounded off with no decimal points, given uncertainties)

NORTH CAROLINA MERCURY INVENTORY SOURCE		Mercury Lbs/Yr Utility	Mercury Lbs/Yr Non-utility	Industry, with major mercury source
1	Progress Energy - Roxboro Plant	704		EGU, coal boilers
2	Duke Energy - Belews Creek Steam Station	552		EGU, coal boilers
3	Duke Energy - Marshall Steam Station	483		EGU, coal boilers
4	Duke Power - Allen Steam Station	265		EGU, coal boilers
5	Progress Energy - Mayo Facility	249		EGU, coal boilers
6	PCS Phosphate Company Inc. - Aurora		236	Fertilizer, coal calciners
7	Nucor Steel		205	Steel, electric arc furnace
8	Duke Energy - Cliffside Steam Station	174		EGU, coal boilers
9	Progress Energy – L V Sutton Plant	144		EGU, coal boilers
10	Progress Energy - Asheville	118		EGU, coal boilers
11	Progress Energy - F Lee Plant	105		EGU, coal boilers
12	Duke Energy - Riverbend Steam Station	103		EGU, coal boilers
13	Duke Power - Buck Steam Station	95		EGU, coal boilers
14	Progress Energy - Cape Fear Plant	82		EGU, coal boilers
15	Duke Energy - Dan River Steam Station	50		EGU, coal boilers
16	New Hanover County WASTEC		43	Municipal waste, boiler
17	DAK Americas LLC		42	Fibers, coal boilers
18	Progress Energy, W.H. Weatherspoon Plant	34		EGU, coal boilers
19	Blue Ridge Paper Products - Canton Mill		34	Paper, coal boilers
20	Gerdau Ameristeel US Inc.		29	Steel, electric arc furnace
21	KapStone Kraft Paper Corporation		29	Paper, coal boilers
22	Carolina Stalite Company		26	Aggregate, coal kilns
23	Elementis Chromium		23	Chromium, oil fired kilns
24	Domtar Paper Company, LLC		23	Paper, coal boilers
25	Miller Brewing Company - Eden Plant		22	Brewery, coal boilers

Mercury Air Emission Estimates

The mercury emissions for utility sources are estimated from Electric Power Research Institute (EPRI) correlation equations based on various factors such as control device configuration, along with the mercury, chlorine, and sulfur content of coal.[1] The mercury emissions for non-utility sources are estimated from site-specific stack test data and federal EPA documents such as AP-42 Compilation of Air Pollutant Emission Factors, Volume 1: Stationary Point and Area Sources. Some facilities such as Nucor Steel and the medical/municipal waste incinerators conduct annual stack testing, while other facilities may rely on a one-time stack test. There is uncertainty involved with using a one-time stack test to estimate annual emissions. There is even more uncertainty involved with utilizing a published emission factor based on average test data of possibly non-similar sources. The fact that there are three published emission factors that facilities can choose to use further exacerbates the uncertainty in the emission estimates. A few North Carolina sources may be over-estimating their emissions based on using an "uncontrolled" AP-42 emission factor where there was no obvious alternative. Future year inventories should focus on obtaining more current site-specific test data where justified, and should focus on better emission factors for some facilities that may be significantly over-estimating their emissions. Mercury emission estimates from coal-fired industrial boilers are worthy of future inquiry.

Table 2 illustrates other key points in the uncertainty in the emission estimates. It presents the published mercury emission factors used for many of the industrial boilers in the 2006 North Carolina emission inventory. The table also contains values derived from the inventory for EGU emission factors and the level of mercury in coal (coal mercury). Both mercury emission factors and coal mercury values are presented in the same units of measure, pounds of mercury per trillion British thermal units (lb mercury / TBtu coal). Review of Table 2 indicates that:

- For the first set of data on utility and industrial coal fired boilers, there are three published emission factors, ranging from 4-16 lbs mercury / TBtu coal, that facilities can choose to use, independent of the type of emission control applied. Facility A could estimate lower emissions than Facility B, even though it burns twice as much coal and has a less effective type of emission control because it could select a smaller (4 times smaller) emission factor than Facility B. Note that while these emission factors were developed from bituminous and sub-bituminous coals, only bituminous coal is burned in NC. It is no longer the practice of NC EGUs to use AP-42 emission factors.
- For the second set of data on NC EGUs, there are emission factors, ranging from 1-6 lbs mercury / TBtu coal, derived from the EPRI correlation equation estimates. These emission factors were developed specifically from NC EGUs burning bituminous coals for the respective type of emission control device applied.
- For the third set of data on coal mercury, the EGU coal factors, ranging from 4-9 lbs mercury / TBtu coal, were derived from available coal use and coal content data in the 1999 EPA ICR for coal-fired utilities and the 2006 North Carolina emission inventory. DAQ has not found any coal mercury data for North Carolina industrial boilers. If North Carolina industrial boilers are burning comparable coal as NC EGUs, then this data suggests mercury emission factors for industrial boilers could be less than 9 lbs mercury / TBtu coal.

[1] *An Assessment of Mercury Emissions from U.S. Coal-Fired Power Plants*, EPRI, Palo Alto, CA: 2000. 1000608.

Table 2. Mercury Emission and Coal Mercury Factors

	Emission Factor lb mercury / TBtu coal	Emission Control	Coal Type
1. EGU and Industrial Coal-fired Boiler Emission Factors			
AP-42 Table 1.1-17	16	Uncontrolled	Bituminous, Sub-bituminous
AP-42 Table 1.1-18	4	ESP, FF, FGD	Bituminous, Sub-bituminous
Industrial Boiler MACT	5	None & all types	Unspecified
2. NC EGUs Emission Factors			
Duke & Progress Energy	6	ESP- HS	Bituminous
	4 - 5	ESP- CS	
	2 - 3	ESP- CS/ FGD	
	1	ESP- CS/ FGD/ SCR	
C. Coal Mercury Factors			
1999 ICR, NC EGUS	4 to 8	Uncontrolled	Bituminous
2006 EI, NC EGUs	7 to 9		
NC Industrial Boilers	Unknown		

Notes:
AP-42 AT HTTP://WWW.EPA.GOV/TTN/CHIEF/AP42/CH01/FINAL/C01S01.PDF
Industrial Boiler MACT (vacated) emission database
NC EGUs Emission Factors derived from 2006 Emission Inventory (EI)
ESP = Electrostatic Precipitator, CS = Cold-side, HS = Hot side
FF = Fabric Filter
FGD = Flue Gas Desulfurization scrubber
SCR = Selective Catalytic Reduction
1999 ICR = EPA Information Collection Request for Coal-fired Utilities in 1999

2006 ACTUAL MERCURY AIR EMISSIONS INVENTORY – OTHER EGUS

Table 3 presents six additional coal burning EGUs of interest that were not included in Table 1 because 2006 emissions were below 20 lbs. The EGUs in Table 3 generally have lower emissions than the other EGUs in Table 1, due to lower coal throughput and/or modern emission controls.

Table 3. 2006 Actual Mercury Air Emissions Inventory – Other EGUs

North Carolina Mercury Inventory Source	Mercury, Lbs/Yr
Primary Energy of North Carolina LLC - Southport	4.2
Roanoke Valley Energy Facility	2.7
Primary Energy of North Carolina LLC - Roxboro	2.1
Edgecombe Genco, LLC	1.9
Elizabethtown Power, LLC	0.1
Lumberton Power, LLC	0.1

Other Mercury Emissions (Non-Point Source)
All the above emission data represents North Carolina point source levels, which are estimated to be approximately 4,150 lbs of mercury for 2006. Other types of sources emitting mercury in North Carolina include non-point sources and mobile sources. The EPA 2002 National Emissions Inventory (NEI) suggests an additional 325 lbs of anthropogenic mercury emissions in North Carolina from on- and off-road mobile sources, industrial fuel use, crematoria, fluorescent lamp breakage, dental alloy production, and residential fuel combustion.

2. Estimates of the amounts of the different species of mercury being emitted

Definitions:
The three "different species of mercury being emitted" means speciated mercury that includes: elemental mercury vapor, "oxidized" mercury (also known as reactive gaseous mercury), and particulate matter (PM) bound mercury. "Estimates" means calculations approximating the amount of mercury subdivided into the three different mercury species.

Speciated Mercury Emission Estimates
Prior to 1999, there was no widely accepted reference method in the United States (US) to speciate mercury emissions. EPA proposed a reference method to speciate mercury emissions as part of the 1999 Information Collection Request for EGUs.[2] Since then, results from numerous studies on coal-fired EGU mercury control with the reference method were produced to develop emission estimates of the three species. However, information is limited on speciated mercury emissions for the remaining non-EGU sources.

Table 4 presents the estimated mercury species being emitted in 2006 for the top 25 principal sources in North Carolina. The speciated data were estimated as follows:

- 14 EGU coal boilers. The speciated mercury emissions for the EGU facilities are estimated from EPRI correlation equations based on control device configuration and

[2] American Society for Testing and Materials (ASTM) Method D6784-02 adopted in 2002.

mercury, chlorine, and sulfur coal contents.[3] Facility-specific coal data provided by each EGU boiler were used as inputs for the correlation equations.

- 5 Non EGU coal boilers. Given the similarity between EGU and non-EGU coal-fired boilers, speciated mercury emission estimates were derived using the EPRI correlations for the average case coal boiler: Elemental, 47%; PM, 1 %; Oxidized, 52%.

- 6 Other sources. There is limited information on speciated mercury emissions for the remaining industries. Their estimates were based on other references for the following industries:
  - for two steel mills and one fertilizer facility with coal-fired calciners,[4]
  - for one municipal waste combustor (boiler),[4] and
  - for the three facilities with coal and oil-fired kilns, assuming the same speciation, profile as was applied for the non-EGU coal-fired boilers.

Table 4. Speciated Mercury Emission Estimates of North Carolina Principal Sources for 2006

North Carolina Mercury Emission Source Ranking		Elemental Mercury	PM Mercury	Oxidized Mercury	Elemental	PM	Oxidized	Industry, with major mercury source
		Lbs/Yr			Percent of Total Mercury			
1	Progress - Roxboro	202	11	492	29%	2%	70%	EGU, coal boilers
2	Duke -Belews Creek	177	11	364	32%	2%	66%	EGU, coal boilers
3	Duke - Marshall	155	10	319	32%	2%	66%	EGU, coal boilers
4	Duke - Allen	85	5.3	175	32%	2%	66%	EGU, coal boilers
5	Progress - Mayo	72	3.2	174	29%	1%	70%	EGU, coal boilers
6	PCS Phosphate	111	3.5	123	47%	1%	52%	Fertilizer, coal calciners
7	Nucor Steel	96	3.1	107	81%	15%	4%	Steel, electric arc furnace
8	Duke - Cliffside	59	2.5	112	34%	1%	65%	EGU, coal boilers
9	Progress - Sutton	41	2.1	101	28%	1%	70%	EGU, coal boilers
10	Progress - Asheville	90	1.8	27	76%	2%	22%	EGU, coal boilers
11	Progress - F Lee	32	1.5	72	30%	1%	68%	EGU, coal boilers
12	Duke - Riverbend	41	1.0	61	40%	1%	59%	EGU, coal boilers
13	Duke - Buck	38	0.9	56	40%	1%	59%	EGU, coal boilers
14	Progress - Cape Fear	22	1.2	59	27%	2%	72%	EGU, coal boilers
15	Duke - Dan River	18	0.7	31	36%	1%	62%	EGU, coal boilers

[3] *An Assessment of Mercury Emissions from U.S. Coal-Fired Power Plants*, EPRI, Palo Alto, CA: 2000. 1000608.
[4] US EPA, 2002 National Emissions Inventory Data and Documentation – Mercury Speciation, available in May 2008 at http://www.epa.gov/ttn/chief/net/2002inventory.html
[4] US EPA, "Mercury Study Report to Congress, Vol. III," EPA-452/R-97-005, December 1997.

