

FLORIDA DEPARTMENT OF ENVIRONMENTAL PROTECTION

Division of Environmental Assessment and Restoration

Bureau of Watershed Restoration

Final REPORT

Mercury TMDL for the State of Florida

Watershed Evaluation and TMDL Section



October 24, 2013

Executive Summary

The Florida Department of Environmental Protection (FDEP) is charged with developing Total Maximum Daily Loads (TMDLs) that identify the needed reductions in pollutant loads such that impaired waterbodies may be restored and achieve their designated uses. The State of Florida leads the nation in the establishment of water quality standards, thereby acting to protect its water resources and to manage the environments under its authority. These efforts protect the environment, the people of Florida, our many visitors, and our wildlife.

In 1999, the U.S. Environmental Protection Agency (EPA) entered into a consent decree (CD) in response to a suit brought in federal court by Earthjustice to enforce Clean Water Act provisions requiring development of TMDLs for impaired waters. This suit was one of nearly forty actions filed nationally. The CD set a timeline for EPA to adopt TMDLs for Florida waters listed as impaired (see **Figure 1-ES**). The State of Florida worked cooperatively with EPA to produce TMDLs for CD-identified waters, when the water also was impaired according to Florida rules. FDEP shares the state-developed TMDLs with EPA, who then reviews and approves the TMDLs.

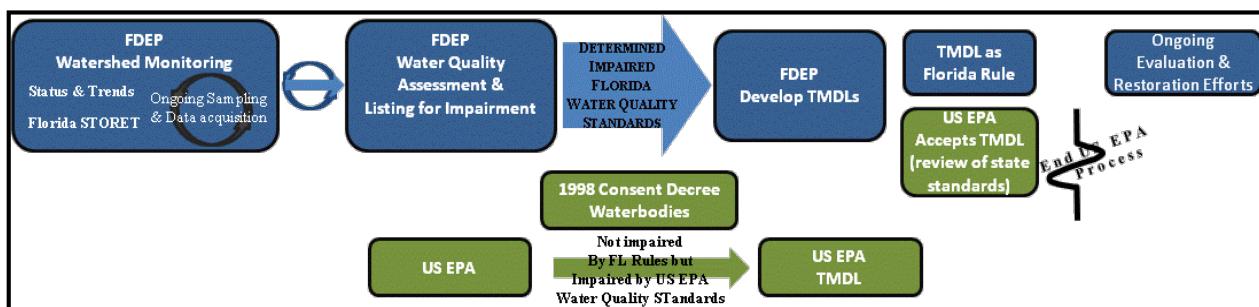


Figure-1-ES Flow chart on process Consent Decree TMDLs by Florida & US EPA

Basis of Mercury Impairments and a Statewide Approach

Florida's Statewide Mercury TMDL for fresh and marine waters addresses impairments in Florida waters resulting from elevated levels of mercury (Hg) in fish tissue. Water quality impairments in Florida are made when total mercury in fish tissue exceeds Florida Department of Health (FDH) advisory thresholds. The FDH sets two thresholds for fish consumption advisories: (1) a general population advisory, where the total mercury in fish is equal to or exceeds 0.3 ppm, and (2) an advisory for women of child-bearing age and young children, where the total mercury in fish is equal to or exceeds 0.1 ppm.

Mercury is unique among impairments for which TMDLs have been produced to date, in that impairments are made based upon potential risks to human health, not upon whether concentrations of a pollutant exceed the state's water quality criteria (Chapter 62-302.530, Florida Administrative Code). Florida's water quality criterion for mercury is not violated, and it does not form the basis of impairment. In other words, no waterbody in Florida has been identified as impaired for mercury because of the concentrations of mercury in the water. Instead, FDEP assigned impairments based on exceedances of the FDH guidelines for fish consumption. Human exposure to mercury is through consumption of fish species having

elevated mercury levels in their tissues. [Note: Many species of fish do not have elevated mercury levels, and fish are an excellent source of protein and Omega-3.] Florida's 1998 303(d) list of impaired waters included 102 waterbodies as impaired for mercury based on fish consumption advisories, which were then identified on the 1999 CD. Since the signing of the CD, additional fresh waters in Florida have been identified as impaired based on added sampling of fish tissue.

Additionally, some waters have been listed as impaired because of adjacency to waters where sampled fish had elevated mercury levels. Almost all coastal and estuarine waters have been listed as impaired, based upon a combination of fish tissue sampling and the mobility of marine species known to have very elevated levels of mercury. While many of Florida's freshwaters (streams, rivers, and lakes) have yet to be sampled, longer-lived, higher level trophic fish would likely be found to have elevated mercury.

The most comprehensive approach offering the most protection for the people of Florida was to establish a statewide mercury TMDL for fresh and marine waters. This approach addressed the following concerns: possible elevated levels of mercury in fish in Florida's fresh and marine waters that were not assessed, adjacency of waterbodies, mobility of marine species, and atmospheric deposition of mercury (the dominant source of mercury, see below).

Mercury Sources

Mercury in the environment of Florida is overwhelmingly from atmospheric deposition. This means that activities across the globe can emit mercury into the air, where the mercury is transported in the high atmosphere before ultimately being deposited on Florida's land and waters. Sources of mercury into the atmosphere include those that are anthropogenic (man-made, such as emissions from burning coal and other fossil fuels) and those coming from natural sources, such as volcanoes or forest fires. Based on peer-reviewed literature, FDEP assumed 30 percent of the deposited mercury was natural, with the remaining 70 percent from anthropogenic sources. The overwhelming majority of the mercury that is deposited from the atmosphere onto Florida's land and waters comes from anthropogenic international sources, outside of North America (see Figure 3.2 Global Natural Emissions and Figure 3.3 Anthropogenic Geographic Percent Contributions).

Mercury Risk

Human mercury risk stems from exposure to methylated mercury, with that exposure occurring primarily through consumption of fish with elevated mercury levels. Of the mercury deposited in the environment only a very small portion is methylated, and this methylated mercury then enters the food chain. Once methylmercury is in fish tissue, almost 100 percent is transferred to subsequent piscivorous (fish-eating) fish consumers. Because diets vary, the same is not true for other members of the animal kingdom (including humans) that consume fish. This bioaccumulation among fish results in higher trophic level fish having higher levels of methylmercury in their tissues.

The mercury in fish tissue is most often measured as "total mercury," i.e., mercury in any molecular form. The amount of total mercury is always greater than the methylmercury present. Thus, seeking to have reductions based upon total mercury is one way to introduce a margin of safety, as it is the methylmercury that causes harm. The ratio of methylmercury to total mercury

in fish tissue can vary by fish species, but is in the upper 90 percent as reported for most species. Mercury movement through the food web is illustrated in Figure 2.1 Mercury Cycling and Bioaccumulation.

FDEP's Pioneering Efforts to Better Understand the Mercury Issue

FDEP undertook a pioneering effort to understand and document mercury origins and to explain its relationships in Florida's waters. This took two parallel, but independent tracks: (1) atmospheric deterministic modeling, and (2) aquatic inferential, correlative modeling. The aquatic modeling evaluated water quality and sediment quality conditions, with estimated atmospheric deposition of mercury – from the atmospheric modeling – to evaluate correlations between these measures and the levels of mercury in fish (see Appendix L). The data developed explicitly for this project consisted of water quality measures at 133 lakes and 131 streams across Florida, sediment quality in the lakes, and a suite of fish collected at or near the water quality sampling sites. FDEP identified general water quality categories from more than 30 years of data, and created a stratified random sampling plan.

No strong relationships were determined between the measures evaluated, though a very rigorous effort of statistical evaluations were performed. This does not mean there is no relationship between environmental and ecological conditions and mercury levels in fish tissue; it only means that the measures collected and analyzed in this study did show any strong statistical relationships. Mercury moves through watersheds, flowing waters, and lakes in a complex manner; and mercury enters biota and moves into the primary production end of the food chain through complex biological processes.

The atmospheric modeling (see Appendix F) consisted of several interdependent parts: (a) determination of mercury emissions, source locations, source categories, and loads; (b) determination of meteorological conditions and movement via scaled modeling; (c) modeling of mercury's very complex atmospheric chemistries so as to predict transport and atmospheric deposition within Florida; and (d) Source-Receptor Modeling to identify potential source types of measured deposition at six sites across Florida. This atmospheric modeling went from a global scale and resolution of 80 km, to a Florida resolution, at a 4 km scale. In addition to being the most spatially resolute atmospheric modeling done to date for mercury, this effort also pioneered using a “tagging” system that allowed both origin location and category type (See Appendix F). Additionally, FDEP staff performed scholarly investigations of the peer-reviewed literature and had discussions with global experts on mercury sources, atmospheric modeling, fish consumption, fish harvesting, and numerous other subjects. The atmospheric modeling showed the overwhelming sources of mercury deposition are global in origin, transported by global weather patterns, and pointed to only a very small percentage of mercury deposition from U.S. or Florida sources.

Based on an examination of all available effluent monitoring data, a limited amount of mercury (0.5 percent of the total mercury load to Florida's waters, or about 23 kilograms per year) was identified as being discharged directly to Florida's surface waters from industrial and domestic wastewater facilities with National Pollutant Discharge Elimination System (NPDES) permits.

Mercury TMDL Reductions

The ultimate objective of reducing mercury is to prevent risks to public health. This requires additional holistic analyses of dietary habits of Floridians and the expected resulting mercury levels within those populations from consuming a variety of fish species with differing mercury concentrations.

Two approaches to setting a mercury fish tissue were taken. First, to more clearly present the estimated level of risk associated to Florida's primary high risk population (i.e., women of child-bearing age), the Department examined the data distributions for a wide range of women's body weights combined with the actual likelihood of exposure to mercury based on the likelihood of eating those fish species consumed in Florida. This uses the identified reference dose and exposure for limiting risk. This would cover fish consumption across Florida from marine and fresh water, thus representing all aquatic systems and is referred to as the "Market Basket approach." The second approach describes work that has been done to broadly assess Florida fresh waters (thereby supporting the statewide approach to setting the TMDL) using the Largemouth Bass (*Micropterus salmoides*) as the primary indicator species and is referred to as the "Large Mouth Bass approach." In both cases, the concentrations of mercury in fish tissue, the natural and anthropogenic fractions are ultimately divided as to identify where human controls, reductions in mercury loads, will limit exposure.

The results of these analyses are discussed in detail in Chapter 7 of the TMDL Report and both approaches support an 86% reduction of anthropogenic mercury emissions.

Acknowledgments

This report, and the studies described within it, could not have been completed without the help of many groups and individuals, within and outside of FDEP. The authors and editors of this report would like to thank:

Dr. Tom Atkeson
Dr. Don Axelrad
Barbara Donner
FDEP's Division of Air Resource Management
FDEP's Division of Waste Management
FDEP's Watershed Assessment Section
FDEP's Standards and Assessment Section
Tom Frick

Russ Frydenborg
John Glunn
Joel Hansel (US EPA)
Dr. Matt Landis (US EPA)
Ted Lange (FWCC)
Denise Miller
Tom Rogers
Ken Weaver
Tim Wool (US EPA)

Financial project support by the Florida Legislature

Management support by Jerry Brooks, Andrew Bartlett, and Trina Vielhauer

Consultants

Deterministic Atmospheric and associated modeling, and wet chemistry analyses
University of Michigan
Dr. Jerry Keeler, Dr. J. Timothy Dvonch, Dr. Frank Marsik, Dr. Sandy Sillman, and their dedicated staff notably: Laura Sherman, Jim Barres, Dr. Masako Morishita, Ms. Naima Hall, Mr. Matt Salvadori, and Dr. Jason Demers

CNR-Institute of Atmospheric Pollution Research

Dr. Nicola Pirrone, Ian Hedgecock, Teresa Lo Feudo, Gerlinde Jung, and Gregor Schürmann

ICP-MS Analyses of Filter Aliquots

U.S. Environmental Protection Agency
Human Exposure and Atmospheric Sciences Division
Environmental Characterization and Apportionment Branch

Monitoring

Atmospheric Research and Analysis, Inc.
Eric Edgerton, Brad Gingrey, Ray Compton

Florida Fish and Wildlife Conservation Commission
Ted Lange, and team

Inferential Aquatic Modeling

Aqua Lux Lucis, Inc.
Dr. Curt Pollman

Statistical Review

Florida State University
Dr. Xu-Feng Nui

in memoriam Dr. Jerry Keeler

Professor Jerry Keeler, Ph.D. (1960-2011):

Jerry Keeler was an environmental researcher and teacher whose efforts had a profound impact around the world. His research focused on the sources and fate of air toxics, and their impacts on human and environmental health, as well as on the development of new measurement and analytical tools toward the improved characterization and understanding of air toxics. As a leading expert on air pollution and mercury issues, Dr. Keeler worked cooperatively with state, federal, and international agencies.

