

ABSTRACT

A Baseline Assessment of Local Mercury Deposition from Coal-Fired Power Plants in Central Texas

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Coal-fired power plants represent the largest source of anthropogenic mercury in the world. The Central Texas region as represented by the Heart of Texas Council of Governments contains two coal-fired power plants located in Freestone and Limestone Counties. A third plant, Sandy Creek, is currently being proposed for McLennan County. The primary objective of the study is to estimate the amount of mercury being deposited via wet deposition in 2003 from two existing power plants in Central Texas, Big Brown and Limestone, and predict deposition from a proposed plant, Sandy Creek. The Industrial Source Code Short-Term model was used to estimate wet deposition, and empirical data was collected to determine the mercury levels in environs near the plants. According to the research and statistical analyses, the Central Texas power plants studied appear to be having no impact on the water quality of area surface waters.

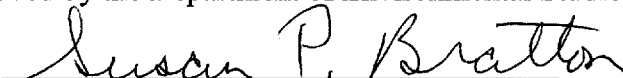
A Baseline Assessment of Local Mercury Deposition
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by

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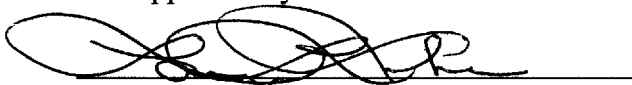
A Thesis

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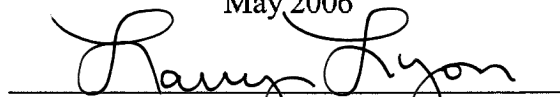
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CONTENTS

LIST OF FIGURES	v
LIST OF TABLES	vii
ABBREVIATIONS	viii
ACKNOWLEDGMENTS	x
Chapter	
1. INTRODUCTION	1
Problem Statement	
Study Area	
Goals and Objectives	
2. LITERATURE REVIEW	4
Historical Perspective	
Mercury Legislation	
The Mercury Cycle	
Natural Emissions	
Toxicological Perspective	
Risk Characterization	
Mercury Deposition Network	
Mercury in the Water Column	
Mercury in Sediment	
Central Texas Anthropogenic Releases	

Need for Local Research	
Research Challenges	
3. METHODOLOGY	18
4. MODELING CONSIDERATIONS.....	22
Technical Issues	
Model Setup	
5. MODEL OUTPUT AND VALIDATION	37
Output by Plant	
Validation of the Model	
6. CONCLUSIONS.....	58
7. APPENDICES	62
Appendix A	
Appendix B	
8. WORKS CITED	101

LIST OF FIGURES

Figure	Page
1. Power Plant Locations and Texas Eco Regions	3
2. Mercury Cycle	7
3. Fish Tissue Mercury Concentrations Averaged by Watershed	11
4. Grid Setup	31
5. Close Grid Setup	32
6. Texas Meteorological Stations	33
7. Wind Rose for Waco Meteorological Station	34
8. Rain Rose for Waco Meteorological Station	35
9. Limestone – Minimum Wet Deposition 2003	38
10. Limestone – Average Wet Deposition 2003	39
11. Limestone – Maximum Wet Deposition 2003	40
12. Limestone – Average Wet Deposition 2003 Close Grid	41
13. Big Brown – Minimum Wet Deposition 2003	43
14. Big Brown – Average Wet Deposition 2003	44
15. Big Brown – Maximum Wet Deposition 2003	45
16. Big Brown – Average Wet Deposition 2003 Close Grid	46
17. Sandy Creek – Minimum Wet Deposition	47
18. Sandy Creek – Maximum Wet Deposition	48
19. Sandy Creek – Maximum Wet Deposition 2003	49
20. Limestone Sampling Locations	51

21. Pearson Correlation for Lake Limestone Water Data.....	53
22. Spearman's Rank for Lake Limestone Water Data	54
23. Big Brown Sampling Locations.....	55
24. Pearson Correlation for Big Brown Sediment Data	57
25. Sandy Creek 24hr High Maximum.....	63
26. Sandy Creek 24hr High Minimum	64
27. Sandy Creek Maximum Concentration	65
28. Sandy Creek Minimum Concentration	66
29. Limestone 24hr High Maximum	67
30. Limestone 24hr High Average.....	68
31. Limestone 24hr High Minimum	69
32. Limestone Maximum Concentration	70
33. Limestone Average Concentration	71
34. Limestone Minimum Concentration.....	72
35. Big Brown 24hr High Maximum.....	73
36. Big Brown 24hr High Average.....	74
37. Big Brown 24hr High Minimum	75
38. Big Brown Maximum Concentration	76
39. Big Brown Average Concentration	77
40. Big Brown Minimum Concentration	78

LIST OF TABLES

Table	Page
1. Wet Deposition Recorded by Texas MDN Station.....	13
2. Mercury Scavenging Coefficients	25
3. Percentages of Oxidized Mercury	26
4. Speciated Mercury Flows	27
5. Source Option Parameters	30
6. Limestone Water Column Data	52
7. Limestone Sediment Data.....	52
8. Big Brown Sediment Data	56
9. Big Brown Water Column Data	56

ABBREVIATIONS

CAA	Clean Air Act
CAIR	Clean Air Interstate Rule
CAMR	Clean Air Mercury Rule
COPAHC	Compact Hybrid Particulate Collector
DOC	Dissolved Organic Content
EPA	Environmental Protection Agency
ESP	Electrostatic Precipitator
FGD	Flue Gas Desulfurization
GEM	Gaseous Elemental Mercury
HOTCOG	Heart of Texas Council of Governments
ICR	Information Collection Request
IDW	Inverse Distance Weighted
MACT	Maximum Achievable Control Technology
MDN	Mercury Deposition Network
NADP	National Atmospheric Deposition Program
NAWQC	National Ambient Water Quality Criterion
RBELs	Risk Based Exposure Limits
RfD	Reference Dose
RGM	Reactive Gaseous Mercury
TRBEL	Texas Risk Based Exposure Level
TRI	Toxic Releases Inventory

USEPA	United States Environmental Protection Agency
UTM	Universal Transverse Mercator

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CHAPTER ONE

Introduction

Problem Statement

The combustion of coal for power plants is the largest source of anthropogenic mercury in the world (Schroeder and Munthe 1998, 811). Mercury, a potent neurotoxin, is one of the most toxic chemicals in the environment, especially dangerous to the development of the fetus and young children. The United States Environmental Protection Agency (USEPA), World Health Organization, Centers for Disease Control and Prevention, and National Academies of Sciences all agree that mercury can pose an unacceptable health risk to certain populations (Northeast States for Coordinated Air Use Management 2003, 5). In 2002, the State of Texas contained five of the ten worst mercury polluters in the United States; including TXU's Limestone plant located less than 50 miles away from Waco. The Limestone plant produced the greatest level of power plant emissions in the nation that year – releasing 1800 pounds of mercury into the atmosphere (USEPA 2004c).

Atmospheric sources are recognized as a significant contributor to the cycling of mercury. The dominant form of mercury in the atmospheric reservoir is gaseous elemental mercury (GEM) ($\approx 95\%$). GEM because of its low water solubility can remain in the atmosphere anywhere from .5 – 2 years (Poissant 1997, 341). Mercury pollution is therefore considered a global issue because its atmospheric transport can allow it to travel thousands of kilometers before deposition.

The rate at which mercury is removed from the atmosphere varies depending on the environmental, chemical, and physical factors contributing to the transformation or partitioning of mercury between its various oxidation states. Due to its transport characteristics, recent mercury legislation is designed to disregard the local effects of point source polluters as companies are allowed to trade emission credits statewide as long as aggregate emissions meet a certain level (Great Lakes Directory 2004). This system ignores the effects of local deposition of mercury and could allow for disproportionate levels of mercury to be deposited in a specific area or region.

Mercury flux from the atmosphere to any one place is compromised of contributions from the natural global cycle, the natural cycle perturbed by human interference, regional contributions, and local contributions (USEPA 1997c, 2-2). The proposed research would assess the magnitude of local mercury contributions caused by coal-fired power plants in Central Texas.

Goals and Objectives

The primary objective of the study is to estimate the amount of mercury being deposited locally via wet deposition in 2003 from two existing power plants in Central Texas, Big Brown and Limestone, and predict deposition from a proposed plant, Sandy Creek. In order to accomplish the primary task of the study, secondary goals must be completed which include: 1) identify point sources of mercury pollution that may significantly impact Central Texas, 2) collect and collate data on these point source polluters, 3) model local deposition of mercury using the Industrial Source Code Short-Term 3 (ISCST3) air dispersion model , 4) create maps of potential mercury loading from

point sources for the Central Texas area, and 5) identify at-risk water bodies threatened by local wet deposition of mercury.

Study Area

The study area consists of a 50km radius around each of the three power plants. All three plants each have populations of over 100,000 being exposed within a 50km radius; nearly one quarter of the populations are under the age of 18 (Clean Air Task Force 2002). The land type is generally rural consisting mostly of rangeland and farmed areas, and the area typically receives slightly over 30 inches of rain a year. Figure one below displays the plants geographical location along with their eco regions.

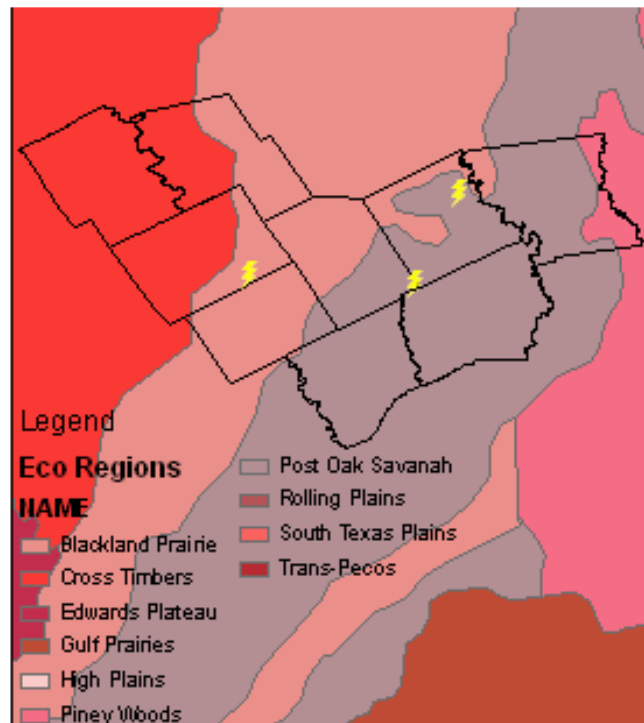


Fig. 1. Power Plant Locations and Texas Eco Regions

CHAPTER TWO

Literature Review

Historical Perspective

The primary contributors to anthropogenic mercury releases are coal fired power plants, chlor-alkali plants, and municipal and hospital waste incinerators. Several authors have made attempts to estimate the global mercury pool before the industrial era, but it is difficult to distinguish between anthropogenic mercury and natural mercury due to the intricacies involved with the mercury cycle (USEPA 1997c, 3-12). Collective estimates reveal that anywhere from 40-75% of total annual input of mercury into the atmosphere is due to anthropogenic causes (USEPA 1997c, 2-3). Estimates of annual anthropogenic releases in the US were derived from an EPA study conducted from 1994-1995 which determined releases to be 158 tons. Nearly 90% of these emissions, almost 142 tons, were thought to be released from the combustion of fossil fuels. The single largest contributor of mercury to the atmosphere was coal-fired utility boilers accounting for over 30% (USEPA 1997b, 4-1 – 4-3). In spite of the high efficiency of electrostatic precipitators (ESPs) and other pollution control devices, mercury in the atmosphere over North America is increasing by 1.5% a year (Menoumou and Presley 2003, 11). Despite seemingly high mercury emissions, the United States is only responsible for approximately 1% of annual global mercury emissions (USEPA 1997b, 5-3).

The US National Ambient Water Quality Criteria (NAWQC) defines threshold levels for specific chemicals in ambient water. They are designed to be protective of aquatic life and to protect water bodies with designated uses. States and tribes may

define and regulate their own criteria as long as they are more stringent than the NAWQC unless site-specific variables allow for the criteria to be higher. This is often the case for a number of metals in which the freshwater criteria is a function of hardness. Criterion maximum concentration (acute levels) and criterion continuous concentration (chronic levels) for mercury in freshwater systems as defined by the NAWQC as 1400 ng/L and 0.770 ng/L respectively (USEPA Office of Water 2002, 12). Texas specific risk-based exposure limits (RBELs) for aquatic organisms are 2.400 ng/L (acute levels) and 1300 ng/L (chronic levels). RBELs for Texas are notably higher than the NAWQC; this is primarily due to increased water hardness in the state. The 2005 the Texas Risk Based Exposure Limit (TRBEL) for human consumption of water and organism was 12.2 ng/L (TCEQ 2005a, 4, 19)

Mercury Legislation

In March 2005 the United States became the first country to enact legislation to cap and reduce mercury emissions from coal-fired power plants. The Bush Administration's Clean Air Mercury Rule (CAMR) will reduce mercury emissions by 70%, from 48 tons to 15 tons a year, by the 2018. The legislation is built upon the framework of the Clean Air Interstate Rule (CAIR) and will work in two distinct phases. The first phase, is a cap set at 38 tons and will be achieved through co-benefit reductions of sulfur dioxide and nitrogen oxides under the CAIR. The second phase, scheduled to be completed by 2018 will reduce nationwide emissions to 15 tons a year (USEPA 2005a).

The second and vastly more polemical side to the legislation is the onset of a cap-and-trade system under the CAMR. Under the cap-and-trade system of the CAMR the EPA has delegated mercury emission budgets for each of the 50 states and two tribes.

Within each entity, companies are allowed to buy and sell mercury emission credits not limiting the amount of mercury a single plant can emit. Therefore, mercury deposition on local environments is essentially ignored (USEPA 2005a). The EPA cites the Acid Rain Program which operates under a similar premise as proof of its efficacy.

Dissenters of the ruling are calling for mercury to be dealt with as a Hazardous Air Pollutant. Under Section 112 of the Clean Air Act (CAA), this would call for Maximum Achievable Control Technology (MACT) to be implemented as a means of reduction (Feeley 2005, 2-4). It is believed by some EPA officials that MACT could reduce mercury emissions by as much as 90% in a matter of years (Great Lakes Directory 2004). This alternative would be vastly more expensive for industry.

Currently, there are 26 active projects funded by the Department of Energy explicitly dealing with mercury reduction in coal fired power plants (Feeley 2005, 4). One such project is currently being conducted at the Big Brown facility. The two year, 2.3 million dollar grant seeks to determine the efficiency and economical feasibility of activated carbon injection (Feeley 2005, 7). The EPA contends that MACT technology would not be an appropriate plan of action with shifts in coal use and economic growth. They contend MACT such as activated carbon would cause nationwide mercury reductions to erode overtime and serve as a disincentive to technological innovation (USEPA 2005a).

The Mercury Cycle

Mercury in the environment is subject to constant recycling through a biochemical cycle. Figure two illustrates mercury's path as it travels through the environment.

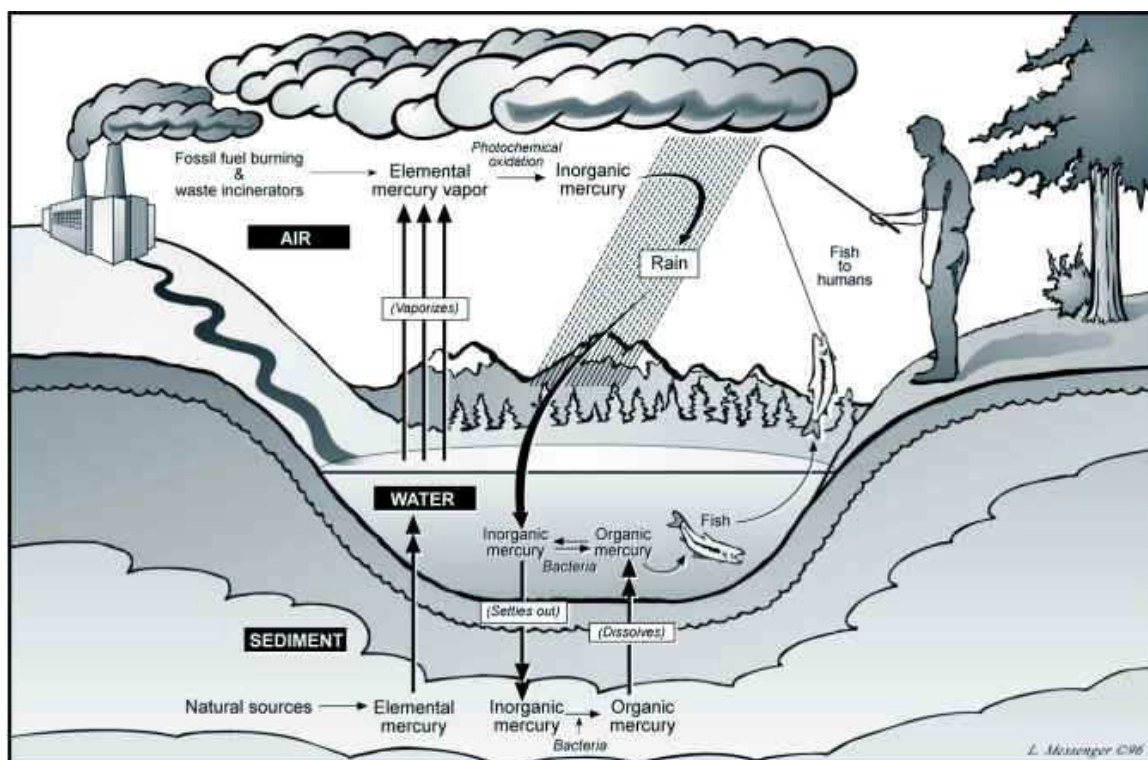


Fig. 2. Mercury cycle (provided by the Mercury in Schools Project)

Mercury cycles through the environment in six steps: 1) Release of mercury from either natural or anthropogenic resources, 2) atmospheric travel of mercury in its gaseous form, 3) deposition of mercury on either land or surface waters, 4) conversion of mercury into insoluble mercury sulfide, 5) conversion into a more soluble or volatile form such as methylmercury, 6) and either re-entry into the atmosphere or bioaccumulation in the foodchain (Morel, Kraepiel, and Amyot 1998, 544-546).

Although the general mercury cycle is well understood, there are many knowledge gaps concerning transport and fate (Sullivan et al. 2003, 1). One of these unknowns is the effect of point sources such as coal power plants on local deposition. The vast majority of mercury released from coal fired plants enters the global cycle, making it irrelevant where it was first introduced into the atmosphere. But, due to soluble forms of mercury rapid deposition characteristics, evidence suggests that cutting emissions of a particular anthropogenic source can result in some local deposition reduction (Hanisch 1998, 176A-177A, Sullivan et al. 2003, 1-15). In the EPA's mercury report to Congress, local deposition modeling found that from 2% - 45% of the total mercury emitted deposits within 50km of the source (USEPA 1997c, 5-36-5-41).

Natural Emissions

Mercury is a naturally occurring element that is released into the environment in a number of different manners. Natural sources and emissions of mercury ranging from an estimated 2,500 to 30,000 tons per year globally are often overlooked. It is important to note that due to the large increase in anthropogenic mercury releases, natural mercury emissions estimates are dated and not the subject of frequent research. More accurate natural emissions estimates are integral to help researchers better understand anthropogenic emissions (Schroeder and Munthe 1998, 810-811).

The dominant pool of mercury is contained in terrestrial systems ($\approx 95\%$) with the remainder held in the atmosphere and ocean (Ericksen et al. 2005, 1). Natural releases primarily occur primarily in the vapor phase by outgassing of the earth's mantle material, evasion of surficial surfaces, water bodies, vegetation surfaces, and geothermal surfaces (Schroeder and Munthe 1998, 1). A recent study attempting to better quantify air soil

exchanges of mercury estimates that US soils alone release approximately 1,000,000 kilograms of mercury each year. The same study estimated evasion of mercury from water and terrestrial surfaces to be approximately equal to deposition, with slightly more being emitted than deposited. Evasion of mercury from soils is a highly convoluted science and appears to be driven by several interacting factors which can include mercury concentration and speciation in substrate, light, wind, turbulence, and soil moisture and type (Ericksen et al. 2005, 1, 11-13).

Toxicological Perspective

Mercury is a known human toxicant, and concentrations of mercury in the tissues of wildlife species have been reported at levels associated with adverse effects in laboratory studies (USEPA 1997f, 4-2). Neurotoxicity has been observed following exposure to high amounts of mercury, and consumption of highly contaminated food also has produced overt mercury neurotoxicity. Chronic symptoms include a decrease in motor skills, tremors, inability to walk, convulsions, and death (USEPA 2001).

Toxicokinetics of mercury refers to the absorption, distribution, metabolism and excretion of the substance, and is highly dependent on the form of mercury to which a receptor has been exposed. Elemental mercury is rapidly absorbed through the lungs, but is poorly absorbed from the gastrointestinal tract. The elimination of elemental mercury occurs through urine, feces, sweat, and saliva. Conversely, methylmercury is rapidly absorbed by the gastrointestinal tract and is relatively stable in humans and animals. It easily penetrates the blood-brain and placental barriers and is very slowly demethylated. Studies examining adverse health affects concerning exposure to elemental mercury are limited, many of which are incomplete or inadequate compromising the validity of their

results (USEPA 1997e, ES-2). In general, effects on the nervous system appear to be the most sensitive toxicological endpoint concerning exposure to elemental mercury.

Studies considering the health effects of methyl mercury in both humans and animals are much better documented. Neurotoxicity in offspring is the most commonly seen effect and the effect seen at the lowest exposures. Methyl mercury's toxicity is most critical for the nervous system (USEPA 1997e, ES1 – ES9).

The transformation of mercury to methyl mercury is dependant on many factors and not completely understood. The end result of this chemical change is methyl mercury's bio-concentration and magnification by a factor of a million or more through ecological trophic levels (predators exhibit higher methyl mercury concentration) (Pennsylvania State University 2003, 6). Nearly 100% of the mercury that bioaccumulates in fish tissues is methylated via microbial processes. There is little evidence that fish play a role in methylating or demethylating mercury (Boening 2000, 1338-1340).

The EPA has produced a set of nationwide mercury maps in order to relate changes in mercury air deposition rates to changes in mercury in fish tissue. Figure three was produced using variations of two environmental models: the Mercury Cycling model and the IEM-2M watershed model. They are used to assess how reductions in air deposition would result in reducing mercury loading in fish tissue.

Although the proposed research does not quantify mercury in fish tissue, it is important to note the mercury maps were constructed around the correlation between air depositions and increased levels of mercury in fish tissues (USEPA 2001a, 1-15).

A similar study by Lutter (2002, 26) linked anthropogenic sources and elevated mercury levels in fish through a statistically valid correlation. His results estimated a 10% decrease in local sources would translate into a 0.6% decrease in fish tissues.

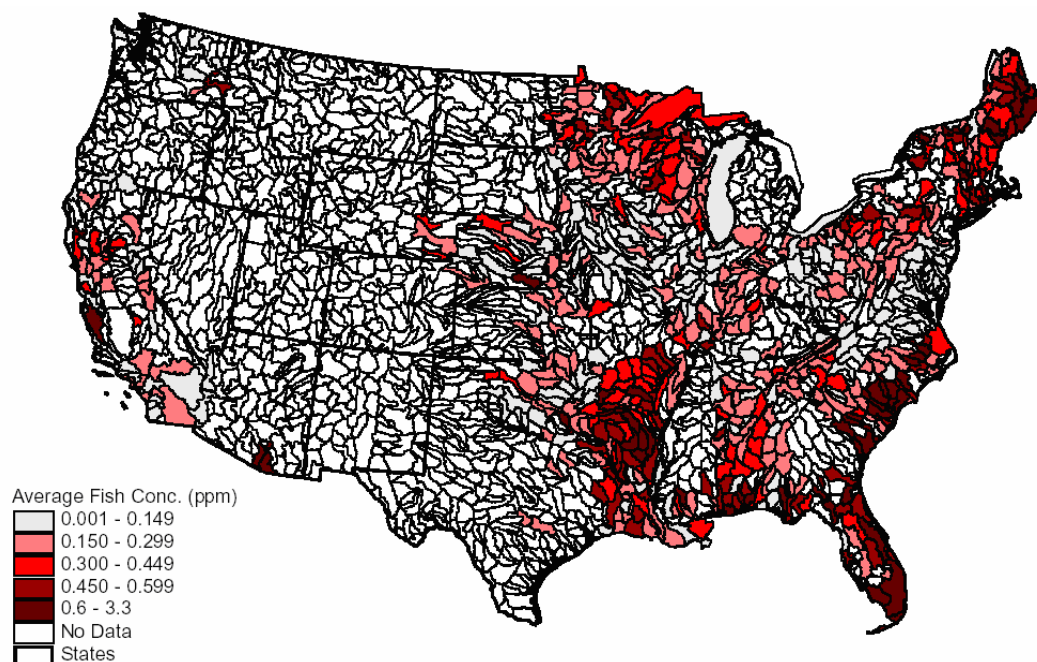


Fig. 3. Adapted from Fish Tissue Mercury Concentrations Averaged by Watershed (provided by USEPA Office of Water)

Risk Characterization

Some demographic groups, such as women of childbearing age, can be particularly affected due to threats methylmercury poses to unborn children. An EPA risk assessment concluded that between one and three percent of women of childbearing age, in excess of 4 million women, are exposed to methyl mercury in excess of the EPA reference dose (RfD) (.0001 mg/kg-day) (USEPA 1997g, 5-28).

Based on diet surveys, 10% of women of childbearing age eat five times or more fish than the average consumer. If the fish have average mercury concentrations of 0.1

ppm to 0.15 ppm this would result in dietary consumption of slightly over the RfD to double the RfD (USEPA 2001b, 4-6).

Offspring of women exposed to methyl mercury have displayed delayed onset of walking, delayed onset of talking, cerebral palsy, altered muscle tone, and reduced neurological test scores (USEPA 1997e, ES-3).

A recent study in Texas discovered apparent links between the amount of local anthropogenic mercury and increased rates of autism. The study of 1,184 Texas school districts found that an increase of 1,000 pounds of anthropogenic mercury resulted in a 63% increase of local autism (Palmer et al. 2006, 203-208).