16	New Hanover Co. WASTEC	39	1.0	3		60%	10%	30%	Municipal waste disposal, boiler
17	DAK Americas LLC	20	0.6	22		47%	1%	52%	Textile, coal boilers
18	Progress - Weatherspoon	9	0.5	25		27%	2%	72%	EGU, coal boilers
19	Blue Ridge Paper	16	0.5	18		47%	1%	52%	Paper, coal boilers
20	Gerdau Ameristeel	14	0.4	15		81%	15%	4%	Steel, electric arc furnace
21	KapStone Kraft Paper	14	0.4	15		47%	1%	52%	Paper, coal boilers
22	Carolina Stalite	12	0.4	14		47%	1%	52%	Aggregate, coal kilns
23	Elementis Chromium	11	0.3	12		47%	1%	52%	Chromium products, oil fired kilns
24	Domtar Paper	11	0.3	12		47%	1%	52%	Paper, coal boilers
25	Miller Brewing - Eden Plant	10	0.2	11		47%	1%	52%	Brewery, coal boilers

Duke = Duke Energy; Progress = Progress Energy

Table 5 summarizes the speciated mercury emission estimates of North Carolina's principal sources based on the 2006 emission inventory. Review of the summary table shows:

- Most EGU speciated emission estimates, on average, are indicated to be 65% oxidized mercury, followed by 33% elemental mercury and 2% PM-mercury. Nearly all the EGUs use ESPs for control, with oxidized mercury emissions typically in the 60-70% range.
- The one exception is the Progress Energy Asheville EGU that is controlled by ESPs and FGD scrubbers; the FGDs collect additional oxidized mercury, reducing total mercury emissions, thereby changing the exhaust to contain 76% elemental mercury. The second boiler was connected to the scrubber in May of 2006.
- Non-EGU emissions, on average, are distributed such that the oxidized and elemental mercury are virtually the same at 49% each, with 2% being PM-mercury.
- Five of the non EGUs use coal-fired boilers with the same general mercury speciation distribution as EGUs; the majority being oxidized mercury followed by elemental with a very small amount of PM-bound mercury.
    - According to the references, of the remaining six sources, three are expected to contain speciation distribution with higher percentages of elemental mercury:
    - For two steel mills, mercury emissions would be approximately 80% elemental.
    - For the one municipal waste combustor or boiler, mercury emissions would be approximately 60% elemental.

Table 5. Summary of Speciated Mercury Emission Estimates of North Carolina Principal Sources for 2006

North Carolina Speciated Mercury Emissions	Elemental Mercury	PM Mercury	Oxidized Mercury	Elemental	PM	Oxidized	Averages
	Lbs/Yr			Percent of Total Mercury			
EGU Subtotal	1,039	52	2,067	35%	2%	63%	EGU Average
Non EGU Subtotal	354	11	351	54%	4%	41%	Non-EGU Avg
Total	1,393	63	2,418	33%	2%	65%	Average of Total
EGU % of Each Mercury Species				75%	83%	85%	
Non EGU % of Each Mercury Species				25%	17%	15%	
EGU Total Mercury - Total Emissions			3,158				
Non EGU Total Mercury - Total Emissions			715				

3. Create a mercury balance for North Carolina, including imported, exported, and in-state mercury emissions and the fate and transport of mercury in the air and waters of the state

DAQ expects to complete this modeling effort in-house using state implementation plan (SIP) modeling input files. This will be a demanding assignment for the DAQ staff; however, there are advantages to doing this work internally because of the in-depth staff working experience with this model. A long-term multi-year commitment of DAQ staff resources will be needed.

This is a cost effective answer to a lack of funds to support hiring a private contractor for a complex long-term project. This work will evolve in stages and should fit with the 2012 report schedule.

Several studies relating to the emission, transport, and deposition of atmospheric Hg has recently been completed. They show a need for increased information about Hg emissions and deposition rates. The State of Virginia used a contractor to accomplish a similar task. They reported preliminary results at a Virginia Mercury Symposium in October 2007. Final results of that study will soon be available and may inform and direct efforts by DAQ in North Carolina.

Approach for Mercury Modeling

The Atmospheric Sciences Modeling Division (ASMD) of NOAA's Air Resources Laboratory (ARL) was established to collaborate with the U.S. Environmental Protection Agency (EPA) in developing advanced air quality models that can simulate the transport and fate of pollutants in the atmosphere.

The Community Multi-scale Air Quality model (CMAQ) simulates atmospheric processes within a 3-dimensional array of predefined finite volume elements and can model complex interactions between all pollutants that may exist within each volume element. CMAQ was previously

developed to simulate photochemical oxidants, acidic and nutrient pollutants, and aerosol particulate matter; all of these pollutants have been shown to interact with mercury in air and in cloud water, and influence its deposition to sensitive aquatic ecosystems. The "one atmosphere" approach of CMAQ where all pollutants are simulated together just as they exist in the real atmosphere, has been extended to atmospheric mercury modeling at AMD.

New information about chemical and physical processes affecting mercury continues to be published, and refinement of the mercury version of CMAQ (CMAQ-Hg) is an ongoing process. The model's treatment for the sorption of Hg2+ compounds by elemental carbon aerosols in aqueous suspension in cloud water is currently under examination. The CMAQ-Hg aqueous chemistry mechanism was recently optimized to more efficiently calculate the mercury chemistry in concert with the standard CMAQ mechanism. Further modification of the CMAQ-Hg chemical mechanisms for mercury in both the gaseous and aqueous phases is expected as additional chemical reactions are identified.

Hg Deposition

Mercury deposition is the dynamic process of deposition, chemical conversion, and re-emission of different forms of Hg that creates a "bi-directional dynamic," which is central to the multimedia behavior of Hg. This task addresses targeted multimedia model development for: (1) coupled surface exchange of Hg between the atmosphere and the Earth's surface (primarily water); and (2) the estimation of regional to long-range Hg transport and deposition sensitivity to secondary transformation and surface exchange. This task supports the mercury balance component to modeling efforts and seeks to understand the transport and fate of mercury from release to receptor.

Mercury Modeling Efforts

As mentioned previously, several studies relating to the emission, transport, and deposition of atmospheric Hg have been completed recently. A resounding theme found in these reports is the need for increased Hg information (emission and/or deposition rates). As the data surrounding Hg increases, the science as it relates to modeling becomes increasingly more reliable.

One of the largest challenges to modeling Hg properly is the use of correct emissions information. Currently, the National Emissions Inventory (NEI) published by EPA provides the most up-to-date emissions data in the United States. A study by Gbor et al. (2007) has shown that Hg modeling based on NEI, coupled with an additional natural emissions model, has led to relatively decent CMAQ performance. With this in mind, it is believed that the current emissions inventories would be sufficient for accurate utilization of CMAQ for modeling the transport (intra and interstate) and fate of atmospheric Hg.

An additional area of concern surrounding Hg modeling studies is the general lack of information regarding Hg deposition. The National Atmospheric Deposition Program (NADP) has two active Hg wet deposition monitors located in North Carolina. The Mercury Deposition Network (MDN) analyzes precipitation samples for total- and methylmercury. Although there is currently no method in place to evaluate the ability of CMAQ to simulate dry deposition of mercury, research studies are currently being conducted.

In addition to the study mentioned previously, other research (Lin et al., [2007]) regarding mercury simulation is centered on the continental United States. NC DAQ could simulate mercury modeling at a 36-km horizontal grid spacing based on the same domain used for studies regarding the Visibility Improvement State and Tribal Association of the Southeast (VISTAS). By utilizing a large domain, NC DAQ would be able to utilize a greater number of MDN monitoring sites for model verification.

4. What are the projected mercury emissions for 2015, 2018, 2023, and 2025?

Definition: "Projected mercury emissions" means calculated future annual airborne mercury released into the atmosphere from coal-fired electrical utility boilers located in North Carolina.

Answer:

Projected Mercury Emissions		
	All Controlled (Lbs. per Year)	**Maximum Controlled (Lbs. per Year)**
2015	2287	2287
2018	2067	1876
2023	2255	2047
2025	2334	2120

The "All Controlled" column shows estimated annual emissions with the required controls planned for the CSA, the CAIR, and the use of activated carbon injection at small boilers as all operating electric utility boilers must be controlled by 2018 for mercury.

The "Maximum Controlled" column shows estimated annual emissions if selective catalytic reduction (SCR) units are required at facilities where scrubbers are scheduled to be installed. The use of SCRs with scrubbers improves mercury capture by the scrubber by an estimated 48%. However, SCRs are expensive to install and operate, especially when justified by marginally improved mercury capture at non base-loaded boilers.

This table does not purport to accurately reflect the actual number of pounds of mercury emissions anticipated by Duke Energy and Progress Energy. For example, the emission estimate does not take into account Duke Power's agreement in the Cliffside permit to shut down coal-fired units at Buck (units 4 and 5), Dan River (units 1 through 3), and River Bend (units 4 through 7) to offset carbon dioxide emissions for the new Cliffside unit. The table does reflect reduced mercury emissions from the FGD scrubber to be built for Cliffside unit 5 in 2012. It is based solely on the 2006 mercury emission inventory reported to DAQ. Mercury control efficiencies are assumed and subject to revision.

The process data and assumptions used to calculate mercury emissions are:

1. Duke Energy's annual growth projection of 1.7% (2007-2016).[5]
2. Progress Energy's annual growth projection of 1.8% (2007-2016).[1]

[5] Annual Report NC Utility Commission October 2007

3. NC DAQ 2006 mercury emissions inventory numerical values were used as the initial 2006 emissions from Duke Energy and Progress Energy's facilities. The NC DAQ 2006 inventory is reported by facility (total for multiple boilers). Mercury emission allocation for each boiler was calculated based on its percent relative load at the facility (average of BTU input for three highest years 1998-2002).
4. US EPA assumed control efficiency values were used to calculate each boiler's annual mercury emissions.
5. The calculation of mercury emissions in 2012 from the new Cliffside #6 boiler is based on an analysis of the utilization of base-loaded boilers in North Carolina (83%), the average load carried during operations (57%), and the permit emission limit of 0.019 lbs of mercury per giga-watt-hour. The calculated emission value is 63 lbs in 2012. That value is changed in 2013 by 1.7% and each year after to reflect growth in electric demand.
6. Activated carbon injection with hot-side electrostatic precipitator Hg capture efficiency is assumed to be 80%.
7. Activated brominated carbon injection with cold-side electrostatic precipitator Hg capture efficiency is assumed to be 90%.
8. Reported annual mercury emission totals do not reflect changes in fuel type redistribution (i.e., more load growth provided by new renewable energy sources or additional nuclear power).