A rigorous scientist and enthusiastic teacher, Professor Keeler published more than 120 peer-reviewed papers, while teaching a variety of graduate and undergraduate environmental, atmospheric and climate-change courses. During his tenure at the University of Michigan, he mentored and served as principal adviser to more than 40 master's and doctoral degree students. During this 20-year career, Professor Keeler created and was director of the University of Michigan's Air Quality Laboratory, a research group that initiated multi-, intra-, and cross-disciplinary research. Dr. Keeler's inter-disciplinary research served not only to document source and deposition, but also to manage issues of air toxics, and their impacts on humans and the environment.

Professor Keeler's research was global, working from the Arctic, to the Florida Everglades, across the Great Lakes, and in direct support of global projects. Amongst his final efforts was being a lead contributor to a report by the United Nations Environment Program's global partnership on atmospheric mercury transport and fate. Dr. Keeler's approach of science for management and change has greatly improved health prospects of people worldwide. His efforts continue in not only the research publications that he has authored, but his greatest contribution is his legacy, in the many professionals he trained, mentored, and influenced, that continue advancing efforts in understanding and addressing air toxics.

For additional information on the Mercury TMDL, contact:

Jan Mandrup-Poulsen, Section Administrator
Florida Department of Environmental Protection
Bureau of Watershed Restoration
Watershed Evaluation and TMDL Section
2600 Blair Stone Road, Mail Station #3555
Tallahassee, FL 32399-2400
Email: jan.mandrup-poulsen@dep.state.fl.us
Phone: (850) 245-8448
Fax: (850) 245-8434

Gregory White, D.Sc.
Florida Department of Environmental Protection
Bureau of Watershed Restoration
Watershed Evaluation and TMDL Section
2600 Blair Stone Road, Mail Station #3555
Tallahassee, FL 32399-2400
Email: gregory.white@dep.state.fl.us
Phone: (850) 245-8347
Fax: (850) 245-8434

Table of Contents

Executive Summary	ii
<i>in memoriam Dr. Jerry Keeler</i>	vii
Chapter 1: Introduction	1
1.1 Purpose of Report	1
1.2 Clean Water Act and TMDL Program	1
1.3 State and Regional Air Regulations	2
1.3.1. Overview of Clean Air Act Requirements and Mercury Emissions	2
1.3.1.a Regulation of Mercury under the CAA	2
1.3.1.b Coal-Fired Electric Utilities and the Clean Air Act	2
1.3.1.c Portland Cement Facilities and the Clean Air Act	3
1.3.1.d Solid Waste to Energy Facilities and the CAA	4
1.3.2 Florida State Air Regulations	4
1.4 Applicable Water Quality Criteria	4
1.5 Impaired Waterbodies in Florida Listed for Mercury Impairment	5
1.6 Other Mercury TMDLs in the United States	10
1.6.1 Minnesota Statewide Mercury TMDL (MPCA, 2007)	11
1.6.2 Northeast Regional Mercury TMDL for Fresh Waters (NE Regional TMDL, 2007)	12
1.6.3 TMDL for Mercury Impairments Based on Fish Tissue Caused by Air Deposition to Address 122 Waters Statewide, New Jersey (New Jersey DEP, 2009)	12
1.6.4 Mercury in Fish Tissue TMDLs for Watersheds in Arkansas TMDL (FTN Associates, Ltd. 2002)	13
1.6.5 Mercury TMDLs for Subsegments within Mermentau & Vermilion-Teche River Basins, Louisiana (FTN Associates, Ltd. 2002)	14
Chapter 2: Basis of Concern	16
2.1 Mercury Dynamics in Natural Environment	16
2.1.1 Mercury Cycling	16
2.1.2 Bioaccumulation of Mercury in Fish	17
2.2 Human Health Effects	19
2.3 Florida Human Case Studies	20
2.3.1 Human Risk	21
2.4 Wildlife Health Effects	21
2.4.1 Wildlife Risk	22
Chapter 3. Dynamics of Mercury in Natural Environments and Source Identification	23

3.1 Introduction on Mercury Sources	23
3.2 Natural Sources	24
3.3 Anthropogenic Sources	26
3.3.1 Global Sources	26
3.3.2 Sources in the United States	28
3.3.3 Sources in the State of Florida	31
3.4 Mercury Deposition and Re-Emission	39
3.5 Mercury Movement in the Environment	41
3.5.1 Mercury transport and fate in forest ecosystems	41
3.5.2 Mercury in Wetlands: transport and transformation	42
3.5.3 Mercury in surface waters	42
3.5.4 Mercury moving through organisms	43
Chapter 4: TMDL Approach	45
4.1 General Approach	45
4.2 Mercury Atmospheric Deposition Monitoring	48
4.3 Mercury Atmospheric Modeling	48
4.4 Mercury Aquatic Cycle Modeling	48
4.5 Sampling of Fish Tissue and Collection of Chemical and Biochemical Data from the Water Column and Sediment	48
4.6 Historic Data for Fish Tissue Mercury Concentration and Water Column Chemistry	52
Chapter 5: Monitoring Results	53
5.1 Fish Tissue Results	53
5.2 Total and Methylmercury, and other Water Column Parameters	54
5.3 Sediment Mercury	57
Chapter 6. Model Results	60
6.1 Summary of Atmospheric Modeling Results	60
6.2 Overview Inferential Aquatic Modeling	61
Chapter 7: TMDL Target Setting	62
7.1 Setting a Reduction Target Based on Mercury in Fish Tissue	62
7.1.1 Reduction Target for Fish Consumption by Humans	62
7.2 Reduction Target for Fish Consumption by Wildlife	79
7.3 Demonstration of Protection of Water Quality Standards	82
Chapter 8: Determination of the TMDL	83
8.1 Expression and Allocation of the TMDL	83

8.2 Load Allocation	83
8.3 Wasteload Allocation	84
8.3.1 NPDES Wastewater Discharges	84
8.3.2 NPDES Stormwater Discharges	85
8.4 Margin of Safety	86
Chapter 9: Ongoing Activities and Implementation Plan Development	87
9.1 Implementation Plan Development	87
9.2 Ongoing Mercury Reduction Activities in Florida	87
9.3 Considerations in Wasteload Allocation	92
9.4 Considerations in Load Allocation	92
9.5 Identification of Impaired Waters	94
References	95

List of Tables

Table 1.1 Number of Water Segments Listed on the 1998 Consent Decree List for Mercury Impairment Based on Fish Consumption Advisory	6
Table 1.2 Number of WBIDs and Miles/Square Miles Impaired for Mercury (in Fish Tissue) by Waterbody Type	8
Table 3.1 Examples of Mercury Speciation from Emission Sources	30
Table 3.2. Sources of Mercury Emissions in the U.S.	30
Table 3.3 2005 National Emissions Inventory (NEI) - Florida (US EPA, 2005)	31
Table 3.4 Estimated Mercury Reduction Associated with the Mercury Air Toxic Standards Rule (MATS) (Source DARM, 2012)	35
Table 3.5 Estimated Mercury Reduction Associated with the Mercury Air Toxic Standards Rule (MATS) (Source DARM, 2012) Repeat header next page	37
Table 3.6 2009 Florida Portland Cement Production and Estimated Mercury Emissions (source DARM, 2012)	38
Table 3.7 2009 Mercury Emissions Inventory in Florida (DARM & UMAQL, 2011)	39
Table 4.1 Initiation & End Dates of Supersite and Wet Only Site Data Collections	48
Table 5.1 Mean and Standard Deviations for all Parameters Measured or Collected in Waters Sampled for the Statewide Mercury TMDL	56
Table 5.2 Statistics Summary of Other Sediment Parameters (mg/kg)	58
Table 7.1 List of market basket species, consumption probability distribution function or proportion (for occasionally consumed items) and mean Hg tissue concentration. Probability distribution functions are listed in Appendix J. Consumption rates for the remaining items were assigned based on proportion of the total consumption distribution (lognormal distribution).	70
Table 7.2 Summary of calculation of consumption weighted mean total mercury tissue concentration for the other Florida seafood category. Total consumption was calculated as the total Degner survey reported consumption for women of childbearing age.	71
Table 7.3 Summary of calculation of consumption weighted mean total mercury tissue concentration for the other non-Florida seafood category. Total consumption was calculated as the total Degner survey reported consumption for women of childbearing age.	71
Table 7.4. Example calculation of mercury exposure and dose	73

Table 7.5. Mercury exposure and dose for the example women from Table 7.4. The example woman weighs 63 kg and consumes fish and seafood items according to the patterns listed in FCi column below. Mercury exposures were calculated based on the FL species reduction scenario tissue concentration levels.

75

*Table 7.6 Summary of baseline (current condition) and reduction scenario methyl mercury exposure risks. Certainty represents the confidence that the population is at or below the reference dose (0.1 µg/kg·day). Reduction scenarios were run by reducing fish tissue concentrations by a reductions factor (i.e., RF*species mean concentration) necessary to achieve 90 percent certainty assuming no reduction in non-Florida species. Additional scenarios were run under the assumptions that non-Florida species are reduced to levels ranging from ≤0.10 to 0.3 mg/kg.*

78

Table 8.1 TMDL Components for Mercury in Florida's Fresh Water Lakes, Streams, and Estuarine and Coastal Waters

84

Table 8.2 TMDL Comparison of Wasteload Allocations for Mercury as a Percentage of Total Mercury Load for Florida and Other State or Regional TMDLs

85

List of Figures

Figure 1.1 Consent Decree Listed Waterbodies for Mercury Fish Tissue Impairment _____	7
in Florida _____	7
Figure 1.2 Waterbodies on Department's Verified Lists for Mercury Fish Tissue Impairment in Florida _____	9
Figure 1.3 States with EPA Approved Mercury TMDLs (2012) _____	11
Figure 2.1. Mercury Cycling and Bioaccumulation _____	17
Figure 2.2 Example of a Trophic Pyramid _____	18
Figure 3.1 Worldwide Distribution of Mercury Emissions (United Nations Environment Program Global Atmospheric Mercury Assessment: Sources, Emissions and Transport, 2008, using 2005 data, as presented by the Arctic Monitoring and Assessment Program Secretariat) _____	24
Figure 3.2. Global Natural Emissions (Derived from UNEP, 2008) _____	25
Figure 3.3 Anthropogenic Geographic Percent Contributions _____	27
Figure 3.4 Global Anthropogenic Sources _____	27
Figure 3.5 Percentage of US Emission Sources _____	28
Figure 3.6 Trend of US Mercury Mobilization in Industrial/Consumer Goods and Fuels (Source: Husar and Husar, 2002) _____	29
Figure 3.7 Trend of Estimated US Mercury Emissions to the Atmosphere (Source: Husar and Husar, 2002) _____	29
Figure 3.8 Florida mercury flow in electrical devices (source Husar and Husar, 2002) _____	31
Figure 3.9 Trend of anthropogenic mercury flow in Florida (Source Husar and Husar, 2002) _____	32
Figure 3.10 Comparison of waste incineration emissions for Broward, Dade, and Palm Beach counties (source: Husar and Husar, 2002) _____	33
Figure 3.11 Monthly Volume-Weighted Mean Hg at Florida MDN sites _____	34
Figure 4.1 Overview of Technical Components of a Statewide Mercury TMDL Project _____	47
Figure 4.2 Statewide Mercury TMDL Project Sampling Sites _____	51
Figure 5.1 Cumulative Frequency of Fish Tissue Mercury Concentration in Lakes and Streams. _____	53
Figure 5.2 Dynamics of Fish Tissue Mercury Concentration in Florida Waters in the Period from 1983 through 2011 _____	54
Figure 5.3a Cumulative Frequency of Total Hg and Methyl-Hg Water Column Concentrations in Lakes _____	54
Figure 5.3b Cumulative Frequency of Total Hg and Methyl-Hg Water Column Concentrations in Streams _____	55
Figure 5.4 Cumulative Frequency Curve for the Methyl to Total Mercury Water Column Ratio in Lakes and Streams _____	56
Figure 5.5 Cumulative Frequency of Sediment Total and MeHg Concentration _____	57