Mercury Deposition Network

The Mercury Deposition Network (MDN) began in 1996 and consisted of 13 sites across North America. In 1996, the MDN became an official network within the National Atmospheric Deposition Program (NADP). Currently, there are 26 sites in operation taking weekly total mercury measurements from precipitation. The objective of the network is to create a national database consisting of weekly readings of total mercury in rainfall. The data can then be used to further the understanding of mercury deposition and help to develop information on spatial and seasonal trends in deposition (National Atmospheric Deposition Program 2005). Two of the 26 stations are located in Texas; Fort Worth and Longview. The Longview station has been in operation since 1996 and the Fort Worth station since 2002. Table 1 presents total wet deposition for an entire year for Longview and Fort Worth.

The average wet deposition for years 1998-2004 in Longview was approximately $12.3 \mu\text{g}/\text{m}^2/\text{yr}^{-1}$. Fort Worth's three year average was $9.7 \mu\text{g}/\text{m}^2/\text{yr}^{-1}$. For the purpose of

TABLE 1
WET DEPOSITION RECORDED BY
TEXAS MDN STATIONS

Year	Fort Worth ($\mu\text{g}/\text{m}^2/\text{yr}^{-1}$)	Longview ($\mu\text{g}/\text{m}^2/\text{yr}^{-1}$)
2004	10.8	13.7
2003	07.3	09.5
2002	11.1	09.8
2001	ND	15.7
2000	ND	14.5
1999	ND	10.5
1998	ND	12.5

a baseline deposition for the Central Texas area, $12 \mu\text{g}/\text{m}^2/\text{yr}^{-1}$ will be used for average yearly wet deposition. This is the logical choice considering the Longview Station contains more data than Fort Worth and more closely resembles the rural setting of the modeled areas.

Dry deposition is believed to account for somewhere between 50-100% of wet deposition. As is the case with wet deposition, dry deposition of mercury is dependent upon numerous factors. Among the most important are land cover, atmospheric stability, and chemical interactions. It is well documented by Schroeder and Munthe that dry deposition is highly affected by foliar interactions and therefore rivals wet deposition only in heavily forested areas (Schroeder and Munthe 1998, 813).

For the purpose of discussion, baseline dry deposition levels will be assumed to be approximately two thirds of wet deposition ($\approx 8 \mu\text{g}/\text{m}^2/\text{yr}^{-1}$). Dry deposition estimates were based off of land type (mostly range and farm lands), and it is believed they will fall closer to 50% of wet deposition rather than 100%.

Therefore, baseline levels for total mercury deposition for both wet and dry processes will be assumed to be $20 \mu\text{g}/\text{m}^2/\text{yr}^{-1}$ in the Central Texas area. This number is

congruent with other literature estimates documenting total deposition in Texas and the rest of the United States (Suter et al. 2003, 12, USEPA 1997c, 3-5 – 3-9).

Mercury in the Water Column

Limited empirical data is available concerning mercury in freshwater systems. Levels are also difficult to quantify because they are directly affected by water-air exchange, seasonal fluctuations, humic content, dissolved organic content (DOC), pH, and water temperature. In general, mercury in surface waters is well under 20 ng/L, typically under 5 ng/L (USEPA 1997c, 3-8 – 3-10).

Surface waters affected by anthropogenic sources may reflect higher concentrations, but do not appear to be as affected as precipitation. In the EPA's report to Congress two separate studies in Washington and Arkansas found mercury levels in surface water to range from .15 – 1.2 ng/L (USEPA Vol. 3 1997, 3-8 – 3-10). Present day levels of mercury in freshwater systems are thought to range from 2-7 times higher than pre-industrial times (USEPA 2001b, 12-13).

Mercury in Sediment

Mercury levels in sediment are generally higher than in the water column. Levels of over 200 ppb are not uncommon in United States Sediments. A study of 80 Minnesota lakes found a mean concentration of mercury in sediments of 174 ppb. A study conducted by the New Jersey Department of Environmental Protection found typical mean mercury averages in the United States to range from 70-310 ppb (USEPA 1997c, 3-10 – 3-13). The Texas Risks Reduction Program (TRRP) lists the mean background concentration of mercury in Texas sediment's as 40 ppb (TCEQ 2005c)

Central Texas Anthropogenic Releases

The area of Central Texas represented by the Heart of Texas Council of Governments (HOTCOG) includes Bosque, Falls, Freestone, Hill, Limestone, and McLennan Counties. In 2003, the Toxic Releases Inventory (TRI) reported point source mercury emissions from only three entities in three separate counties in HOTCOG. Chemical Lime LTD in Bosque County reported four pounds of mercury emissions in 2003. Big Brown and Limestone generating facilities were the only other two facilities reporting mercury emissions in the six-county area in 2003.

Need For Local Research

Forty-one states, including Texas, have issued 2,242 fish advisories for mercury (USEPA 2001b, 1). In the area by the HOTCOG, no fish advisories have been released.

Two coal-fired plants are located in the HOTCOG territory: Big Brown generating station located in Freestone County, and the Limestone plant, located in Limestone County. A third plant, Sandy Creek, is currently being proposed near Riesel.

Using EPA local deposition estimates (2% - 45%), in 2002 the Limestone plant would have deposited between 36-810 pounds of mercury in the area. Mercury concentrations for bass in Lake Limestone were obtained in 1986. A small sample of 30 fish, collected by Texas Parks and Wildlife, revealed average mercury concentrations of 0.013 ppm (13 ppb) wet weight (Personal e-mail Roxie Mills 2005). No analytical procedures were obtained or documented for this particular fish study. In 1986, the Limestone generating unit had been operating for one year. An average of .013 ppm is greater than a magnitude lower than the national average for largemouth bass 0.46 ppm

(USEPA Office of Water 2001, 5). More recent fish tissue data would be considerably valuable to this study as it would help to chart the rate of mercury increase.

Big Brown was another large mercury polluter in 2002, it's 633 pounds of mercury releases made it the sixth worst mercury polluter in the state that year (Sustainable Energy and Economical Development 2005). In Freestone County, application of EPA local deposition estimates predicted 13-285 pounds of mercury being deposited locally. The major water bodies of concern near the Big Brown plant are Lake Fairfield (the plant's water source), Richland Chamber Lake, and the Trinity River.

The Sandy Creek plant has applied for a permit to emit up to 1,080 pounds of mercury per year. If the maximum were released, local deposition estimates range from 22-486 pounds per year. The water bodies within a 50 km radius of the plant include Lake Creek Lake (the plant's water source), Lake Waco, and the Brazos River.

Research Challenges

Due to the significantly different deposition characteristics of mercury in the atmosphere, different species of mercury must be explicitly examined when considering emission inventories (Schroeder 1998, 809 - 810). Although it is known that certain species of mercury deposit more readily than others, accurately quantifying the amount of individual species along with the rate of their emission is not exact. The need for better methodology for determining mercury speciation and the chemical interactions with which they undergo were outlined as needed areas of research in the EPA's mercury report to Congress (USEPA 1997a, 14).

Identification of chemical form of mercury released from coal fired power plants requires assessment of a number of variables including fuel composition, combustion

characteristics, pollution control technology, meteorological data and physical plant parameters (Edgerton 2004, 3 and New Zealand Ministry for the Environment 2004). Therefore, mercury speciation and local deposition are unique from one plant to the next, and must be studied independently to be accurately assessed.

As in the case of the EPA maps (USEPA Office of Water 2001a), most of the research/modeling of mercury deposition has focused on national and global effects. The body of research lacks regional and local studies that have assessed mercury loading due to atmospheric deposition and baseline data relating to mercury concentrations in surface water and sediment. A regional study would be useful to evaluate potential risks to water quality that can result from increased deposition. In addition, the study could result in a transportable model/methodology for other regions. The EPA reported in its extensive mercury study provided to Congress that local and regional modeling studies were areas needing further research (USEPA 1997a, 16).

CHAPTER THREE

Methodology

The methodological steps for achieving the goals and objectives identified on page two encompass the following tasks.

1). Collect and collate existing data about point source emissions in the study area. This includes the identification of all point source polluters within the HOTCOG area. Data on these mercury emitting entities are provided by EPA's TRI. Data concerning mercury releases from the proposed Sandy Creek plant are provided via the permit application obtained from the Texas Commission on Environmental Quality (TCEQ).

2). Collect information on the coal-fired plants and manipulate data to an acceptable format for the model. This includes analysis of data in order to understand emission rates, amounts of mercury released, and the chemical speciation of the mercury. The TRI inventory reports mercury releases in pounds per year. In order to be used in the model, these values will be converted to grams per second by converting pounds to grams ($1\text{lb} = 453.59\text{g}$) and dividing by 31,536,000 (the number of seconds in a year). Other data including stack height, stack diameter, exit velocity, and release temperature were provided by plant engineers and will be converted to metric units to facilitate computation software parameters.

3). Determine chemical speciation of the mercury releases. Mercury speciation data are available from the Mercury Information Collection Request (ICR) authorized by

Section 114 of the Clean Air Act. Both Limestone and Big Brown were required to submit speciation data as part of the ICR.

4). Obtain and process meteorological data to comply with the variables used for the dispersion model. The meteorological data consists of twice daily mixing heights and hourly surface data including wind speed, wind direction, rainfall amounts, and rainfall intensity for an entire year.

5). Model local wet deposition for the existing and newly proposed coal fired power plants in Limestone, Freestone, and McLennan Counties using the EPA recommended air dispersion model ISCST3. This model is the most widely used for assessing local deposition of air born toxins. Aggregate emissions in grams/second were divided into two categories, elemental mercury (Hg^0) and oxidized mercuric mercury (Hg^{+2}), representative of the percentage emitted in the Mercury ICR Performance Test Report. Since the amount of oxidized mercuric mercury (Hg^{+2}) was believed to be the most important factor affecting local deposition, a minimum, maximum, and arithmetic mean value was determined in order to complete the modeling. Separate modeling runs were completed for each plant representing minimum deposition, maximum deposition, and an average deposition.

Since no real data exists for the Sandy Creek power plant, the national averages of mercury speciation derived from the Performance Test Reports were used to complete the modeling for this plant. Emissions for Sandy Creek were modeled by using the maximum value of allowable mercury releases as outlined in the permit application and 50% of that number.

6). Establish a network of discrete receptor locations will in order to estimate deposition within a 50 kilometer radius of each plant. Once modeling was completed for a 50 kilometer radius, a second, much smaller, network of discrete receptors was created to more closely model local deposition.

7). Create mercury maps for the six county constituency represented by the HOTCOG. These maps will represent local mercury wet deposition resulting from the coal fired plants located in the Limestone and Freestone counties. Maps will also be created for potential mercury loading that would result if the proposed Sandy Creek power plant were constructed less than thirty miles from Waco.

ESRI's ArcView GIS will be used to produce the maps from the data collected by the EPA recommended air dispersion model ISCST3. The data provided by the dispersion model will be manipulated to suit ArcView's interpolation process. Discrete receptors must be in the Universal Transverse Mercator system (UTM) followed by the receptor's specific concentration of the pollutant. This will allow ArcView to interpolate a surface that will represent concentrations in nine different color coded categories. Water bodies will be included in the maps to determine surface waters most at risk for local deposition of mercury. Results of the mapping will help to guide water, sediment, and fish tissue analyses in order to determine the efficacy of the model.

8). Conduct water and sediment analyses at Lake Limestone and Lake Fairfield, to ground truth the efficacy of the models. These two water bodies represent the closet surface waters to the already existing power plants. Sampling locations from various deposition gradients will be chosen to determine if the maps accurately describe locations of increased deposition.

9). Conduct statistical analyses in order to determine if a statistically valid correlation exists between varying deposition gradients and sampled environs.

CHAPTER FOUR

Modeling Considerations

Technical Issues

Mercury Speciation and its Effect on Flow Rates and Deposition

The chemical and physical properties of mercury influence its atmospheric path, deposition, and threat as a contaminant. The process of mercury being removed from the atmosphere via rain or snow is referred to as wet deposition. Precipitation can readily remove both RGM and particulate mercury from the atmosphere oftentimes within a few miles from where it was emitted (Schroeder and Munthe 1998, 809). Levels higher than 1000 ng/L have been reported in precipitation downwind of anthropogenic sources (USEPA 1997c, 3-5).

Mercury in the atmospheric environment can exist in the elemental, oxidized ($+1$ and $+2$), or particulate state. The $+1$ oxidation state exists very rarely, if at all (Schroeder and Munthe 1998, 811). In ambient air, approximately 95% of mercury is in the elemental phase. RGM is significantly more water soluble than GEM and partitions easily to precipitation. Therefore, it is expected to deposit within a few tens to a few hundreds of kilometers from its source (Suter et al. 2003, 7-8, Cohen et al. 2004, 248-249).

Mercury can also bind itself to particulate matter after its release from the stack. Particulate mercury is expected to deposit somewhere in between elemental and oxidized depending on the amount of mercury in ambient air, diameter/mass of the particulate, and land type. For the purposes of this study, dry deposition of mercury was omitted due to

the absence of ambient air data and the low amount of particulate mercury (less than 1 percent) exiting the stack. Also, dry deposition of mercury is believed to rival that of gaseous mercury only in heavily forested areas (Schroder and Munthe 1998, 813).

Prior, to the 1980s inventories of anthropogenic mercury releases were recorded only as total mercury (Schroeder and Munthe 1998, 809-810). Similarly, the TRI database only displays total mercury releases, omitting speciation estimates.

Due to the different transport and fate characteristics, mercury species should be accurately estimated to produce valid modeling results. Mercury speciation in flue gas depends largely on the type of fuel used, pollution control technology, and operating temperature (Capri 1997, 244-247).

Atmospheric chemical interactions can affect mercury speciation. Though mercury can exist in one of three chemical states, each of the forms of mercury can be transformed into the other in the atmosphere (Cohen et al. 2004, 248, Carpi 1997, 244-246, Poissant et al. 2004, 2-4, Schroeder and Munthe 1998, 809-810). Emission sources, regional atmospheric conditions, and near-ground micrometeorological conditions all affect the distribution of mercury speciation and the rate of transformation (Poissant et al. 2004, 1).

Large seasonality variations of atmospheric mercury have been fairly well documented (Poissant et al. 2004, 10-12, Cohen et al. 2004, 247-255). It is generally understood that larger amounts of gaseous elemental mercury are present in winter and spring (Poissant et al. 2004, 10-12). For modeling purposes, speciation was assumed to stay constant after its release from the stack. It's realized that this is a simplification of reality, but determining accurate rates of speciation change in the stack and atmosphere

were beyond the scope of the study. Fortunately, atmospheric speciation changes are not expected to significantly affect local deposition modeling results due to the rather slow transformation of GEM to RGM in the atmosphere (Cohen et al. 2004, 248-249).

Mercury Scavenging Coefficients

A scavenging coefficient is a parameterization of the rate of loss of gases or aerosol particles from the atmosphere by their incorporation into larger drops, such as rain or other forms of precipitation. In order to model wet deposition, a scavenging ratio approach is employed in order to determine the deposition of gases and particles via wet removal (USEPA 1995b, 2-2).

The ISC model estimates wet deposition using rainfall data (ie intensity and amount) and the pollutant's scavenging coefficient. The scavenging coefficient is dependent on the characteristics of the pollutant (reactivity and solubility for gases, and size for particles) as well as the form of precipitation (liquid or frozen) (USEPA 1995b 1-61). Wet deposition is the product of the scavenging ratio (precipitation intensity times scavenging coefficient) and the concentration of the pollutant over the vertical dimension (Sullivan et al. 2003, 4-5).

Direct measurements of scavenging parameters for mercury are not available. However, using washout ratios (concentration in precipitation to concentration in air), scavenging calculations were estimated and provided in the EPA's report to Congress. A washout ratio was determined using an assumed similarity between divalent mercury and gaseous nitric acid (USEPA 1997c, 4-3). The different ratios for the separate species are listed in table two.

TABLE 2
MERCURY SCAVENGING COEFFICIENTS

Form of Mercury	Liquid Scavenging Coefficient (s-mm/hr) ⁻¹	Liquid Washout Ratio
Hg(0)	3.3 10(-7)	1200
Hg ⁺²	2.5 10(-4)	1.6 10(6)

Electric Utility Steam Generating Unit Information Collection Request (ICR)

Using its authority as defined in Section 114 of the Clean Air Act, the EPA required Electric Steam Utility Generating Units to provide empirical data in an attempt to calculate annual mercury releases from each unit. A number of plants were also selected in the ICR to measure elemental, oxidized, and particulate mercury at the inlet and outlet of the last pollution control device (USEPA 1999a). Both the Limestone Generating Unit and the Big Brown Station were selected to take part in the mercury speciation testing. Mercury speciation testing was conducted using the Ontario Hydro method for both power plants (METCO Environmental 1999 and Radian International 2000).

The ICR required three test runs to be conducted for mercury speciation. Each test run provided a percentage of elemental, oxidized, and particulate mercury in flue gas. For modeling purposes, a low, high, and arithmetic mean was taken for oxidized mercury since it is recognized as being the most important factor in local deposition. Table three enumerates the different oxidized mercury percentages as provided by the three test runs. Since no real data exists for the Sandy Creek Power Plant, the national average provided by the ICR was used for the modeling effort.

Three modeling scenarios were created for Big Brown and Limestone: maximum deposition (using the highest percentage of oxidized mercury), average deposition (using

the average percentage of oxidized mercury), and minimum deposition (using the lowest percentage of oxidized mercury). In all three scenarios elemental mercury was modeled as the remainder of total mercury after RGM had been accounted for. For example, the minimum deposition run will contain the lowest amount of RGM and the highest amount of GEM.

TABLE 3
PERCENTAGES OF OXIDIZED MERCURY

Scenario	Big Brown Hg ⁺² (%)	Limestone Hg ⁺² (%)	Sandy Creek Hg ⁺² (%)
Low	0.397	0.0692	
High	0.455	0.1640	
Mean	0.420	0.1257	0.40

Speciated Flow Rates

Speciation percentages were determined for each power plant and applied to emissions to produce speciated flow rates. Flow rates are reported as pounds per year by the TRI, and were converted to grams per second. Yearly emission values were divided into elemental flows and oxidized flows depending on the modeling scenario (maximum, average, or minimum deposition).

No data exists on speciation statistics or mercury emissions for the proposed Sandy Creek plant. Modeling runs were conducted using the maximum amount of mercury releases as outlined in the permit application (1080 pounds) and 540 pounds with the national ICR speciation average used to determine elemental and oxidized flow rates. Table four lists the speciated flow rates for the different modeling scenarios.

TABLE 4
2003 SPECIATED MERCURY FLOWS (g/s)

Plant	kg	g/s total Hg	Low		High		Mean	
			Hg ⁺²	Hg(0)	Hg ⁺²	Hg(0)	Hg ⁺²	Hg(0)
Big Brown	201	0.0064	0.0025	0.0038	0.0029	0.0035	0.0027	0.0037
Limestone	629	0.0200	0.0014	0.0186	0.0033	0.0167	0.0025	0.0174
Sandy Creek	490	0.0155					0.0062	0.0090
	245	0.0078					0.0031	0.0045

Power Plants Coal and Pollution Control Technology

Although the Limestone plant emits nearly three times the amount of mercury as the Big Brown plant, emissions of oxidized mercury are nearly equal. Both plants fire Texas lignite and are subject to similar processes. The major difference between the two relates to pollution control technology. Both employ ESPs, but the Limestone plant uses a Flue Gas Desulfurization (FGD) prior to the flue gas exiting to the stack. The Big Brown plant uses a series of COPAHC (Compact Hybrid Particulate Collector) baghouses to treat the flue gas prior exit to the stack.

The difference in these methods is the likely cause for the elevated levels of oxidized mercury being emitted from Big Brown in comparison to Limestone. Wet lime/limestone FGDs have been shown to remove between 8 and 75 percent of mercury from flue gas (Meij 1991, 20-24). Due to oxidized mercury's affinity for water, it is believed that the FGDs role in mercury reduction is primarily through the removal of oxidized mercury via precipitators. Hence, there will be significantly less local deposition when wet FGDs are used as part of pollution control. Therefore, modeling results should reflect local deposition of mercury to be fairly similar between the two plants despite incongruent emissions.

Model Setup

Industrial Source Complex (ISC) Model

The Industrial Source Complex (ISC) air dispersion model was, during the time of the research, the EPA approved air dispersion model for short term wet deposition of a pollutant. The EPA maintains the Guidelines on Air Dispersion Models which provide the agency's guidance on the regulatory applicability of the models in the review and preparation of new source permits and other regulated air quality activities. As of December 9, 2005, the EPA has currently switched its recommended air dispersion model for assessing criteria pollutants under the Clean Air Act from ISC to AERMOD (Federal Register 2005, 1). This new generation of dispersion model has been in development since 1990, and is still based on the Gaussian plume dispersion equation.

The greatest advantage AERMOD has over the ISC model is predicting accurate pollutant levels when complex terrain and/or building downwash is involved. There would be a negligible difference between the two models due to relatively simple terrain and the absence of building downwash in the modeling scenarios. The EPA has also recommended a one year phase out of the ISC model to end on December 6, 2006 (Federal Register 2005, 2-12).

The ISCST3 model consists of two basic input types: the input runstream file and the meteorological data file (Old Dominion 2000). There are five major modeling options needed to be defined for proper modeling within the input runstream file: dispersion options, source options, receptor options, meteorological options, and output options. The second major input, the meteorological data file, contains hourly meteorological data in order to define plume rise, transport, diffusion, and deposition.

Dispersion Options

The ISC model was created in order to address the EPA's regulated modeling activities and dispersion options were setup with a default mode in order to maintain congruities concerning the use of stack tip downwash, final plume rise, processing averages during calm winds, and vertical temperature gradients. Since there were no aberrant situations concerning the plants modeled in this study, the default dispersion options were used (USEPA 1995a, 3-3 – 3-8).

The options also include the selection of either “rural” or “urban” concerning the release point. This option affects the vertical potential temperature gradients and wind profile exponent. All three plants were modeled with the “rural” option (USEPA 1995a, 3-3 – 3-8).

Source Options

Source options allow the user to define specifics of the source and pollutants being modeled. These include location, type, dimensions, exit velocity, flow rate, and scavenging coefficients for gases and particulates. It also allows the user to adjust the sensitivity of the model. Since detection levels for mercury are extremely low, ppb or ppt, the model was adjusted for deposition from g/m^2 to $\mu\text{g/m}^2$ (USEPA 1995a, 3-24 – 3-28). Source parameters for the model runs were obtained from plant managers and permit data. These are presented in table five.

Flow Rates

Flow rate is defined as the physical measurable amount of pollutant exiting the stack at any given time. The model measures flow rates in grams per second, and allows

TABLE 5
SOURCE OPTIONS PARAMETER INFORMATION

Plant	Source	Location (UTM)	Stack Height (m)	Exit Temp (K)	Stack Diam (m)	Exit Vel (m/s)
Limestone	Point	761113 3479756	172	344	8.25	21.6
Big Brown	Point	778748 3524327	122	459	6.80	21.6
Sandy Creek	Point	691396 3482803	168	347	7.50	21.6

for variable monthly emission rates when conducting modeling. Unfortunately, enough information did not exist to allow for variable emission modeling. Total pounds per year were converted evenly for the entire year to grams per second.

Receptor Options

The model offers considerable flexibility in regards to receptor number and location depending on the purpose of the modeling exercises. Receptors can be setup as either a Cartesian or Polar grid receptor network. A maximum number of 500 receptors is allowed for short term modeling. A discrete Cartesian receptor network was produced extending 50 kilometers in each direction of the plant using 496 receptors. An example of the Cartesian network used to interpolate the deposition surface is pictured below in figure four.

A similar receptor network was constructed around each of the three power plants. Once outer limits of significant mercury deposition were determined, a finer grid using the same amount of receptors was created to more accurately model highly impacted areas. An example of the fine grid is provided below in figure five.

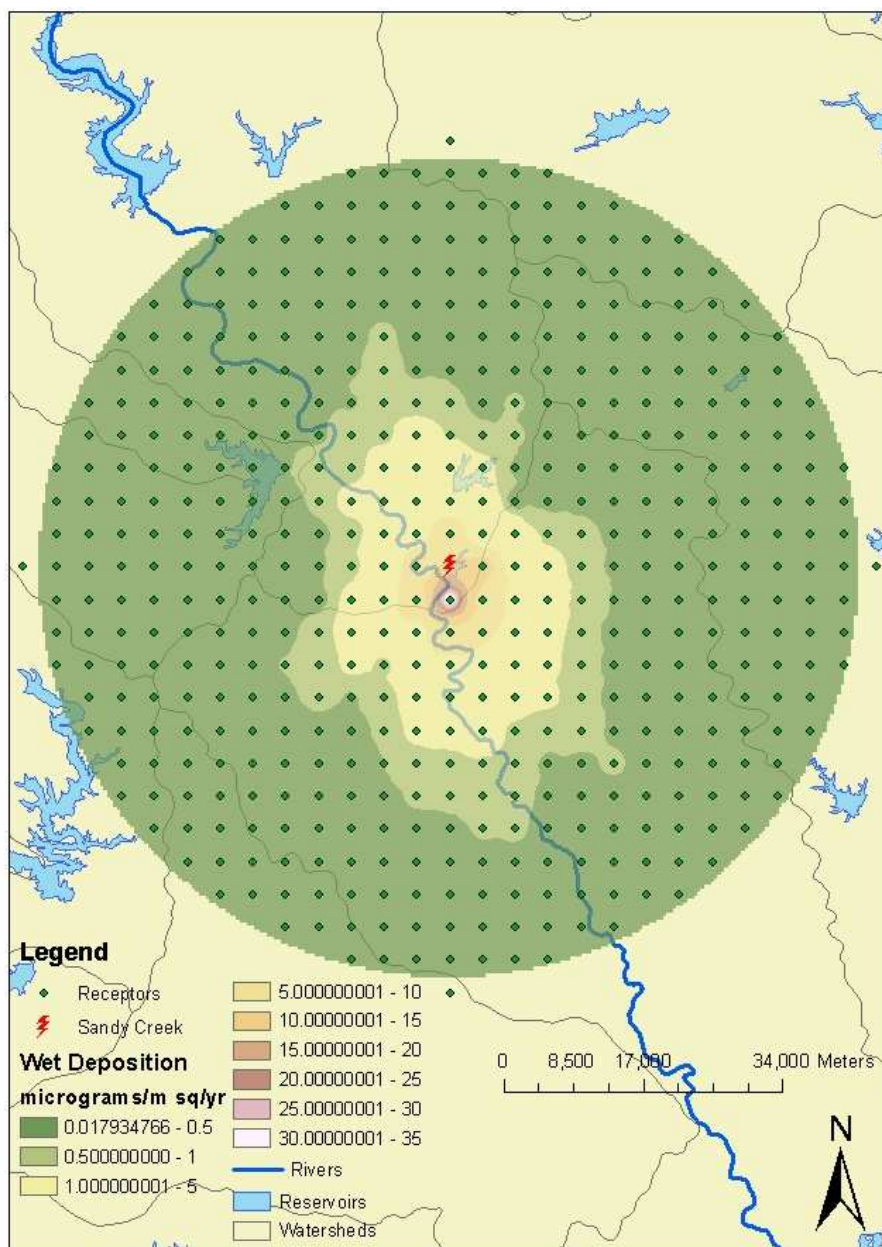


Fig. 4. 50k Grid Setup

This receptor network is roughly 11 x 12 kilometers, and is placed around the plant in order to display water bodies and areas of maximum deposition. All three plants were modeled and mapped in the same manner.