5. Discuss the amount of new source growth and projected new units growth through 2025

Definition: "New source growth" means coal-fired units that use new source mercury allocations from the State's mercury allowance. These units will be operating without the benefit of having a mercury allocation listed in Paragraph 15A NCAC 02D .2503(a).

Definition: "Projected new unit growth" means new coal-fired utility boiler units proposed by the utilities to the State's Utility Commission, to be built and operated to meet projected future increases in electric power demand.

Answer: Cliffside # 6 is the only new coal-fired electrical generating unit currently planned or permitted. This new boiler is an 800-megawatt unit.

Cliffside # 6 boiler will be equipped with low NOx burners with overfire air, and state-of-the-art selective catalytic reduction (SCR) for control of NOX, a spray dry absorber (SDA) unit with baghouse to control acid gases, followed by a wet FGD scrubber for control of SO_2. Mercury is not a PSD pollutant and is not subject to PSD or NSR BACT. However, the emission control systems that constitute BACT for the other regulated pollutants, like particulate and sulfur dioxide, effectively control emissions of mercury.

The combination of a spray dry absorber (SDA) using a lime slurry injection followed by a fabric filter will control sulfuric acid. This acid gas control is achieved by controlling the amount of water (temperature reduction through evaporation) based on the acid dew point of the flue gas. Little sulfur dioxide will be removed as compared to a conventional spray dry FGD system

because the spray dryer does not operate at the low approach to adiabatic saturation temperature and because the limited amount of lime injection will preferentially react with sulfuric acid.

In a typical SDA, the flue gas passes through a spray dryer vessel where it encounters a fine mist of lime slurry. The lime slurry is injected into the SDA through either a rotary atomizer or fluid nozzles. The moisture in the droplets evaporates and the lime reacts with the acid gases in the flue gas to form calcium salts. A fabric filter then allows for further reaction of the lime with the acid gases in the flue gas. This is due to the layer of porous filter cake on the surface of the filter that contains the reagent that all flue gas must pass through. This allows for increased efficiency of control of sulfuric acid mist, hydrogen chloride, and mercury as compared to wet scrubbers.

Mercury is not a PSD pollutant and is not subject to PSD or NSR BACT. However, Paragraph (f) of 15A NCAC 02D .2511, Mercury Emission Limits, requires new coal-fired electric steam generating unit which begins construction after the effective date of the Rule shall install and operate best available control technology for mercury. From the Rule, "best available control technology" means an emissions limitation based on the maximum degree of reduction of mercury from coal-fired electric steam generating units that is achievable for such units taking into account energy, environmental, and economic impacts and other costs. For the purposes of 2D .2511, the Director has identified the current control design for the Cliffside # 6 boiler as best available control technology for mercury.

6. What is the state of mercury control technology, including technological and economic feasibility?

This is a two-part question. The first part concerns the state of mercury control technology. The answer comes with an explanation of how various coal-fired boiler emission control equipment operates together, along with the science that makes it work. The description of the equipment used to control mercury emissions is followed by a discussion on the technological and economic feasibility in North Carolina.

The "state of mercury control technology" means the science, equipment, and operating techniques used to reduce mercury emissions. Technologies that directly capture and remove mercury emissions are flue gas desulfurization scrubbers (dry and wet FGD) and powder activated carbon injection (PAC) used in conjunction with electrostatic precipitators or baghouses to remove the activated carbon from the flue gas flow.

Pollution emission controls on coal-fired boilers remove mercury (Hg), sulfur dioxide (SO_2), nitrogen oxides (NO_x), and particulate. This effort requires several pieces of equipment operated in series, in a manner to maximize removal of all four pollutants.

Prior to the CSA, the NOx SIP Call, and CAIR, there were two emission control configurations on North Carolina's coal-fired utility boilers. They were low nitrogen oxide (NO_x) burners that are designed to reduce the formation of NO_x emissions and either a hot-side electrostatic precipitator (HS-ESP) or a cold-side electrostatic precipitator (CS-ESP) to remove particulate. The difference between the two types of electrostatic precipitators is the temperature of the flue

gas as it passes through the precipitator. The typical temperature range is 270-330ºF for CS-ESPs and 600-750ºF for HS-ESPs. Duke Energy uses HS-ESPs at 15 of their 29 boilers. Progress Energy uses HS-ESPs at 6 of their 21 boilers. The remaining boilers operate with CS-ESPs. The flue gas temperature is influenced by the use of a preheater.

Combustion air preheaters are part of combustion control equipment. The purpose of the preheater is to increase fuel efficiency through heat recovery. The preheater is a heat exchanger that recovers heat from flue gas leaving the boiler and transfers the waste heat to combustion air entering the boiler. It is the physical position of the preheater relative to the electrostatic precipitator that determines if the precipitator is a HS-ESP or a CS-ESP.

When the preheater is placed after the ESP, the ESP is a HS-ESP. If the preheater is placed between the boiler and the ESP, then the ESP is a CS-ESP. The purpose of installing the preheater after a HS-ESP is to keep the flue gas temperature above the formation temperature of sulfuric acid, that will destroy the steel in a HS-ESP. CS-ESPs are designed to withstand an acid attack. Both types of ESPs are expensive to buy and operate. The CS-ESP is the most expensive. The same high temperature flue gas that protects the HS-ESP from acid formation inhibits mercury capture.

Bituminous coal is burned in NC utility boilers and typically contains mercury in the range of 0.06 to 0.12 parts per million (ppm)[6] or less than 15 lb/TBtu.[7] When combusted in utility boilers at 2500ºF, all the coal mercury is initially vaporized and exists as elemental mercury. As it leaves the boiler and cools, a portion of the elemental mercury tends to be transformed into the other species of oxidized mercury and particulate matter (PM)-bound mercury. Mercury speciation is principally influenced by coal chlorine content, flue gas temperature, and several other factors.

Mercury vapor does not condense until the flue gas temperature drops to approximately 350°F. Consequently, boilers with hot-side ESPs that need mercury control have no alternative to capital-intensive projects like adding secondary cold-side particulate collectors or converting their hot-sides to cold-sides. A third option is to inject water into the hot flue gas down stream from the HS-ESP and prior to the injection of powder activated carbon (PAC) into the flue gas. The PAC is removed with the use of a baghouse. The fourth option involves installing a lime spray dryer with a bag house or a wet-scrubber. Both lime spray dryers with bag houses or wet scrubbers can be installed on boilers equipped with either cold-side or hot-side electrostatic precipitators.

The extent of mercury capture in most existing PM emission control equipment (ESPs and fabric filers [baghouses]) typically depends on mercury speciation. More specifically, existing control technology performance tends to be proportional to the amounts of oxidized and PM-bound mercury at the inlet to the control device. At typical HS-ESPs temperatures of 700ºF, the percentage of elemental mercury remains relatively high, low amounts of oxidized mercury

[6] Pavlish, J.H. et al, "Status review of mercury control options for coal-fired power plants," Fuel Processing Technology, 82 (2003) pp. 89-165.
[7] U.S. EPA, "Control of mercury emissions from coal-fired electric utility boilers; Interim Report," EPA-600/R-01-109, April 2002.

exists, and virtually no PM-bound mercury is formed. This tends to explain why HS ESP capture efficiency is typically in the low range of 10-20%, given the low amounts of oxidized and PM-bound mercury present. At lower temperatures typical of CS-ESPs of 300-350ºF, the distribution of the mercury speciation tends to shift, as more of the elemental mercury converts to oxidized mercury and PM-bound mercury. This presents a more collectible distribution of mercury species, and accounts for why CS-ESP capture efficiency is typically in the moderate range of 30-50%. Fabric filters typically collect 80-90% of mercury, given the gas temperature is 300ºF and the flue gas passes through the dust (PM)-cake, providing excellent gas-PM contact across the dust cake.

Activated carbon injection has the potential to achieve moderate to high levels of mercury control from 50-90%. The performance of activated carbon is related to its physical and chemical characteristics. Generally, the physical properties of interest are surface area, pore size distribution, and particle size distribution. The capacity for mercury capture generally increases with increasing surface area and pore volume. Carbon sorbent capacity is dependent on temperature, the concentration of mercury in the flue gas, flue gas composition, and other factors.

Some combustion situations may not have adequate chlorine present in the flue gas for sufficient mercury capture by standard powdered activated carbon. Accordingly, halogenated PAC sorbents have been developed to overcome some of the limitations associated with PAC injection for mercury control in power plant applications. Relative to standard PAC, the use of halogenated PAC may expand the usefulness of sorbent injection to situations where standard PAC may not be as effective.

February 2007 testing conducted at Progress Energy's Lee Unit 2 with a hot-side ESP and a brominated powdered activated carbon for high temperature applications showed that the sorbent achieved a mercury reduction of 60% at an injection rate of 10 lb/MMacf (million actual cubic foot) at high load and 790 F average temperature. There was a mercury reduction of 75% at low load and 570 F average temperature at the same injection rate.

Using an ESP to capture the spent PAC or halogenated PAC improves the cost effectiveness of mercury capture by avoiding the installation of downstream fabric filter.

There are two types of flue gas desulfurization scrubbers; dry and wet flue gas desulfurization (FGD) units. FGDs remove 90-98% of sulfur dioxide gas in the flue gas. Wet-FGDs operate using a wet well which means the lime still contains water when it reaches the bottom of the scrubber. A dry-FGD has a dry well as the lime starts at the top of the scrubber as a liquid slurry and dries out as it passes through the flue gas. Because the ground limestone is dry before reaching the bottom of the scrubber, lime particulate becomes entrained in the flue gas and would enter the atmosphere as particulate emissions. This is why a dry-FGD has a bag house to control particulate emissions. Both wet and dry FGDs appear to share equivalent benefits.

As a cobenefit, oxidized mercury is captured in the scrubber slurry and removed. However, little to no elemental mercury is captured by a FGD and that may account for total mercury control performance ranging from 60-90% control, depending on the distribution of mercury species.

Flue gas desulfurization scrubbers have two basic operational designs: wet scrubber and lime spray dryer. The scrubber most often installed on coal-fired utility boilers is the wet scrubber. Studies show that flue gas desulfurization scrubbers following cold-side ESPs have higher performance and are more cost-effective in mercury removal than those following hot-side ESPs.

A current issue with many FGD units is re-emission of mercury previously captured. Typically 95% of oxidized mercury is captured in FGDs, but no elemental mercury is captured. This means the same amount of elemental mercury that enters should equal what exits the FGD. Re-emission is demonstrated by higher levels of elemental mercury measured at the FGD outlet than at the inlet. Mixed results have been seen as to the effectiveness of the various additive chemicals to mitigate mercury re-emission. Additives are effective on certain coals and not on others. Re-emission can vary from 0-40% for elemental mercury and significantly reduce total mercury collection performance. [8]

Indirect technologies improve mercury capture efficiently by changing the mercury species. Examples of indirect technologies include the use of:

- selective catalyst reactors (SCR) to reduce NO_x emissions while increasing oxidized mercury as a percentage of total mercury,
- increase the percentage of unburned carbon in the flue gas (decreases fuel efficiency),
- controlling flue gas temperatures, and
- blending coal types to optimize coal chemical characteristics.