<i>Figure 5.6 Cumulative Frequency of Sediment Methyl to Total Mercury Ratio</i>	58
<i>Figure 7.1. Tissue Mercury Concentrations for Florida Fish</i>	63
<i>Figure 7.2. Women of childbearing age 7-day consumption rate (grams per week) lognormal distribution (location=21.11, $\mu=5.36$, $\sigma=0.85$) for canned tuna.</i>	66
<i>Figure 7.3 Example (canned tuna) process followed to generate species/item specific and total seafood consumption rates for women of childbearing age.</i>	67
<i>Figure 7.4. Average daily (g/day) canned tuna consumption rate distribution for women of childbearing age. The distribution was developed based on simulating 52 weeks of consumption for 10,000 individuals and developing a composite distribution from the simulated individual daily average consumption rates. Average daily individual consumption was calculated as the sum across all 52 weeks divided by 364.</i>	68
<i>Figure 7.5. Average daily (g/day) total consumption distribution for women of childbearing age.</i>	69
<i>Figure 7.6 Baseline scenario cumulative probability distribution of methyl mercury dose for women of childbearing age based on the market basket analysis.</i>	75
<i>Figure 7.7 Sixty percent reduction in Florida species methyl mercury scenario cumulative probability distribution of methyl mercury dose for women of childbearing age based on the market basket analysis.</i>	77
<i>Figure 7.8 Box plot (left) and cumulative frequency distribution plot (right) comparing standardized (15 inch length) largemouth bass (LMB) total mercury concentrations in fish tissue collected in the Everglades measured from 2008–2010. Box plots represent median and 25th, and 75th percentiles; whiskers represent 10th and 90th percentiles; and points are outliers. Sample numbers are as follows: Everglades = 32, Florida lakes = 130, and streams = 120 (Axelrad, D., et al., 2012)</i>	80
<i>Figure 7.9 Wood Stork Rookeries and Foraging Areas in Everglades Protection Area</i>	80
<i>Figure 7.10 Mercury in TL3 fish (bluegill, redear sunfish, and spotted sunfish) collected from 25 locations in the Everglades Protection Area from 2000 to 2011. Data include the median (black horizontal line), mean (red horizontal line), 25-75th percentiles in yellow, 10-90th percentiles as whiskers, and 5-95th percentiles as points.</i>	81

Web sites

Florida Department of Environmental Protection, Bureau of Watershed Management

Total Maximum Daily Load (TMDL) Program

<http://www.dep.state.fl.us/water/tmdl/index.htm>

Identification of Impaired Surface Waters Rule

<http://www.dep.state.fl.us/water/tmdl/docs/AmendedIWR.pdf>

STORET Program

<http://www.dep.state.fl.us/water/storet/index.htm>

2010 Integrated Report

http://www.dep.state.fl.us/water/docs/2010_Integrated_Report.pdf

Criteria for Surface Water Quality Classifications

<http://www.dep.state.fl.us/water/wqssp/classes.htm>

Basin Status Reports

http://www.dep.state.fl.us/water/tmdl/stat_rep.htm

Water Quality Assessment Reports

http://www.dep.state.fl.us/water/tmdl/stat_rep.htm

Allocation Technical Advisory Committee (ATAC) Report

<http://www.dep.state.fl.us/water/tmdl/docs/Allocation.pdf>

U.S. Environmental Protection Agency

Region 4: Total Maximum Daily Loads in Florida

<http://www.epa.gov/region4/water/tmdl/florida/>

National STORET Program

<http://www.epa.gov/storet/>

Chapter 1: Introduction

1.1 Purpose of Report

This report presents the statewide Total Maximum Daily Load (TMDL) for waters within the State of Florida that have been verified for mercury impairment, based on elevated mercury levels in fish tissue. These impaired waters are included on the Verified Lists of impaired waters that were adopted by Secretarial Orders for all hydrological basin groups across the state during two water quality assessment cycles (2002-2006 and 2007-2011). According to the 1999 Florida Watershed Restoration Act (FWRA), Chapter 99-223, Laws of Florida, once a waterbody is included on the Verified List, a TMDL must be developed. The purpose of the statewide mercury TMDL is to establish the allowable loadings and needed reductions of mercury into Florida's fresh and marine waters that would restore these waterbodies so that the human health concern associated with the elevated mercury in fish tissue impairment will be addressed.

1.2 Clean Water Act and TMDL Program

Section 303(d) of the Clean Water Act (CWA) requires states to submit to the United States Environmental Protection Agency (EPA) lists of surface waters that do not meet applicable water quality standards (impaired waters) after implementation of technology-based effluent limits, and establish TMDLs for these waters on a prioritized schedule. TMDLs establish the maximum amount of a pollutant that a waterbody can assimilate without causing exceedances of water quality standards. As such, development of TMDLs is an important step toward restoring impaired waters to their designated uses. In order to achieve the water quality benefits intended by the CWA, it is critical that TMDLs, once developed, be implemented as soon as possible. The TMDL alone does not create new legal authorities and the LA and WLA discussed herein are enforceable to the extent independent legal authorities exist under state law. The Florida Watershed Restoration Act (FWRA), Chapter 99-223, Laws of Florida, sets forth the process by which the 303(d) list of impaired waterbodies is refined through more detailed water quality assessments defined in the Identification of Impaired Surface Water Rule (IWR, 62-303, F.A.C.). It also establishes the means for adopting TMDLs, allocating pollutant loadings among contributing sources, and implementing pollution reduction strategies.

Implementation of TMDLs refers to any combination of regulatory, non-regulatory, or incentive-based actions that attain the necessary reduction in pollutant loading. Non-regulatory or incentive-based actions may include development and implementation of Best Management Practices (BMPs), pollution prevention activities, and habitat preservation or restoration. Regulatory actions may include issuance or revision of wastewater, stormwater, or environmental resource permits to include permit conditions (including waste minimization plans) consistent with the TMDL. These permit conditions may be numeric effluent limitations or, for technology-based programs, requirements to use a combination of structural and non-structural BMPs needed to achieve the necessary pollutant load reduction.

1.3 State and Regional Air Regulations

1.3.1. Overview of Clean Air Act Requirements and Mercury Emissions

The Clean Air Act (CAA) Amendments of 1990 (Clean Air Act) and its implementing rules regulate air emissions of mercury from most industrial sources. These regulations are codified in 40 Code of Federal Regulations (CFR) Part 63 and also 40 CFR Part 60 (municipal solid waste-to-energy facilities).

1.3.1.a Regulation of Mercury under the CAA

In Section 112 of the CAA, Congress identified a list of hazardous air pollutants, including mercury, and directed EPA to develop a regulatory program to reduce these emissions from air pollution sources that emit such pollutants over certain thresholds. This program is called the Maximum Achievable Control Technology program (MACT) and requires EPA to establish rules, by industry type, that require existing facilities in that industry to comply with air pollution emission limits achieved by the best performing 12% in that industry. New sources in these industry categories must meet the maximum reduction in emissions that is achievable and cannot be less stringent than the best-controlled, existing similar source. Discussion on the status of EPA's rules to implement MACT for the largest sources of air emissions of mercury follows.

1.3.1.b Coal-Fired Electric Utilities and the Clean Air Act

In establishing what industry types should be covered by the MACT program, Section 112 of the CAA relied heavily on other CAA programs that had already identified specific industrial sources for air emissions programs. Electric utilities, however, were separately addressed under Section 112. In Section 112(n), Congress required EPA to conduct a study on those hazardous air pollutants "reasonably anticipated to occur" from electric utilities and to regulate electric utilities under Section 112 if EPA finds it is "appropriate and necessary" to do so.

In December of 2000, EPA determined it was "appropriate and necessary" to regulate hazardous air pollutant emissions from coal and oil-fired utilities under Section 112 of the CAA. However, in 2005, EPA altered its course and attempted to delist electric utilities from regulation under Section 112 of the CAA. Relying upon its delisting action, in March of 2005, EPA promulgated the Clean Air Mercury Rule (CAMR) which established an air pollutant cap-and-trade system for mercury emissions from coal-fired power plants under authority of Section 111 of the CAA. This rule was promulgated in coordination with the Clean Air Interstate Rule (CAIR). CAIR established a cap-and-trade program for the pollutants sulfur dioxide (SO₂) and nitrogen oxides (NO_x). Under both CAIR and CAMR, many of Florida's electric utilities would not have enough pollutant allowances to cover their NO_x, SO₂, and mercury emissions. Therefore, many of these facilities would either have to install air pollution controls or purchase credits from other electric utilities. EPA recognized in this rulemaking package that the air pollution control equipment (electrostatic precipitator, selective catalytic reduction, and wet flue gas desulfurization or "scrubber") that would yield NO_x and SO₂ reductions under CAIR would also result in the control of mercury emissions necessary under CAMR. The CAIR's NO_x trading program was scheduled to take effect January 1, 2009 with the SO₂ program to have begun in 2010.

Both CAIR and CAMR were challenged by states, industry groups, and environmental interest groups. While litigation on CAIR and CAMR was pending, many of Florida's coal-fired electric utilities proceeded to design and install air pollution control systems to reduce NO_x, SO₂ and mercury emissions in anticipation of the CAIR and CAMR programs.

On February 8, 2008, the D.C. Circuit Court of Appeals vacated CAMR, stating that EPA had not properly delisted electric utilities from CAA Section 112's industry list and, as such, it could not regulate coal-fired electric utility mercury under Section 111 of the Clean Air Act. On December 23, 2008, the D.C. Circuit Court remanded, but did not vacate, CAIR. Therefore, the CAIR trading programs are still in place.

On August 8, 2011, EPA promulgated a rule intended to replace CAIR called the Cross-State Air Pollution Rule. This rule was challenged and on December 30, 2011, the D.C. Circuit Court of Appeals stayed the implementation of this rule pending a further decision on the full case. The court also indicated the former rule, CAIR, would remain in place in the interim. On February 16, 2012, EPA promulgated final rules for hazardous air pollutants for coal-fired electric utilities under Section 112 of the Clean Air Act. This rule as currently written would result in approximately a 90% reduction in mercury emissions from coal-fired electric utilities based on pre-controlled emissions. Challenges to this rule are pending in the D.C. Circuit Court of Appeals.

In light of the still pending litigation related to CAIR, CAMR and their replacement rules, it is not certain what mercury emission reductions will ultimately be required under the CAA implementation. However, in Florida, most of the coal-fired electric utilities have already implemented air pollution controls that have significantly reduced mercury emissions from these facilities.

1.3.1.c Portland Cement Facilities and the Clean Air Act

In 1999, EPA established MACT regulations for the Portland cement industry, but did not include emission limits for mercury. This rule was challenged and on December 15, 2000, the U.S. Court of Appeals for the D.C. Circuit remanded parts of the 1999 rule and required EPA to set standards for mercury.

EPA amended this rule in December 2006 to include mercury emission limits and address other issues raised by the Court. At the same time, EPA announced that it would reconsider the emission limits for mercury for new cement kilns contained in the final rule and also granted petitions to reconsider the mercury limits for existing cement kilns.

In September 2010, EPA again amended the MACT for cement kilns. EPA anticipates that by 2013, this rule will reduce mercury emissions from the Portland cement industry by 92% based on projected 2013 emissions. In January, 2011, EPA clarified that existing cement kilns had to comply with the mercury limits contained in the 2006 rules until such time as the new emission limits for mercury in the 2010 rule take effect in 2013 (Note, EPA has filed a notice extending the implementation date to 2015).

The mercury emission limit in the MACT rule is 55 lb Hg/million tons of clinker, with compliance required by the end of 2013. The estimated 2009 mercury emission from cement plants in Florida is 395 lbs. Under the new cement MACT, assuming the same production, the mercury emissions would be 233 lbs, a 41% decrease. It should be noted that 2009 was a depressed

year for this industry and that maximum clinker production in the state is 10,000,000 tons/year. If production increased to this level, the maximum mercury emissions would be 550 lbs/year at the MACT limit.