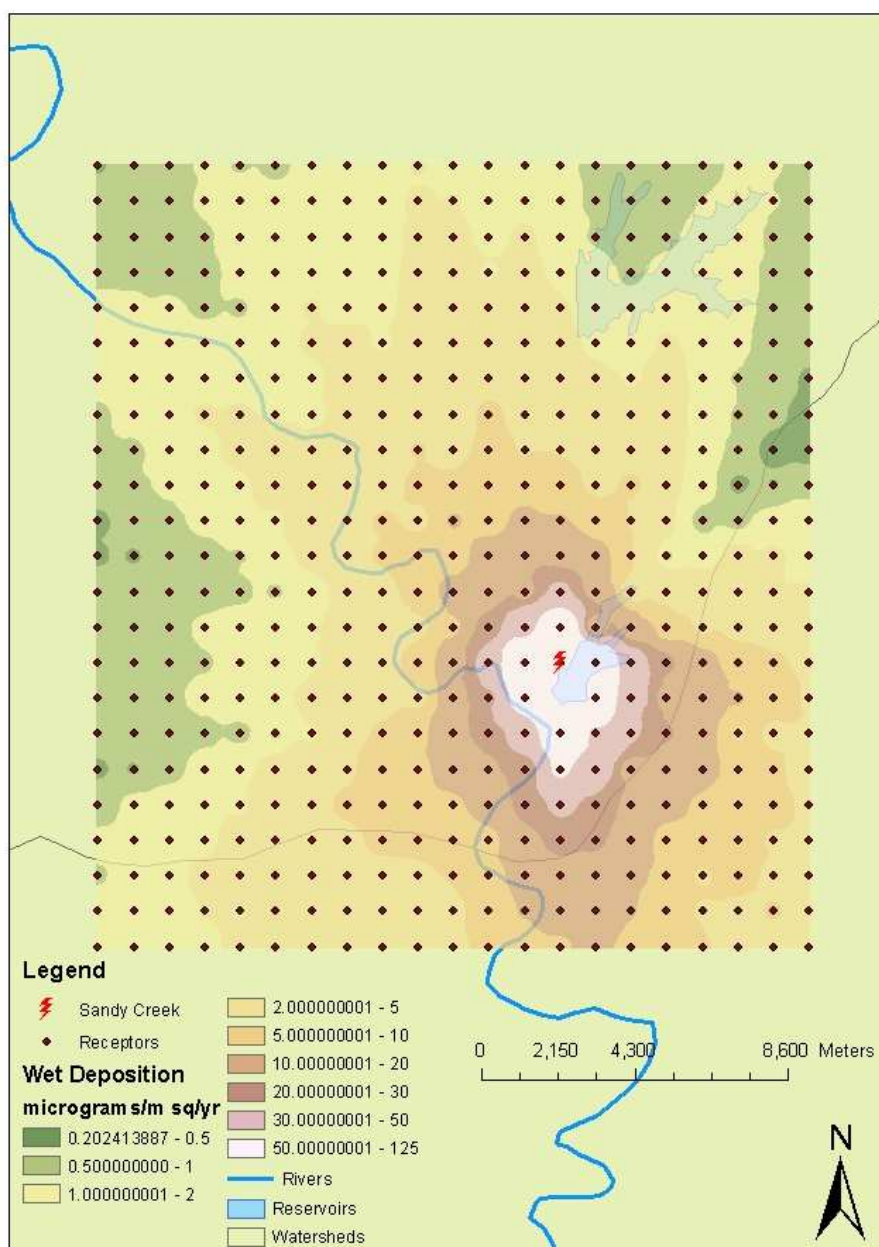


Fig. 5. Close Grid Setup

Meteorological Options and Input

The meteorological option within the input runstream file is a path description telling the model where the meteorological input data input can be found. This input is an ASCII file and was constructed with PCRAMMET, ISC's meteorological pre-

processor. The meteorological file includes surface and upper air data. In order to utilize the wet deposition algorithms, precipitation data must also be present.

There are currently 16 surface stations in Texas recording data compatible with the wet deposition options and nine upper air stations. Surface stations data collect sequential hourly data consisting of vector flow (in degrees), wind speed, ambient temperature, stability class, wind profile exponent, vertical potential temperature gradients, friction velocity, Monim-Obukhov length, surface roughness, and precipitation intensity. Upper air data consists of twice daily mixing heights. Figure six below displays the station's locations in respect to the power plants.

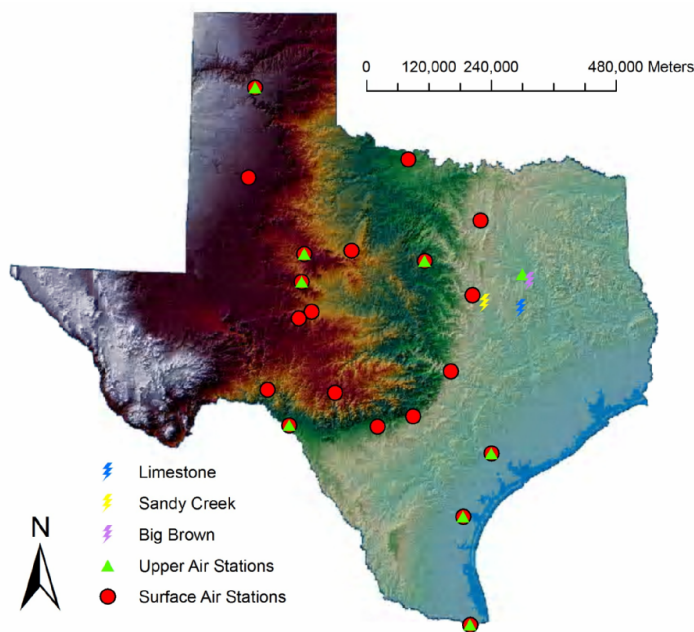


Fig. 6. Texas Meteorological Stations

The meteorological station chosen for each power plant was based on geographic proximity. All three power plants used Waco Municipal airport's surface data. Twice

daily mixing heights were recorded from the Longview station for both Limestone and Big Brown, while Sandy Creek used mixing heights from Stephenville.

The most recent year available for the Waco surface station was 1992, Longview upper air 1991, and Stephenville upper air 1990. Deposition modeling could be more accurate if up to date meteorological data were available. The most recent data was used in all cases.

Figure seven is a wind rose plot created from the Waco airport's surface data via Web Lakes WRPLOTView program. This wind rose represents the intensity and vector of the winds for the year 1991.

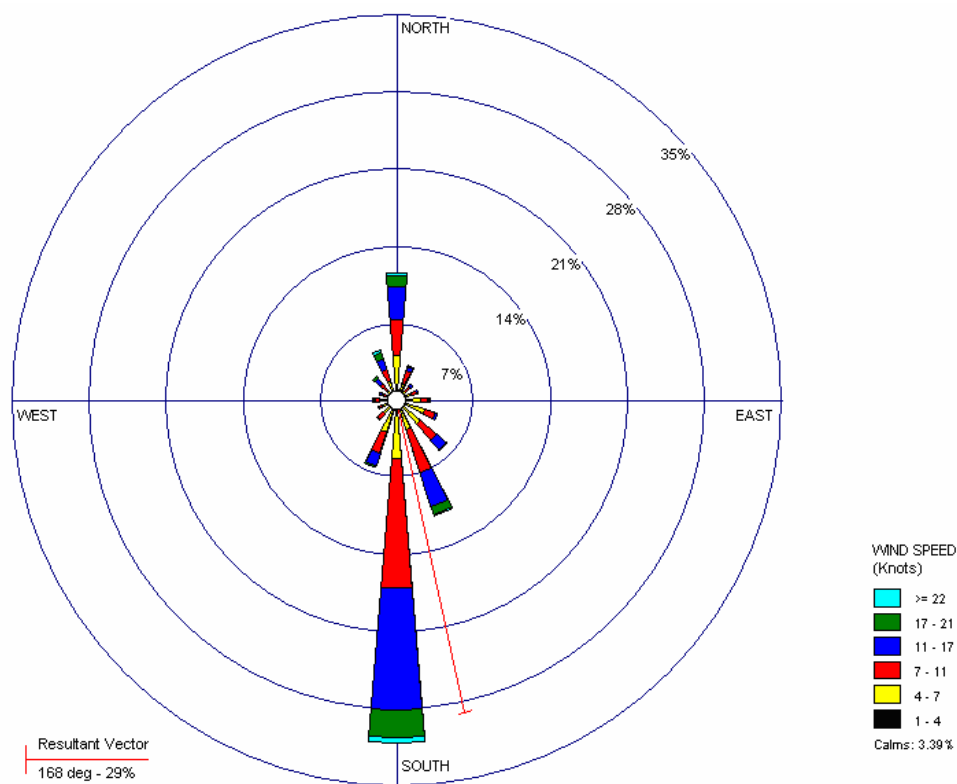


Fig. 7. Wind Rose for Waco Meteorological Station

Winds are blowing on a direct south to north heading approximately 30% of the time, with the predominant resulting vector blowing in a north – northwest direction.

Figure eight is a rain rose and was compiled using the same surface station data. It is assumed that modeling results should closely resemble the rain rose's vector and intensity.

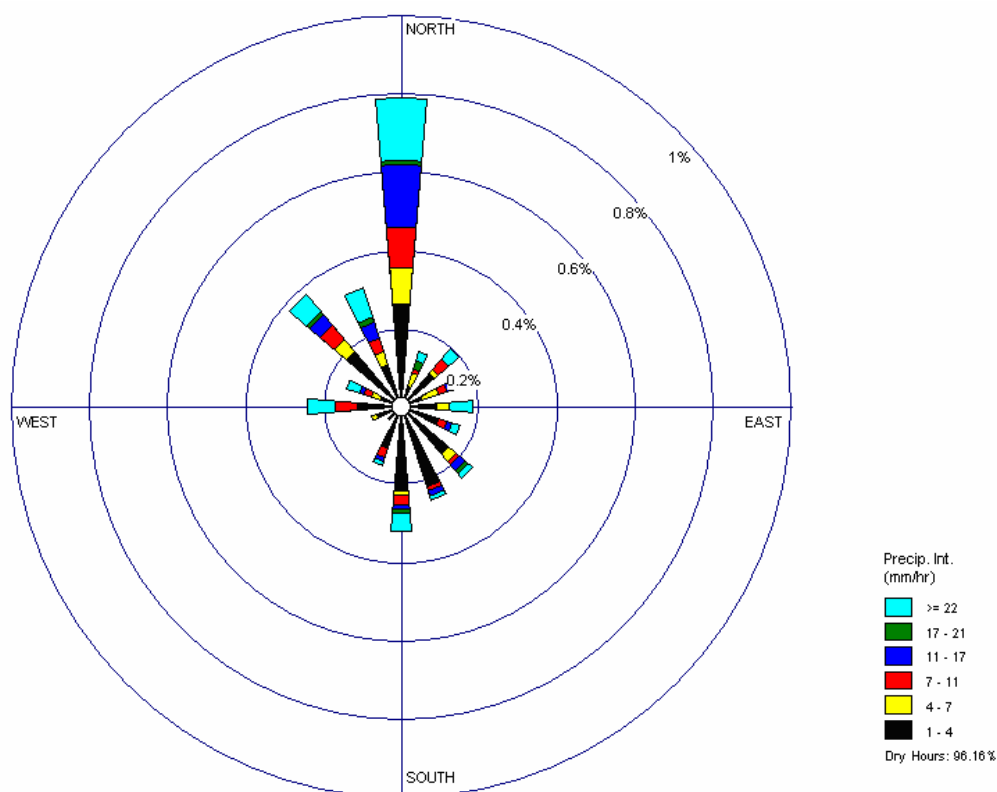


Fig. 8. Rain Rose for Waco Meteorological Station

While the predominant winds are south to north, during rainfall events the predominant winds are from north to south. Judging from the rain rose, local deposition should mostly occur to the south and southeast of the power plants.

Output Options

The model can produce outputs for a variety of purposes depending on the modeling exercise. In this case the model was manipulated to produce average deposition values for an entire year at each of the 496 six receptors. Once the values were determined, a surface was interpolated using ESRI's ARCVIEW software. The result is a nine color surface ranging in mercury deposition values from 0-125 $\mu\text{g}/\text{m}^2/\text{yr}^{-1}$.

The Inverse Distance Weighted (IDW) was utilized to interpolate the raster. IDW works best for evenly spaced sample points, and allows closer sample points closer to the cell have a greater influence on the cell's estimated value than those points further away.

Maps were also constructed depicting average ground level concentrations during the year and average maximum daily concentrations. The maps appear in the appendix A, pages 63-78.

CHAPTER FIVE

Model Output and Validation

Output by Plant

Lake Limestone Generating Unit

The Lake Limestone Generating Unit is located on 3,800 acres in Limestone County at the nexus of Limestone, Leon and Freestone Counties, approximately 120 miles north/northwest of Houston. The plant is owned by Texas Genco, one of the largest wholesale electric power generators in the United States. There are two steam units on site with a net generating power of 1,612 MW. The first unit was placed in commercial operation on December, 1 1985 (Texas Genco 2005). The power plant is located within three kilometers of Lamb's Creek on the eastern side of the lake. Water is pumped from Lake Limestone to serve as auxiliary cooling water.

The station fires Texas lignite and uses a cold-side ESP and wet FGD to treat flue gas. As the flue gas exits the boiler it first passes through regenerative air preheaters before entering the ESP for particulate control. The gas is then divided up into four ducts feeding the FGD which uses a system of spray tower absorbers for flue gas contractors. The FGD reagent is ground limestone slurry containing dibasic acid. Once the flue gas leaves the FGD it exits through the stack (Radian International 2000).

In 2003, the Limestone Generating Unit reported 1,386 pounds of mercury releases. Figures 9-11 represent mercury deposition in order of speciated flow rates: minimum, average, and maximum, displayed on a 50km radius grid.

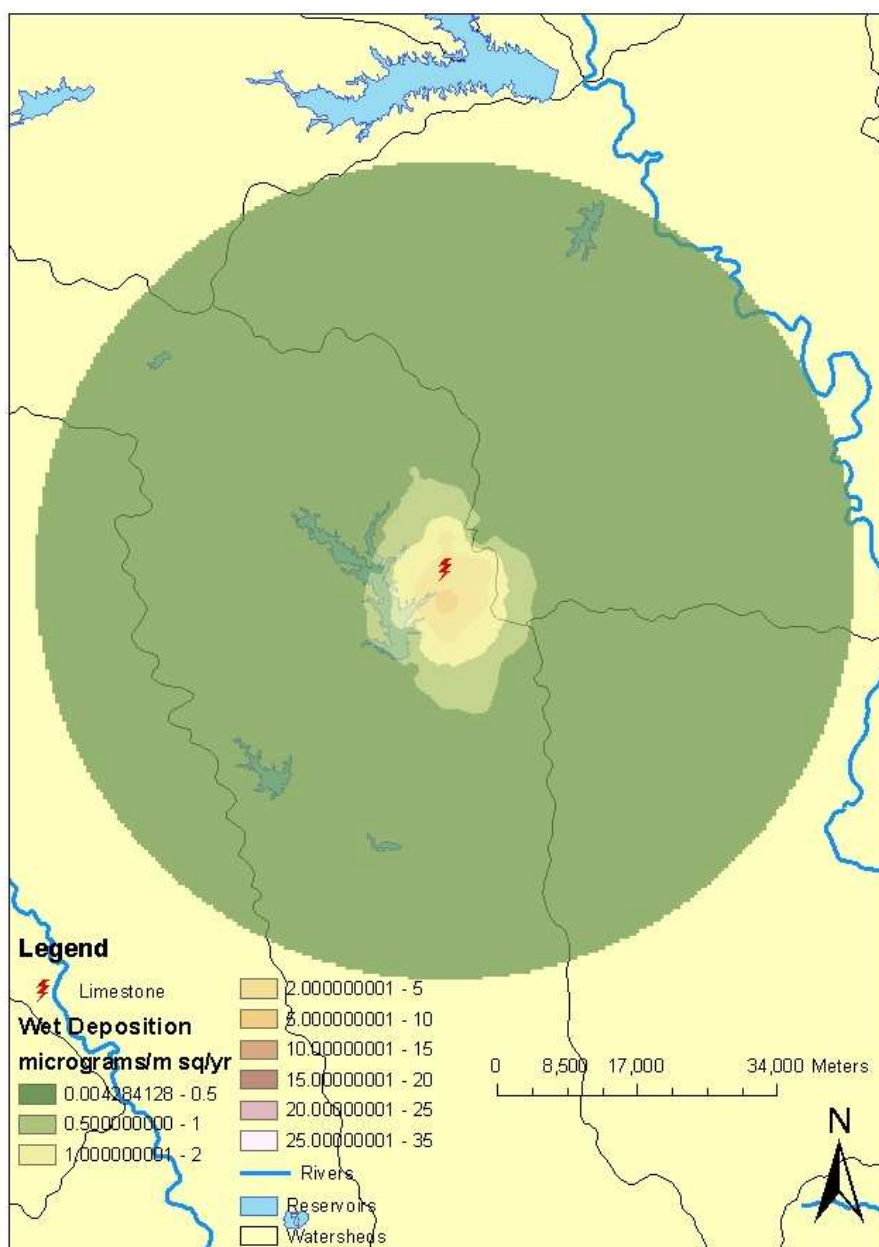


Fig. 9. Limestone – Minimum Wet Deposition 2003

Figure twelve is the same modeling run using the average speciation flow rates on a much finer grid. This allows a clearer picture of how much and where deposition is occurring, since the vast majority is within 20 km of the plant.

As expected, the highest deposition values, over $50 \mu\text{g}/\text{m}^2/\text{yr}^{-1}$, occur directly south of the stacks within a few kilometers of release. This highest level to make

contact with Lake Limestone is between 10 and 20 $\mu\text{g}/\text{m}^2/\text{yr}^{-1}$ occurring at the furthest reach of Lamb's Creek.

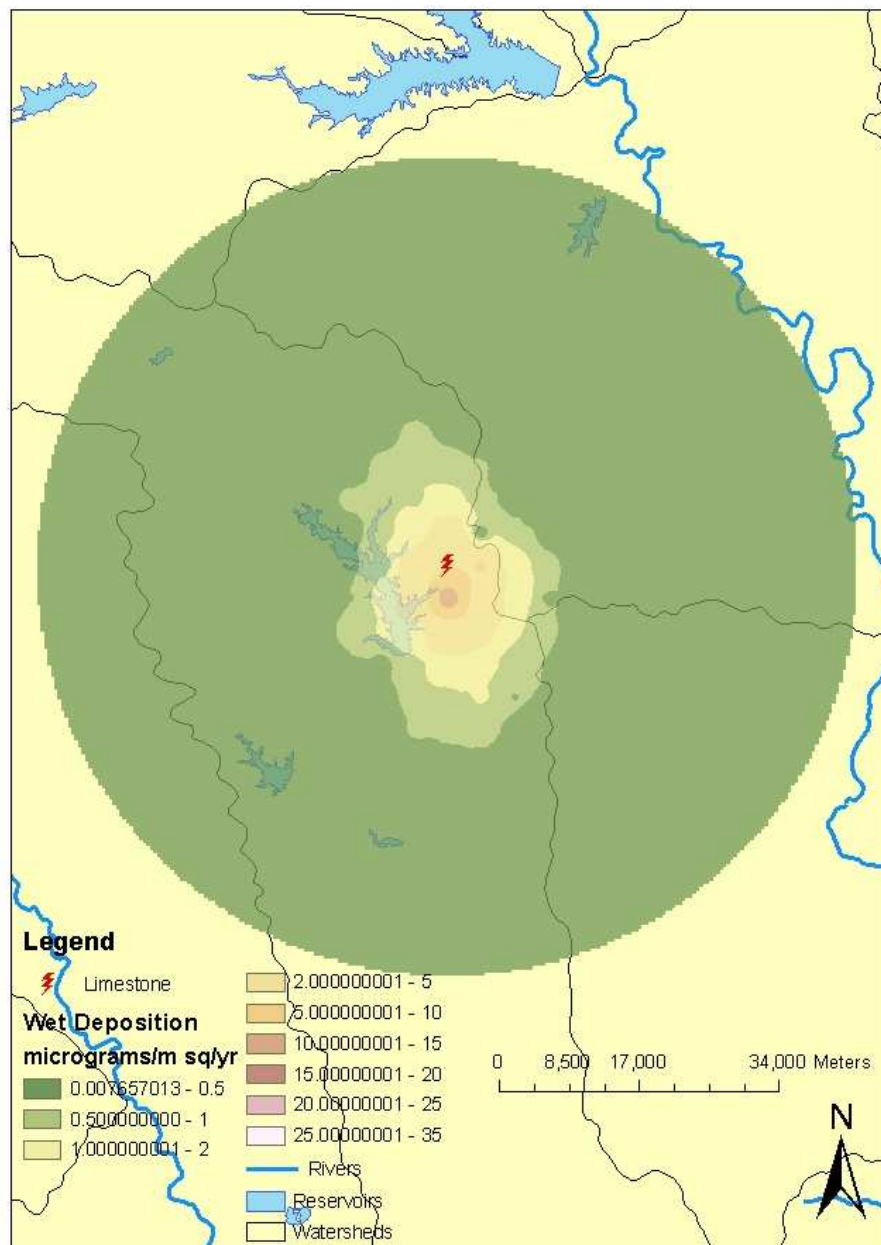


Fig. 10. Limestone – Average Wet Deposition 2003

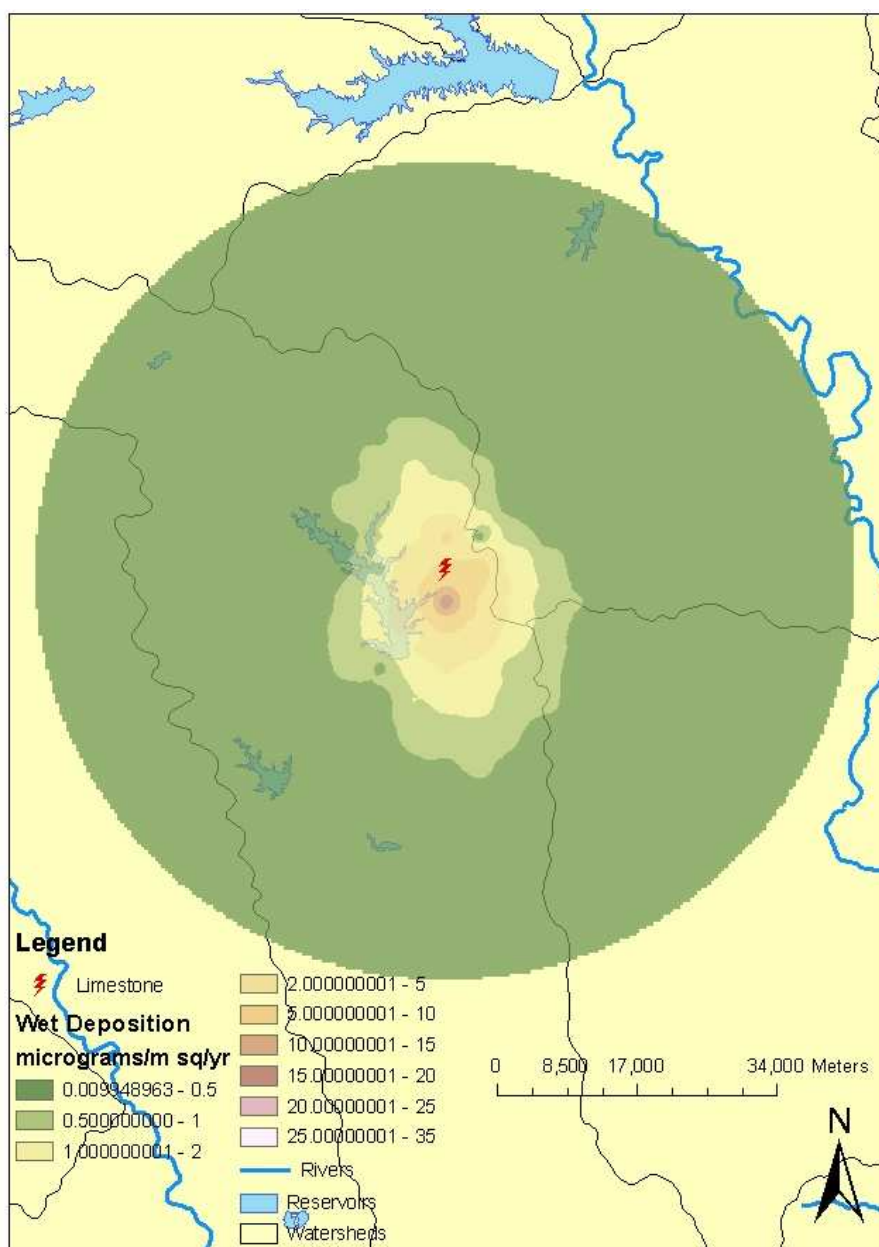


Fig. 11. Limestone – Maximum Wet Deposition 2003

Big Brown

The Big Brown Steam Electric Station is located just five miles northeast of Fairfield, Texas on the northern bank of Lake Fairfield. The plant is owned and operated by TXU and was the first lignite-fueled power plant constructed in Texas in 1971 (TXU 2005). The station fires lignite from nearby mines and also lignite from the Western

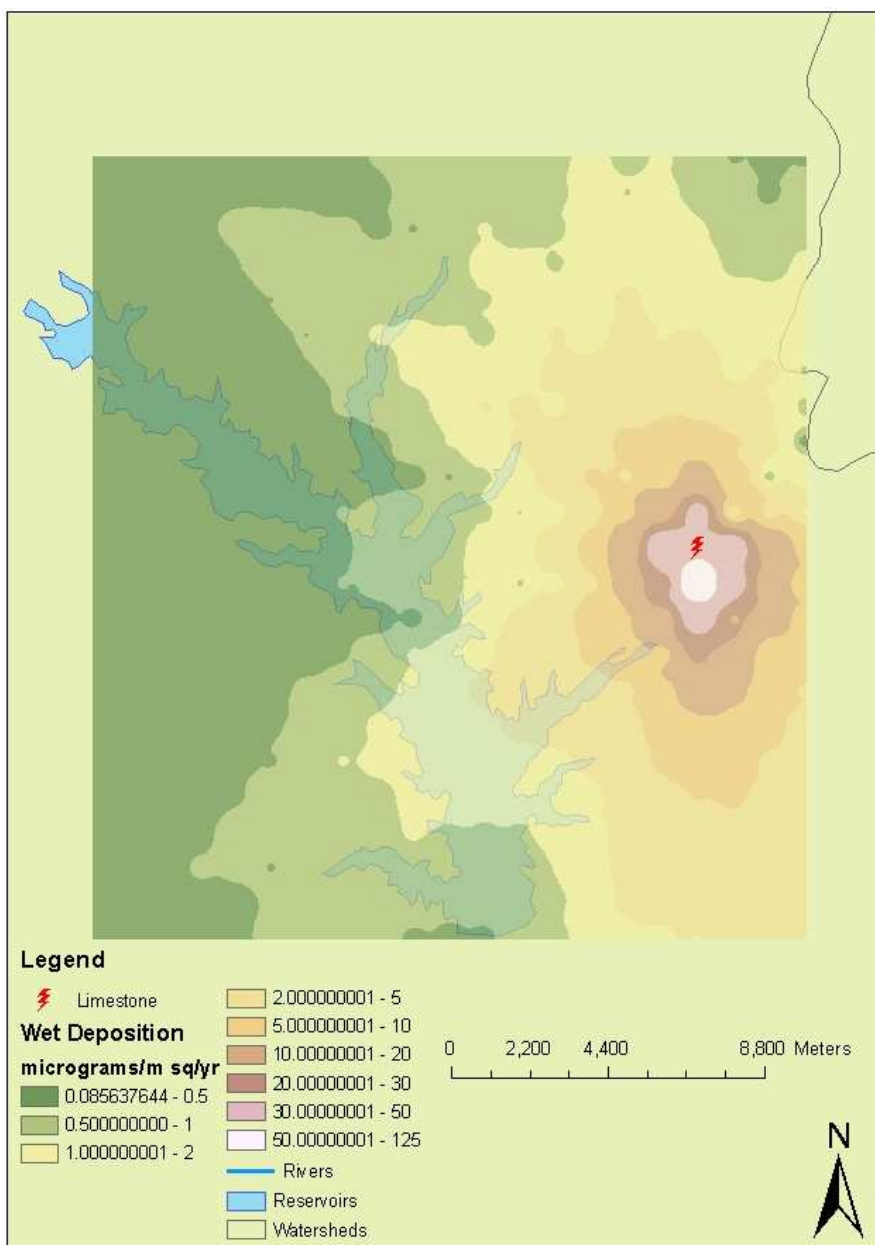


Fig. 12. Limestone – Average Deposition 2003 Close Grid Setup

United States (TXU 2005). It employs an ESP along with COPAHCs as a means of pollution control technology.