The second part of the question concerns the application of mercury capture technology to North Carolina's utility boilers in an economic manner. Economics and control efficiency will be reviewed after a short discussion of technological constraints at existing facilities. The application of specific mercury controls at existing facilities is dictated by the original design of the equipment, the physical location of each piece of main and auxiliary equipment, and the space available to position additional pollution control equipment.

Physical space is limited at many installations. Burning coal is a major material handling exercise. Coal is normally delivered in railroad cars and off-loaded to storage piles. Bottom ash and flyash require collection and disposal. To install wet scrubbers at some facilities has required a complete repositioning of existing controls, material handling equipment, and major ductwork modification. Lengthening ductwork increases flue gas flow resistance, which if left unaccounted for, can change flame dynamics in the boiler combustion chamber, leading to lower fuel combustion efficiency. Often, force draft blowers must be replaced with larger units when system changes are made. Each facility is unique regarding existing physical and engineering challenges to install viable mercury control technology.

Information on the economic feasibility of mercury control equipment installation is in its early stages. The answer to Item 7 in this report provides a computer program generated model plant with only emission controls being varied to demonstrate mercury capture and the economic cost estimate information available today.

[8] Curie, J.F. et al., "Enhanced Mercury Control by Wet GFD Systems," in Proceedings of Air Quality VI Conference, Arlington, VA, September 2007.

The 2012 report will contain the combined experience of many different plants and should provide the appropriate "comfort level" to formulate reasonable regulations. However, detailed engineering information on specific technologies applicable at North Carolina utilities and the resulting economic evaluations are not yet available.

Mercury removal efficiency for various combinations of pollution control equipment is currently best estimated in the table shown below. There are many variables that influence the efficiency of mercury control equipment notwithstanding the current ability to measure mercury emissions with a plus or minus of 20% accuracy.

Mercury Removal Rates from Pulverized Coal Units Assumed by EPA

Pulverized Coal Mercury Control Efficiency*	
Pollution Controls in Place	**Bituminous Coal**
Cold-Side Electrostatic Precipitator	36%
Cold-Side Electrostatic Precipitator/Flue Gas Desulfurization Unit (Scrubber)	66%
Cold-Side Electrostatic Precipitator/Dry Flue Gas Desulfurization Unit	36%
Cold-Side Electrostatic Precipitator/Selective Catalytic Reduction Unit (SCR)/Flue Gas Desulfurization Unit	90%
Fabric Filter	89%
Fabric Filter/Flue Gas Desulfurization Unit	90%
Fabric Filter/Dry-Flue Gas Desulfurization Unit	95%
Fabric Filter/Selective Catalytic Reduction Unit/Flue Gas Desulfurization Unit	90%
Hot-Side Electrostatic Precipitator	10%
Hot-Side Electrostatic Precipitator/Flue Gas Desulfurization Unit	42%
Hot-Side Electrostatic Precipitator/Dry Flue Gas Desulfurization Unit	40%
Hot-Side Electrostatic Precipitator/Selective Catalytic Reduction Unit/Flue Gas Desulfurization Unit	90%
*Rate based on percentage removal from amount in coal entering boiler.	

7. Assessment of cost and performance of Hg control technology as it may be applied to uncontrolled sources of Hg in North Carolina, including both coal-fired electric steam generating units and other sources that emit Hg, and including an assessment of technology used to satisfy requirements of the Clean Smokestacks Act (CSA) (G.S. 143-215.107D), and other requirements for controlling nitrogen oxide (NOx) and sulfur dioxide (SO_2) emissions

The first part of this assessment requires a listing of uncontrolled coal-fired boilers and other sources that emit mercury and then to assess the cost and performance of mercury control technology that these sources might reasonably use to reduce their mercury emissions. There has not been enough time or information to conduct a study of non-electrical generating units such as PCS Phosphate and Nucor Steel.

The second part of the assessment requires an evaluation of the performance and cost of emission control equipment installed by North Carolina's utilities to meet the requirements of the CSA and the CAIR through the reduction of NO_x and SO_2. Defensible and definitive information required to make such an assessment is not available at this time.

Listed below are the facilities that emit greater than one percent or 20 lbs/yr of the statewide total amount of mercury anticipated being on the order of 2,000 lbs per year, that may be emitted after the requirements of the CSA and CAIR are met. Estimated mercury emissions listed in the table are from the DAQ 2006 inventory as reported by the facilities. Note the large EGUs with existing or planned scrubbers (Progress Energy's Roxboro, Mayo, and Asheville; and Duke Energy's Belews Creek, Marshall, and Allen) are not listed in the table, given they are considered to be well controlled. The mercury controls are not listed as information is not available at this time to be engineered for a definitive performance and economic justification.

Source	2006 Inventory Hg Emissions (lbs./yr)	Type of Combustion Equipment	Mercury Controlled
PCS Phosphate	238	Fertilizer, coal calciners	No
Nucor Steel	206	Steel, electric arc furnaces	No
Duke - Cliffside	174	EGU, coal boilers	#1 - 4 No, #5 - 6 Yes
Progress - Sutton	144	EGU, coal boilers	#1 & 2 No, #3 Yes
Progress - F Lee	106	EGU, coal boilers	No
Duke - Riverbend (will cease operations 2018)	103	EGU, coal boilers	No
Duke - Buck (will cease operations 2018)	95	EGU, coal boilers	No
Progress - Cape Fear	82	EGU, coal boilers	No
Duke - Dan River (will cease operations 2018)	50	EGU, coal boilers	No
New Hanover Co. WASTEC	43	Municipal waste disposal, boiler	No
DAK Americas LLC	43	Textile, coal boilers	No
Progress - Weatherspoon	35	EGU, coal boilers	No
Blue Ridge Paper	35	Paper, coal boilers	No
Gerdau Ameristeel	29	Steel, electric arc furnace	No
KapStone Kraft Paper	29	Paper, coal boilers	No
Carolina Stalite	26	Aggregate, coal kilns	No
Elementis Chromium	23	Chromium products, oil fired kilns	No
Domtar Paper	23	Paper, coal boilers	No
Miller Brewing - Eden Plant	21	Brewery, coal boilers	No

8. Provide a recommendation of mercury control technology, including the cost and expected reductions in mercury emissions

In 2013, both Duke Energy and Progress Energy will be required to submit mercury control plans identifying the technology for use at each unit to achieve maximum reduction in mercury emissions that is technically and economically feasible without relying on mercury allowances obtained through any trading system. DAQ anticipates that Item 8 information in the 2012 DAQ report will include an analysis of possible mercury control scenarios with costs for comparison.

Published project costs and control efficiency information for mercury control has not progressed to the quality and volume of data needed to develop an initial plan. Instead, the 2008 discussion presents scenarios of various emission control configurations at a model plant to compare mercury capture efficiencies and emission control costs.

A model 500-megawatt coal-fired electrical generating unit is used in a computer program named "Integrated Environmental Control Model with Carbon Sequestration" or "IECM Interface." It accounts for the impacts on multi-pollutant emissions, plant-level resource requirements, costs (capital, operating, and maintenance), and net plant efficiency. The program was developed for the U.S. Department of Energy's National Energy Technology Laboratory and based on its research. It was developed by Carnegie Mellon University, Department of Engineering and Public Policy.

Comparisons of control efficiencies and costs are made more visible by minimizing input variables. All variables such as boiler size, mercury content in the coal, load factor, and operating hours, are treated as constants. Only compatible types of mercury controls are combined to make each scenario. Additionally, low nitrogen oxide (NO_x) burners and electrostatic precipitators are considered part of the plant costs, but are not included in the estimated control costs. However, for this discussion, wet or dry scrubbers are considered in the mercury control costs even though scrubbers are primarily designed to capture sulfur dioxide (SO_2).

The model plant program results include current capture efficiency estimates, an annual cost to own and operate the controls, and an estimate of costs to remove one pound of mercury per year for the control scenario.

One caveat requires explanation. It is related to the use of the IECM Interface program. The program does not provide scenarios for the use of hot-side electrostatic precipitators (HS-ESP) used for particulate capture. Capture efficiencies for HS-ESP scenario configurations comes from US EPA's assumed mercury emission factors for HS-ESP. Mercury forms weak bonds with fly ash and unburned carbon. Scenario results are calculated by changing the amount of mercury captured when using a cold-side electrostatic precipitator (CS-ESP) in the IECM Interface program. Mercury removal for HS-ESP is assumed to be 10%, while CS-ESP mercury removal is assumed to be 36%. This natural capture is important, as electrostatic precipitators are not included in the estimated control costs.

The IECM Interface program is used to show mercury capture through the use of various control configurations. The 14 scenarios start from a baseline configuration of existing equipment and then adding on an additional piece of control equipment to create the next associated scenario. The table contains five associated groups of possible scenarios. A group is a boiler with a particulate control system followed by scenarios that builds on equipment compatible with the first scenario of that group. Groups 1 and 2 have hot-side electrostatic precipitators (HS-ESP). As discussed earlier, Duke Energy uses HS-ESP at 15 of their 29 boilers. Progress Energy uses HS-ESPs at 6 of their 21 boilers. The rest of their boilers use cold-side electrostatic precipitators (CS-ESP). Groups 3 through 5 use CS-ESP to capture particulate.

Group 1 has three scenarios. The first scenario, or baseline, is a boiler with a hot-side electrostatic precipitator (HS-ESP) to collect particulates. Ninety percent of mercury leaving the boiler escapes into the atmosphere. In other words, scenario 1 has 10% mercury control as it exists. If a wet flue gas desulfurization (Wet-FGD) unit is added to scenario 1, then there is a 70% control of mercury emissions (Scenario 2). Scenario 3 adds a hot-side selective catalytic reduction (HS-SCR) to the equipment in scenario 2 and increases total mercury capture to 91%. The increased 21% mercury control by the inclusion of the SCR in the equipment train is due to the SCR's ability to oxidize mercury, thereby improving mercury capture by the Wet-FGD.

Scenario 1 = **HS-ESP** 10% with no SO_2 control
Scenario 2 = HS-ESP + **Wet FGD** (scrubber) 70%
Scenario 3 = **HS-SCR** + HS-ESP + Wet FGD 91%

Group 2 has two scenarios. Scenario 4 removes the wet scrubber from scenario 3, but introduces activated carbon injection with water spray (to cool but not saturate the flue gas) upstream of a new fabric filter (FF). Scenario 4 control equipment captures 73% of the mercury, but the sulfur dioxide control is missing as a wet scrubber is not compatible with a fabric filter. Scenario 5 adds a HS-SCR to the equipment in scenario 4 with no improvement in mercury capture. Apparently, information used to develop the IECM Interface program did not demonstrate the high capture rates more recently reported in the 90 plus percentiles. The author anticipates that adding a HS-SCR will improve the final mercury capture but be judged not economically feasible for the marginal increase.