A settlement agreement was signed by EPA, the Portland Cement Association and various cement companies such that EPA proposed a new cement MACT in June 2012. While the Portland Cement Association has expressed support for the new MACT^{*}, concerns have been raised previously about the impacts of these additional regulations on an industry that is still feeling the impacts of the recent economic downturn. In addition, studies have been conducted to determine the net environmental costs or benefits if additional regulations in the United States cause a shift in cement production to countries with less restrictive environmental requirements.[†] Several have concluded that the shifting of cement production to less restrictive countries will significantly reduce or eliminate the environmental benefits ascribed to EPA's proposed rule and may actually lead to additional mercury emissions globally.[‡]

1.3.1.d Solid Waste to Energy Facilities and the CAA

Solid waste to energy facilities are regulated under Section 129 of the CAA and requires EPA to establish emission limits for mercury. EPA updated rules for the solid waste to energy facilities in May 2006. Mercury emissions from the solid waste to energy facilities in Florida have decreased dramatically over the last two decades.

1.3.2 Florida State Air Regulations

Florida implements the federal CAA requirements relevant to this TMDL through its State Implementation Plan (SIP). The Department regularly adopts federal rules and incorporates them into chapter 62-204, Florida Administrative Code. These rules are then incorporated into Florida's air permits for these sources. In addition to the federal MACT requirements, new major sources of air emissions in Florida that have the potential to emit more than 200 pounds per year of mercury are subject to the prevention of significant deterioration (PSD) permitting program which requires the best available control technologies. Alternatively, issued permits can include mercury limits and measures to ensure emissions are less than 200 lb/year. Examples include mercury permit limits set for certain waste-to-energy projects, as well as cement plants that triggered the Department's PSD rules.

1.4 Applicable Water Quality Criteria

Florida's surface waters are protected for five designated use classifications, as follows:

Class I	Potable water supplies
Class II	Shellfish propagation or harvesting
Class III	Recreation, propagation, and maintenance of a healthy, well-balanced population of fish and wildlife
Class IV	Agricultural water supplies

* http://www.cement.org/newsroom/EPA_NESHAP_June2012.asp.

† See http://www.cox.smu.edu/c/document_library/get_file?p_l_id=68463&folderId=229433&name=DLFE-3104.pdf; http://www.cement.org/newsroom/Kings_College/Kings_College_Study.pdf;

‡ See http://www.cox.smu.edu/c/document_library/get_file?p_l_id=68463&folderId=229433&name=DLFE-3104.pdf; http://www.cement.org/newsroom/Kings_College/Kings_College_Study.pdf;

Class V**Navigation, utility, and industrial use (there are no state waters currently in this class)**

The State of Florida has adopted (in Chapter 62-302 of the Florida Administrative Code, or F.A.C.) a series of water quality criteria for its five classes of waters, each designed to protect the associated designated use of the classification. These criteria require that the total mercury concentration in ambient water should be less than 0.012 µg/L (12 ng/L) for Class I and Class III freshwater waterbodies, should be less than 0.025 µg/L (25 ng/L) for Class II and Class III marine waterbodies, and should be less or equal to 0.2 µg/L (200 ng/L) for Class IV and Class V waters [per 62-302.530(41), F.A.C.]. Chapter 62-302.500, F.A.C., provides direction for the Department to ensure Minimum and General Criteria are being met in surface waters of the state. Specifically, the Minimum Criteria provide that waters should be “free from” substances that are acutely toxic or “5. Are present in concentrations which are carcinogenic, mutagenic, or teratogenic to human beings or to significant, locally occurring wildlife or aquatic species, unless specific standards are established for such components in Rules 62-302.500(2) or 62-302.530, or (6) Pose a serious danger to the public health, safety or welfare.”

There has been recognition of the potential for elemental mercury to be transformed into other forms of mercury (e.g., methylmercury - MeHg) which have been identified as being a human health risk. However, so far, no ambient water MeHg criteria have been established. Florida has not yet adopted criteria limiting the amounts of mercury in fish tissue. Instead, the Department’s rules identify waterbodies impaired for mercury pollution based on fish consumption advisories issued by the Florida Department of Health, which are in turn based on observations that mercury tissue concentration in fish samples exceeds the 0.3 mg total mercury /kg of fish tissue as recommended by EPA for human health protection. To provide an added level of protection, this TMDL also assesses impact to the more sensitive populations in Florida, specifically women of childbearing age and young children, using a target of 0.1 mg total mercury per kilogram of fish tissue, as identified by the Florida Department of Health in their fish consumption advisories. Total mercury always equals or exceeds the methylmercury.

1.5 Impaired Waterbodies in Florida Listed for Mercury Impairment

For assessment purposes, the Department has divided the entire State of Florida into 6,638 water assessment polygons, with each watershed or waterbody reach (including lakes, rivers, estuaries, and coastal waters) having been assigned a unique waterbody identification (WBID) number. In the mid-1990s, several environmental groups filed “Notices of Intent to Sue” with the US EPA for failing to take significant action to address the nation’s polluted surface waters. In total, almost 40 actions were filed across states, many of which resulted in the signing of court ordered Consent Decrees between the EPA and petitioning groups. In Florida, a Consent Decree was signed in June, 1999, which laid out a 10-year schedule for the examination of almost 2000 potentially impaired waterbody/pollutant problems identified on Florida’s 1998 303(d) list. The EPA’s 1999 Consent Decree listed 102 Florida waterbodies (freshwater and marine) as impaired for mercury based on fish consumption advisories issued by Florida’s Department of Health and therefore were presumed to need TMDLs (**Figure 1.1**). Due to the acknowledged complexity and many unknowns of the science tied to mercury moving through the environment, the mercury listings were identified as a parameter needing considerable additional data collection and study; therefore, these were to be addressed in the final year of the Consent Decree (2012).

Table 1.1 summarizes the number of WBIDs listed by the Consent Decree for mercury impairment by waterbody types. A complete list of waterbodies identified on this list is provided in **Appendix A**.

Table 1.1 Number of Water Segments Listed on the 1998 Consent Decree List for Mercury Impairment Based on Fish Consumption Advisory

Waterbody Type	Number of WBIDs Listed
Streams	63
Lakes	13
Estuaries	26

The Department assesses mercury impairments based fish consumption advisories issued by the Florida Department of Health (DOH). The IWR (62-303.470, F.A.C.) requires that at least twelve fish be collected for the assessed waterbody, with an average mercury concentration above the current DOH fish tissue concentration threshold. If this occurs, based on the most current data, those waters are placed on Florida's Verified List of impaired waters. **Subsequent to the consent decree, some freshwater WBIDs are impaired based upon assumed movement of fish between WBIDs, i.e., probably of fish with elevated levels of mercury moving between spatially coincident WBIDs** For the case of marine fish advisories, the Department lists all coastal waters in acknowledgement that many marine fish are highly mobile (especially pelagic species) and could be caught/consumed in all coastal WBIDs, regardless of whether or not fish tissue data are available for each costal WBID. This is based on Rule 62-303.470(2), F.A.C., which states "Waters with advisories determined to meet the requirements of this section or waters where scientifically credible and compelling information meeting the requirements of Chapter 62-160, F.A.C., indicates that applicable human health-based water quality criteria are not met shall be listed on the verified list."

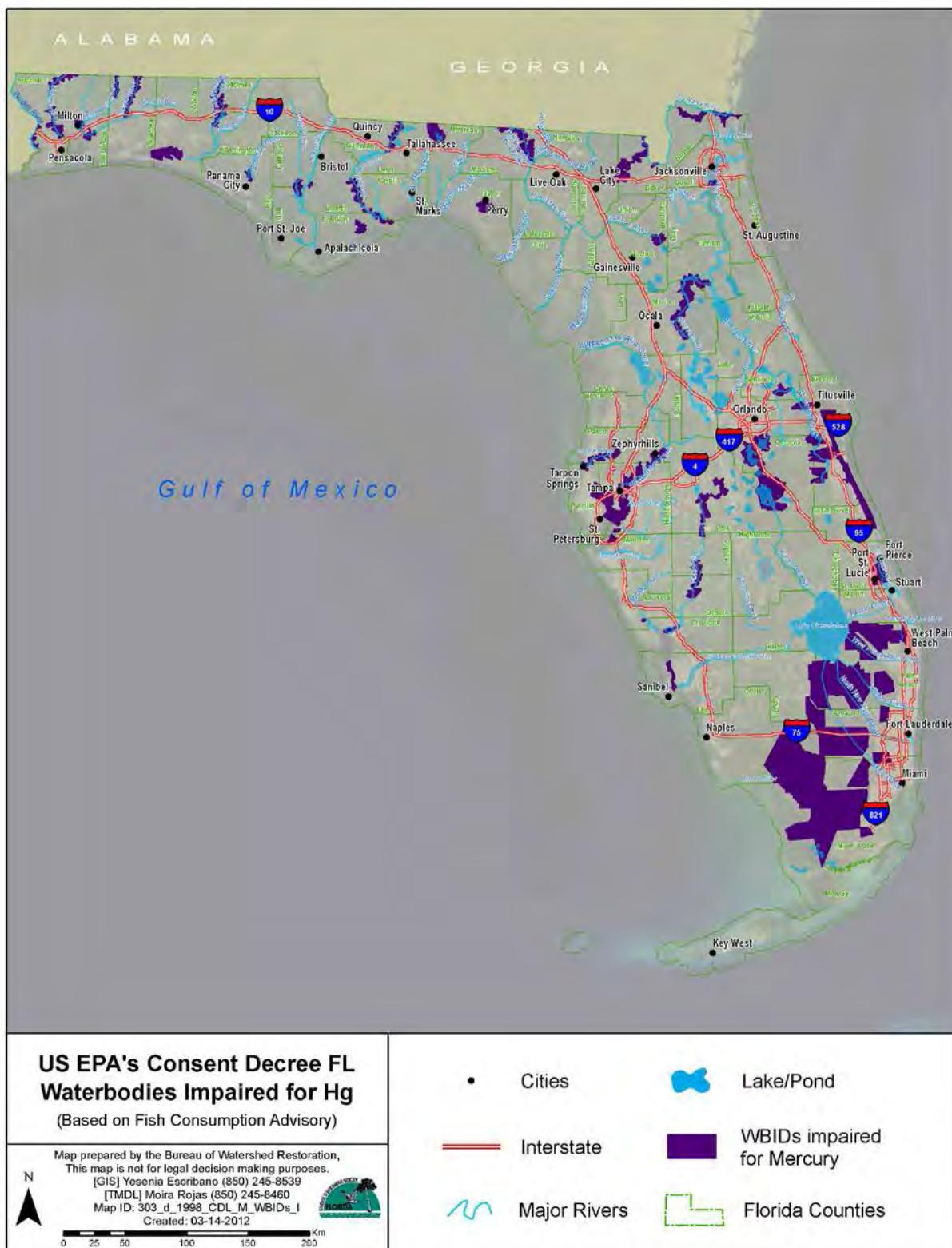


Figure 1.1 Consent Decree Listed Waterbodies for Mercury Fish Tissue Impairment in Florida

Currently in Florida, there are a total of 1,132 WBIDs listed for mercury impairment based on fish tissue data, which represent 12,994 square miles of lakes, estuaries, and coastal waters, and 2,903 miles of streams and rivers. **Table 1.2** presents a breakdown of the number of WBIDs and miles/square miles assessed with mercury fish tissue impairments for different waterbody types. **Figure 1.2** shows the WBIDs on Department's Verified List for Mercury Fish Tissue Impairment. A complete list of freshwater waterbodies verified for mercury impairment is provided in **Appendix B**. Data presented include WBIDs from the most recently completed cycle of the basin rotation (i.e., Cycle 2). **Appendix C** includes regional maps showing WBIDs verified for mercury fish tissue impairment using the IWR listing process.