Flue gas is treated with sulfur trioxide and ammonia agents before entering the ESP. Once flue gas exits the boiler it enters the ESP where it exits to the COHPAC baghouses and is then funneled to the stack (METCO Environmental 1999).

In 2003, the plant reported 443 pounds of mercury releases to the air. Figures 13-15 represent mercury deposition in order of speciated flow rates: minimum, average, and maximum, displayed on a 50km radius grid.

Figure sixteen is the same modeling run using the average speciation flow rates on a much finer grid. This allows a clearer picture of how much and where deposition is occurring, since the vast majority is within 20 km of the plant.

The highest levels of mercury deposition were in the $30 - 50 \mu\text{g}/\text{m}^2/\text{yr}^{-1}$ range, occurring mostly to the south of the stacks within a few kilometers of release. The lake appears to receive a significant amount of the higher contour levels due to its location just to the south of the facility. This is due to the predominantly southern winds occurring during rainfall events.

Sandy Creek Power Plant

The Sandy Creek Energy Station is a proposed power generating facility to be located near the city of Riesel in McLennan County. Sandy Creek Energy Associates is proposing the power plant to be located on Lake Creek Lake approximately 40 kilometers from Waco. It will produce up to approximately 800 megawatts of electricity utilizing pulverized coal from the Powder River Basin.

Emission controls will include low NOx burners, over fire air, selective catalytic reduction, dry scrubbing, and baghouses. The current permit, which is still under review, allows up to 1,080 pounds of mercury releases to the air in a twelve month period.

Figures 16-18 represent deposition from 540 pounds of release (minimum deposition) and 1,080 pounds of release (maximum deposition). Speciation data is based

on the national average as provided by the EPA's mercury ICR (Sandy Creek Energy Associates, 2005).

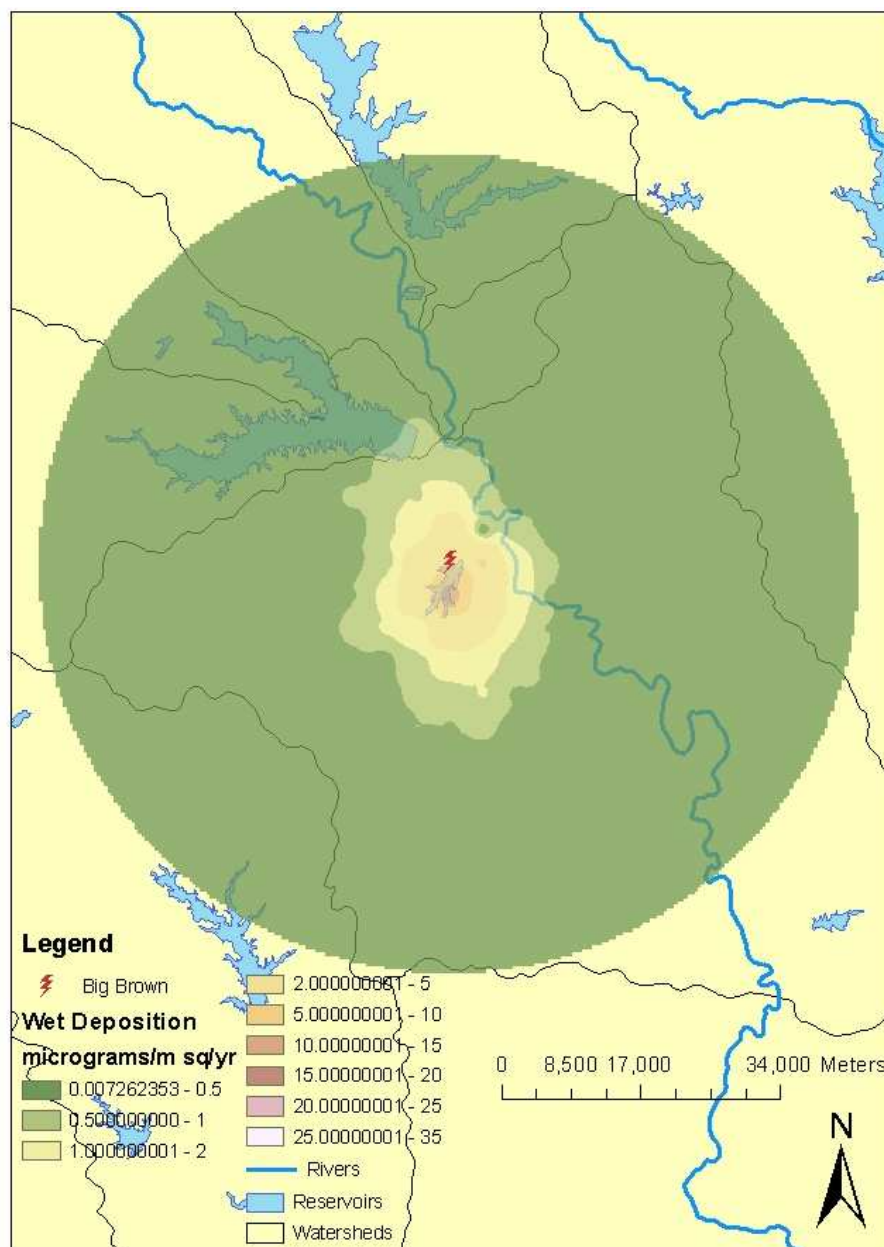


Fig. 13. Big Brown - Minimum Wet Deposition 2003

The most affected waterbody from the proposed Sandy Creek plant appears to be Lake Creek Lake (water source) and the Brazos River, receiving 50-125 $\mu\text{g}/\text{m}^2/\text{yr}^{-1}$ in

certain areas. Lake Waco the City of Waco appears to receive negligible deposition from the proposed plant.

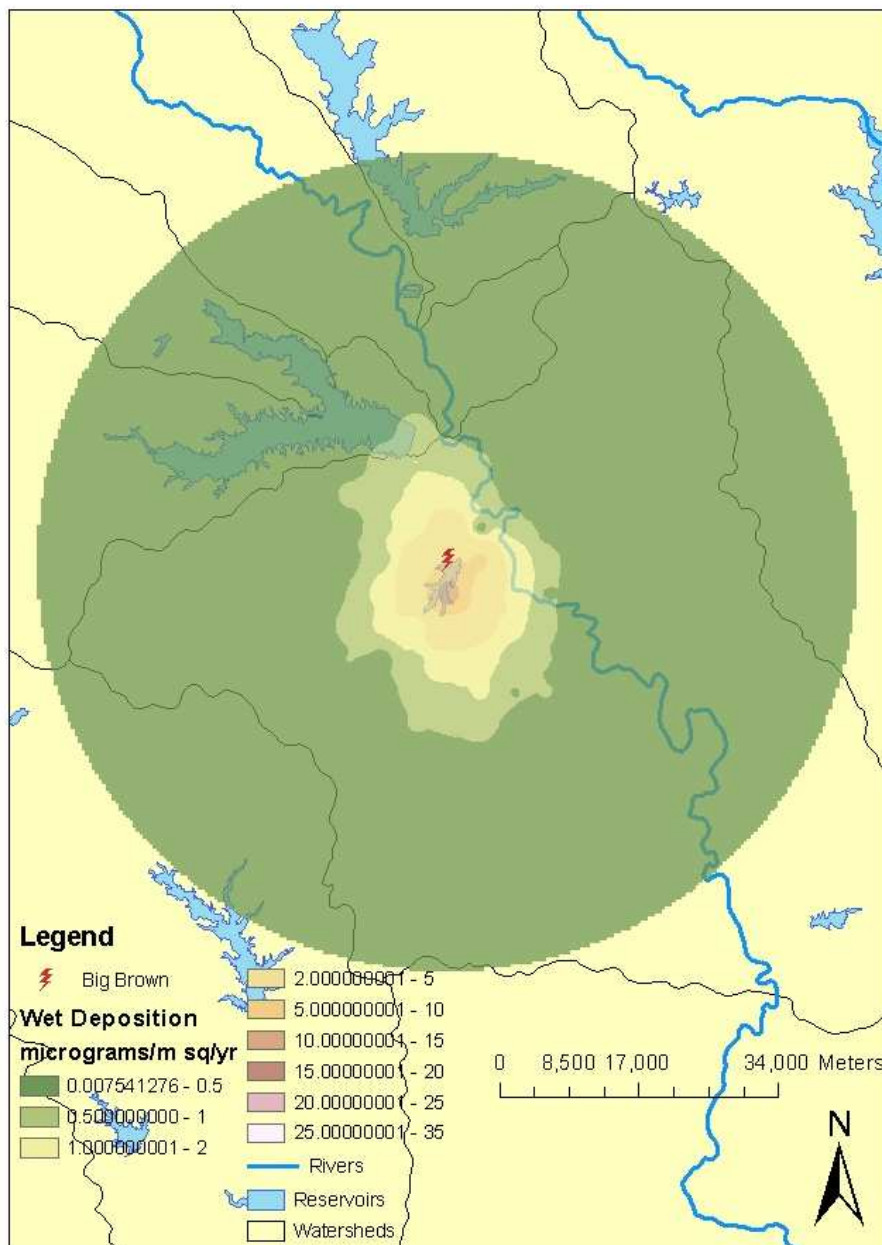


Fig. 14. Big Brown - Average Wet Deposition 2003

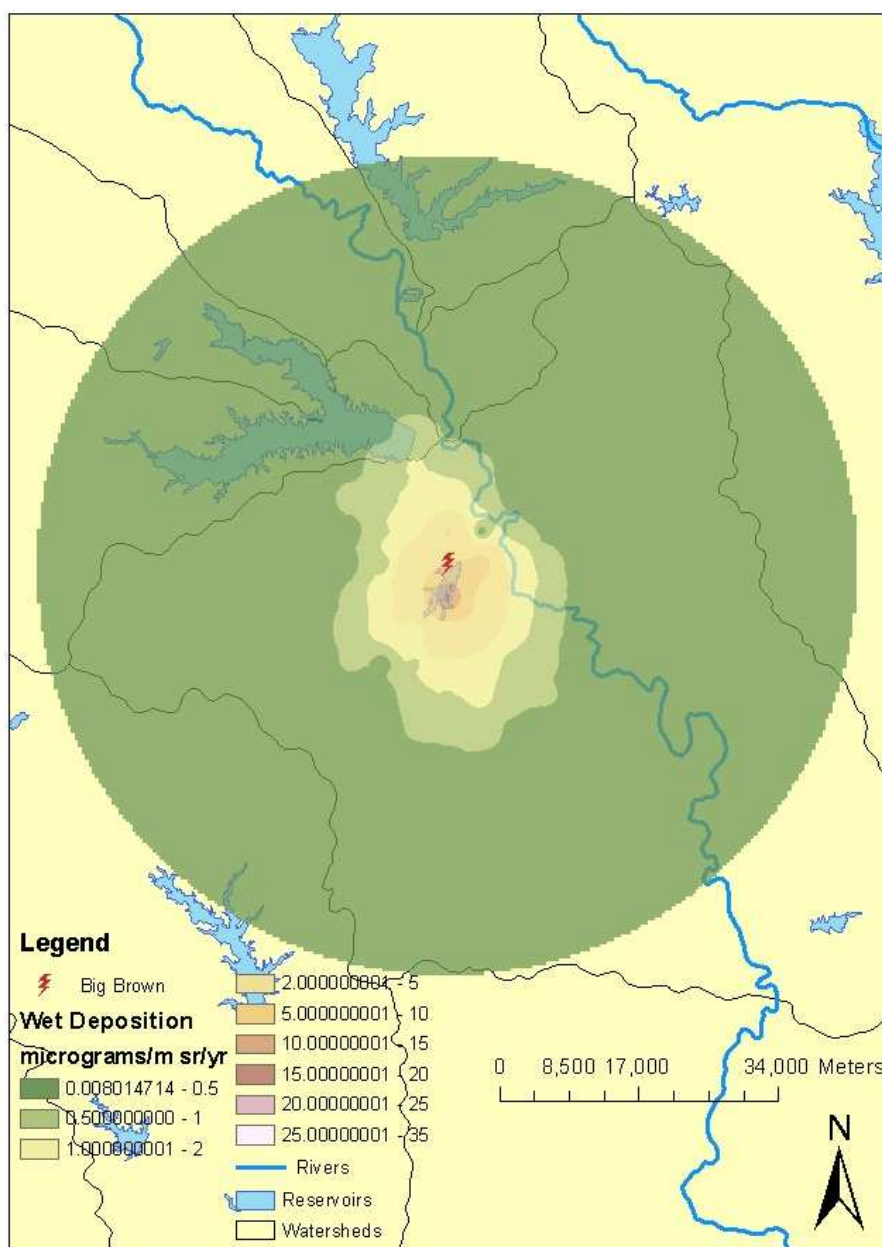


Fig. 15. Big Brown - Maximum Wet Deposition 2003

Validation of the Model

An attempt was made to validate the model in order to determine the accuracy of the predictions. Field sampling was conducted to determine low level mercury content in the water columns and sediments of Lake Limestone and Lake Fairfield. These two water bodies represent the two most impacted surface waters from modeling results.

Sampling results were used to assess the spatial correlation between empirical data and the mapped results.

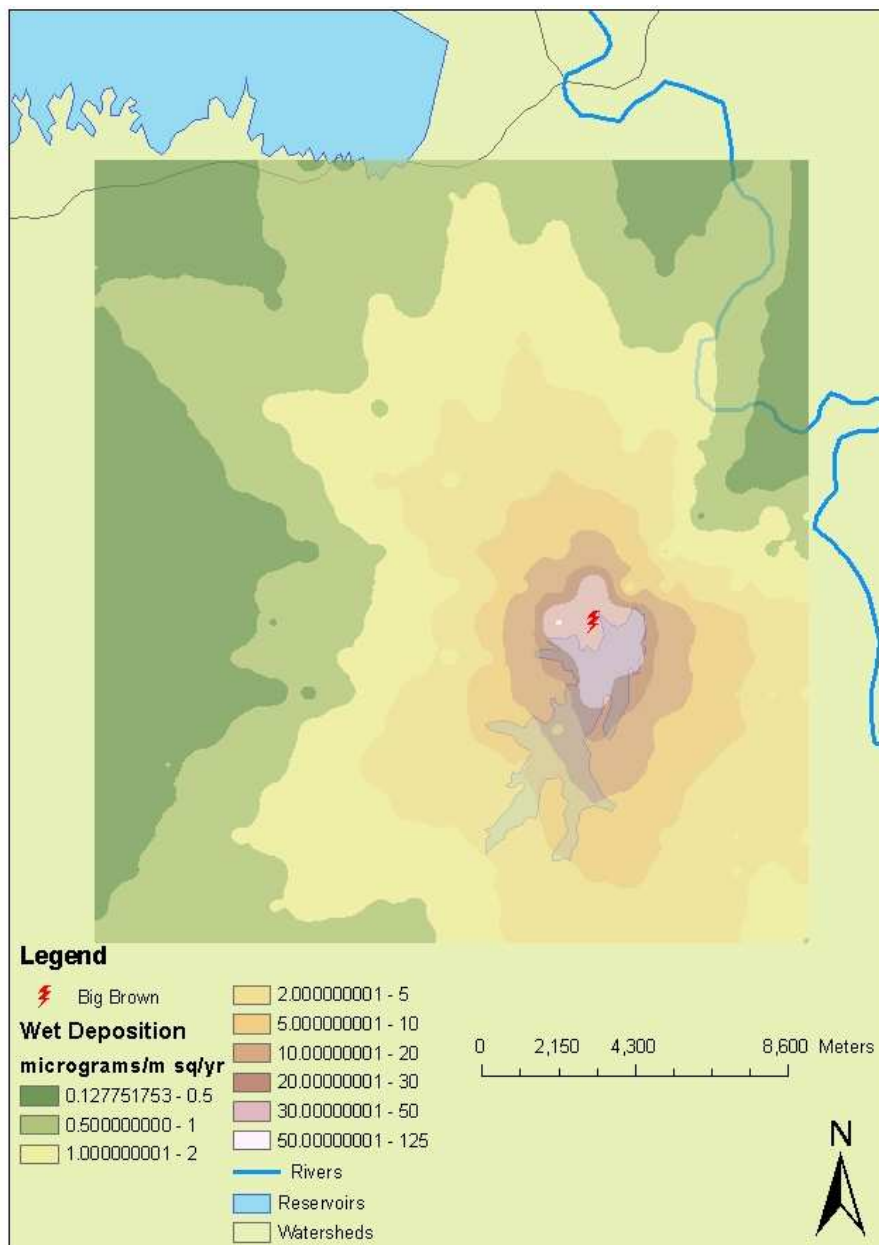


Fig. 16. Big Brown Average Wet Deposition 2003 Close Grid Setup

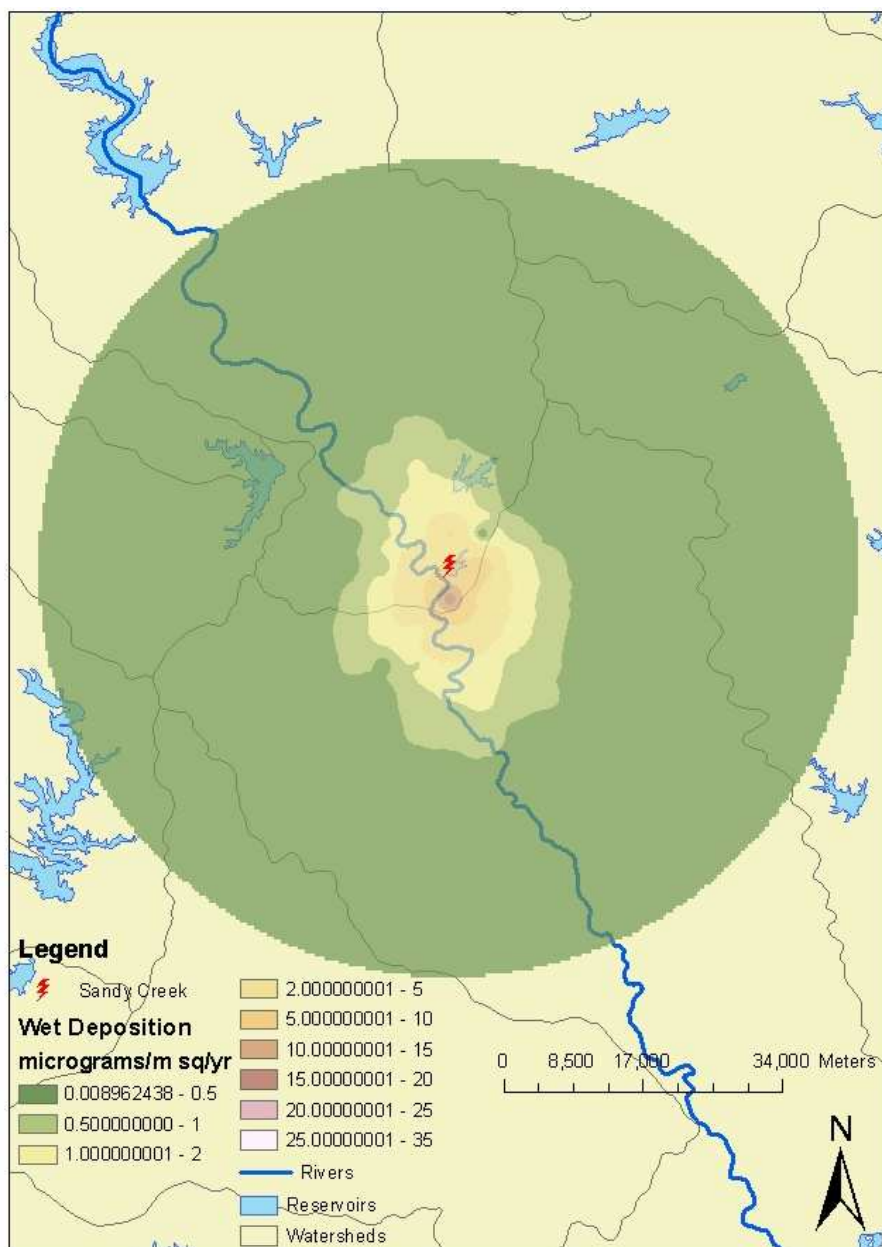


Fig. 17. Sandy Creek - Minimum Wet Deposition

Methods Used

Sampling for both lakes was conducted by Kleinfelder Environmental Consultants. Severn Trent Laboratories (STL) completed the low level mercury analysis in compliance with EPA's Method 1631: mercury in water by oxidation, purge and trap, and cold vapor atomic fluorescence spectrometry. STL provided Kleinfelder with the

proper pre-cleaned glass jars. Water samples were collected using methods using “clean hands dirty hands” procedures as cited in Methods 1669 and 1631.

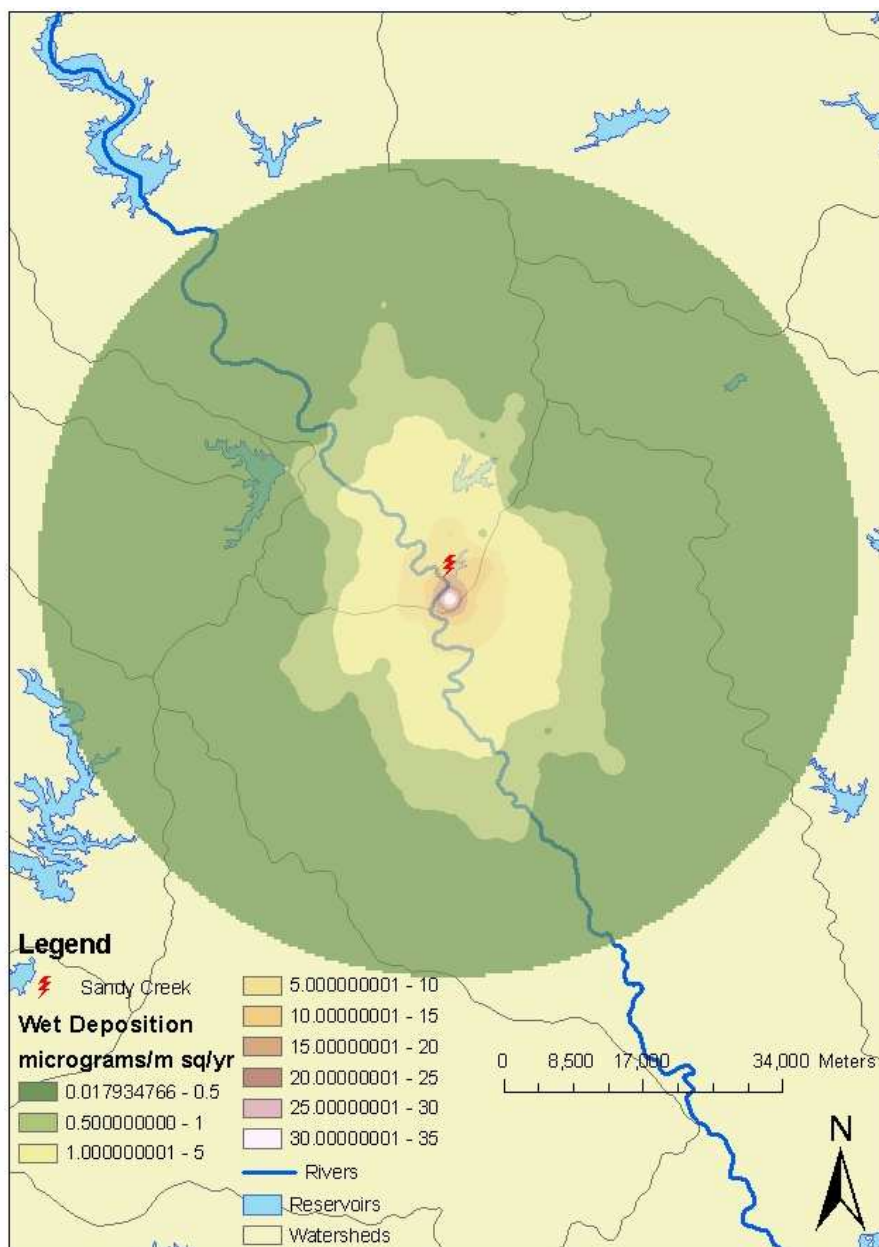


Fig. 18. Sandy Creek - Maximum Wet Deposition

A non-metallic canoe was used to collect the samples along with the appropriate shoulder length gloves and wind suits. Sample locations were approached from the down

wind and down current direction to avoid sample contamination. Water samples were collected approximately one foot below the water without allowing the sample to be exposed to air.