Scenario 4 = **HS-ESP** + **ACI with water** + **FF** 73% with no SO_2 control
Scenario 5 = **HS-SCR** + HS-ESP + ACI with water + FF 73% with no SO_2 control

Group 3 is the first group of scenarios with a cold-side electrostatic precipitator (CS-ESP). Scenario 6 has only a CS-ESP as a control and an estimated 31% mercury control. Scenario 7 adds a wet FGD that improved mercury capture to 77%. Scenario 8 adds a HS-SCR to scenario 7 and captures 93% of mercury leaving the boiler. Scenario 9 replaces the Wet-FGD with a lime dryer and FF. Mercury capture drops to 31%. DAQ has information that mercury capture, when using lime-dryers, can be as high as 95%. As stated earlier, production size equipment operating experience is new and limited. The issue should be settled by 2012.

Scenario 6 = **CS-ESP** 31% with no SO_2 control
Scenario 7 = CS-ESP + **Wet FGD** (scrubber) 77%
Scenario 8 = **HS-SCR** + CS-ESP + Wet FGD (scrubber) 93%
Scenario 9 = HS-SCR + CS-ESP + **lime dryer and FF** 31%

Group 4 starts with a cold-side electrostatic precipitator with activated carbon injection (ACI). Because the preheater is located between the boiler and the CS-ESP, the flue gas temperature has dropped into the 300°-350°F. Activated carbon powder is injected in scenario 10 upstream from the CS-ESP. This saves costs for the purchase and operation of a FF. Scenario 10 has a mercury control efficiency of 70%. Scenario 11 adds a Wet-FGD and increases mercury control to 77%. Adding a HS-SCR to scenario 11's equipment increases mercury capture for scenario 12 to 93%.

Scenario 10 = **ACI + CS-ESP** 70% with no SO_2 control
Scenario 11 = ACI + CS-ESP **Wet FGD** (scrubber) 77%
Scenario 12 = **HS-SCR** + ACI + CS-ESP Wet FGD (scrubber) 93%

Group 5 has two scenarios that address CS-ESP + lime dryer + ACI and FF. Scenario 13 has these controls in series and is calculated by the program to capture 70% mercury. Scenario 14 adds a HS-SCR with no improvement in mercury control.

Scenario 13 = CS-ESP + lime dryer + ACI and FF 70%
Scenario 14 = HS-SCR + CS-ESP + lime dryer + ACI and FF 70%

The three most successful scenarios, according to the IECM Interface program, that reduce mercury emissions at the model plant to 16 lbs of mercury per year, are scenarios 3, 8, and 12. These scenarios capture 93% of mercury leaving the boiler. They share the common feature of a wet scrubber along with other installed control devices.

The following table begins with an existing 500-megawatt plant with either HS-ESP or CS-ESP to control particulates. The scenarios are identical to the discussion above, except costs are evaluated. For each group, the costs start with the base plant. A control is added to the base plant scenario and the cost of only the added equipment is divided into the marginal increased mercury capture. For example, adding a Wet-FGD to an existing HS-ESP results in an additional 139 lbs of mercury captured for an additional $22,000,000 per year. Dividing the $22,000,000 by the 139 lbs of additional mercury captured yields an annual cost of $159,058 per pound.

The least cost per pound of mercury captured per year is estimated to be $81,000, by injecting activated carbon upstream of the CS-ESP. The greatest cost per pound is $1,384,927 when a Wet-FGD is added to ACI. However, the primary rationale for building and operating a Wet-FGD is to capture SO_2 emissions, not mercury. This multi-pollutant control distorts the costs if the removal value of SO_2 is not calculated, which is not in this discussion.

Scenario	Control Configuration Scenarios	Mercury Emission Reduction Due to Added Equipment (lbs.)	Cost of Additional Equipment (M$/year)	Cost per pound of addition mercury captured ($/lbs./yr)
1	**HS-ESP***	0	0	Base
2	HS-ESP, **Wet-FGD**	139	22	$159,058
3	HS-ESP, **HS-SCR**, Wet-FGD	49	6	$121,104
	*10% Hg reduction by HS-ESP included.			

Scenario	Control Configuration Scenarios	Mercury Emission Reduction Due to Added Equipment (lbs.)	Cost of Additional Equipment (M$/year)	Cost per pound of addition mercury captured ($/lbs./yr)
4	HS-ESP, ACI+H2O, FF	146	16	$109,741
5	**HS-SCR**, HS-ESP, ACI+H2O, FF	146	22	$148,598
6	**CS-ESP**	0	0	Base
7	CS-ESP, **Wet FGD**	107	22	$207,393
8	**HS-SCR**, CS-ESP, Wet-FGD	37	6	$157,937
9	HS-SCR, CS-ESP, **Lime Dryer, FF**	0	38	No Additional Hg
10	ACI, CS-ESP	91	7	$80,825
11	ACI, CS-ESP, **Wet-FGD**	16	22	$1,384,927
12	**HS-ESP**, ACI, CS-ESP, Wet-FGD	37	6	$157,937
13	CS-ESP. Lime Spray Dryer, ACI, FF	91	32	$348,165
14	**HS-SCR**, CS-ESP. Lime Spray Dryer, ACI, FF	0	37	No Additional Hg

The table provides a generalized path toward understanding control-to-cost relationships. A much improved understanding should be available in 2012 for evaluating Duke Energy's and Progress Energy's required 2013 mercury control plans that will identify the technology for use at each of their units to achieve the maximum level of reductions in mercury emissions that is technically and economically feasible.

9. Results of studies and monitoring on mercury and its species in fish in North Carolina, including an evaluation of the impact of reduced mercury emissions from coal-fired power plants on the levels of mercury observed in fish tissue

"Mercury and its species" means all compounds or forms of mercury that are routinely analyzed in fish tissue bioassays. Fish tissue samples collected in North Carolina are typically analyzed for total mercury, which exists almost entirely (95-100%) as methylmercury among mid-trophic and top predator species of consumable size.

Executive Summary

A primary objective of the Division of Water Quality (DWQ) fish tissue monitoring program is to provide state health officials with information about mercury concentrations among game fish populations for the protection of North Carolina's citizens who consume them. This goal has been met with relatively small datasets from locations throughout the state, which have routinely shown fish-mercury contamination at various levels in most waterbodies. Routine statewide monitoring of total mercury among one of the state's most popular sport fish, Largemouth Bass

(*Micropterus salmoides*), has resulted in a statewide consumption advisory for this apex predator species.

The rate and degree to which mercury bioaccumulates within fish and other aquatic biota are dependent on a host of environmental factors such as a waterbodies' food chain length and productivity, which are in part, defined by its physical and chemical characteristics. Waterbodies located in North Carolina's Coastal Plain ecoregions (roughly east of I-95) are known to be particularly susceptible to mercury contamination and bioaccumulation in fish because of their specific environmental conditions. Relative to the piedmont and mountain areas of the state, the coastal plain's low-lying fresh water systems include wetlands and slow-moving streams that are typically characterized by warm, low pH waters with high dissolved organic carbon (DOC). These factors are likely related to increased mercury methylation and bioaccumulation in these systems.

Notwithstanding these basic environmental correlations to fish mercury body burdens in the eastern part of North Carolina, a comprehensive understanding of the introduction and transport of mercury through aquatic food chains is lacking. Such knowledge is critical to the management of its environmental resources. In light of the current scheduled mercury reductions from North Carolina's coal boiler facilities per 15A NCAC 2D.2509, there is a need to establish several statewide monitoring stations for long-term fish-mercury trend analysis.

Proposed fish mercury monitoring sites

Thirteen fish tissue collection sites across the state have been proposed for fish mercury trend analysis (Figure 1). These locations should support the DAQ required action given that:

- 4 sites (# 3, 4, 5, 8) are located in lakes next to North Carolina's largest coal boiler facilities currently with, or soon to have scrubbers (Marshall, Belews Creek, Roxboro, Mayo).
- 3 sites (# 1, 6, 10) are located in lakes within 20 miles of coal boiler facilities with, or soon to have scrubbers (Asheville, Cape Fear, Mayo).
- 1 site (# 2) is located in a lake within 50 miles of a coal boiler facility currently with scrubbers (Asheville).
- 3 sites (# 7, 11, 12) are located on North Carolina's main rivers.
- 2 sites (# 9, 13) are located in lakes where DAQ has greater than 10 years of mercury deposition network monitoring data.

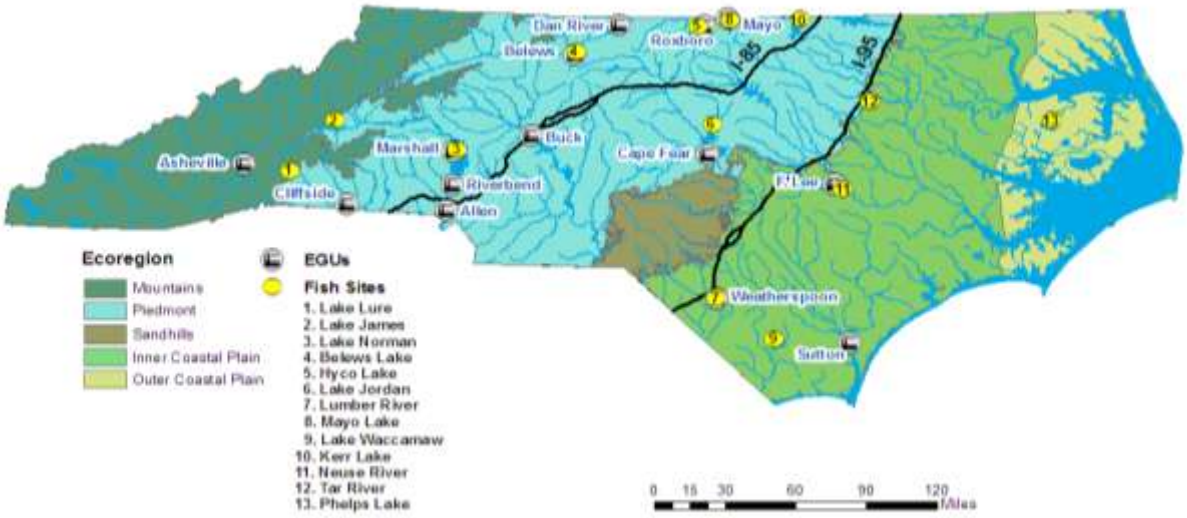


Figure 1. Proposed long term fish-mercury monitoring sites.

DWQ Fish Mercury database

DWQ has collected fish tissue samples for total mercury analysis (considered equivalent to methylmercury) since 1980 as indicators of human and wildlife health concerns related to fish consumption. Although NC DWQ began monitoring for fish mercury in 1980, to maintain sample consistency, data is typically reported from 1990 to the present following a change in laboratory analysis protocols. From 1990 to 2006, the Division processed and analyzed approximately 5,750 fish tissue samples for mercury analysis from approximately 275 statewide sampling locations (Figure 2). This data set represents an average of approximately 20 mercury tissue samples of various fish species per collection site.

A majority of the records in the DWQ mercury database are associated with the following five fish species: Largemouth Bass (*Micropterus salmoides*), Bowfin (*Amia calva*), Bluegill (*Lepomis macrochirus*), Redear Sunfish (*Lepomis microlophus),* and Channel Catfish (*Ictalurus punctatus*). Collective records for these species represent greater than 60% of the DWQ fish tissue mercury data collected from 1990 to 2006. Seven of the most common fish species included in the DWQ mercury database (i.e., Largemouth Bass, Bowfin, Chain Pickerel, Warmouth, Yellow Perch, Spotted Sucker, and Yellow Bullhead) are characterized by mercury data that meets or exceeds the state's fish consumption advisory action level of 0.4 mg/kg in greater that half of their respective records. This list is represented by either top predator or bottom feeding species in which mercury bioaccumulation is most pronounced.