About two-thirds of all freshwater fish analyzed in Florida exceed the EPA MeHg criterion (0.077 milligrams per kilogram [mg/kg]) for fish-eating wildlife (such as wading birds, osprey, otters, and Florida panthers). One-third of the freshwater fish sampled in Florida exceed the EPA-recommended Total Hg criterion (0.3 mg/kg) for human health. Currently, over 300 freshwater waterbodies in Florida have a consumption limit on recreationally caught fish. Twenty species of freshwater fish are under some level of DOH advisory (FDEP, 2012).

Table 1.2 Number of WBIDs and Miles/Square Miles Impaired for Mercury (in Fish Tissue) by Waterbody Type

Waterbody Type	Number of WBIDs Impaired	Miles Impaired
Streams/Rivers	249	2,903
Waterbody Type	Number of WBIDs Impaired	Square Miles Impaired
Lakes	127	1,344
Estuaries	504	5,163
Coastal	221	6,487

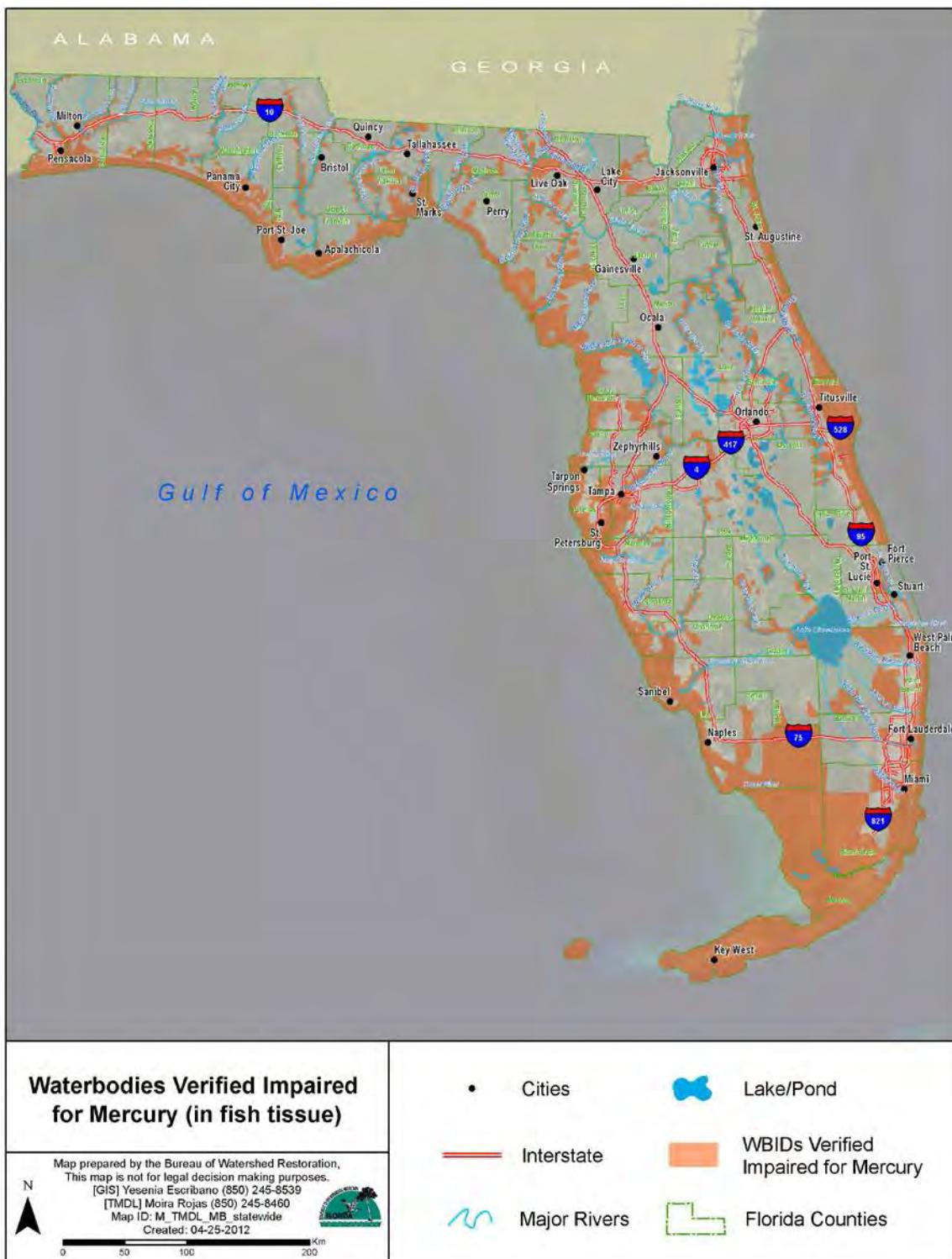


Figure 1.2 Waterbodies on Department's Verified Lists for Mercury Fish Tissue Impairment in Florida

1.6 Other Mercury TMDLs in the United States

Within the United States, 26 states have EPA approved mercury TMDLs (**Figure 1.3**) for some or all waterbodies. These TMDLs are based on either mercury contamination in fish tissue, water column mercury concentrations, or both. This section provides a synopsis of some of those completed mercury TMDLs, specifically those TMDLs that set a target based on mercury in fish tissue. This section conveys an overview of the different geographic scales (ranging from waterbody-specific to multi-state), approaches that have been used, and ranges of mercury concentrations selected as targets. What they all have in common is the determination that nonpoint sources (i.e., atmospheric emissions resulting in deposition) are dominant contributors to the mercury entering the environment, and that the focus of each is a reduction in emissions assigned under the Load Allocation fraction of the TMDL. Another common message is the clear need to have a comprehensive approach applied to address mercury emissions. No one state has the regulatory authority to resolve all of the atmospheric mercury loads being deposited onto its landscape, as emissions sources to deposited mercury can be external to state boundaries. However, the State of Florida is committed to addressing those sources under its control.

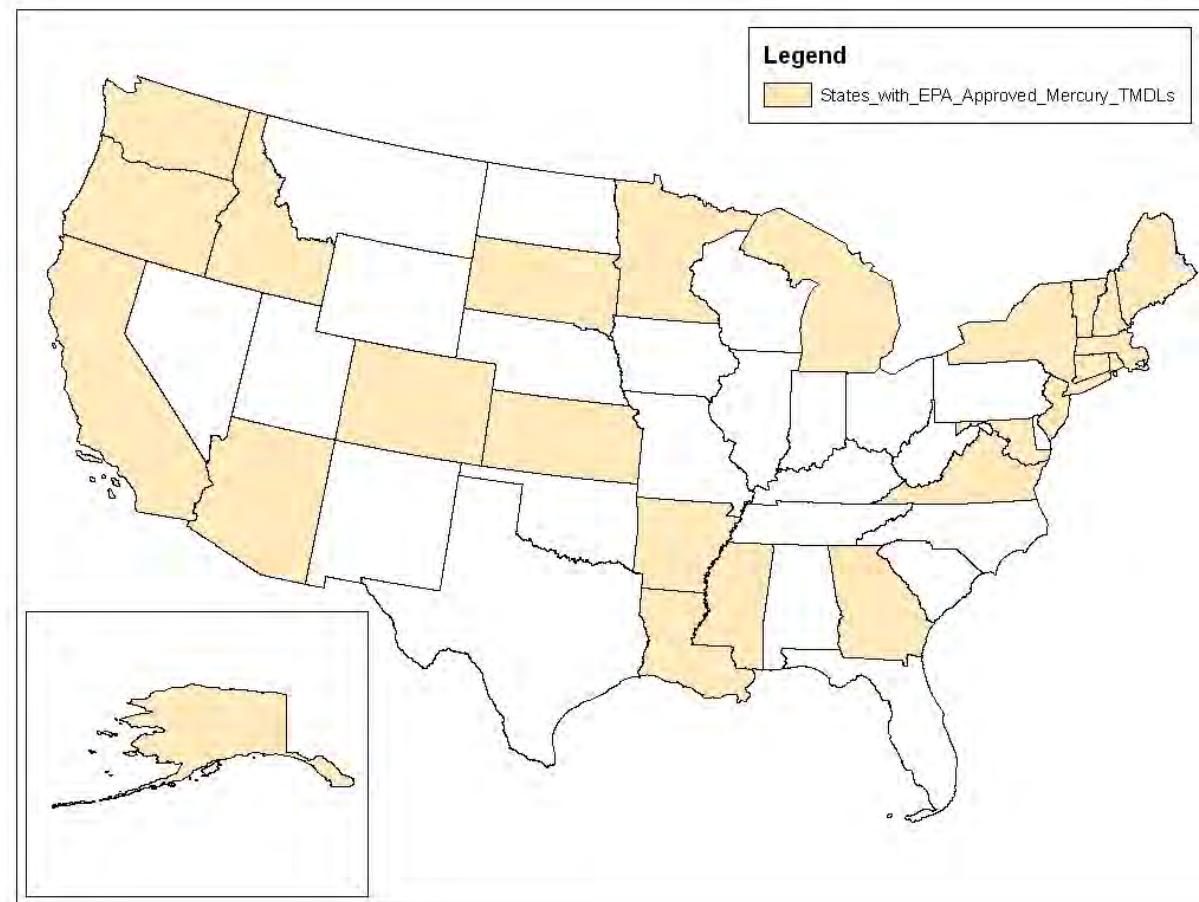


Figure 1.3 States with EPA Approved Mercury TMDLs (2012)

1.6.1 Minnesota Statewide Mercury TMDL (MPCA, 2007)

The Minnesota Statewide Mercury TMDL used a statewide regional approach. The state was divided into two regions: northeast and southwest identified by eco-region boundaries. Land-water mercury transport processes and concentrations in fish differ between the two regions. A statewide mercury TMDL was developed because of similarities in sources and processes. In Minnesota, the 1,239 impairments by mercury consist of 820 lake impairments and 419 river impairments. Twelve lakes and 20 river reaches are impaired for mercury in fish tissue and mercury in the water column; 808 lakes and 399 river reaches are impaired for fish tissue only.

Minnesota's target level for mercury in fish is 0.2 mg/kg (parts per million, ppm). Minnesota's fish tissue mercury criterion is lower than EPA's 0.3 ppm criterion because of the higher fish consumption rate in the state. The 0.2 ppm (mg total mercury, THg, per Kg fish fillet) corresponds to the Minnesota fish consumption advisory threshold for one meal per week[§]. Above 0.2 ppm THg the consumption advice is one meal per month for women who are pregnant or intending to become pregnant and children under 15 years of age.

For these regional TMDLs, target levels of mercury concentrations were determined in standard size top predator fish: northern pike (*Esox lucius*) and walleye (*Sanders vitreus*). Because mercury bioaccumulates and biomagnifies, concentration is highest at the top of the food web; therefore, achieving the mercury target concentration in the top predator fish is expected to provide protections for the whole food web, including the water column, achieving the target level. The target level of 0.2 ppm was applied to the 90th percentile mercury concentration. The difference between the regional 90th percentile concentration for the standard size fish and 0.2 ppm is the reduction factor (RF) needed to meet water quality standards. The RF is greater for the NE than the SW for both walleye and northern pike. Mercury concentrations in walleye were slightly higher than northern pike levels in both regions and, therefore, the RF for walleye was selected for load reduction calculations to provide a margin of safety. The resulting RFs for total mercury were 65% for the NE and 51% for the SW.

The total source load (TSL) is the sum of the point source loads (PSL) and the nonpoint source loads (NPSL). Point source loads include the NPDES permitted facilities in the state, excluding cooling water discharges. PSL for the region is the product of facility design flow and the average measured effluent mercury for wastewater treatment plants in the state (5 ngL). Non-point source load is the product of atmospheric deposition flux in 1990 (12.5 g km⁻² yr⁻¹) and regional surface area. The subsequent 1990 TSLs for NE and SW regions were 1153 kg/y and 1628 kg/y, respectively. About one percent of the TSL is attributable to PSL. Ten percent of the mercury deposition is attributed to anthropogenic sources within the state. As natural sources cannot be controlled and are not expected to change, all mercury reductions must come from anthropogenic sources. The state's percentage of the anthropogenic sources is 14.3% (10% of total divided by 70% of total). The state's contributions to the load allocations (LA) are 0.16 kg/d for the NE and 0.31 kg/d for the SW. The out-of-state contributions to the LA are 0.94 kg/d for the NE and 1.86 kg/d for the SW.