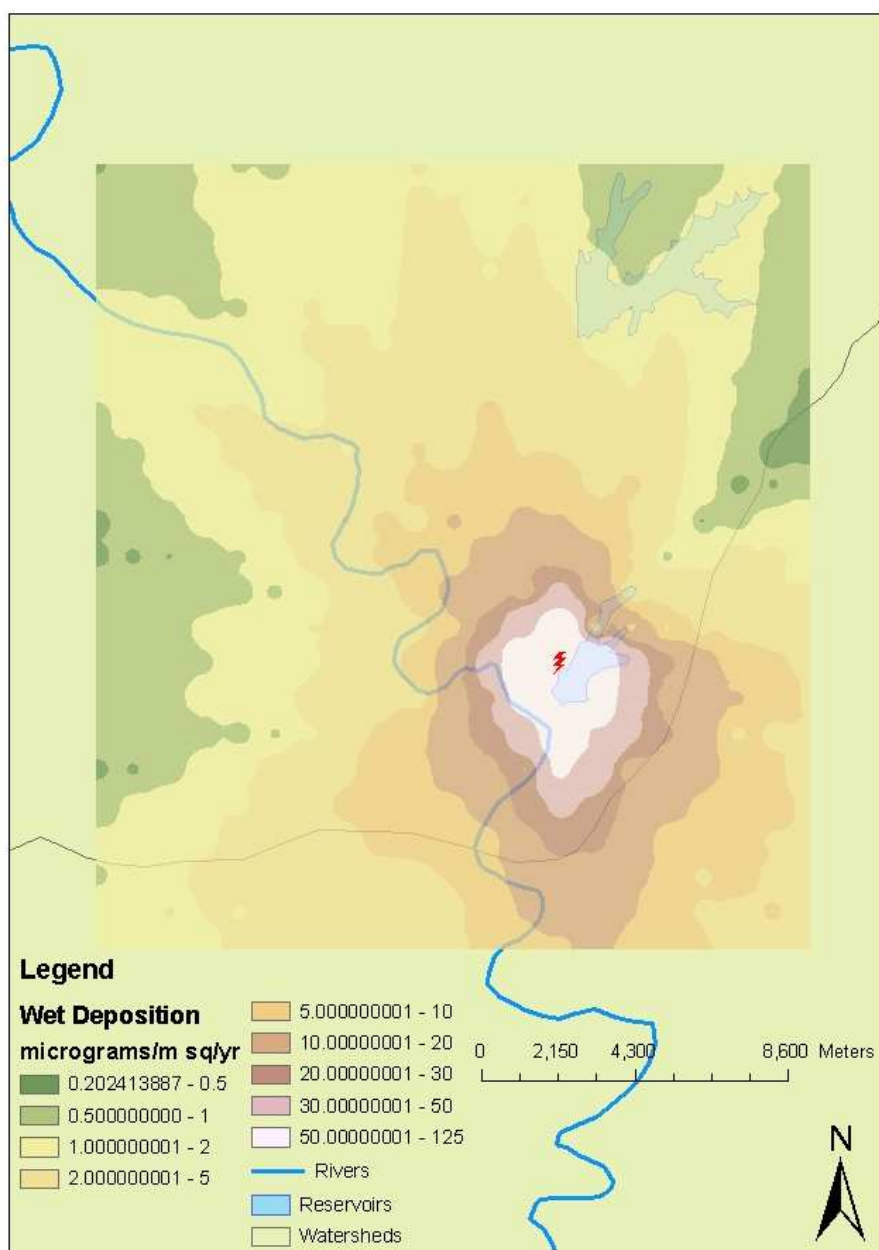


Fig. 19. Sandy Creek - Maximum Wet Deposition Close Grid Setup

Sediment samples at Lake Limestone were collected using a pvc pipe attached to a non-metallic pole. Sediment samples at Lake Fairfield were collected using a ponar device attached to a nylon rope. Sample (9a) (Lake Fairfield) was collected with a glass container, the sample was split and transferred through the ponar to a second glass container (S-9) in order to assess sample contamination from the ponar. Sediment samples were taken as grab samples during both sampling efforts. Field notes, chain of custody, and other documents pertaining to the sampling project are contained in the appendix B pages 79-100.

Lake Limestone

Three sediment samples, eleven water samples, and a field blank were collected at Lake Limestone. Numbers 11 and 6 are duplicate samples and were taken in succession. Figure twenty displays the sampling locations along with the modeling results.

The sediment and water column results of the Lake Limestone field testing project are displayed in tables six and seven.

Water

All water and sediment samples are well within or below the range for typical background levels, despite varying deposition gradients up to $20 \mu\text{g}/\text{m}^2/\text{yr}^{-1}$. Typical surface water content of mercury is generally 5 ng/L or less. The Texas Risk Based Exposure Level (TRBEL) level for human consumption of water and organism is 12 ng/L. The highest mercury content (sample 7) was obtained from the furthest reach of Lamb's Creek closest to the power plant. Five ng/L more than doubled any other surface water sample, but the mercury content measured was within range of typical background

mercury levels. Sample seven's location was the only area to fall within the 5-10 $\mu\text{g}/\text{m}^2/\text{yr}^{-1}$ range. This value represents a 42-83% increase in typical background wet deposition using 12 $\mu\text{g}/\text{m}^2$ as a yearly ambient wet deposition rate.

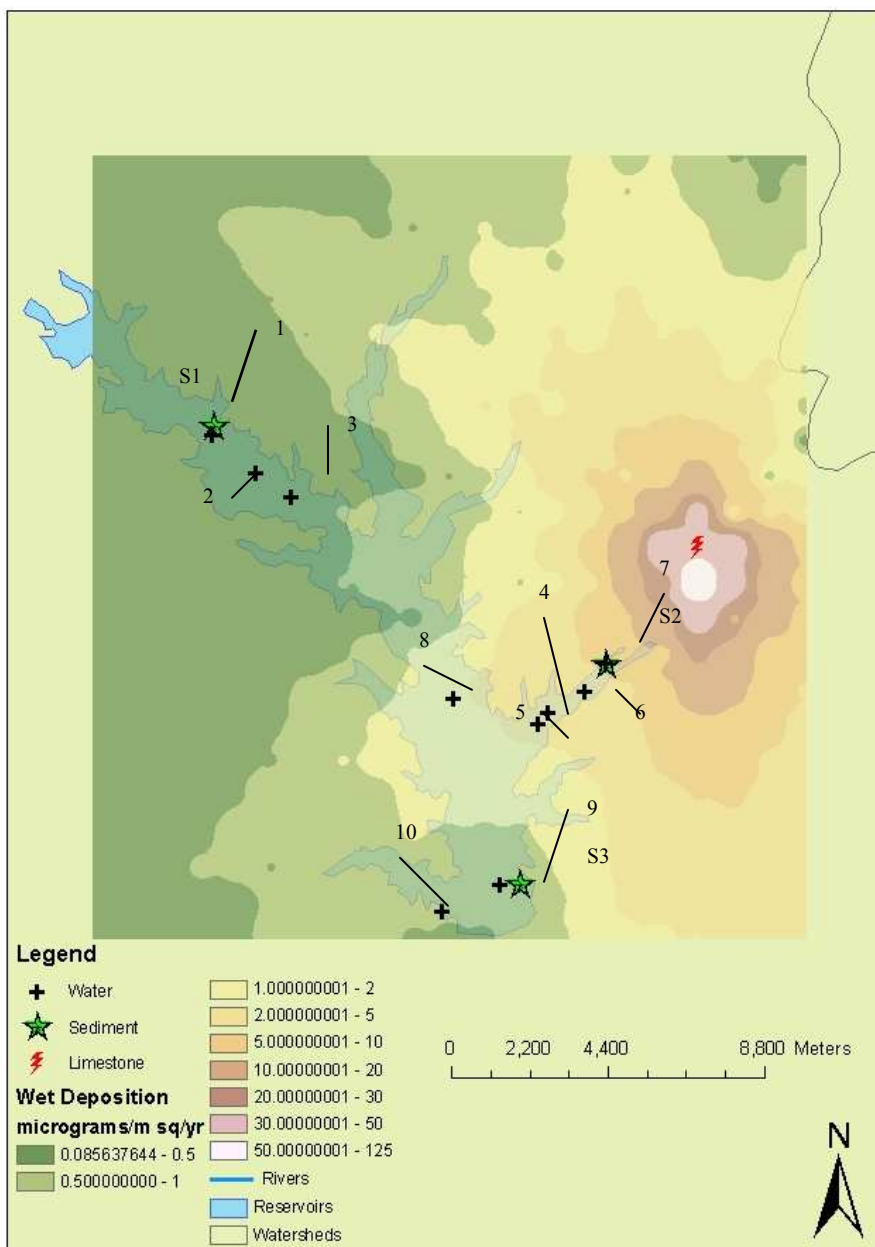


Fig. 20. Limestone Sampling Locations

TABLE 6
LIMESTONE WATER COLUMN DATA

Sample ID	Total Mercury ng/L
1	2.30
2	1.70
3	1.80
4	1.40
5	0.97
6	1.60
7	5.00
8	1.10
9	1.20
10	1.20
11	1.90
Field Blank	No Data

TABLE 7
LIMESTONE SEDIMENT DATA

Sample ID	Total Mercury µg/kg
1	06.8
2	49.9
3	01.3

Statistical Analysis

A Pearson Correlation was used to determine if a relationship existed between deposition and mercury content. The test was designed and conducted with the Minitab® statistical package to see if a relationship existed between the varying deposition gradients and elevated or decreased mercury levels. The Limestone water column data set contained ten samples falling across five different deposition gradients. Figure twenty-one below displays the data on a scatter plot with a linear correlation coefficient (r) drawn through the data.

The r value for the data set is 0.665 with a p value of 0.036. Due to the small sample size (n=10) the assumptions of normality cannot be met. Therefore, a non-

parametrical (Spearman's Rank) test was conducted to measure correlation between the variables. This test is a preferred measure of correlation with a small sample size or when possible outliers exist. Figure twenty-two displays the data on a scatterplot with a linear correlation coefficient (r) drawn through the data.

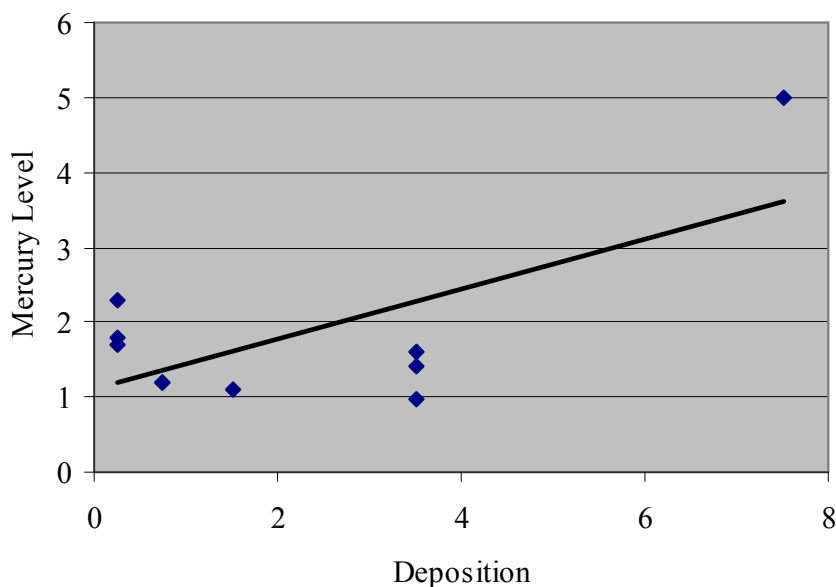


Fig. 21. Pearson Correlation for Lake Limestone Water Data

The r value for the Spearman Rank test is -0.188 with a p value of 0.604. This value represents a small inverse relationship between higher deposition gradients and increased mercury levels.

Sediment

Three sediment samples were taken from three distinct deposition gradients. While the sediment levels for sample seven's location were significantly higher (> 700%) than the other two, it is believed this has more to do with sediment type than location. The sediment in Lamb's creek was of a clay and loamy consistency, while the other two

sampling locations were grainy and sandy. All sediment samples were well within the range of typical background levels.

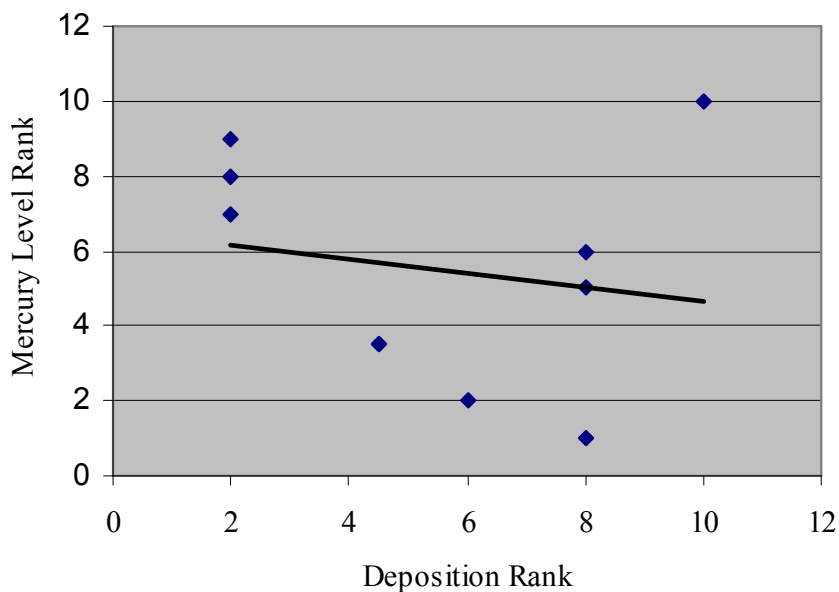


Fig. 22. Spearman's Rank for Lake Limestone Water Data

Lake Fairfield

Ten sediment samples along with two water samples were taking from Lake Fairfield as described in the methods section. Figure twenty-three displays sampling locations along with deposition contours .

As with Lake Limestone, sampling locations were done across different deposition contours in order to determine if spatial variations existed.

The sediment and water column results of the Lake Fairfield field testing project are displayed below in tables eight and nine.

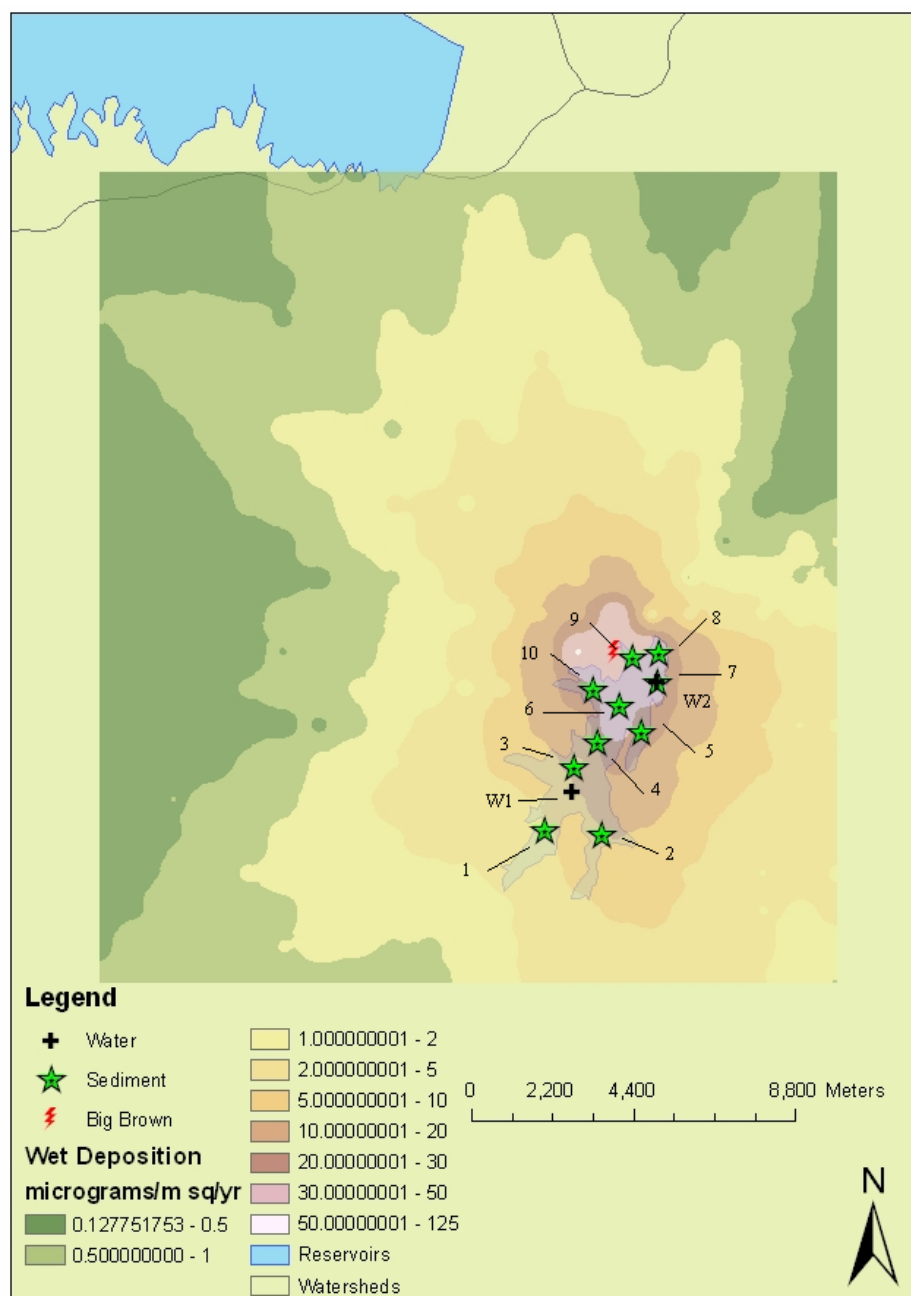


Fig. 23. Big Brown Sampling Locations

Sediment

Consistent with Lake Limestone, water and sediment samples appear to be similar across varying gradients. Both water and sediment samples were found with in typical range of background levels. Sediment samples varied also varied considerably with type.

The four sandy/grainy samples all exhibited levels under six $\mu\text{g/kg}$. Loamy/clay like samples fell within the range of 36 - 51 $\mu\text{g/kg}$. The Pearson Correlation was used to determine if a relationship existed between deposition gradients and empirical data. Only like sediment samples were compared in the analysis for consistency. Sandy sediment samples (7, 8, and 9) were excluded from the statistical analysis in order to avoid skewing the data. Five samples (water and sediment) were taken within the contour of 30-50 $\mu\text{g/m}^2\text{yr}^{-1}$. This level represents an increase above background levels of $\approx 250\text{-}400\%$, yet all environmental media appear to contain typical or below typical mercury levels.

TABLE 8

BIG BROWN SEDIMENT DATA

Sample ID	Total Mercury $\mu\text{g/kg}$
1	50.6
2	36.9
3	45.2
4	41.1
5	36.3
6	49.4
7	05.9
8	03.7
9a	03.9
9	04.9
10	41.1

TABLE 9

BIG BROWN WATER COLUMN DATA

Sample ID	Total Mercury ng/L
1	0.85
2	1.20

The Pearson Correlation revealed a value of 0.077 with a p value of 0.869. The scatterplot along with the linear regression line is displayed below in figure twenty-four.

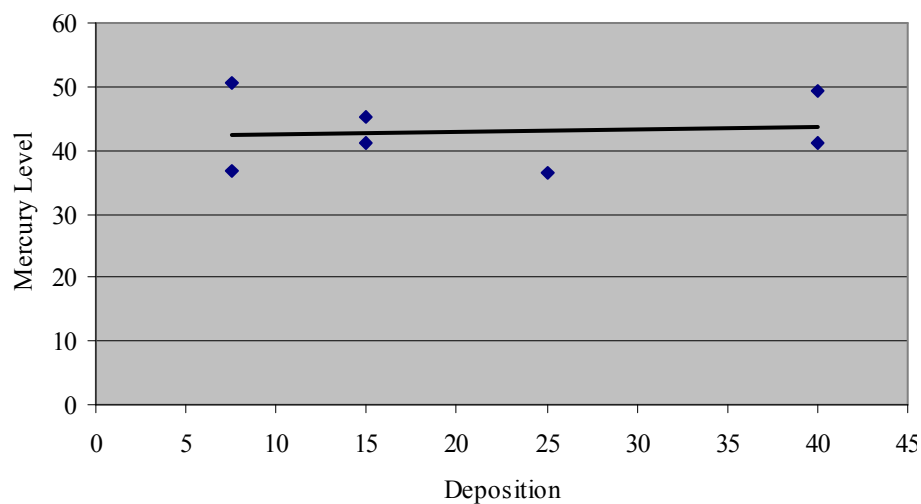


Fig. 24. Pearson Correlation for Big Brown Sediment Data

Water

A very small sample (n=2) was tested for mercury concentrations in the water column. As with Lake Limestone, both samples were consistent with ambient levels.

CHAPTER SIX

Conclusions

The primary objective of the research was to determine the amount of mercury being deposited via wet deposition from two existing coal-fired power plants in Central Texas, Big Brown and Limestone, and predict deposition from a proposed plant, Sandy Creek. Completion of research objectives required a series of sequential tasks related to identification of meteorological and topographical data and mercury loading at the plants. Other point sources of mercury pollution were also identified and examined in order to determine if empirical data taken from Lake Limestone and Lake Fairfield were affected by anthropogenic releases other than the power plants.

No point source facilities were discovered in the area believed to have significant effects on the lakes. Data was collected and collated on the power plants in order to complete the modeling runs. This process included collection of emissions, speciation data, weather data, plant parameters, and land use characteristics.

Modeling scenarios were then conducted for all three plants in order to determine deposition rates. Maps, using ESRI's ArcView software were created in order to reflect the output of the model. At-risk water bodies were identified and tested for mercury content in order to prove the accuracy of the models. Efficacy of the models was evaluated by collecting and analyzing sediment and water samples from the water bodies identified.

Statistical analyses of the water and sediment samples were conducted in order to determine if a statistically valid correlation existed between increased modeled deposition

and tested mercury levels. The Pearson Correlation conducted on Lake Limestone water samples revealed an r value of 0.665 with a p value of 0.036. The value represents a statistically valid correlation between elevated gradient values and elevated sample values. Examination of the data set merited a non-parametrical test to be conducted in case of the presence of outliers. The Spearman's Rank correlation test revealed an r value of -0.188 a slight inverse relationship with a p value of 0.604. Due to the relatively small sample size ($n=10$), and the apparent heteroscacity of the data points in the Spearman's Rank test, it is believed little or no correlation exists.

The Pearson Correlation conducted on sediment samples from Lake Fairfield revealed an r value of 0.077 with a p value of 0.869. This data set reveals no correlation between increased modeled values and increased sample values.

According to the research, the Central Texas power plants studied appear to be having no impact on the water quality of area surface waters. No spatial relationships appear to exist between proximity of the power plants and elevated mercury levels. Despite the fact that Big Brown is the oldest lignite fueled power plant in Texas, and has EPA established elevated oxidized mercury levels, its impact on water quality in Lake Fairfield appears to be negligible.

The modeling scenarios for the proposed Sandy Creek power plant estimate wet deposition to occur at a rate between 25 and 125 $\mu\text{g}/\text{m}^2/\text{yr}^{-1}$ at the most heavily impacted areas. This level represents more than double to slightly more than ten times estimated ambient wet deposition. According to the model, increased levels of deposition over one $\mu\text{g}/\text{m}^2/\text{yr}^{-1}$ are not occurring over 30km from the power plant. The heaviest levels of deposition occur within kilometers of the release point.

There are a number of reasons for why elevated mercury levels may not have been discovered, one could be explained by inaccuracy of the model. A fairly common complaint of the ISC model in the regulatory field is that it tends to over estimate deposition rates.

Another reason for inaccurate predictions could be the inputs. The model is only as precise as its inputs allow, and a number of assumptions were made. Weather data from the early 1990's was utilized in order to model emissions from 2003. Not only was the weather data dated, but the stations from where the data was collected were at times a hundred miles or more from the actual plants. Weather patterns affecting plume dispersion could have greatly differentiated from the data collection stations. The speciation data that is of such great importance for estimating local deposition was derived from only three test runs in the late 1990's. Different plant operating scenarios produce different levels of GEM, RGM, and particulate mercury. Modeling was conducted using an estimated speciation rate from the ICR throughout the entire year. Emissions inputs were also subject to assumptions. Total output provided by the TRI was modeled as occurring evenly across the entire year.

A third explanation for no evidence of anthropogenic releases affecting the surface waters studied is the lakes ability to transform mercury allowing its release back into the atmosphere. In order to determine the validity this explanation, deposition rates would have to be quantified and near surface chemical interactions studied. Fish tissue data would be useful in providing answers to this hypothesis due to the bio-accumulative properties of methyl mercury. A scenario could exist where water and sediment contain normal mercury levels while fish tissue levels are elevated. Empirical data on mercury

content in rainfall would also determine whether increased deposition is occurring and being released. The method of rainfall analysis is how the MDN creates its deposition maps.

There may however be significant loading in other media, i.e. biological tissue such as fish and plants. However, quantification and evaluation of these media was beyond the scope of the study.