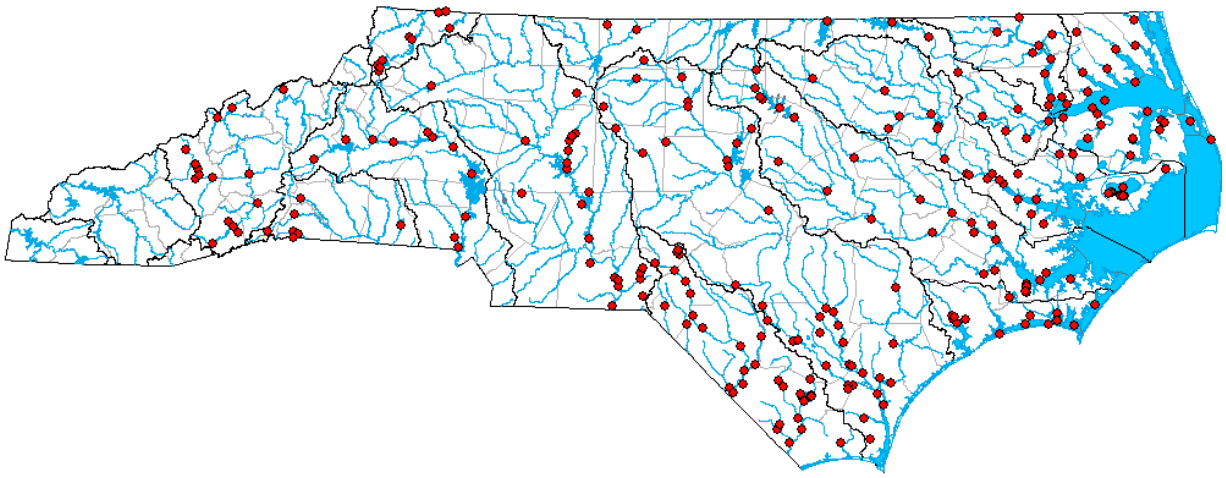


Figure 2. 1990-2006 NC DWQ Statewide Fish Mercury Sampling Stations. Note: Many overlapping sites are not visible at this resolution.

Largemouth Bass embody the largest data subset within the DWQ fish mercury database, representing 2,208 or 38% of the 5,745 records. Most of the elevated mercury concentrations among this subset occur within the Coastal Plain ecoregion, which is effectively equivalent to locations found east of I-95 (Figure 3). However, mercury concentrations in Largemouth Bass that exceed the state's fish consumption advisory action level of 0.4 mg/kg occur statewide. The highest mercury burdens of Largemouth Bass have been found in the southernmost part of the state in the Waccamaw River watershed, with mercury concentrations reaching a maximum of 3.6 mg/kg. The Sandhills Ecoregion, which includes the upper reaches of the Lumber River Basin in Scotland, Richmond, Hoke, and Moore counties, also holds numerous Largemouth Bass samples that are well above the state's fish consumption advisory action level.

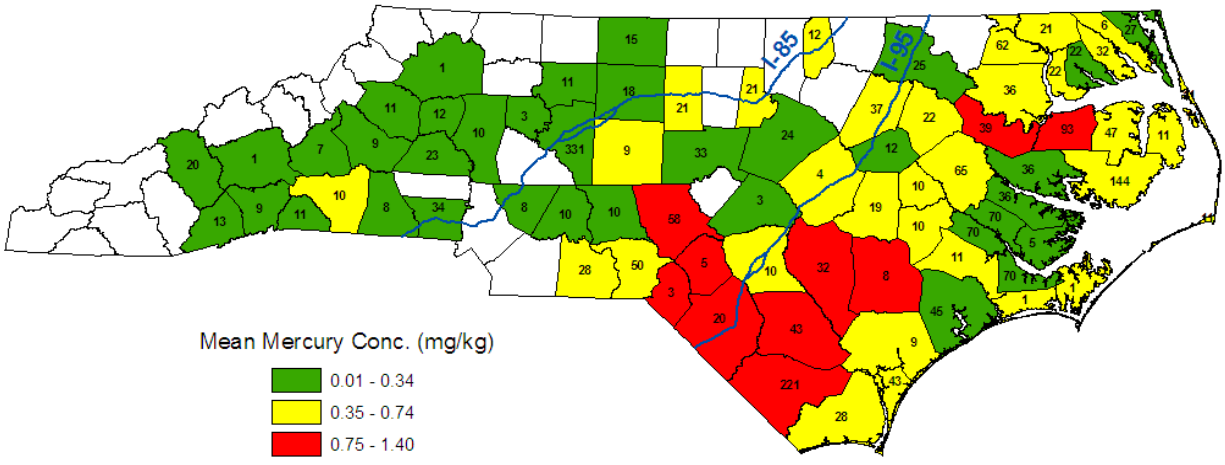


Figure 3. 1990-2006 NC DWQ Largemouth Bass Mercury Concentrations. Values indicate number of samples analyzed in each county.

DWQ Eastern Regional Mercury Study

In 2002 and 2003, the DWQ conducted the Eastern Regional Mercury Study (ERMS) to answer some basic questions about mercury in the eastern area of the state and to provide information that may be used in water quality standard and total maximum daily load (TMDL) development. An objective of the ERMS was to relate concentrations of inorganic mercury in ambient waters to fish mercury burdens within 13 eastern North Carolina waterbodies. Results of this study determined that:

- Only some of North Carolina's smaller fish are protected by the current surface water quality standard of 12 ng/L.
- Using site-specific mercury bioaccumulation factors (BAF) alone as predictors of fish mercury burdens is limited in scope. The BAF method only addresses surface water mercury levels, and not the host of site-specific factors thought to effect mercury methylation and bioaccumulation (mercury deposition, basin morphometry and use, chemical factors, and biotic factors). These factors must be considered when attempting to describe the variability among fish mercury concentrations.

Current North Carolina Fish Mercury Research Projects

The following research projects at NCSU and UNC at Chapel Hill (either funded or proposed) will (or would) benefit the DAQ mercury workgroup in fulfilling the current mercury mandate.

North Carolina State University

NCSU is currently conducting a WRRI funded study (2007-2008) titled "*Exploring mercury transport mechanisms in aquatic systems: A statewide assessment of factors affecting methylmercury contamination of food webs and fish.*" This research is being conducted under the direction of Dr. Derek Aday of the Department of Zoology. The principal objective is to gain a more mechanistic understanding of mercury dynamics in North Carolina waterbodies for the development of predictive models for fish mercury risk assessment. The specific objectives for the first stage of this research include the following:

- Compile all existing North Carolina mercury databases for fish tissue, atmospheric deposition rates, and relevant environmental (physical, chemical, and biological) data.
- Perform a comprehensive statistical and GIS-based assessment of these existing datasets.
- Develop a preliminary predictive model for risk assessment use in North Carolina waterbodies based on currently available data.
- Identify data gaps and research needs that will better inform both human health and environmental assessments for mercury contamination in fish and state waterbodies.

2008-2009 WRRI funding was approved for the renewal/continuation of the NCSU project listed above. Goals of this second phase of the study include the following:

- Conduct a field investigation in which commonly consumed fish species from multiple trophic levels will be collected at 10 sites throughout North Carolina that: (1) are near to (<10km) or far from (>30km) point sources of mercury, and (2) exhibit variation in the abiotic factors determined to be important to mercury dynamics in North Carolina waterbodies.
- Bolster the growing statewide fish mercury database with new, comprehensive collections in 2008-2009, and conduct focused statistical and GIS-based analysis on the evolving database aimed at a more mechanistic understanding of mercury dynamics.

- Use data from the statewide fish mercury database and field investigations to continue building upon a predictive model for risk assessment in North Carolina waterbodies.

University of North Carolina at Chapel Hill
UNC at Chapel Hill (UNC) is currently conducting a WRRI funded (2008-2009) study titled: *Improving the effectiveness of water quality monitoring using the spatiotemporal integration of data from multiple sources*. This research is being conducted under the direction of Dr. Marc Serre of the School of Public Health Department of Environmental Sciences and Engineering. The ultimate goal of this case study is to show, using as an example, a subset of mercury data for the Lumber and Cape Fear River basins, that spatiotemporal methods can produce more accurate estimation maps of water quality parameters than classical linear methods in areas of impairments or data deficiencies. In addition to demonstrating how the methodology will work, this study will also begin to address an additional research priority identified by the WRRI related to mercury and environmental conditions that favor mercury in the environment. The four primary objectives of this investigation are as follows:

- Analyze pH and Dissolved Organic Carbon (DOC) as environmental indicators that favor mercury accumulation.
- Assess fish tissue mercury and its relationship to surface water mercury using site-specific bioaccumulation factors and local fish tissue data.
- Assess surface water mercury for all river segments in North Carolina by doing a spatiotemporal integration of data from multiple sources, including the ERMS (summarized above), fish tissue, atmospheric deposition, as well as pH and DOC monitoring.
- Determine a more effective monitoring strategy for mercury (i.e., optimal frequency and location of surface water and fish tissue mercury sampling).

10. A summary of mercury-related health problems in North Carolina, including accumulation of mercury in humans, toxicity, and mercury exposures from non-air emitting sources

In the Statement of Work submitted to the Environmental Management Commission (EMC), two goals were established for the work effort to be accomplished for the 2008 Interim Report:

- GOAL 1: to undertake to update the Secretary's Science Advisory Board on Toxic Air Pollutants (NC SAB) 2000 report, "Mercury in the Environment."
- GOAL 2: report on the mercury-related health problems existing before installation of mercury controls on EGUs.

GOAL 1
The NC SAB reviewed its 2000 report, "Mercury in the environment" and determined that the information was current and no changes were indicated.

GOAL 2
In August 2006, the Centers for Disease Control and Prevention (CDC) and the NC Department of Health and Human Services (NC DHHS) conducted a pilot study to identify a group of people who consumed at least six ounces of locally caught fish twice per week (defined as a "large amount") and

had measurable concentrations of serum mercury. Specifically, the objectives of this study were:

- To determine whether there were persons with elevated Hg concentrations living in areas identified by EPA to have high Hg emissions and deposition.
- To assess the feasibility of identifying, recruiting, and enrolling these persons.
- To create sampling procedures for establishing baseline Hg concentrations in a highly exposed population and subsequently monitoring future trends in the same geographical areas.
- To determine the public health impact of high levels of Hg emission and deposition in the environment by collecting blood Hg data from subsistence fishermen who routinely consume fish from these areas.

If successful, this pilot project would be used to evaluate a larger group over time (as long as a decade) across multiple NC locations. In this way, the benefits to human health of regulatory efforts to reduce mercury emissions, as measured by reduced levels of serum Hg, may be observed in those whose diets consist of the consumption of a "large amount" of locally caught fish.

Columbus and Brunswick counties were selected for this study because: (1) EPA had determined that there was elevated mercury deposition in these counties; (2) environmental conditions were such that the conversion of mercury to methylmercury was efficient; (3) fish tissue was elevated with respect to mercury; and (4) subsistence fishing was common. In addition, a 1993 NC DHHS study of methylmercury (MeHg) concentrations in blood samples from a sample of subsistence fishermen and their families indicated elevated levels (mean = 7.5 μg/L).