[§] For Minnesota a meal of fish equals 8 ounces pre cooked fish for 150 lb bodyweight \pm 1 ou. for each 20lb bodyweight

Mercury load reduction goals for each regional TMDL were calculated by applying the RF to the baseline mercury load. Reductions can only come from anthropogenic sources; therefore, load reduction goals require anthropogenic source reductions of 93% (65% reduction goal divided by 70% of total that is anthropogenic) in the NE region and 73% (51% of reduction goal divided by 70% anthropogenic) in the SW region. Mercury load reduction goals are applied to emission reductions for the state. Atmospheric deposition of mercury is considered uniform across the state, and in-state emissions disperse across both regions; therefore, the emissions goal is applied statewide rather than by region. The northeast's greater regional reduction goal (i.e., 93% of anthropogenic sources) determines the TMDL's emission reduction goal. In 1990, the total mercury emissions from in-state sources were 11,272 lbs (5513 kg); the TMDL emissions goal is seven percent of the 1990 emissions: 789 lbs (358 kg). Minnesota's 1990 mercury emissions were reduced 70% by 2005, which is equivalent to 76% statewide emissions reduction goal, leaving 24% of the emissions reductions goal remaining. Going from 3,341 lbs mercury emissions in 2005 to the emissions goal of 789 lbs constitutes another 76% reduction in mercury emissions.

1.6.2 Northeast Regional Mercury TMDL for Fresh Waters (NE Regional TMDL, 2007)

The Northeast Regional Mercury TMDL is a plan to reduce mercury concentrations in fish so that water quality standards can be met. The plan covers freshwater in the states of Connecticut, Maine, Massachusetts, New Hampshire, New York, Rhode Island, and Vermont and was developed in cooperation with the New England Interstate Water Pollution Control Commission (NEIWPCC). Based on statewide fish advisories and monitoring data 10,192 lakes, ponds, and reservoirs, 46,199 river miles, and an additional 24 river segments were listed as impaired for mercury.

Using an existing fish concentration 1.14 ppm, and the initial target fish tissue mercury concentration of 0.3 ppm, a reduction factor of 0.74 was calculated. The TMDL was calculated in a way that sets multiple target endpoints that are geographically based, due to variations in respective state standards. The goal of this TMDL is to use adaptive implementation to achieve a target of 0.3 ppm for Massachusetts, New Hampshire, New York, Rhode Island, and Vermont; 0.2 ppm for Maine, and 0.1 ppm for Connecticut. The total existing source load was calculated from the point source load (wastewater discharges) and nonpoint source load (atmospheric deposition based on modeling of mercury emissions), and is equal to 6,647 kg/yr. Modeling produced an estimate of the amount of mercury deposited to the region from regional, national, and international sources. Based on this modeling, the baseline mercury atmospheric deposition load to the region was 6,506 kg/yr with 4,879 kg attributable to anthropogenic sources. This leaves 141 kg/yr originating from wastewater discharges. The TMDL was then calculated using the total source load and the reduction factor. The wasteload allocation was determined by keeping the wastewater contribution equal to the same percentage as it was in the total source load, as it is ~2% of the total load. The load allocation was calculated by subtracting the wasteload allocation from the TMDL and then was divided between natural and anthropogenic sources. Because over 97 percent of the total load is due to atmospheric deposition, reductions focus on the load allocation (nonpoint source deposition).

1.6.3 TMDL for Mercury Impairments Based on Fish Tissue Caused by Air Deposition to Address 122 Waters Statewide, New Jersey (New Jersey DEP, 2009)

The *New Jersey 2008 List of Water Quality Limited Waters* identified 256 fresh waters as impaired with respect to mercury, as indicated by the presence of mercury concentrations in fish

tissue in excess of New Jersey fish consumption advisories and/or not complying with the Surface Water Quality Standards (SWQS) for mercury at N.J.A.C. 7:9B. A TMDL was developed to address mercury contamination based on fish tissue concentration whose sources were linked to largely air deposition in 122 waters. Waters where there are other significant sources of mercury in a waterbody, as indicated by a water column concentration in excess of the Surface Water Quality Standards, documentation of high levels of mercury in ground water or the presence of hazardous waste sites where mercury was a contaminant of concern, were deferred pending additional study. Tidal waters were also excluded because the approach used in this TMDL was intended for waters not affected by tidal dynamics.

The target for the TMDL was a concentration of 0.18 ppm in fish tissue, the concentration in fish consumption for the high risk population and not more than 1 meal per week** of top trophic level fish. At this concentration unlimited consumption is appropriate for the general population. Methods similar to those used in the Northeast Regional TMDL (2007) are employed below to calculate the TMDL.

To allow a consumption rate for the high risk population of one meal per week, the required reduction is 84.3% ($1 - 0.18/1.15 = 84.3\%$). The total existing loading from air deposition and the treatment facilities discharging into non-tidal waters is 601.kg/yr. In this load, 6.8 kg/yr (about 1%) comes from NJPDES regulated facilities with discharges to surface water in non-tidal waters. Due to the insignificant percentage contribution from this source category, reductions from this source category are not required in this TMDL. Therefore, individual WLAs are not being assigned to the various facilities through this TMDL. Individual facilities have been and will continue to be assessed to determine if a water quality based effluent limit should be assigned to prevent localized exceedances of SWQS and to ensure that the aggregate WLA is not exceeded. Based on results of several paleolimnological studies (NEIWPCC, et.al. 2007) in the Northeast, the natural mercury deposition is estimated to range between 15% and 25% of deposition fluxes for circa 2000. Natural sources cannot be controlled and are expected to remain at the same long-term average. It is assumed, in this study, that 25% of the background and background reemission is due to natural sources and cannot be reduced (Ruth Chemerys and John Graham, Pers. Comm. April 28, 2009). Twenty-five percent of the background and background reemission load is about 81.5 kg/yr, which is 13.6% of the total existing load. Including the load of 6.8 kg/yr attributed to surface water dischargers, the portion of the existing load that was not expected to be reduced is about 14.7%. In order to achieve the overall 84.3% reduction of the existing load to attain the target of 0.18 mg/kg in fish tissue, a reduction of 98.8% of the anthropogenic source load would be needed. An implicit margin of safety (MOS) was used in this study.

1.6.4 Mercury in Fish Tissue TMDLs for Watersheds in Arkansas TMDL (FTN Associates, Ltd. 2002)

The Arkansas 1998 Section 303(d) List included stream reaches and lakes that were impaired due to excessive concentrations of mercury in fish in several watersheds (Ouachita River Basin, Lake Winoa and Lake Sylvia Watershed, Spring lake Watershed, Shepherd Springs Lake Watershed, South Fork Little Red Watershed, Bayou Dorcheat Watershed and Fourche La Fave Watershed). The waterbodies included in these TMDLs are located predominantly in central and northern Arkansas, although there is a couple in the southwest corner of the state. Waterbodies that were close together and had similar watershed characteristics were grouped

** For New Jersey a meal is 8 ounce uncooked fillet for a 140lb bodyweight

together because of similar causative factors such as atmospheric and geologic contributions. There are fish consumption advisories in all of these waterbodies because of mercury contamination of fish. The mercury Action Level for fish consumption advisories in Arkansas is 1 ppm (mg fish fillet/kg bodyweight). The safe target level for all fish species used in this TMDL study is 0.8 mg/kg. This incorporates a 20% margin of safety (MOS) for the Action Level.

The predominant sources of mercury loading to the watersheds were watershed nonpoint sources, watershed natural background, and non-local source atmospheric deposition. NPDES point sources accounted for less than 1% of the watershed mercury loads. Half of the watersheds did not have NPDES point sources of mercury.

The TMDLs were developed using a two-step approach. The first step was to estimate the mercury loads to the watersheds from NPDES point sources, local emission sources, atmospheric deposition from non-local emission sources, watershed nonpoint sources, and watershed natural background sources. In the second step, average largemouth bass fish tissue mercury concentrations measured in the watersheds were used to estimate the reduction in fish tissue mercury needed to achieve the safe target level. A linear relationship was assumed between mercury levels in fish and mercury loading to the watersheds. The reduction in fish tissue mercury to achieve the target safe level was then used to determine the reduction needed in the mercury load to the watersheds.

1.6.5 Mercury TMDLs for Subsegments within Mermentau & Vermilion-Teche River Basins, Louisiana (FTN Associates, Ltd. 2002)

The Mermentau basin TMDL addresses four waterbodies listed for mercury, including Bayou Des Cannes, Bayou Plaquemine Brule, Seventh Ward Canal, and a portion of the Gulf of Mexico. The Vermilion-Teche TMDL addresses two waterbodies listed for mercury, including Chicot Lake and a portion of the Gulf of Mexico. The segments were listed by the state due to excessive levels of mercury in edible tissues of one or more fish species. The data used to make this determination were collected as part of a statewide study of mercury contaminant levels in Louisiana biota, sediments and surface waters. Fish consumption advisories were issued by the state based on the risk from long-term consumption by the general population and sensitive sub-populations. Issuance of a “fish consumption advisory” indicates non-support of the state water quality standards. The standards state that “no substances shall be present in the waters of the state or the sediments underlying said waters in quantities that alone or in combination will be toxic to human, plant or animal life or significantly increase health risks due to exposure to substances or consumption of contaminated fish or other aquatic life.” These TMDLs are intended to achieve the “fishable” beneficial use over time.

These TMDLs take into account mercury bioaccumulation observed in all six segments collectively. This is justified as EPA and the state believe that atmospheric deposition is the predominant source of mercury. Atmospheric deposition includes a combination of local, regional scale and background (global) inputs. Here the highest average tissue concentration for the species and water bodies sampled served as a “worst case” measure of bioaccumulation. The waterbody and species with the worst case average tissue concentration was bowfin in Bayou Plaquemine Brule. The ratio of this concentration (1.191 ppm) to the “safe” tissue concentration of 0.4 ppm (the risk based fish tissue concentration of 0.5 ppm, factoring in a 20% margin of safety) indicates that a 67% in loading is needed. This assumes a linear relationship between atmospheric loading and resulting bioaccumulation. The target wet

deposition loading rate for both basins, calculated as one-third of the National Mercury Deposition Program (NMDP) wet deposition data was 79.6 ng/m²/wk (11.4 ng/m²/day).

Additional EPA approved TMDLs for mercury contamination based on fish tissue concentration that use a “watershed approach” are located in **Appendix D**.