Changes to the modeling study could be made at several instances. The plants could have been modeled with the newer AERMOD model which is viewed as an overall improvement over ISC. A procedure could have been designed to estimate variable emissions of mercury based on output of energy. This would have allowed for emission rates to be modeled on a month to month basis. Weather data from 2003 could have been compared to other years when surface data was collected. This might have produced an older data set being used with more similar weather patterns. Lastly, instead of using national ICR averages to predict Sandy Creek's speciation rates, unique estimates could have been provided through an examination of a plant with similar pollution control devices.

This research could be used in a more comprehensive Central Texas mercury studies. The next step beyond a local deposition study would be a watershed study. The work represented in this study creates a framework to integrate a soil, water, and biota study that tracks the movement of mercury across and within a particular watershed.

APPENDICES

APPENDIX A

Air Concentration Maps

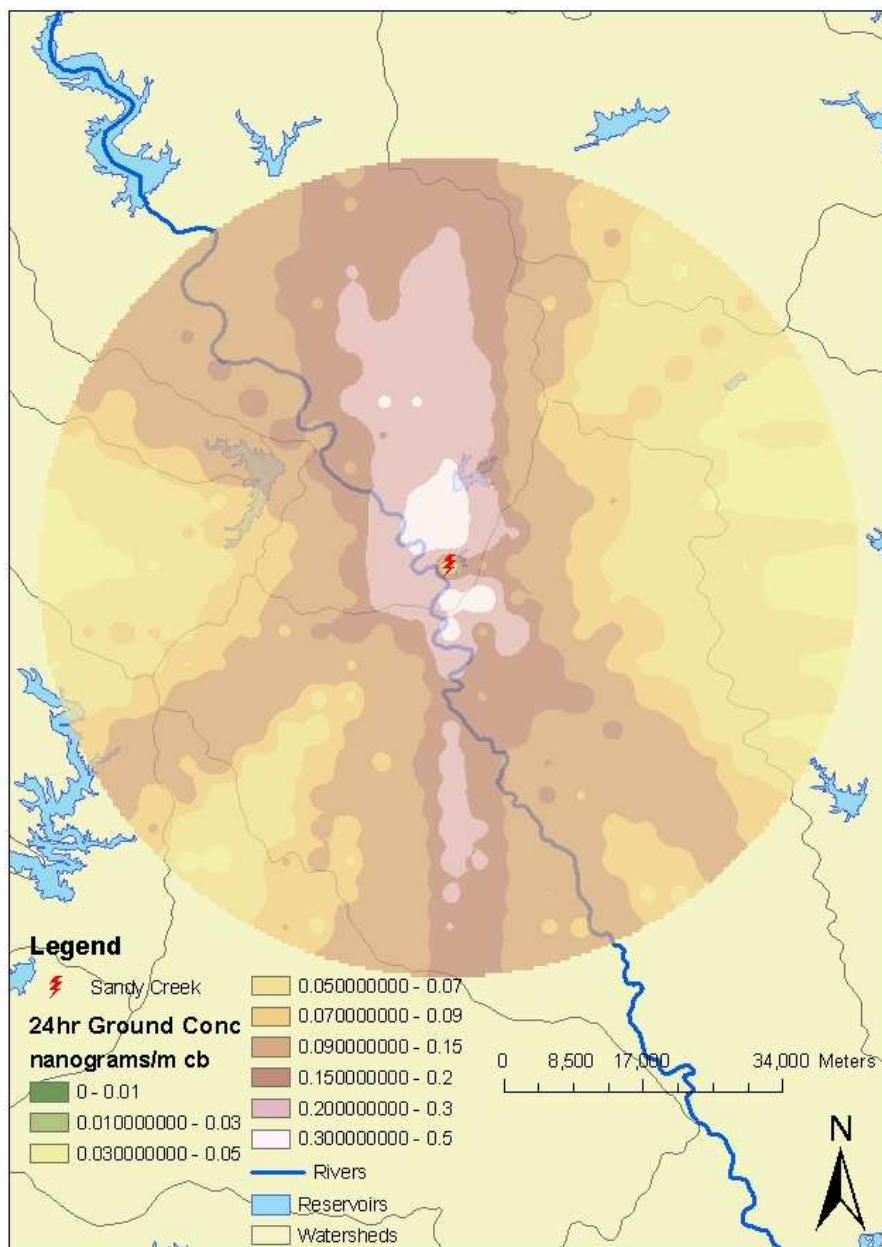


Fig. 25. Sandy Creek 24hr High Maximum

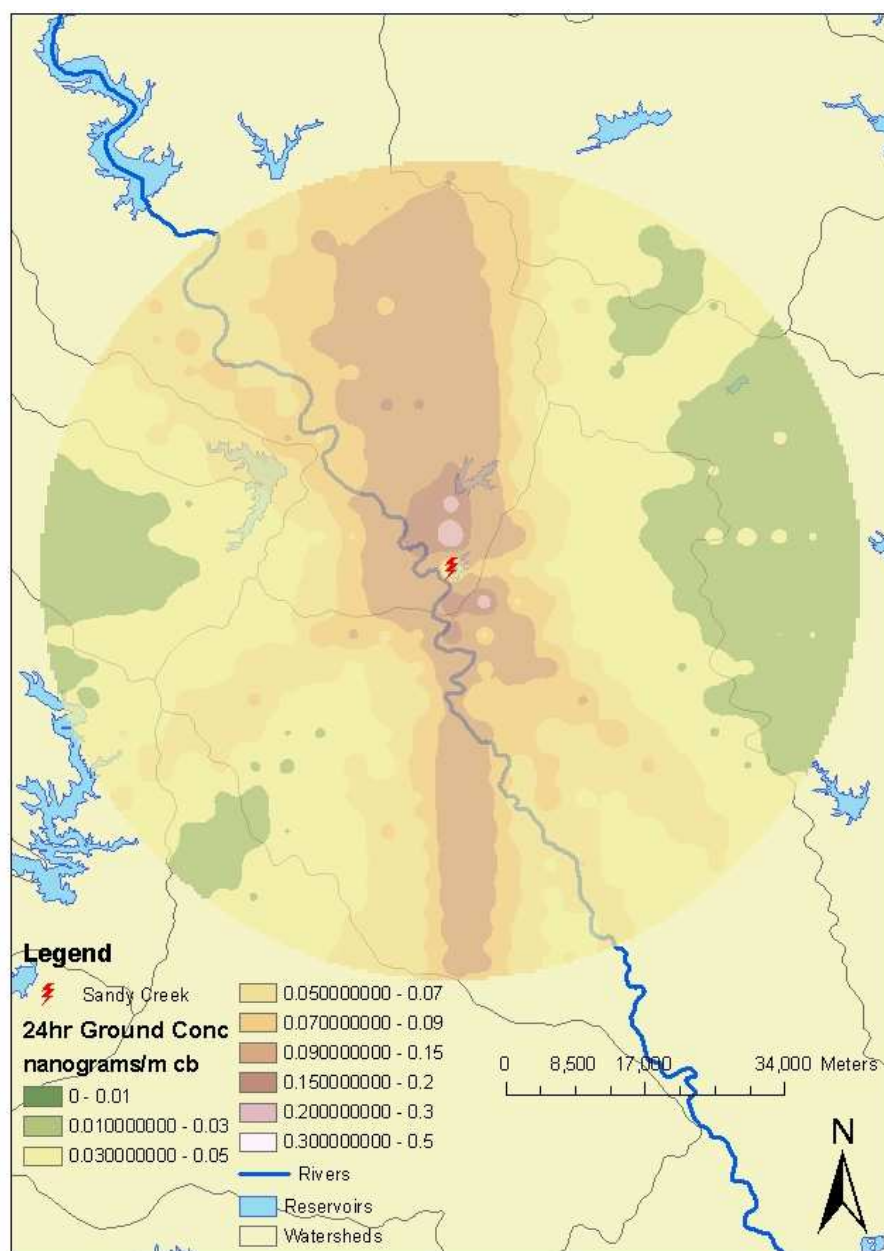


Fig. 26. Sandy Creek 24hr High Minimum

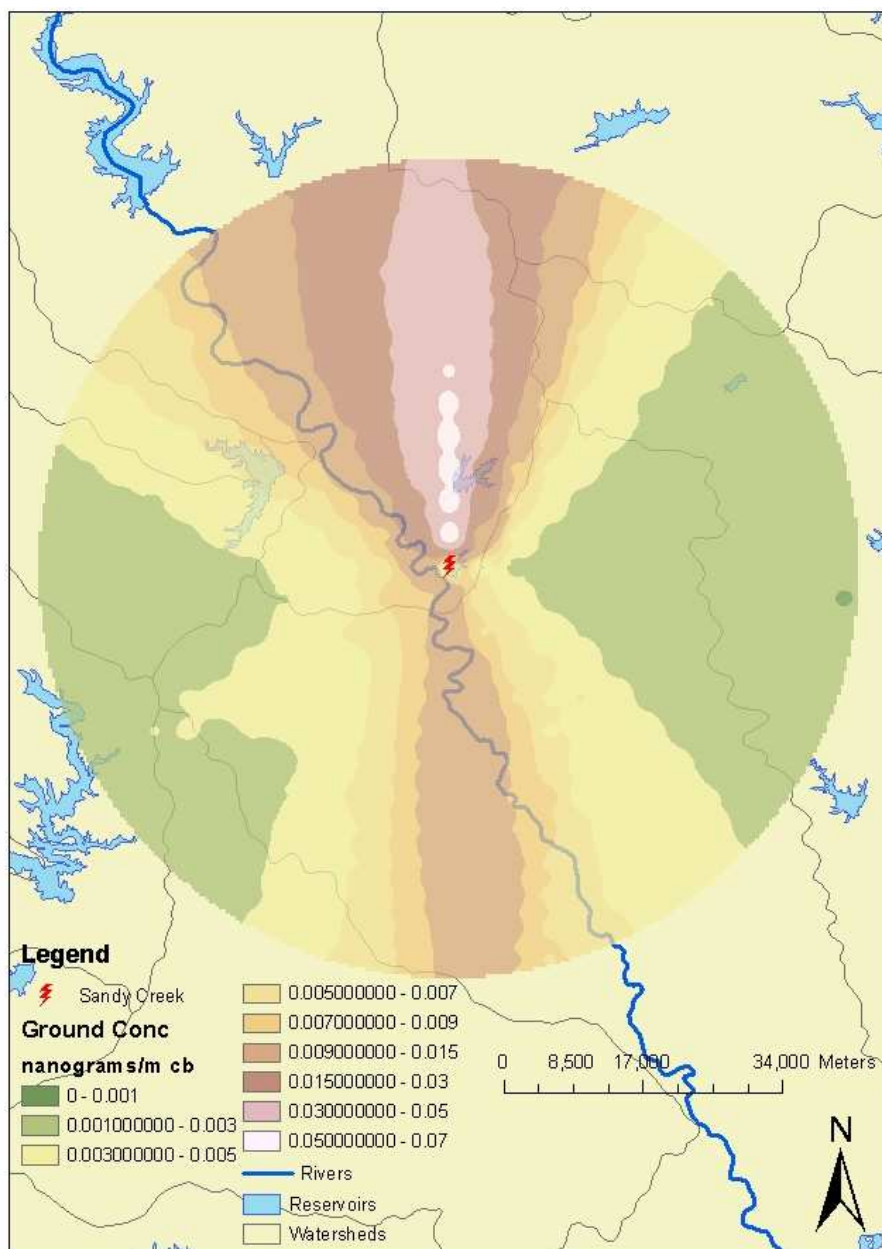


Fig. 27. Sandy Creek Maximum Concentration

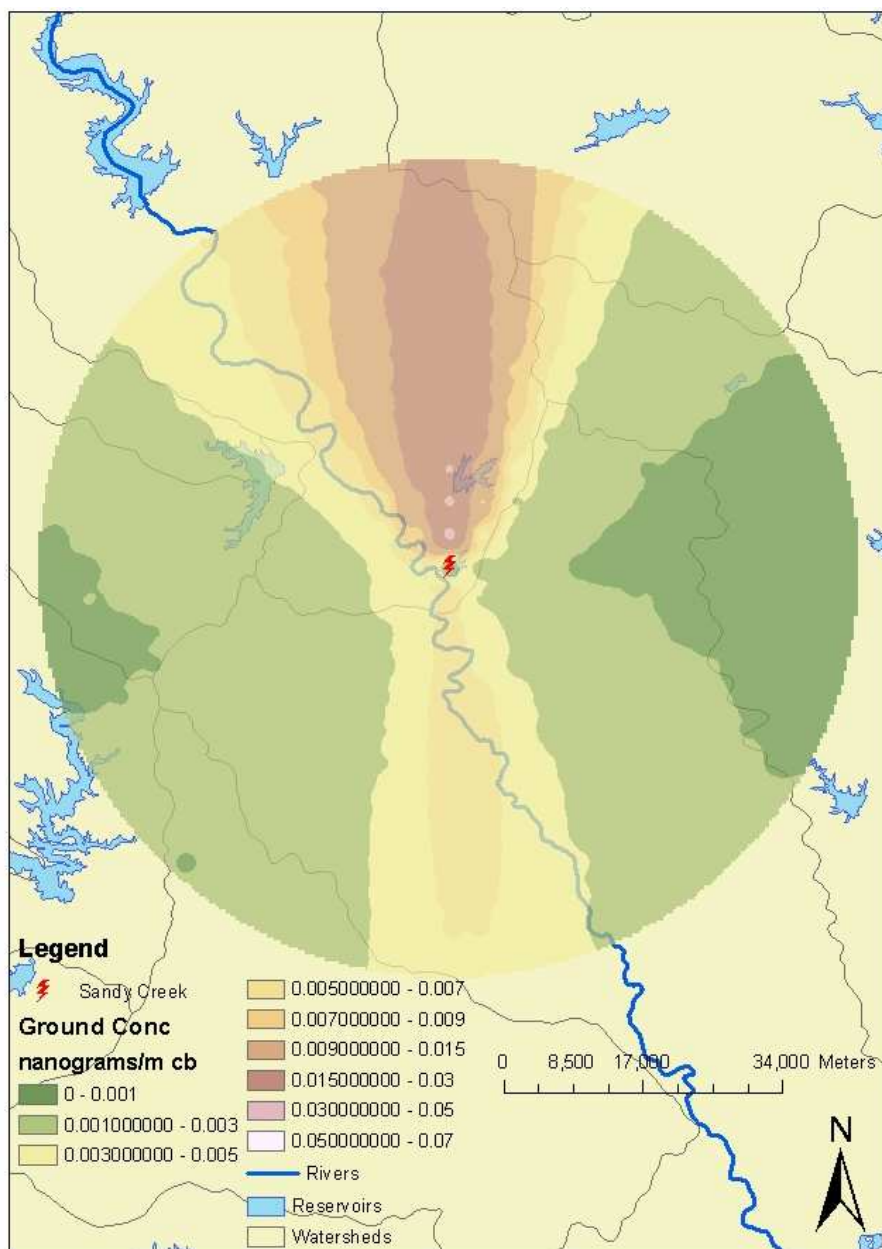


Fig. 28. Sandy Creek Minimum Concentration

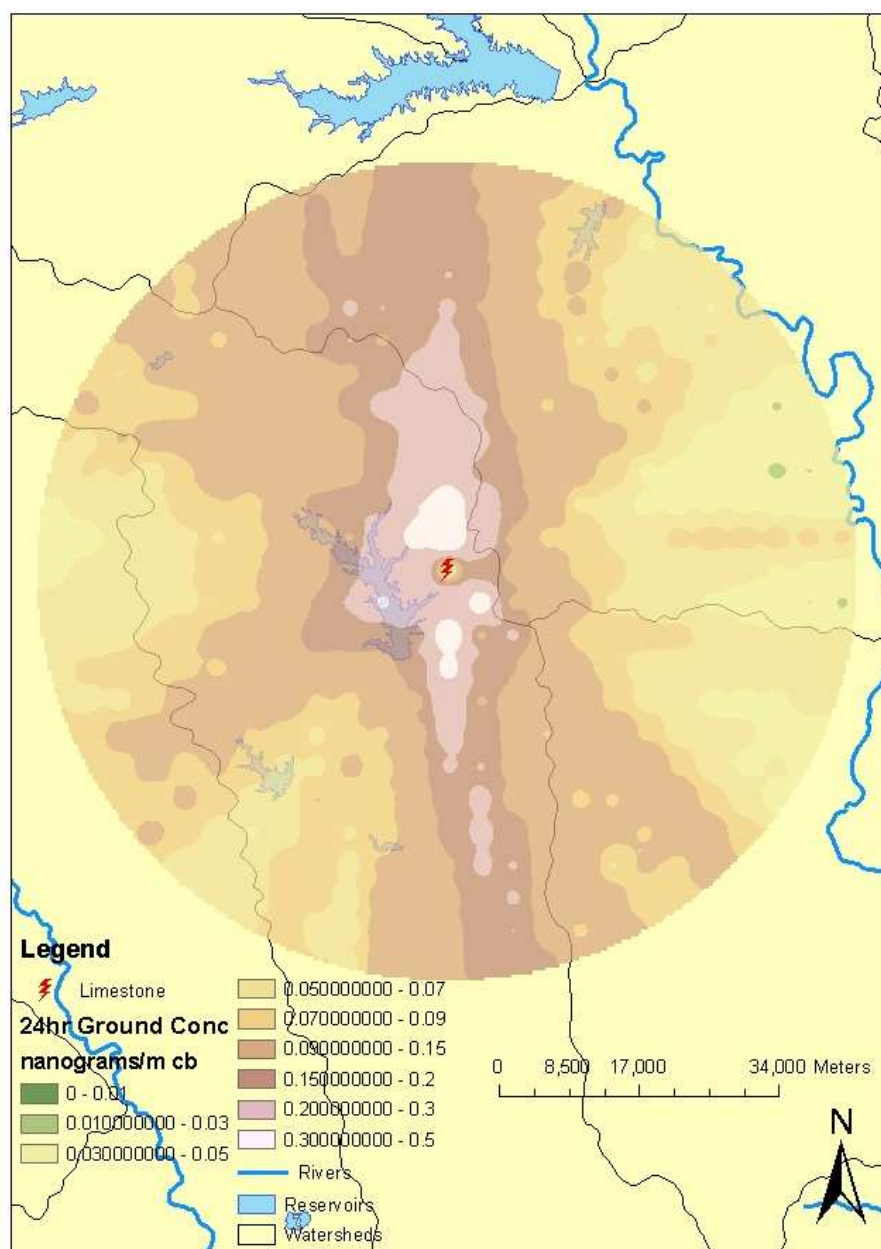


Fig. 29. Limestone 24hr High Maximum

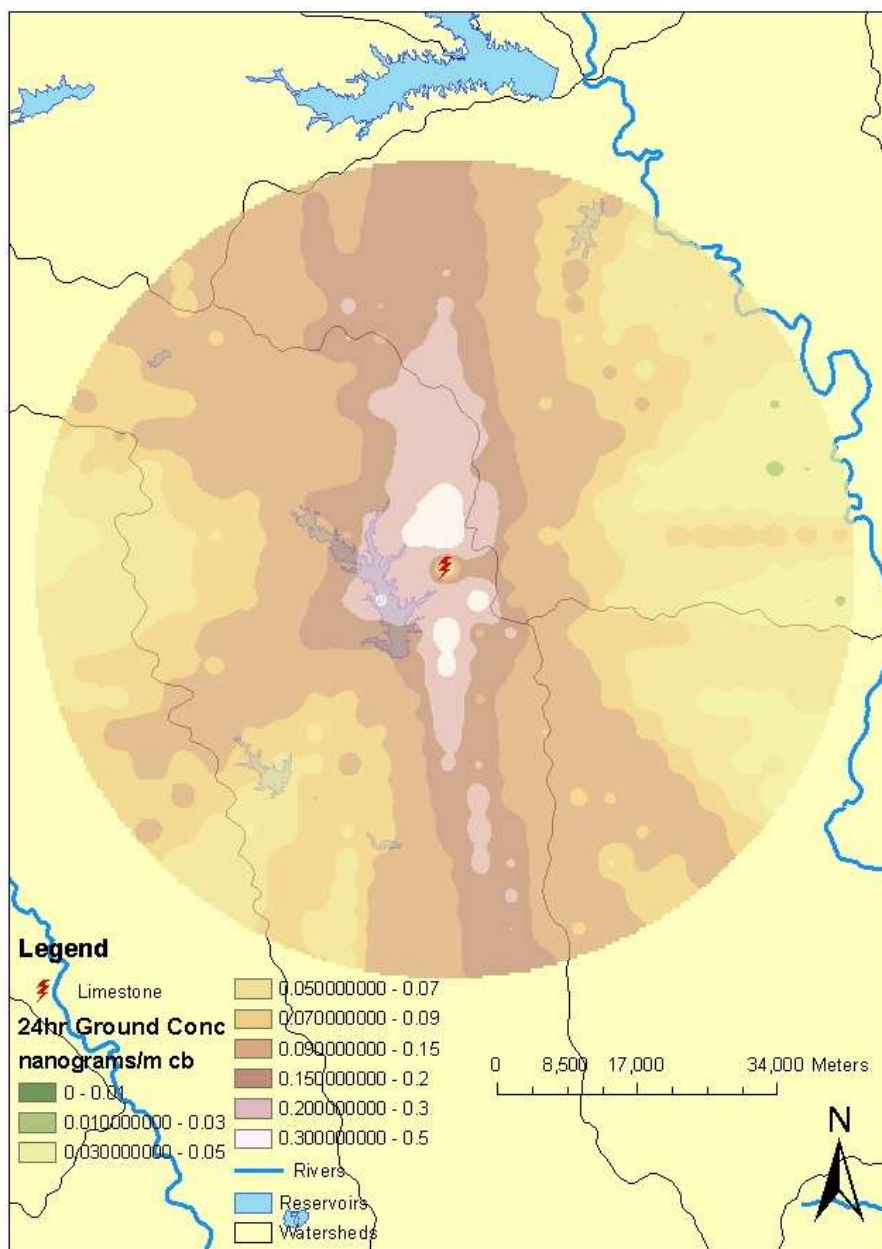


Fig. 30. Limestone 24hr High Average

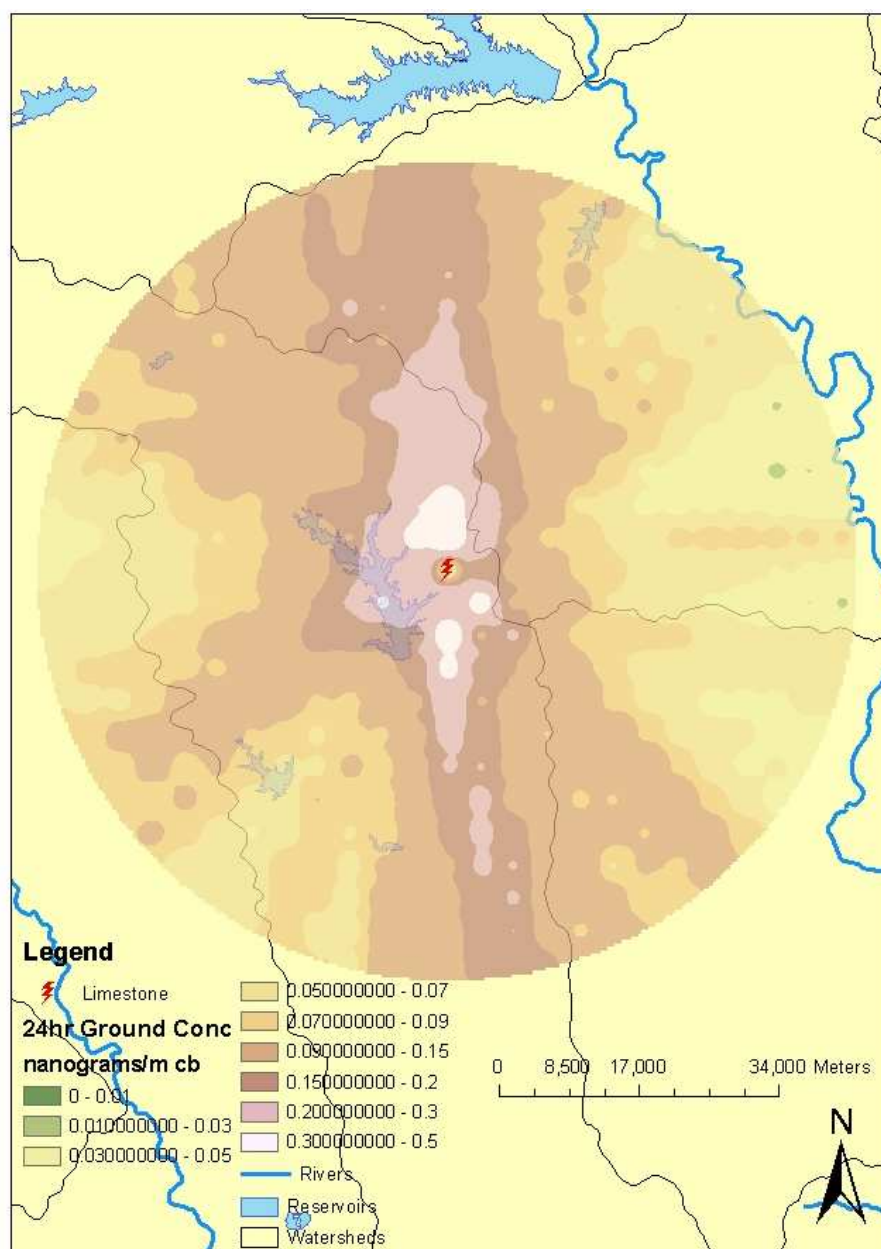


Fig. 31. Limestone 24hr High Minimum

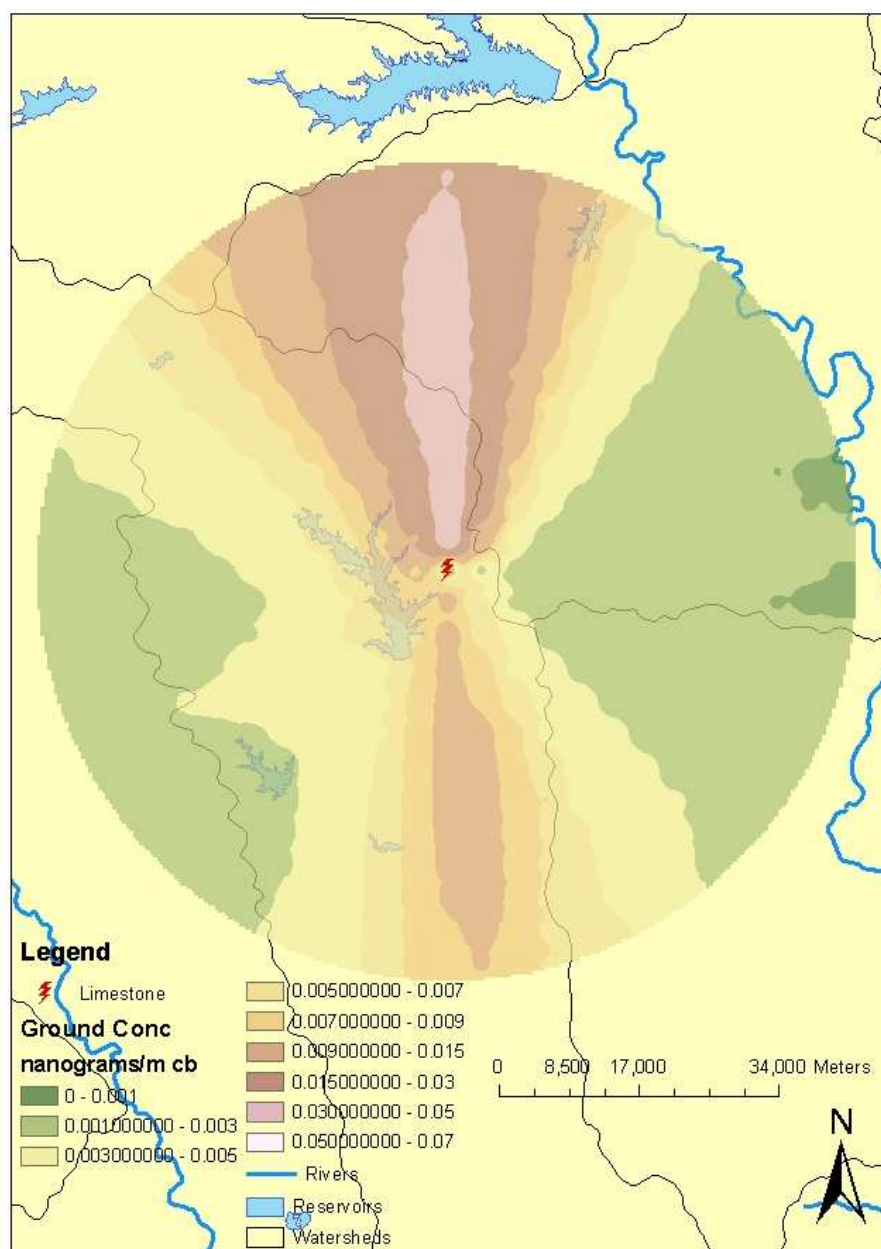


Fig. 32. Limestone Maximum Concentration

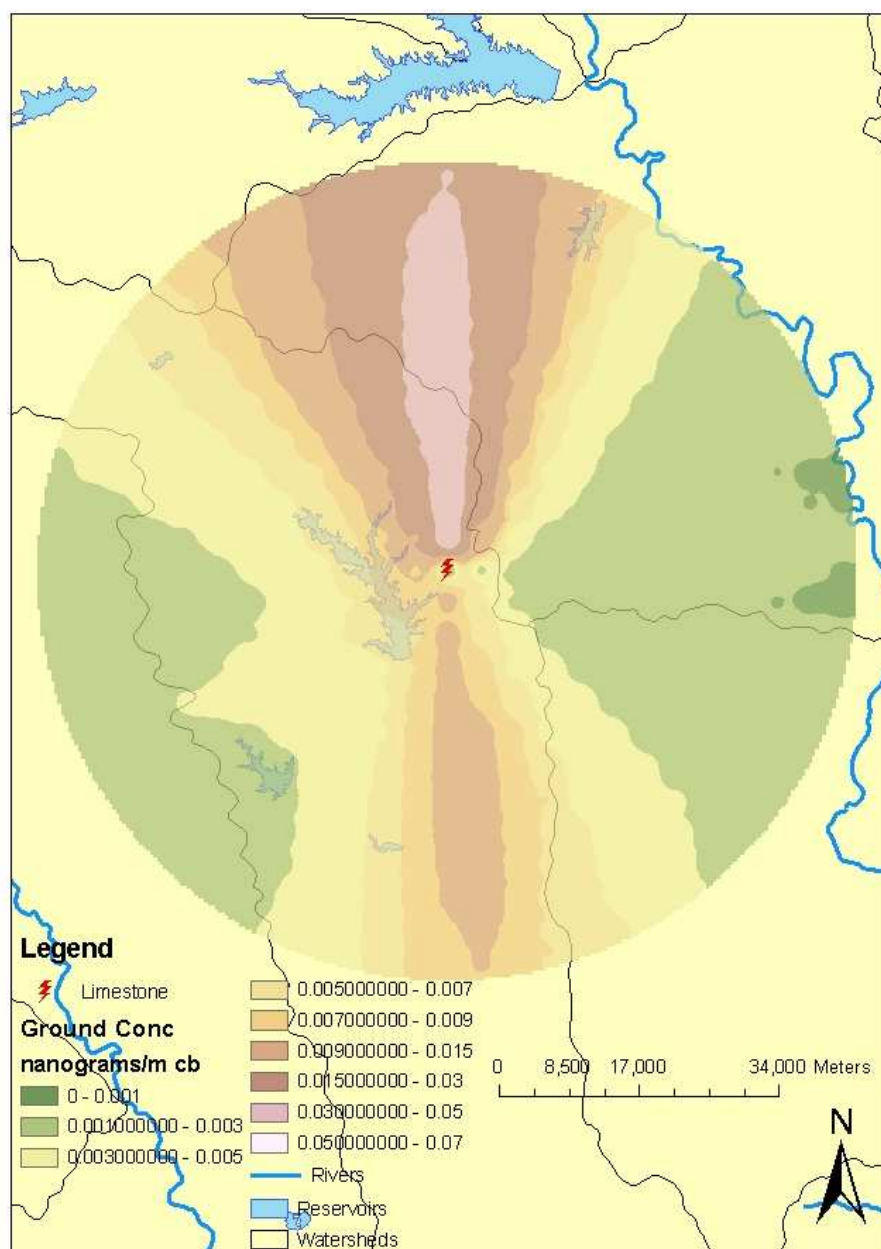


Fig. 33. Limestone Average Concentration

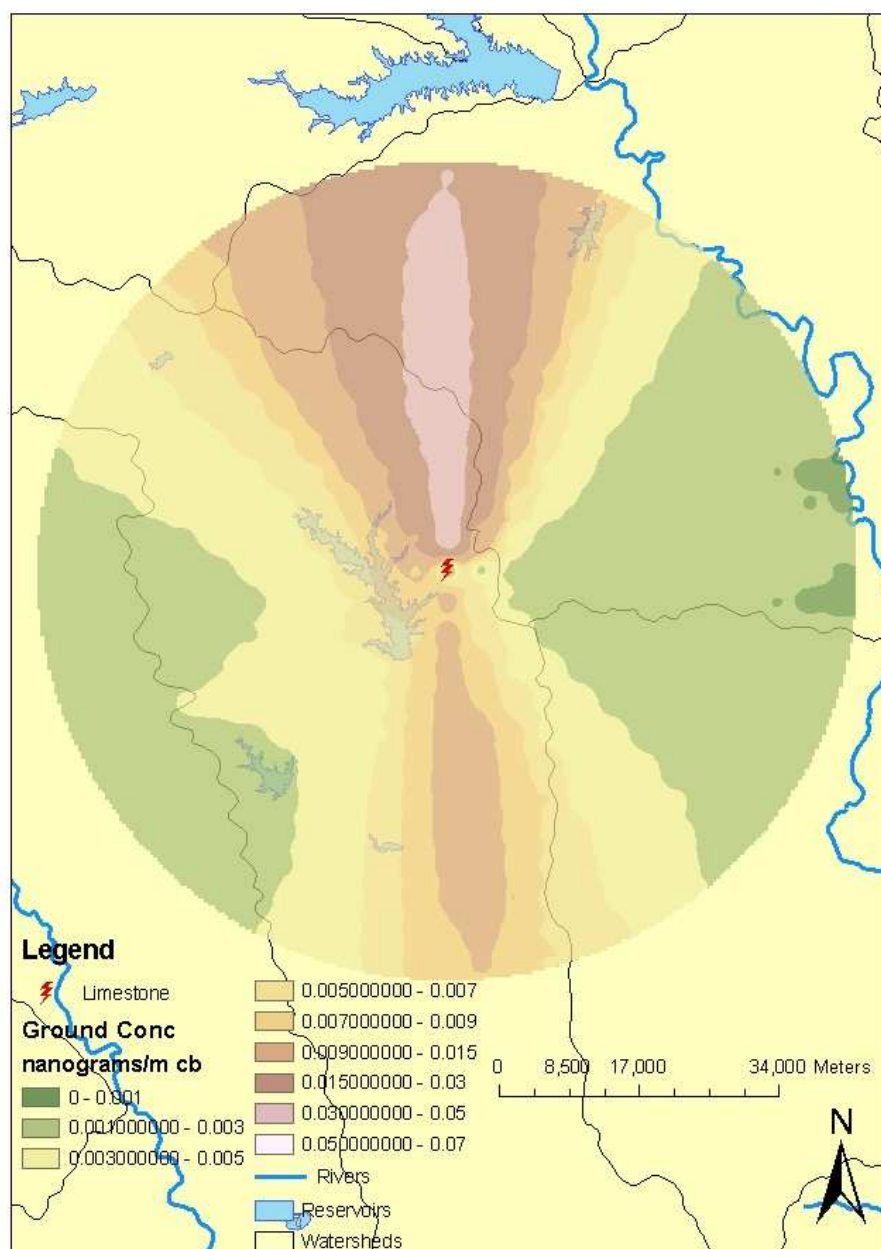


Fig. 34. Limestone Minimum Concentration

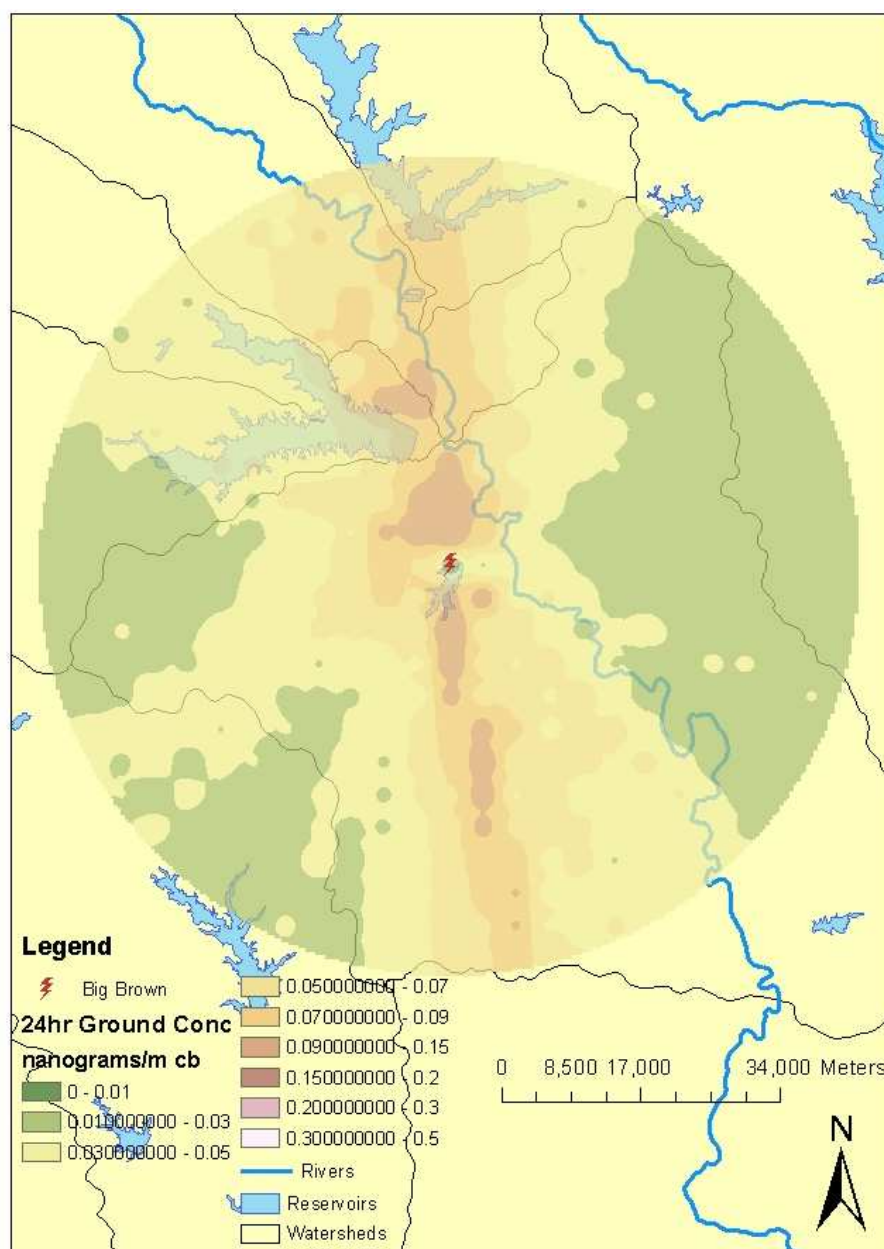


Fig. 35. Big Brown 24hr High Maximum

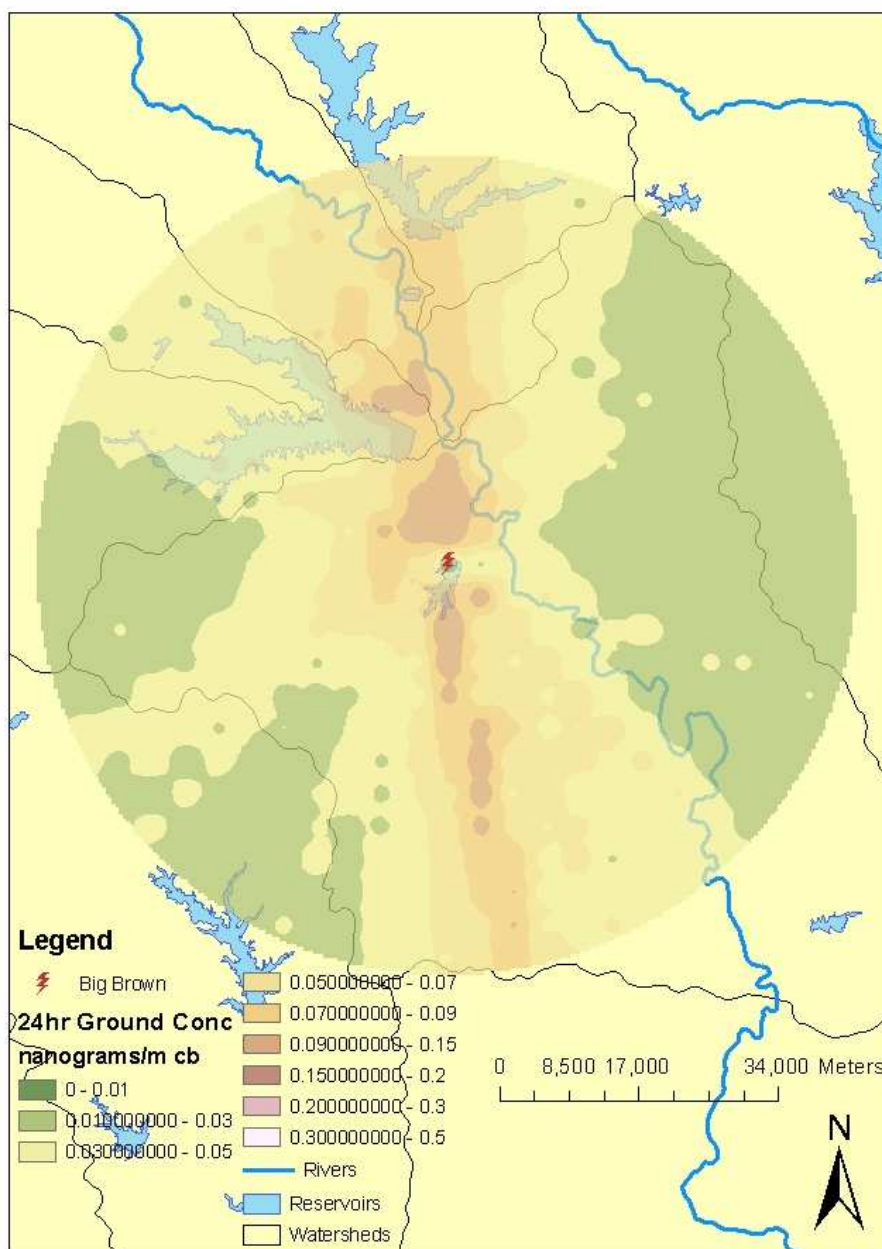


Fig. 36. Big Brown 24hr High Average

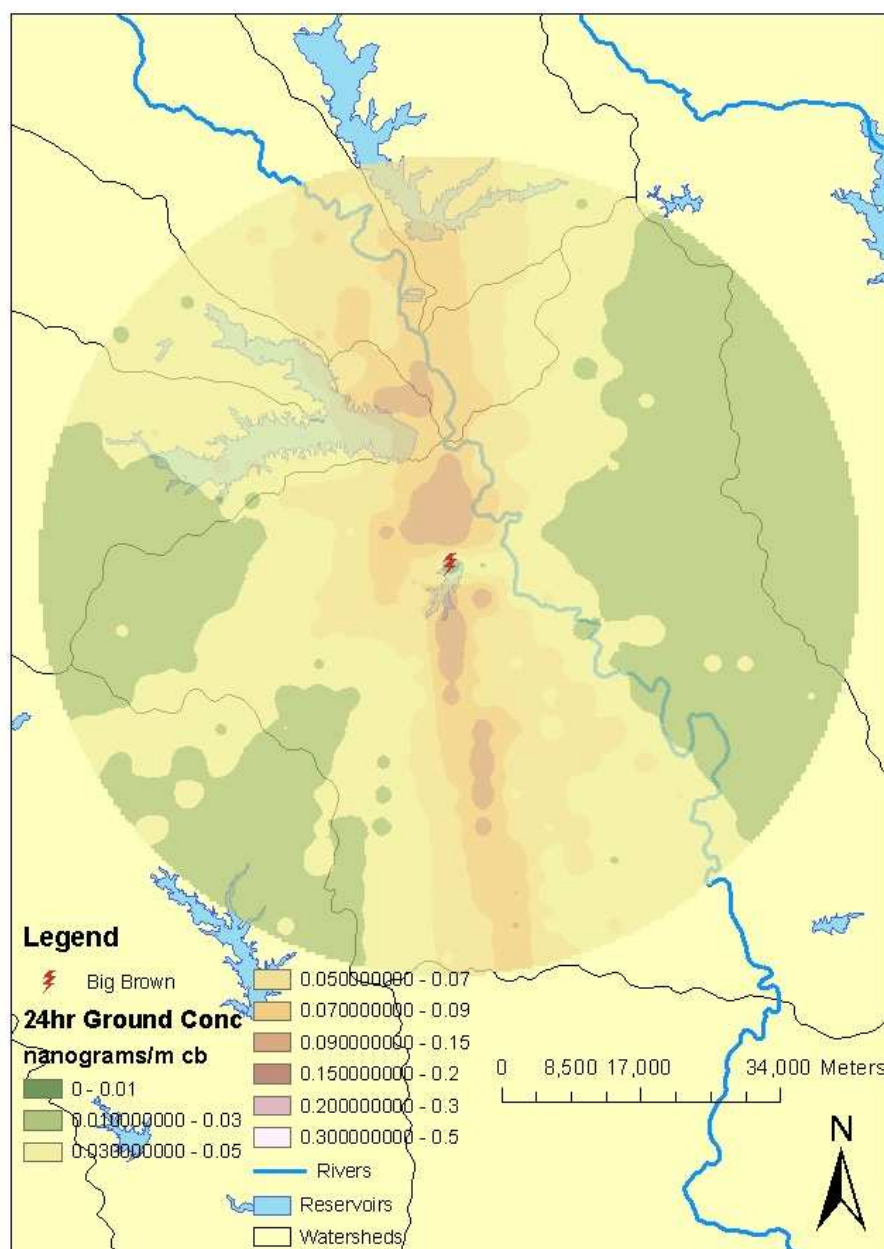


Fig. 37. Big Brown 24hr High Minimum

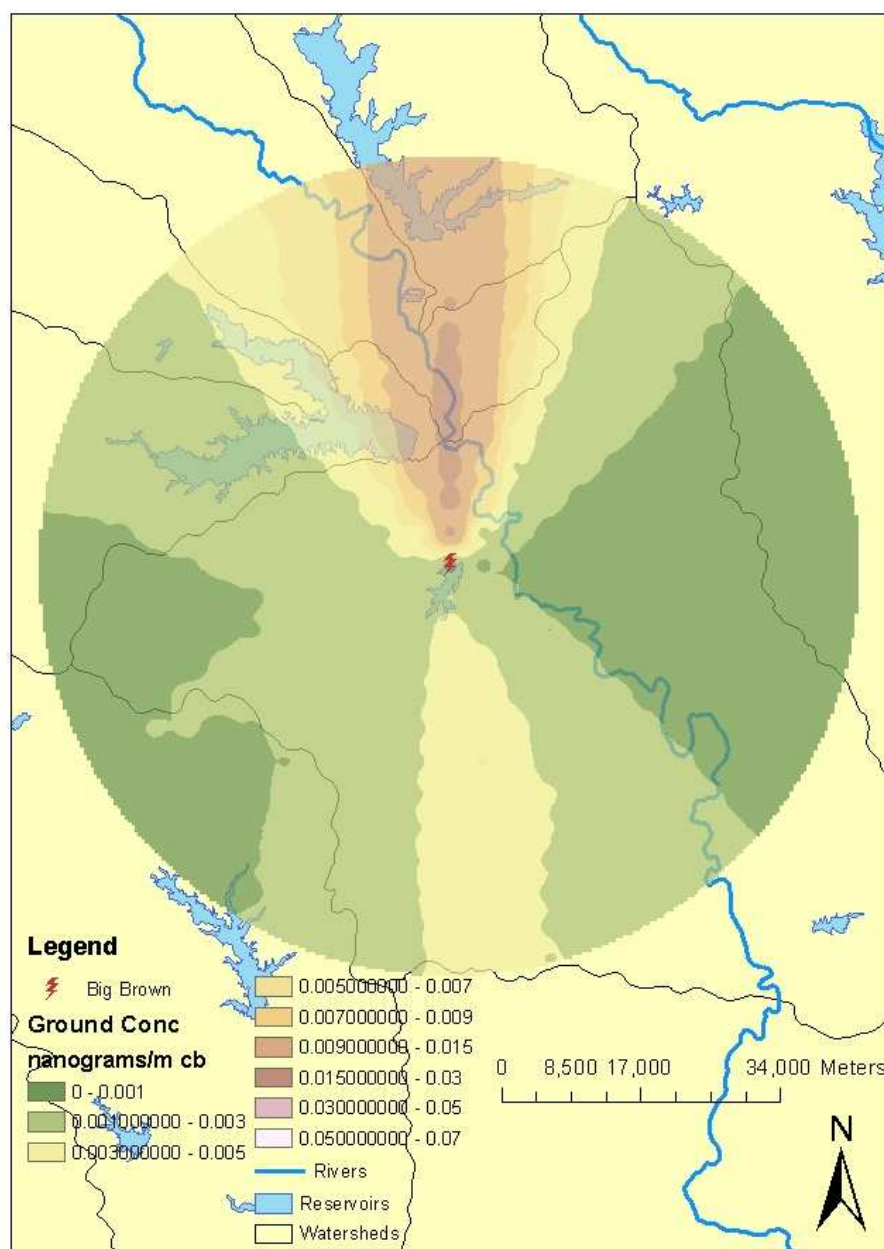


Fig. 38. Big Brown Maximum Concentration

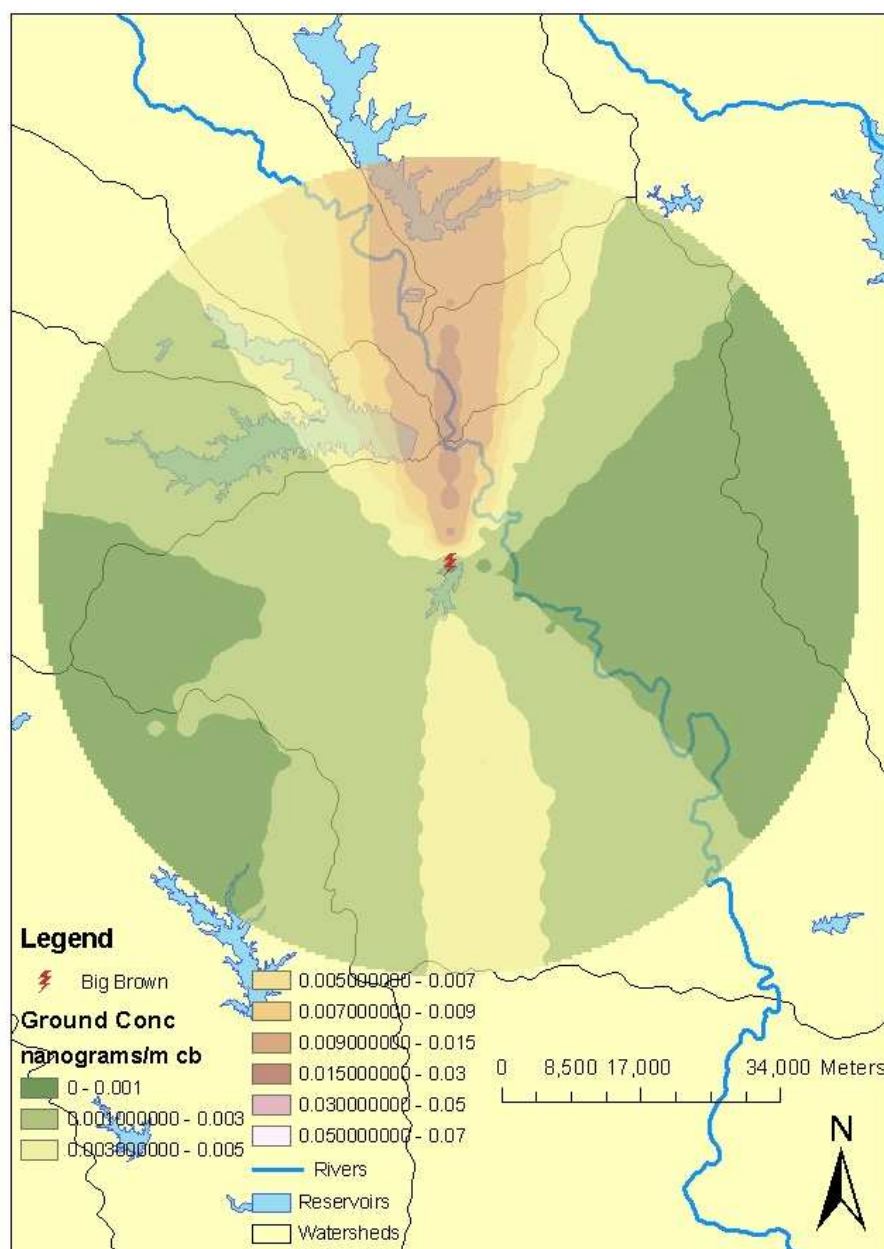


Fig. 39. Big Brown Average Concentration

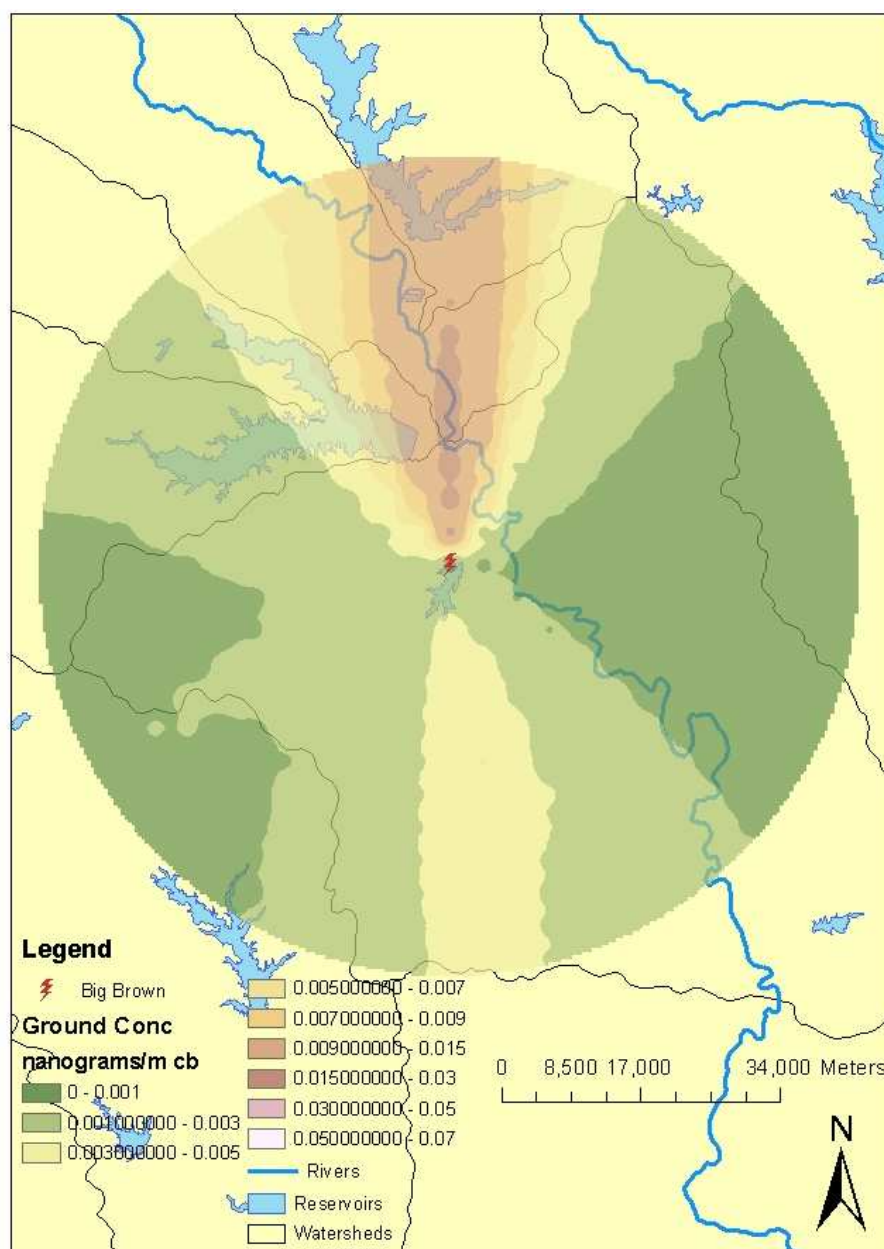


Fig. 40. Big Brown Minimum Concentration

Appendix B

Field Data and Testing Results

**STL**

Date: 09/22/05
Time: 13:02:37
(Mountain Time)

From: Jeff Smith
STL North Canton
4101 Shuffel Drive NW
North Canton, OH 44720

To: Larry Lehr
Baylor University
254-7540478

voice: 330-497-9396
fax: 330-497-0772

Number of Pages
Including Cover Sheet: 05

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Lot Number: A51150292
Project Number:
Project Name/Site: LIMESTONE MAPPING PROJECT

SEVERN TRENT LABORATORIES, INC.

PRELIMINARY DATA SUMMARY

The results shown below may still require additional laboratory review and are subject to change. Actions taken based on these results are the responsibility of the data user.

Lot #: A51150292 Baylor University
LIMESTONE MAPPING PROJECT Date Reported: 9/22/05 PAGE 1

PARAMETER	RESULT	REPORTING LIMIT	UNITS	ANALYTICAL METHOD
Client Sample ID: #1				
Sample #: 001 Date Sampled: 09/13/05 09:00 Date Received: 09/15/05 Matrix: WATER				
Mercury, Low Level Mercury, CVA Fluorescence				Reviewed
Mercury	2.3	0.50	ng/L	CFR136A 1631E
Client Sample ID: #2				
Sample #: 002 Date Sampled: 09/13/05 10:00 Date Received: 09/15/05 Matrix: WATER				
Mercury, Low Level Mercury, CVA Fluorescence				Reviewed
Mercury	1.7	0.50	ng/L	CFR136A 1631E
Client Sample ID: #3				
Sample #: 003 Date Sampled: 09/13/05 11:10 Date Received: 09/15/05 Matrix: WATER				
Mercury, Low Level Mercury, CVA Fluorescence				Reviewed
Mercury	1.8	0.50	ng/L	CFR136A 1631E
Client Sample ID: #4				
Sample #: 004 Date Sampled: 09/13/05 13:00 Date Received: 09/15/05 Matrix: WATER				
Mercury, Low Level Mercury, CVA Fluorescence				Reviewed
Mercury	1.4	0.50	ng/L	CFR136A 1631E
Client Sample ID: #5				
Sample #: 005 Date Sampled: 09/13/05 13:15 Date Received: 09/15/05 Matrix: WATER				
Mercury, Low Level Mercury, CVA Fluorescence				Reviewed
Mercury	0.97	0.50	ng/L	CFR136A 1631E

(Continued on next page)

SEVERN TRENT LABORATORIES, INC.

PRELIMINARY DATA SUMMARY

The results shown below may still require additional laboratory review and are subject to change. Actions taken based on these results are the responsibility of the data user.

Lot #: A5i150292 Baylor University
LIMESTONE MAPPING PROJECT Date Reported: 9/22/05 PAGE 2

<u>PARAMETER</u>	<u>RESULT</u>	<u>REPORTING LIMIT</u>	<u>UNITS</u>	<u>ANALYTICAL METHOD</u>
Client Sample ID: #6				
Sample #: 006 Date Sampled: 09/13/05 14:05 Date Received: 09/15/05 Matrix: WATER				
Mercury, Low Level Mercury, CVA Fluorescence				
Mercury	1.6	0.50	ng/L	CFR133A 1631E

Reviewed

Client Sample ID: #7
Sample #: 007 Date Sampled: 09/13/05 14:15 Date Received: 09/15/05 Matrix: WATER

Mercury, Low Level Mercury, CVA Fluorescence			Reviewed
Mercury	5.0	0.50 ng/L	CFR136A 1631E

Client Sample ID: #8
Sample #: 008 Date Sampled: 09/13/05 15:15 Date Received: 09/15/05 Matrix: WATER
Mercury, Low Level Mercury, CVA Fluorescence
Mercury 1.1 0.50 ng/L CFA136A 1631E Reviewed

Client Sample ID: #9
Sample #: 009 Date Sampled: 09/13/05 16:20 Date Received: 09/15/05 Matrix: WATER

Mercury, Low Level Mercury, CVA Fluorescence				Reviewed
Mercury	1.2	0.50	ng/L	CFR136A 1631E

Client Sample ID: #10
Sample #: 010 Date Sampled: 09/13/05 17:30 Date Received: 09/15/05 Matrix: WATER

Mercury, Low Level Mercury, CVA Fluorescence		Reviewed
Mercury	ng/L	
1.2	0.50	CFR136A 1631E

(Continued on next page)

SEVERN TRENT LABORATORIES, INC.

PRELIMINARY DATA SUMMARY

The results shown below may still require additional laboratory review and are subject to change. Actions taken based on these results are the responsibility of the data user.

Lot #: AS1150292 Baylor University
LIMESTONE MAPPING PROJECT Date Reported: 9/22/05 PAGE 3

PARAMETER	RESULT	REPORTING LIMIT	UNITS	ANALYTICAL METHOD	
Client Sample ID: #11					
Sample #: 011	Date Sampled: 09/13/05 16:05	Date Received: 09/15/05	Matrix: WATER		
Mercury, Low Level Mercury, CVA Fluorescence					
Mercury	1.9	0.50	ng/L	CFR136A 1631E	Reviewed

Client Sample ID: FIELD BLANK					
Sample #: 012	Date Sampled: 09/13/05 15:15	Date Received: 09/15/05	Matrix: WATER		
Mercury, Low Level Mercury, CVA Fluorescence					
Mercury	ND	0.50	ng/L	CFR136A 1631E	Reviewed

Client Sample ID: SED-1					
Sample #: 013	Date Sampled: 09/13/05 10:20	Date Received: 09/15/05	Matrix: SOLID		
Mercury, Low Level Mercury, CVA Fluorescence					
Mercury	6.8	1.5	ug/kg	CFR136A 1631E	Reviewed

Results and reporting limits have been adjusted for dry weight.

Inorganic Analysis					