This pilot study consisted of English and/or Spanish speaking subsistence fisherman and family members, 18 years of age or older at the time of the study, who consumed at least six ounces of fish at least twice per week, caught from Big Swamp, the Lumber River, and/or the Waccamaw River. Pregnant women were excluded from the study. One hundred seventeen participants were enrolled in the study. Of this, blood samples were drawn from 100 enrollees and analyzed for total and organic mercury. Organic mercury is indicative of MeHg intake from fish and shellfish.

The mean age of the 73 male and 27 female study participants was 50 years. Eighty-eight percent were from Columbus County and 12% were from Brunswick County. Of these participants; 94% were Caucasian, 4% were Latino, 1% were American Indian, and 1% were other.

In response to a questionnaire completed by each participant, the mean number of servings of locally caught fish (at least 6 oz. serving size) was 2.7 (range 2-8) and the mean number of servings (at least 6 oz. serving size) of any fish was 4.7 (range 2-15). Ninety percent of these participants ate fish caught from the Waccamaw River, 32% from Big Swamp, and 32% from the Lumber River. Twenty-one percent ate fish from other local fishing sites. Blackfish, bowfin, catfish, and largemouth bass were the most popular species consumed, whose tissues tend to be high in mercury concentration. Eighty-eight percent of participants reported that other fish species were also eaten during the previous month: brim, flounder, crappie, perch, and whiting.

Analysis of blood samples taken from the study participants yielded the following information:

- The geometric mean serum Hg level = 2.0 μg/L (95% confidence interval (CI): 1.5, 2.8).

- Females: mean serum Hg level = 0.8 µg/L (95% CI: 0.5, 1.4)
  - Females of childbearing age (18-49 years): mean serum Hg level = 0.4 µg/L (95% CI: 0.2, 0.6). NO FEMALES OF CHILD-BEARING AGE HAD Hg LEVEL GREATER THAN REFERENCE LEVEL OF 3.5 µg/L
- Males: mean serum Hg level = 2.8 µg/L (95% CI: 2.1, 3.7)
- Latinos had significantly higher Hg levels (mean = 6.2 µg/L, 95% CI: 2.3, 62) compared to non-Latinos (mean = 1.9 µg/L, 95% CI: 0.9, 3.4)

- The range of serum Hg levels was less than limit of detection (LOD= 0.33 µg/L) to 44 µg/L.
- 7% of participants had levels greater than 20 µg/L (a warning level for elevated Hg exposure).
- No statistically significant differences in mean serum Hg levels were detected in those whose drinking water source was a well and those who had a municipal source.
- No statistically significant differences in mean serum Hg levels were detected among those who ate fish caught from the Waccamaw River, Big Swamp, or the Lumber River.
- No correlation was found in serum Hg levels and number of fish servings eaten per week.
- Serum Hg levels were compared between the study population and a national reference level for the US.

Source	50^{th} percentile mean (95% CI) (µg/L)	95^{th} percentile mean (95% CI) (µg/L)
NHANES*	0.9 (0.8, 1.0)	6.0 (5.1, 10.7)
NC Cohort	71% had levels greater than 0.9	23% had levels greater than 6.0

* NHANES (National Health and Nutrition Examination Survey, 1999-2002). Only includes females 16-49 years of age

- No significant difference in the number of total servings consumed per week were observed between those with exposures greater than the NHANES 95^{th} percentile (6.0 µg/L) and those with exposure less than the NHANES 95^{th} percentile.
- Inorganic Hg contributed in a minor way to total serum Hg concentrations (median = 7% contribution). The geometric mean of organic Hg was 0.3 µg/L (95% CI: 0.2, 0.6) and the range was from less than the limit of detection (LOD = 0.35 µg/L) to 42 µg/L.

This pilot study suffered from the following design flaws:

- The former Holtrachem facility located in the general area of the Wacamaw River was a chlor-alkali plant that used metallic mercury as a catalyst in its production process. Substantial quantities of mercury leaked into the ground from plant operations and contaminated Lake Waccamaw. Thus, the body burdens of mercury found in this study attributable to emissions from coal-fired plants are confounded by the contribution of Holtrachem.
- As a consequence of the ongoing Holtrachem contribution, reductions in mercury emissions from coal-fired power plants may not be observed either in fish tissue or human serum in this region.
- Conclusions drawn from this study may not be representative of subsistence fisherman throughout the state. It is unknown, because of sample size and confounders if these conclusions are even attributable to subsistence fishermen in Columbus and Brunswick counties.

- The contribution to the total body burden of mercury from freshwater fish versus saltwater fish is unknown in the population consuming both types.
- There were no data collected on the consumption of canned or bagged tuna (no fresh caught). Canned tuna is known to contain elevated levels of mercury.

One of the major difficulties with following-on to this pilot study is that this kind of health study is beyond the mission of NC DAQ. NC DHHS and CDC conducted the pilot study, and health-based studies requiring sampling of human tissues are in the purview of NC DHHS. NC DAQ has been informed by NC DHHS that funding will be required if a follow-on is to be performed. It has been estimated that a study that corrects (or attempts to correct) the defects in the pilot study will require funding at a level of approximately $250,000. It is unknown at this time where this funding would come from, and it is undetermined who would write a grant proposal to obtain funding.

It is further assumed that the North Carolina Legislature will not be a source of funding.

11. Results of studies on mercury deposition, applying monitoring techniques, back trajectory analysis, source attribution methodology, including all other relevant methodologies, to assess the role of coal-fired units in North Carolina deposition

As part of the Statement of Work for the 2008 Interim Report to the AQC, the DAQ was to provide an air monitoring work plan as a means to assess the role of coal-fired units on mercury deposition in North Carolina. The following work plan will be used as a guide for the subsequent air monitoring study plan that will be conducted to obtain data for this assessment.

OBJECTIVE

The study will be conducted to assess the role of coal-fired units on the deposition of mercury in North Carolina by ambient air monitoring. The study will include, as feasibility allows, wet and dry mercury deposition, ambient mercury (elemental) and mercury species (reactive gaseous mercury [RGM] and particulate bound mercury [PBM]) monitoring, nitrous oxide, sulfur dioxide, ozone, particulates, and meteorological data. These particulars may change as the study is designed, based on available financial resources, manpower, and equipment.

STUDY LOCATION

In order to assess the role of coal-fired power on mercury deposition, an air monitoring study would need to be conducted in the vicinity of a coal-fired unit that will be installing control measures as mandated by the Clean Smoke Stacks Act as well as EPA CAMR rules (which have subsequently been vacated.) While these control measures may not be specifically for the removal of mercury and/or mercury species, they will purportedly reduce these species as a secondary benefit.

Criteria for choosing the study location:

- The need to conduct the study in two phases, pre and post installation as well as on a seasonal basis in order to encompass potential seasonal variability in mercury deposition.
- The schedule of installation of control measures.

- Size and type of power generating facilities.
- The spatial location relative to other sources of ambient mercury, such as other power plants undergoing similar installations.
- Typical meteorological conditions in NC, i.e. prevailing wind directions.
- Available funding, equipment, and manpower, which will limit the study to monitoring the area around a "representative" unit that may subsequently be used to infer depositions in other locations by using established engineering principles.

Given these criteria, one study area that met the majority of the above criteria is the area around Progress Energy, Mayo at 10660 Boston Road, Roxboro, NC. This area was chosen for several reasons:

- The unit is scheduled to install the control measures in 2009 which allows sufficient time to plan and execute the pre-installation monitoring.
- The facility has a medium sized single unit that makes it a "simpler, representative" facility to model and account for operational variability if needed.
- The location is downwind during one part of the year and upwind the other part of the year of a "corridor" of similar facilities that are to have already installed control devices, thus making it an ideal location.
- Its proximity to Virginia may make it feasible to have interstate cooperation and sharing of results from the Virginia Department of Environmental Quality (DEQ) ongoing mercury study.

Sampling locations will be located based on modeling and specific siting criteria. There will be at least two sampling sites running simultaneously in upwind and downwind locations on a schedule that allows for optimal data collection. There will potentially be two pairs of sampling sites. One pair will be within a 1 to 5 mile radius of the facility, and one pair in a 5 to 10 mile radius. This is necessary given the transport characteristics of the various mercury species. RGM and PBM tend to deposit nearby the original source and elemental mercury has longer range transport. Additionally, one site may be located in Virginia if collaborative efforts can be agreed upon with the VADEQ.

Monitoring will occur on a semi-continuous basis where feasible and on a schedule that provides adequate data for back trajectories and other data analyses. This schedule may not require intensive sampling on a continuous basis but may only entail intermittent monitoring for periods of 2 to 4 weeks out of each season or yearly quarter. This will make it amenable to sampling at the two pairs of sites without having to incur cost to establish 4 sites simultaneously. This will also minimize the cost and manpower requirement; however, it will not minimize the initial capital expenditure needed to start the study.

Intensive monitoring may be required to obtain rain event specific data. That is, data and samples will need to be collected prior to, and just after rain events to provide additional data for the effects of atmospheric "scrubbing" and rain event wet deposition.

SAMPLING METHODOLOGIES OVERVIEW

As stated earlier, the study should include wet and dry mercury deposition, ambient mercury (elemental) and mercury species (reactive gaseous mercury and particulate bound mercury) monitoring, nitrogen oxides, sulfur dioxide, ozone, particulates, and meteorological data. This section will give a brief overview of the sampling and/or analysis methodologies for each component.

Wet and Dry Deposition. The method for obtaining wet deposition data is the use of Aerochem rainwater collectors and Belfort rain gauges with operation for sample collection and analysis similar in design and operation to the National Atmospheric Deposition Program's Mercury Deposition Network sites. Samples would be sent to the same contract laboratory as the NADP-MDN weekly NC DAQ collected samples. The QA/QC would be exactly the same as those applied to MDN sites (NC 08, 42).

Dry deposition is most often estimated or modeled based on wet deposition data and/or ambient air monitoring of total and elemental mercury, reactive gaseous mercury, and particulate related mercury. This is due to methods for collection and analysis of dry deposition mercury are difficult to perform, labor intensive, and not conducive to routine monitoring. Dry deposition would be estimated based on the data from wet deposition and the data obtained by the continuous mercury monitors, to be discussed in the next section.

Mercury Speciation Monitoring
This will be accomplished using Tekran instruments that provide continuous (semi-continuous) data for elemental mercury (Hg^0), reactive gaseous mercury (RGM) (ionic mercury species such as mercury chloride), and particulate bound mercury (PBM). The instrument takes continuous samples through one of three instruments, Models 2537A, 1130, and 1135 for Hg^0, RGM, and PBM, respectively. The instruments are operated primarily unattended with weekly maintenance visits to replenish the denuder in the 1130 unit and to collect stored data files. These instruments have been operated by NC DAQ on many occasions and QA/QC parameters are established and documented. These monitors would provide data that may subsequently be used to determine dry deposition data.