Chapter 2: Basis of Concern

2.1 Mercury Dynamics in Natural Environment

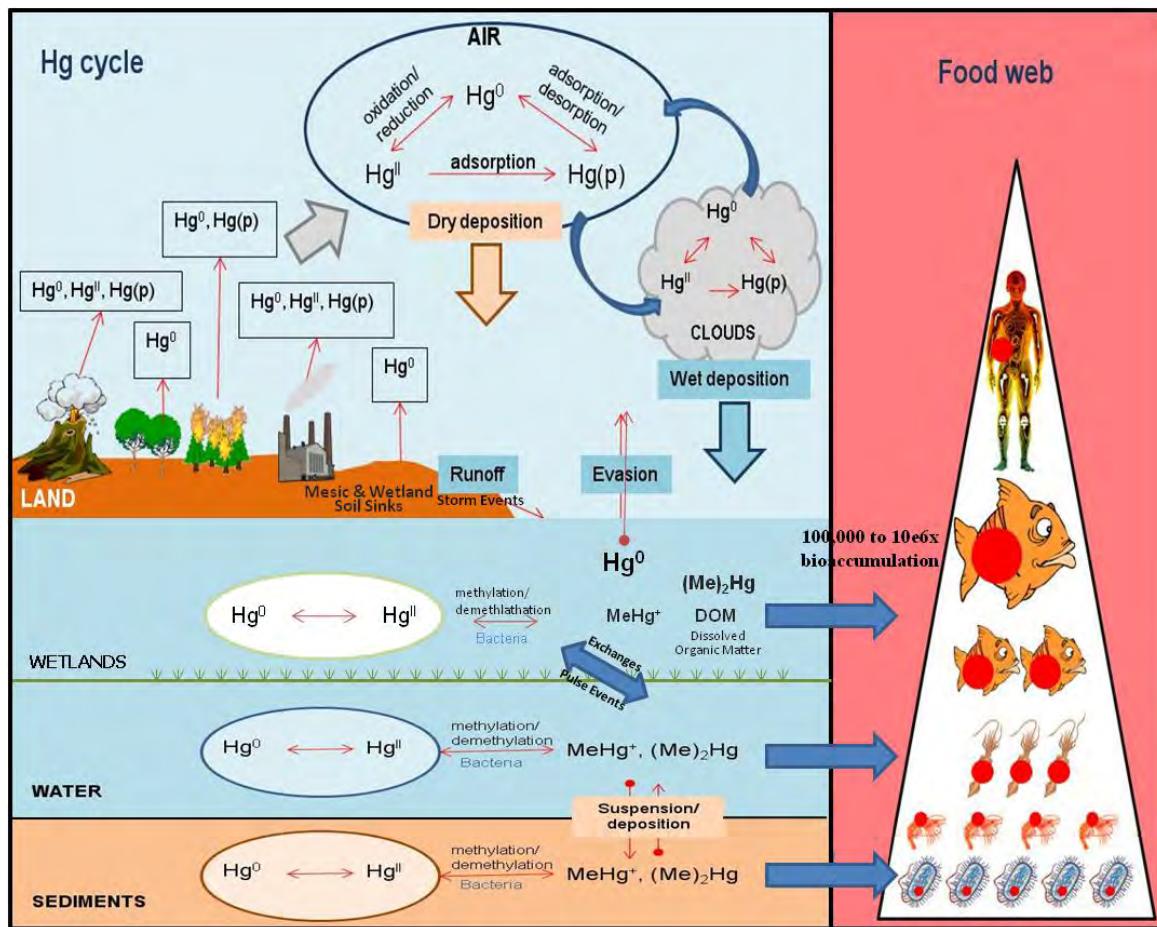
Mercury released into the atmosphere as a result of anthropogenic activities (responsible for on average about 70% of the mercury in the atmosphere globally) which eventually falls on land and water where a small portion of it is converted to a more toxic mercury form, methylmercury (MeHg). This organic mercury concentrates up aquatic food chains, peaking in top predator fish. The majority of human mercury exposure is the result of consuming those few fish species that have elevated levels of mercury. There is variation amongst fish species as to degrees of mercury bioaccumulation, especially related to the species trophic position.

Mercury is an environmentally persistent toxin, in both metallic and organic forms. Estimates as to the longevity of mercury cycling in the environment, i.e., prior to environmental sequestration, range from 100 to 3,000 years, depending upon assumptions made. (Selin, 2007; Selin, 2009) The cycling longevity results from mercury's unique physical properties, most notably being a metal that readily and significantly volatilizes, as well as readily shifts to different species in the atmosphere and aquatic systems. Metallic mercury is broadly thought of as occurring in one of three speciated forms: elemental mercury (Hg^0), ionic or particulate mercury (Hg II), and Reactive Gaseous Mercury (RGM). Each of these forms has differing chemistries in the environment and different patterns of translocation in the environment. Hg^0 when emitted to the atmosphere can readily travel for hundreds to thousands of miles, depending upon wind patterns, prior to deposition. Additionally, Hg^0 readily re-volatilizes after deposition, thus re-entering atmospheric cycles. Hg II, as a large ion, readily binds to other materials from associated emissions as well as other materials otherwise in the atmosphere. When bound to other materials Hg II is often identified as particulate mercury (HgP). Particulate mercury tends to have a shorter atmospheric residence time, due primarily to the physics of being bound to a particle, e.g., larger mass, increased wind resistance, more readily stripped from the atmosphere by precipitation. Hg II is generally thought to be deposited in a range of 30-50 miles from its point of emission to the atmosphere. RGM, as the name implies, is highly reactive, reacting with other environmental constituents (atmospheric, land based, and aquatic) within a few miles of an emission location.

2.1.1 Mercury Cycling

Mercury remains environmentally and chemically active on land, in the atmosphere, and in aquatic systems both freshwater and marine. Once deposited, elemental mercury readily photo-reacts to shift between speciated types and re-volatilizes, again entering the atmosphere. There are significant chemistries that occur with mercury while in the atmosphere, including photo and oxidative chemistries, that are unique to mercury and differ significantly from aquatic chemistries of mercury. While in the atmosphere mercury may switch between speciated forms through reductive, oxidative, and absorption-desorption reactions. The manner and specifics of these reaction categories depends upon the specifics of environmental conditions, such as levels of ozone or halogens, atmospheric levels, and meteorology. The nature and species of these chemistries are important to understand as they allow one to model movement of mercury. The specifics of speciation influence mercury's deposition, and subsequent inclusion in terrestrial or aquatic systems.

Figure 2.1 illustrates the emission, atmospheric chemistry, aquatic chemistries, transmission, cycling and ultimate bioaccumulation and human exposure of mercury. The specifics of mercury speciation and points of entry into terrestrial, wetland, and aquatic (freshwater and marine) ecosystems, as well as specifics of ecological composition of systems, influence the manner, degree, and speed with which mercury is transformed to MeHg. The ecological compositions of systems also influence the bioaccumulation of mercury in food webs, and thus the ultimate anthropogenic risk via exposure through fish consumption.



(Revised from CNR-IIA, Nicola Pirrone)

Figure 2.1. Mercury Cycling and Bioaccumulation

2.1.2 Bioaccumulation of Mercury in Fish

Mercury entering the environment is distributed in water, sediments, and plants (Chasar et al. 2009). Once in the environment, mercury enters food webs through multiple methods dominated by single-cell organisms (Miles et al. 2001). In aquatic systems these form the basis of the food web; the bottom level of the trophic pyramid (Figure 2.2). In the trophic pyramid, each level consumes those below it in the pyramid. With mercury, it is bioaccumulated up the trophic pyramid. Unlike the ecological rule of 10% of the biological energy being passed between food and consumer, mercury is retained being consistently more concentrated in each

subsequent consumer. There is almost no excretion of MeHg consumed. Instead, it is preferentially stored in muscle tissues.

Following deposition, ionic Hg (i.e., HgII, oxidized mercuric species, including complexes and particulate forms) may be reduced and re-emitted to the atmosphere or converted to the more bioavailable form, MeHg. Through bioaccumulation, at a factor of up to 10 million, MeHg accumulates to toxic levels at the top of piscivorous (fish eating) food webs. While implicitly including aquatic food webs, other fish consuming species are impacted by the bioaccumulation in fish, and the bioaccumulation can be passed to other animal groups and food webs external to aquatic food webs. This occurs when birds or mammals have fish as a major component of their diets, and then these piscivorous species are food sources for other wildlife or humans. Examples of piscivorous mammals would include otters, raccoons, and minks, while in marine systems this would include dolphins and toothed whales. Mercury entry into the food chain is not exclusive to aquatic systems as recent studies show insects are a vector from plants to song birds (Evers, et. al., 2012).

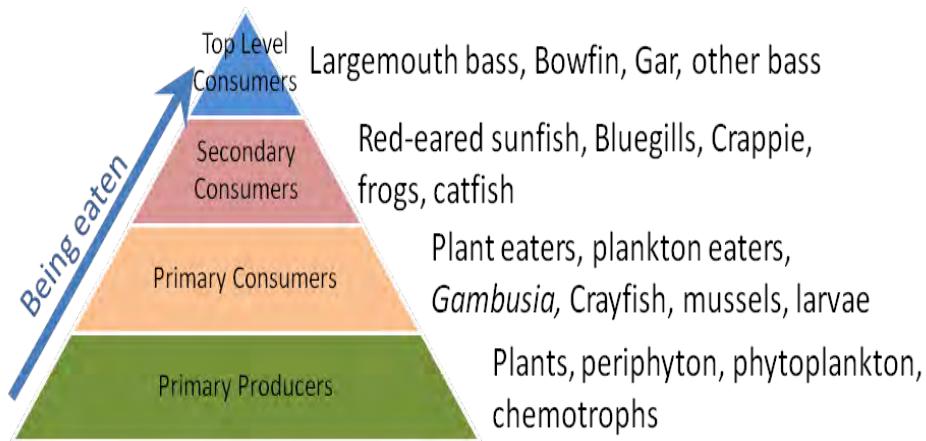


Figure 2.2 Example of a Trophic Pyramid

The term "bioconcentration" refers to the accumulation of a chemical that occurs as a result of direct contact between an organism and its surrounding medium (e.g., uptake of water through the gills and skin tissue) and does *not* include the ingestion of food contaminated with a toxin. The term "bioaccumulation" refers to the net uptake of a contaminant from all possible pathways including direct exposure and contaminated food. The term "biomagnification" refers to the increase in chemical concentration in organisms at successively higher trophic levels as a result of the ingestion of contaminated organisms from lower trophic levels. Mercury is known to bioconcentrate, bioaccumulate and biomagnify. The bioconcentration factor (BCF) is the ratio of a substance's concentration in tissues (generally expressed on a whole-body basis) to its concentration in the surrounding medium (e.g., water or soil) in situations where an organism is exposed through direct contact with the medium. The bioaccumulation factor (BAF) is the ratio of a substance's concentration in tissue to its concentration in the surrounding medium (e.g., water or soil) in situations where the organism is exposed both directly and through dietary sources. The biomagnification factor (BMF) is the factor by which a substance's concentration in the organisms at one trophic level exceeds the concentration in the next lower trophic level. MeHg and total mercury concentrations both tend to increase in aquatic organisms as the trophic level in aquatic food webs increases. In addition, the proportion of total mercury that exists as MeHg generally increases with trophic level (May et al., 1987; Watras and Bloom,

1992; Becker and Bigham, 1995; Hill et al., 1996; Tremblay et al., 1996; Mason and Sullivan, 1997). The BCF in plankton can be 2,000 to 90,000. BCFs for trophic level 4 fish (largemouth bass) are around 50. BCFs calculated for total mercury in aquatic biota ranged from 0.4 to about 50 and, within a given system, and increase with trophic level (US EPA, 1997).

The US EPA (2001) has devised water quality criteria based on fish MeHg concentration and has derived bioaccumulation factors (BAF) for various trophic level fish to allow the estimation of water column MeHg. BAF is the ratio of MeHg in fish tissue to MeHg concentration in the water column where fish were collected. The average value derived for trophic level 4 (piscivorous – fish eating fish) fish is $\log BAF = 6.43$; for trophic level 3, it is 5.83 (Sveinsdottir and Mason, 2005). The bioaccumulation is more a factor of the age of the fish than the size of the fish, as with increased age more meals have been ingested and each meal being a point of added exposure and bioaccumulation. Applying similar logic, a fish that is larger at the same age may have a lower mercury concentration because there is more mass per unit mercury consumed. In Florida fish are identified as being at risk for consumption by size because this is a measure readily made by the public. For the mercury TMDL study, we know the age of each fish by the individual's ear bone (otolith), which receives a new bone layer each year much like the rings in a tree. Thus, we know the age and the size of all the individual fish caught for the study. From this data set, fish were normalized for size and age. This allows the variation in fish to be standardized so the impacts of age and location can be controlled for statistical analyses, allowing all fish to be grouped together for analyses.

To address areas with a dearth of largemouth bass (the study's primary target species) black bass (*Micropterus salmoides*), redear sunfish (*Lepomis microlophus*), and spotted sunfish (*Lepomis punctatus*) were used as surrogate species with a translation assessment being made between species to provide a normalized evaluation between all systems. To represent the Everglades proper, i.e., regional external to Water Conservation Areas and Everglades Agricultural Area, mosquito fish (*Gambusia affinis*) collected under the previous REMAP project were included, with a translation being made for normalization amongst all systems. This analysis addresses that mosquito fish are a trophic level-2 fish (2-3 depending upon the methodology, consumers of primary production, plant material) and of a much shorter age class (median age 1 year, maximum 3 years) than LMB which live to a median age of six years and maximum age of nine years. This walkover analysis allows the areas without LMB in the Everglades to be included in the statistical analyses.