Total Residue as	68.9	10.0	%	MCANW 160.3 MOD	Reviewed
Percent Solids					

Client Sample ID: SED-2					
Sample #: 014	Date Sampled: 09/13/05 14:35	Date Received: 09/15/05	Matrix: SOLID		
Mercury, Low Level Mercury, CVA Fluorescence					
Mercury	49.9	10.2	ug/kg	CFR136A 1631E	Reviewed

Results and reporting limits have been adjusted for dry weight.

Inorganic Analysis					
Total Residue as	49.3	10.0	%	MCANW 160.3 MOD	Reviewed
Percent Solids					

(Continued on next page)

Chain of Custody Record

SEVERN
TRENT

STL

Severn Trent Laboratories, Inc.

STL-4124 (09/01)

Client Daylor University		Project Manager JENNIFER LEHR		Date 9/13/05	Chain of Custody Number 201694
Address BU Box 97266		Telephone Number (Area Code)/Fax Number (254) 710-1819		Lab Number (Fax #) 254 7540478	Page 1 of 2
City Waco	State TX	Zip Code 76798	Site Contact Win McAttee	Lab Contact	
Project Name and Location (State) Limestone mapping project			Carrier/Waybill Number		
Contract/Purchase Order/Quote No.					

Special Instructions/
Conditions of Receipt

Sample I.D. No. and Description (Containers for each sample may be combined on one line)	Date	Time	Matrix					Containers & Preservatives				
			Soil	Sed	Aqueous	SV	Unpres	H2SO4	HNO3	HCl	NaOH	ZnAc
✓ #1	9/13/05	9:00 AM	X									
✓ #2		10:00 AM	X									
✓ #3		11:10 AM	X									
✓ #4		1:00 PM	X									
✓ #5		1:15 PM	X									
✓ #6		2:05 PM	X									
✓ #7		2:15 PM	X									
✓ #8		3:45 PM	X									
✓ #9		4:20 PM	X									
✓ #10		5:30 PM	X									
✓ #11		4:05 PM	X									
Field Blank		3:15 PM	X									

Possible Hazard Identification
☒ Non-Hazard ☐ Flammable ☐ Skin Irritant ☐ Poison B ☐ Unknown ☐ Return To Client ☐ Disposal By Lab ☒ Archive For 1 Months (A fee may be assessed if samples are retained longer than 1 month)

Sample Disposal
☐ Turn Around Time Required
☐ 24 Hours ☐ 48 Hours ☒ 7 Days ☐ 14 Days ☐ 21 Days ☐ Other
 1. Relinquished By *Jim McAttee* Date *9/13/05* Time *7:30 PM*
 2. Relinquished By *Jim McAttee* Date *9/13/05* Time *7:30 PM*
 3. Relinquished By *Jim McAttee* Date *9/13/05* Time *7:30 PM*

Comments
Red Ex Property

DISTRIBUTION: WHITE - Returned to Client with Report; CANARY - Stays with the Sample; PINK - Field Copy

Lake Limestone Field Sampling Data Sheet

Location/Station ID: Sample 1 NW-corner of Lake - water sample
 Date: 9/13 Time: 9:00 AM GPS: 31°27'17.5" N
96°23'45.0" W
 Weather: Mostly Cloudy Temperature: low 80s
 Sampling Team: W. Macatee & C. Furl

Field Data Measurements

Time	Depth	Temperature (°C)	Conductivity (mS/cm)	pH

Water Depth: 5 1/2 ft Current Direction: We approached the sampling Wind Direction: South → North Odors: —
 Sample Containers: pint jars Site from upwind

Observations: We didn't have the equipment to take pH levels, conductivity, ect... on the first sampling site. In the midst of dead trees @ N end of lake green water. Non-turbid samples

Sampling Time: 9:00 AM Date: 9/13

Lake Limestone Field Sampling Data Sheet

Location/Station ID: Sample 2 - Water. 200m at from Dock
 Date: 9/13 Time: 10:00 AM GPS: 31° 26' 40.7 N
96° 22' 59.5 W
 Weather: mostly/partly cloudy Temperature: _____
 Sampling Team: W.M. & C.F

Field Data Measurements

Time	Depth	Temperature (°C)	Conductivity (mS/cm)	pH

Water Depth: 9ft Current Direction: S → N Wind Direction: ↘ Odors: —
 Sample Containers: pint jars

Observations: water still pretty turbid. Sun starting to come out
slightly less cloud cover. Still do not have instruments
for other observations

Sampling Time: 10: AM Date: 9/13

Lake Limestone Field Sampling Data Sheet

Location/Station

ID:

Sample 3 - Water Col.

Date:

9/13

Time:

11:00 AM

GPS:

3° 26' 18.9"

96° 22' 22.2"

Weather:

partly cloudy to sunny

Temperature:

Sampling Team:

W.M. & C.F.

site 3

Field Data Measurements

Time	Depth	Temperature (°C)	Conductivity (mS/cm)	pH
11:00 AM		28.5°C	261	7.9

Water

Depth:

13 ft.

Current

Direction:

consistent w/ wind

Wind

Direction:

S → N

Odors:

Sample

Containers:

pit for J

Observations:

Water still turbid. Sunny now

Sampling Time:

Date:

Lake Limestone Field Sampling Data Sheet

Location/Station ID: 4 - Water
 Date: 9/13 Time: 1:00 PM GPS: 31° 22' 45.7"
96° 18' 5.6"
 Weather: Partly Cloudy Temperature: _____
 Sampling Team: W.M. & C.F.

Field Data Measurements

Time	Depth	Temperature (°C)	Conductivity (mS/cm)	pH
1:00 PM	17.5	29.87	245	8.31

Water Depth: 18.5 ft Current Direction: _____ Wind Direction: S → N Odors: _____
 Sample Containers: _____

Observations: Lamb's Creek mouth, Sampling site is near stumps.
More developed land use, docks, ect., Power plant transmission
lines 1000 ft. to the south.

Sampling Time: _____ Date: _____

Lake Limestone Field Sampling Data Sheet

Location/Station

ID:

5-LL

Date:

9/13

Time:

1:15

GPS:

31°22'55.7"

Weather:

partly cloudy

Temperature:

96 °F 55.3

Sampling Team:

M.M. & C.F.

Field Data Measurements

Time	Depth	Temperature (°C)	Conductivity (mS/cm)	pH
1:15		29.6	244	8.43

Water

Current

Wind

Depth:

Direction:

Direction:

S → N

Odors:

Sample

Containers:

pints

Observations:

200-300 m further up lake CR

then samp. 4

Sampling Time:

Date:

Lake Limestone Field Sampling Data Sheet

Location/Station

ID:

6 - Larks Creek

Date:

9/13

Time:

2:10

GPS:

31°23'25.9"N

96°17'08.1"W

Weather:

Mostly Cloudy

Temperature:

Sampling Team:

K. M. & C. P.

Field Data Measurements

Time	Depth	Temperature (°C)	Conductivity (mS/cm)	pH
2:10	7.5	30.0	244	8.36

Water

Depth:

✓

Current

Direction:

→

Wind

Direction:

S → W

Odors:

Sample

Containers:

Observations:

1/4 of the way from bridge to mouth of Lake, tied to a stump. We took a duplicate of this one labeled 11

Sampling Time:

2:05

Date:

9/13

Lake Limestone Field Sampling Data Sheet

Location/Station ID: 7 - Lanes Creek bridge
 Date: 9/13 Time: 2:30 GPS: 31°23'40.2"N 96°10'51.6"W
 Weather: 3 Sunny / P cloudy Temperature: _____
 Sampling Team: W. M & C. F

Field Data Measurements

Time	Depth	Temperature (°C)	Conductivity (mS/cm)	pH
2:30	2.5ft	30.8	225	7.99

Water Depth: ✓ Current Direction: same Wind Direction: SSW Odors: _____
 Sample Containers: _____

Observations: Lanes bridge. water extremely turbid. More so than the other sites.

Sampling Time: 2:30 Date: 9/13

Lake Limestone Field Sampling Data Sheet

Location/Station

ID:

Date:

Time:

GPS:

Weather:

Temperature:

Sampling Team:

Field Data Measurements

Time	Depth	Temperature (°C)	Conductivity (mS/cm)	pH
3:15	30+	29.9	244	8.11

Water

Depth:

Current

Direction:

Wind

Direction:

Odors:

Sample

Containers:

Observations:

Sampling Time:

Date:

Lake Limestone Field Sampling Data Sheet

Location/Station ID: 9 - Water N 39° 20' 20.1"
 Date: 9/13 Time: 4:25 GPS: W 96° 18' 49.8"
 Weather: Sunny / PC Temperature: _____
 Sampling Team: W. M. F. C. F.

Field Data Measurements

Time	Depth	Temperature (°C)	Conductivity (mS/cm)	pH
4:30	<u>20</u> 18 ft	30.0	246	7.79

Water Depth: _____ Current Direction: _____ Wind Direction: S → N Odors: _____