Nitrogen Oxides (NOx), Sulfur Oxides (SOx), Ozone (O_3)
These three components will be monitored on a continuous basis using Thermoelectron continuous monitors, similar to those currently used by DAQ's Ambient Monitoring Section for criteria pollutants monitoring. *Note: The following information was obtained from the ThermoElectron Corporation webpage as an example of the instrumentation that may be used to monitor these species and is not an endorsement of instruments by the State of North Carolina. (http://www.thermo.com/eThermo/CMA/PDFs/Product/productPDF_24736.pdf*

42C Series – Oxides of Nitrogen (NO-NO2-NOX) Analyzer
Using Chemiluminescence, the 42C series is capable of measuring oxides of nitrogen from sub parts per billion (ppb) to 5,000 parts per million (ppm). Extended troubleshooting diagnostics provide instantaneous indication of instrument operating status. Reliable. Industry standard. US EPA Designated Method RFNA-1289-074.

43C Series – Sulfur Dioxide (SO2) Analyzer
Pulsed Fluorescence design results in long-term zero and span stability in this SO_2 analyzer. Reflective UV filtering offers superior sensitivity with multiple-range settings from 0-5,000 ppm. The 43C series is the benchmark for sensitivity, stability, and selectivity. US EPA Designated Method EQSA-0486-060.

Model 49C – Ozone (O3) Analyzer
Combining the unique, time-shared dual cell design with an enhanced electronics package and user interface, the Model 49C is both powerful and easy to use. US EPA Designated Method EQOA-0880-047.

As these instruments are commonly used by DAQ there is support available for these instruments as well as the requisite QA/QC parameters that are followed as part of the DAQ Ambient Air Quality monitoring network.

Particulates
Particulate monitoring would be accomplished using the same instrumentation currently used by NC DAQ Ambient Monitoring Section. Again, because the instrumentation would be the same as those currently in use.

The NC DAQ and the local agencies measure fine particles (PM 2.5) with two methods. One is a reference intermittent manual method and one is an EPA correlated acceptable continuous method, which is not NAAQS comparable. The continuous method will be a candidate for EPA certification as a stand-alone NAAQS method, starting later this year.

The NC DAQ and local programs use a reference method sampler which pulls an air stream through a PM2.5 size selective inlet. This sample of air is then impacted onto a 47 mm width Teflon filter for a 24-hour period. Sampling is every three days at most sites. The technicians check the monitors for such items as temperature, pressure, weekly maintenance checks, etc. The filters are brought back to a lab and weighed.

The other method the DAQ uses to measure fine particles is a correlated acceptable continuous method that uses a "Tapered Elemental Oscillating Microbalance" (TEOM) to continuously weigh and measure fine particulate. Beginning this year, TEOMs will be eligible to operate as stand-alone units, as an Approved Regional Method (ARM) by EPA, once EPA has reviewed and certified submitted applications.
(Reference: The North Carolina Department of Environment and Natural Resources Division of Air Quality Ambient Air Monitoring Section Public Outreach for Ambient Air Criteria Monitoring in North Carolina May 10, 2007, http://daq.state.nc.us/monitor /monitoring_overview_05082007.pdf

Meteorology
Meteorological data will be collected, using Climatronics stations equipped with a cross arm mounted anemometer, wind vane, temperature, and relative humidity probes, tipping rain gauge, and solar radiation monitor. These data would be continuously monitored and stored for later retrieval and processing. The data would be collected at each site at 10 meters and possibly at 2 meters. The QA/QC parameters are well established and would be adhered to rigorously.

QUALITY ASSURANCE/QUALITY CONTROL (QA/QC)
In general terms, all of the referenced monitoring/sampling methods described above have QA/QC parameters that are established, well documented and will be incorporated into a Quality Assurance Project Plan (QAPP) for this project. This document will then be distributed to the various members of the project team and followed as directed.

DATA ANALYSIS
As stated earlier, this monitoring effort will be conducted in two phases; with Phase 1 concluding after the installation of the control measures. Phase 2 would be considered begun at the commencement of "start up" of the control measures and continue for one season cycle after the "initial shake down" period. Data analysis including back trajectories and/or other modeling efforts, would be conducted using data collected in Phase 1. There would be a report of these

results as Phase 2 continues. Subsequent to the completion of Phase 2, data analysis would be conducted and a report generated.

The data analysis would be conducted by one of three possible entities: internal DAQ modeling group, EPA in Research Triangle Park, or an outside contractor. In any event, the general scope of work for their efforts would be to provide back trajectory analysis, using the data from the studies and any modeling outputs that show the deposition patterns based on the monitoring data.

12. Recommendations, if any, on rule revisions.

On February 8, 2008, the District of Columbia (D.C.) Circuit Court of Appeals, vacated EPA's Clean Air Mercury Rule (CAMR) for Electric Generating Units (EGUs), by setting aside EPA's initial delisting "Revision of December 2000 Regulatory Finding ("Delisting Rule"), 70 Fed. Reg. 15,994 (March 29, 2005). With this vacature, the D.C. Circuit did not discuss the fundamental merits of a national "cap and trade" system for mercury under the NSPS standards, but simply vacated the CAMR because, if EGU's remain listed under 112, then they cannot be regulated under section 111, stating: "EPA promulgated the CAMR regulations for new sources under section 111(b) on the basis that there would be no section 112 regulation of EGU emissions and that the new source performance standards would be accompanied by a national emissions cap and a voluntary cap and trade program."

On March 24, 2008, two petitions were filed in the D.C. Circuit Court of Appeals seeking rehearing *en banc* (all the judges of the Court) of the Court's February 8th decision to vacate EPA's Clean Air Mercury Rule (CAMR). The U.S. Government filed, on behalf of EPA, and the Utility Air Regulatory Group (UARG) filed on behalf of its electric utility member companies. Both petitions pointed out a series of mistakes made by the original panel in arriving at the February 8th decision.

On May 20, 2008, the D.C. Circuit Court of Appeals denied the *en banc* petition by EPA and UARG. The Court's denial of the petitions means that its order to vacate CAMR remains in effect.

Effects of the CAMR Vacature on North Carolina's Electrical Generator Rules

The EMC approved the new Mercury Rules for Electric Generators, Section 15A NCAC 02D .2500 that consists of eleven rules. North Carolina has two State mercury rules that are not included as a part of North Carolina's "Mercury Plan" sent to the US EPA for compliance with CAMR. The remaining nine rules will need to be addressed when the current legal actions are resolved. The remaining two State Rules are 02D .2509, Periodic Review and Reallocations, and .2511, Mercury Emission Limits. The following requirements remain intact:

> Under 02D .2509, DAQ shall report to the Commission, updated information on the regulation of mercury emissions in 2008 and 2012, and based on the 2012 report, the Commission will review the state of mercury technology and decide if any rule changes are

needed. The Director is required to report to the Commission in 2018 and 2023 on the state of mercury control technology, the cost of installation and operation, and changes in fish tissue mercury concentrations in the State.

Under 02D .2511, Duke Energy and Progress Energy shall submit a Mercury control plan to the Director by January 1, 2013. Each plan must identify the technology proposed for use at each unit, the schedule for installation and operation of mercury controls at each unit, and the identity of units that will be shut down. Any unit that does not have mercury controls installed by the end of 2017 is required to be shut down by December 31, 2017. The Director will review the mercury control plans submitted and make recommendations to the Commission. The Commission will approve a mercury control plan if it finds that the plan achieves the maximum level of reductions in mercury emissions at each unit that is technically and economically feasible. Duke Energy and Progress Energy are to complete their control installations required under the CSA. Additionally, each utility will provide NC DAQ with mercury reduction data collected at four boilers before and after the installation of SCRs and scrubbers. New sources are required to install the best available control technology with an emissions limitation, based on the maximum degree of reduction of mercury from coal-fired electric steam generating units that is achievable for such units taking into account energy, environmental, and economic impacts, and other costs.

Although CAMR may not exist, mercury reductions in North Carolina remain on schedule. The controls needed to comply with the North Carolina CSA and Federal CAIR provide significant co-benefits in the form of mercury emission reductions. Therefore, with or without CAMR, mercury emission reductions in North Carolina will be the same through the year 2013. The North Carolina CSA greatly reduces mercury emissions (as a co-benefit of the NO_x and SO_2 controls) from sources within the State, and CAIR will provide similar mercury reductions from our boarder states, thus further reducing mercury deposition in North Carolina.

References

From Item 3

Gbor, P. K., Wen, D., Meng, F., Yang, F., & Sloan, J. J. "Modeling of mercury emission, transport, and deposition in North America." Atmospheric Environment 41 (2007): 1135-1149.

Lin, C. J., Pruek, P., Bullock, Jr., O. R., Lindberg, S. E., Pekhonen, S. O., Jang C., Braverman, T., Ho, T. C. "Scientific uncertainties in atmospheric mercury models II: Sensitivity analysis in the CONUS domain." Atmospheric Environment 41 (2007): 6544-6560.

From Item 11

LIST OF RECENT STUDIES AND/OR PLANNING DOCUMENTS

Plan for Development of a Statewide Total Maximum Daily Load for Mercury, Florida Department of Environmental Protection, Bureau of Laboratories, Division of Water Resource Management, Division of Air Resource Management, September, 2007

Whole-ecosystem study shows rapid fish-mercury response to changes in mercury deposition. Harris, R.C; Rudd, J.W.M, Amyot, M., et al, PNAS Early Edition, www.pnas.org/cgi/doi/10.1073/pnas.0704186104

Virginia Mercury Symposium Proceedings, Newport News, VA, November 28-29, 2007, http://www.deq.state.va.us/info/symposium.html

Virginia Mercury Study website for complete information on the study and the progress thus far. http://www.deq.state.va.us/air/vamercury/vamercurystudy.html

Fink, Larry; Darren Rumbold; and Peter Rawlik. "Chapter 7: The Everglades Mercury Profile." *The Everglades Interim Report,* 1999

Iowa Department of Natural Resources, Air Quality Bureau. *Review of Assessment Methods for Estimating Atmospheric Deposition of Mercury Compounds in Iowa*. April 24, 2006.

Office of Research and Development, National Risk Management Research Laboratory. *Mercury Research Strategy;* EPA/600/R-00/073. U.S. Environmental Protection Agency; Cincinnati, Ohio: September 2000.

Butler, T.; G. Likens; M. Cohen; and F. Vermeylen. *Mercury in the Environment and Patterns of Mercury Deposition from the NADP/MDN Mercury Deposition Network.* Final Report. Institute of Ecosystem Studies. January 2007.

Keeler, Gerald J., Matthew S. Landis, Gary A. Norris, Emily M. Christianson, and J. Timothy Dvonch. "Sources of Mercury Wet Deposition in Eastern Ohio, USA." *Environ*mental *Science* and Technology. 40 (2006): 5874-5881.

Marsik, Frank J.; Gerald J. Keeler; and Matthew S. Landis. "The Dry-Deposition of Speciated Mercury to the Florida Everglades: Measurements and Modeling." *Atmospheric Environment*. 41(January 2007): 136-149.

Michaels, Patrick J.; Philip J. Stenger; Stephen D. Gawtry; and Michael Figura (Virginia State Climatology Office). "Estimating the Transport and Distribution of Mercury in Virginia from Virginia Coal-fired Point Sources." Virginia State Climatology Office Department of Environmental Sciences, Charlottesville, Virginia.