 Sample Containers: prints 

Observations: by the dam. Water is very clear

Sampling Time: 4:20 Date: _____

Lake Limestone Field Sampling Data Sheet

Location/Station

ID:

Date: 9/13 Time: 8:30 GPS: N 31° 19' 57.1Weather: Sunny Temperature: W 96 19' 53.2Sampling Team: W. M. & C. F.

Field Data Measurements

Time	Depth	Temperature (°C)	Conductivity (mS/cm)	pH
5:30	30 ft	29.3	245	7.98

Water Depth: 30 ft Current Direction: _____ Wind Direction: light S-SW Odors: _____
 Sample Containers: pints

Observations: .98 for pH was measured 3 consecutive times.

Sampling Time: _____ Date: _____

Lake Limestone Field Sampling Data Sheet

Location/Station

ID:

11 - Lamps Crk.

Date:

9/13

Time:

GPS:

Weather:

Temperature:

Sampling Team:

Field Data Measurements

Time	Depth	Temperature (°C)	Conductivity (mS/cm)	pH

Water

Depth:

Current

Direction:

Wind

Direction:

Odors:

Sample

Containers:

Observations:

Sampling Time:

Date:

Lake Limestone Field Sampling Data Sheet

Location/Station

ID:

Sample 1 - Sediment NW corner of 14.4

Date:

9/13

Time:

9:20

GPS:

31° 27' 26.4" N
96° 23' 43.3" W

Weather:

mostly cloudy

Temperature:

Sampling Team:

W. M. & C. F.

Field Data Measurements

Time	Depth	Temperature (°C)	Conductivity (mS/cm)	pH

Water

Depth: 3-5 ft.

Current

Direction:

Wind

Direction: S → N

Odors:

Sample

Containers: sed. jar.

Observations: samples were taken in very small quantities over the course of approx. 200 ft. to fill a 1/2 pint jar. First 1-3 in. of sed surrounding land use is rural. There is an oil well located very close. Samples were taken up to 50 ft from shore.

Sampling Time:

9:20

Date:

9/13

shore.

Lake Limestone Field Sampling Data Sheet

Location/Station
ID:

Sed 2

Date: 9/13 Time: 2:35 GPS: grabbed

Weather: _____ Temperature: from

Sampling Team: _____ Location 7

Field Data Measurements

Time	Depth	Temperature (°C)	Conductivity (mS/cm)	pH

Water _____ Current _____ Wind _____

Depth: _____ Direction: _____ Direction: _____ Odors: _____

Sample
Containers: _____

Observations: _____

Sampling Time: _____ Date: _____





January 4, 2006

Attn. Dr. Larry Lehr
 Department of Environmental Studies
 Baylor University
 One Bear Place #97266
 Waco, TX 76798

Reference: Low Level Mercury Sample Collection
 Fairfield Lake, Texas

Dear Dr. Lehr

This letter summarizes our activities pertaining to the above reference project. Our understanding is that the purpose of this investigation is to establish a baseline for low level mercury levels in the surface water and sediments at Fairfield Lake.

On December 12, 2005, Win McAtee, Kleinfelder Environmental Geologist, and Jason Woods conducted ambient low level mercury samples in general accordance with EPA's Method 1669 and Method 1631. The sampling activities included the following work scope:

1. Severn Trent (STL) provided the sampling kits that included the pre-cleaned/certified glass jars, ice chests and general sampling / preservation instructions.
2. Two surface water samples and ten sediment samples were collected from Fairfield Lake.
3. Samples were collected using "clean hands/dirty hands" procedures, as cited in Methods 1669 and 1631. Win McAtee served as the "clean hands" personnel, with contact only with the sample jars and the medium.
4. Samples were collected using a non-metal canoe, with appropriate plastic shoulder-length gloves and wind suits. Sampling locations were approached from a downwind and down current direction.
5. Manual grab samples were collected, which involved sampling the surface water directly into the sample containers. Water samples were collected approximately one foot below the water surface. Glass jars were opened, allowed to fill, and closed below the water surface.
6. Temperature, conductivity, pH, water depth and GPS readings were collected following sample collection at the sampling locations. Other general observations were documented at each sampling location. Results are recorded on Table 1. A map is attached showing the general sample locations.

7. The sediment samples were collected using a ponar sampling device attached to a nylon rope.
8. One duplicate sediment sample was collected: one sample was collected with a glass container (S-9A), and a portion transferred to the ponar device prior to placement in the glass container (S-9).
9. Samples and the Chain of Custody were shipped by Federal Express Priority to the consulting analytical laboratory within 24 hours of collection. Samples were preserved in ice during shipment.
10. Samples were tested for total mercury content by Severn Trent using Method 1631E, and results are reported by a dry weight basis. Table 1 summarizes the results.

Generally, the mercury concentrations appear to be low and within a range typical of soils in Central Texas. The loamy/clayey samples show higher concentrations compared to the sandy samples. The Texas Risk Reduction Program (TRRP) rules list the mean background level of mercury as 0.04 ppm. A USGS publication (U. S. Geological Survey Professional Paper 1270, Elemental Concentrations in Soils and Other Surficial Materials of the United States) indicates that naturally occurring mercury concentrations may be as high as 0.082 ppm in Central Texas.

Table 1 Field Measurements at Lake Fairfield

Location No.	Long/Lat.	Water Depth (ft.)	Temp. °C	pH	Conductivity (uS/cm)	Total Mercury	Notes
S-1	30.89654N 96.85077W	15	17.5	7.33	791	50.6 ug/kg	Greenish color water- algae, near tree stumps, sediment black, loamy/clayey
S-2	31.78351N 96.07291W	18	16	7.64	791	36.9 ug/kg	Greenish color water- algae, sediment black, loamy/clayey
S-3	31.78351N 96.06450W	25	19.6	7.59	798	45.2 ug/kg	Greenish color water- algae, sediment black, loamy/clayey
S-4	31.79215N 96.06161W	30	19.3	7.75	791	41.1 ug/kg	Greenish color water- algae, sediment black, loamy/clayey
S-5	31.79977N 96.05065W	25	18.3	7.77	788	35.3 ug/kg	Greenish color water- algae, sediment black, loamy/clayey
S-6	31.80134N 96.05067W	44	19.0	7.86	788	49.4 ug/kg	Greenish color water- algae, sediment black, loamy/clayey
S-7	31.81497N 96.04302W	15	19.0	8.05	779	5.9 ug/kg	Dense algae near dam, sediment tan, sandy
S-8	31.81497N 96.04607W	22	17.4	7.73	785	3.7 ug/kg	Greenish color water, sediment tan, sandy
S-9A*	31.82063N 96.04900W	1	18.4	7.71	791	3.9 ug/kg	Greenish color water- algae, near shore/reeds & power plant, sediment tan, silty sand
S-9**	31.82063N 96.04900W	1	18.4	7.71	791	4.9 ug/kg	Same as S-9A
B-10	31.81857N 96.06067W	25	18.2	7.78	782	41.1 ug/kg	Dam located upstream tributary
W-1	31.78005N 96.07289W	18	18.5	7.57	789	0.85 ng/L	Greenish color water, near tree stumps
W-2	31.81497N 96.04302W	15	19.0	7.86	779	1.2 ng/L	Greenish color water, dense algae near dam

*Collected duplicate sediment sample with glass sampler

** Collected duplicate sediment sample with ponar sampler (metal)

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