2.2 Human Health Effects

MeHg is a “highly toxic substance” (U.S. EPA IRIS <http://www.epa.gov/iris/subst/0073.htm>) with a number of adverse health effects associated with its exposure in humans and wildlife. The most severe effects reported in humans were observed following high-dose poisoning episodes in Japan and Iraq. These episodes showed empirically that neurotoxicity is a health effect, for very high dose levels. Effects included reduced intellectual functions, cerebral palsy, deafness, blindness, and dysarthria in individuals who were exposed in utero as well as sensory and motor impairment in exposed adults. In other cases chronic, low-dose fetal MeHg exposure from maternal consumption of fish has been associated with more subtle end points of neurotoxicity in children, as well as other teratological issues. Child development end points include poor performance on neurobehavioral tests, particularly on tests of attention, fine motor function, language, visual-spatial abilities, and verbal memory. Young children exposed to fish high in mercury may also be at risk.

To determine an acceptably safe exposure rate to MeHg, the National Research Council (NRC 2000) derived a MeHg reference dose, estimating a daily exposure to the human population (including sensitive subpopulations) that is likely to be without a risk of adverse effects over a lifetime. The NRC derivation of a MeHg reference dose for women of childbearing age (0.1 micrograms of MeHg per kilogram of a woman's body weight per day or 0.1 µg MeHg/kg-BW day) utilized 3-fold uncertainty factors each for toxicokinetic and toxicodynamics, with an overall uncertainty factor of 10. It is estimated that over 99% of women of childbearing age exposed to MeHg at the reference dose level would have fetal (umbilical) cord blood MeHg concentrations less than the benchmark dose lower limit (58 µg/L) – the concentration producing a predetermined increase in adverse neurodevelopment effects on the fetus (NRC 2000; Stern, 2005). This multifold increase in setting of the reference dose for MeHg is one of implicit components of this TMDL's Margin of Safety (MOS).

Although developmental neurotoxicity is currently considered the most sensitive health endpoint regarding chronic exposure, data on cardiovascular and immunological effects are beginning to be reported and provide more evidence for toxicity from low-dose MeHg exposure (USEPA, 2001a; Roman et al., 2011). Cardiovascular effects include coronary heart disease, acute myocardial infarction (AMI), ischemic heart disease, blood pressure and hypertension effects, and alterations in heart rate variability (Mergler, 2007).

Since 1980, the U.S. National Library of Medicine has listed more than 1,000 publications on experimental toxicology of this substance. At present, MeHg is one of the environmental pollutants with the most extensive toxicology documentation (Grandjean et al., 2010).

In 1989, the Florida Department of Environmental Protection (FDEP) through its environmental monitoring program discovered elevated levels of mercury in the edible tissue of fish from streams and lakes throughout the state. Further study has shown that unacceptable mercury levels are also found in many of Florida's marine fish.

The Florida Department of Health (FDH) conducted a study in 2010 collecting hair samples from 408 women between the ages of 18 to 50 who resided in Martin County, Florida (Nair, 2011). The results of the study showed that 25% of the women had mercury levels higher than the EPA advisory level of 1 µg/g. A similar study in Duval County showed that 7% of women had mercury levels higher than the EPA reference dose.

A study done in the Florida Panhandle analyzed hair mercury levels in women of childbearing age from 16-49 (Karouna-Renier et al., 2008). The hair mercury levels were significantly higher in women who consumed fish within the 30 days prior to sampling. Mercury levels ranged from below the Minimum Quantification Limit (MQL) to 22.14 µg/g. Of the 601 women sampled, 15.8% were found to have mercury levels that exceeded the EPA reference dose.

2.3 Florida Human Case Studies

Since 2005, there have been multiple instances reported to the Florida Department of Health (FDH) where human health effects are believed to have been a result of exposure to mercury in Florida. From 2005 to 2008, there were 62 cases reported that were presumed to be primarily related to fish consumption. In 2009, there was a change in case definition, which is more stringent and requires clinical illness. The new case definition classifies all cases reported based on clinical illness, laboratory tests, exposure history, or epidemiologic linkage. Since the change in case definition, the number of confirmed cases decreased to 14 in 2009. It should be

noted that none of these conclusively identified mercury as the toxin of concern; and, in fact only developed a probable causality based upon presumptions of fish consumed.

There were 13 confirmed cases reported in 2010. The potential source of mercury exposure was identified to be fish consumption. Twelve out of thirteen individuals interviewed had eaten fish within a month of reporting, while one patient had an unknown source of exposure. Three of the affected people reported eating less than 12 ounces of fish in a week, six cases reported eating 12 to 30 ounces, and two cases ate 30 to 60 ounces per week. Two cases did not report the amount of fish consumed.

2.3.1 Human Risk

Human risk from environmental exposure to mercury is almost exclusively through exposure by the consumption of fish with elevated levels of mercury. For this reason fish consumption advisories are set for fish with elevated levels of mercury. At a federal level, the US EPA and FDA have set a joint advisory at 0.3 ppm total mercury (THg) in fish tissue. The concentration is calculated from THg in micrograms (μg) per gram (g) of fish tissue (fillets as these represent what is consumed by people). In Florida, the Department of Health has developed two consumption guidelines.

<u>Population description</u>	<u>Consumption guideline</u>
At risk population of women of childbearing age and young children	0.1 ppm
General population	0.3 ppm

These boundary values, 0.1 ppm and 0.3 ppm, are levels at which intelligent choices need to be made about the frequency and volume of fish consumed. To address this exposure pathway a “Market Basket” approach is applied. The Market Basket looks at consumption patterns based upon species of fish, meal size, meal frequency, bodyweight, and fish origin (>85% of fish consumed in Florida come from outside of US waters) as to assess the basis of exposure from fish consumption. The targeting is set to have the THg levels in fish allow the consumption of the recommended amount of fish set by public health organizations. Please see Chapter 7 on TMDL Target Setting for further discussion and specifics.

2.4 Wildlife Health Effects

The highly bioaccumulative form of mercury, MeHg, is a concern due to the neurotoxic threat it poses in particular for wildlife that consume fish. Numerous studies document the toxic effects of MeHg on wildlife (Scheuhammer et al., 2007) and piscivorous (fish eating) species have been found to have greatest MeHg exposure. Recently, Evers et al. (2012) determined that insectivorous (insect eating) birds and bats in the northeast U.S. are at risk of impairment of reproductive success due to elevated MeHg exposures with the associated neurological effects.

Elevated levels of mercury (Hg) in biota in Florida were first reported by Ogden (1974) for the Everglades National Park (ENP or Park), and by Bigler et al. (1985) for peninsular Florida. In 1988, reports of mercury levels in largemouth bass (LMB) (*Micropterus salmoides*) in the Everglades Protection Area's (EPA) Water Conservation Areas (WCAs) exceeding 1 part per million (ppm) [1 ppm = 1 milligram per kilogram (mg/kg) or 1 microgram per gram ($\mu\text{g}/\text{g}$)], prompted expanded sampling of fish and wildlife by state environmental and health agencies.

The risks of elevated mercury tissue concentration to wildlife, and specifically Florida wildlife alligators, Florida panther, pig frogs, Burmese python, others, are not fully established. It is known that elevated mercury levels effect reproduction and behaviors in fish, insects, birds, and mammals (Wolfe et al., 1998; Scheuhammer et al., 2007; Frederick and Jayasena, 2010; Fredrick, 2000). Seasonal variations in mercury within systems have been shown to impact seasonal migrants in California where nesting avifauna had elevated exposures as a consequence of their consumption of fish species with greater concentrations of mercury during spring nesting season (Farmer et al., 2010). Reductions in anthropogenic mercury loads, from any and all sources, are expected reduce levels of exposure in wildlife. The effects of such reductions will be seen most significantly in species lower in food webs, i.e., those species lower in trophic pyramids. Birds that eat smaller fish, such as wading birds will see a faster and more significant response as the small fish they eat will be more limited in exposure with reduced uptake under reduced emissions. Even with reductions in mercury loads, the exposure of top level predators remains tenuous as bioaccumulation in longer lived prey species may still remain high. Thus, long-lived high trophic feeders such as sharks and tuna may remain a concern.

Fish and wildlife monitoring, of MeHg levels and other monitoring, is necessary to (1) assess human and wildlife risks from consumption of mercury-contaminated fish, (2) describe spatial and temporal trends in mercury bioaccumulation, and (3) gain a better understanding of the ecological significance of mercury bioaccumulation in fish and wildlife. **Appendix E** provides summaries of research on the status and trends of mercury in the American alligator, Florida panther, some of Florida's fish-eating birds (white ibis, bald eagle, wood stork, great egret), pig frog, and the non-indigenous invasive Burmese python.

2.4.1 Wildlife Risk

Wildlife are exposed to mercury primarily through the consumption of upper trophic level fish in which there has been a bioaccumulation of mercury. As with humans, mercury levels for wildlife risk protection have been estimated, if not formally established. The Mercury Report to Congress set a value of 0.077 ppm as protective of piscivorous wildlife primarily consuming at a Trophic Level of 3, and 0.346 ppm for wildlife consuming at a Trophic Level of 4 (USEPA, 1997 VI). For piscivorous non-fish species, the majority of their diet is comprised of trophic level 3 fish and lower trophic levels, more smaller fish than trophy sized. Further, the trophic level 4 value of 0.346 is above both of the human targeting values, 0.1 ppm and 0.3 ppm. Thus, assessing targeting and protections at the 0.077 ppm provides additional protections to humans, i.e., an increased margin of safety, while addressing protections to wildlife. Please see Chapter 7 on TMDL Target Setting for further discussion and specifics.

Chapter 3. Dynamics of Mercury in Natural Environments and Source Identification

3.1 Introduction on Mercury Sources

Mercury loading to the environment comes from natural sources and from anthropogenic sources. Natural sources broadly can be divided between land and water in origin. Anthropogenic sources can be broadly categorized into industrial processes, mining operations, and energy production. Relative to Florida mercury TMDL sources are evaluated as (1) Florida sources, i.e., those located in Florida; (2) United States Sources, and (3) Global Sources.

Mercury is emitted from a variety of natural sources, such as volcanoes and geothermal activity, wildfires (including uncontrolled peat and coal fires), and weathering of rocks and soils. The primary source of mercury emissions since the age of industrialization is from various anthropogenic activities. Major anthropogenic sources of mercury include burning of fossil fuels, processing ores from mining especially gold (industrial and artesian operations), and several industrial processes most predominantly in terms of emissions being the chlor-alkali industry. Mercury is also used in commercial and consumer products, and often being released when these products enter waste streams. The U.S. is the third largest emitter of anthropogenic mercury, equating to roughly 5% of the total global emissions. Asia accounts for approximately 67% of all anthropogenic emissions, with China by far the country having the largest source contributions, with India second (UNEP, 2008). Globally, coal combustion is the largest categorical source of anthropogenic mercury emissions, accounting for 45-50% in the global attribution, all gold mining being about 24%, and other mining activities emitting about 10% of the global load. (UNEP, 2008)

Estimates suggest that US emissions of Hg peaked in the 1970s and have since declined (Pirrone et al., 1998); however, atmospheric concentrations remain approximately three times higher than pre-industrial revolution levels (Mason et al., 1994). “Pre-Industrial” defined as before the end of the Industrial Revolution, which ended between 1860 and 1900. Pre-industrial fish samples from museum specimens have been evaluated to determine natural mercury bioaccumulation. One such study found museum samples of tuna and swordfish, with elevated levels of mercury above modern consumption guidelines (Miller et al., 1972). Similar studies have been done with pelagic seabirds in museum collections that show historic levels of mercury would have been a concern, and that mercury levels have been increasing (Vo et al., 2011). What these studies of historic specimens show are two critical points: (1) bioaccumulation resulting in high levels of biomagnifications, perhaps passing 10 million as a bioaccumulation factor, can result in a longer lived top level piscivorous fish (fish eater, fish predator) having levels of mercury that are unacceptable for at risk populations from natural levels of mercury; and, (2) naturally occurring high levels of mercury in wildlife does not necessarily equal a risk to that population, that species, nor to associated species. This research shows that bioaccumulation in some specific food webs and the age of the top predators could contribute to a maximum exposure level seen from even natural mercury levels. The increase of mercury in the environment, its subsequent availability for conversion into MeHg, and this translating to an increase in bioaccumulation of MeHg in many food webs is scientifically irrefutable. The questions are specifics of where mercury originates, where it is deposited relative to the source, how long do differing speciated forms of mercury cycle before becoming ecologically sequestered, and details of the science of translation of mercury to

MeHg; and, what are the synergistic or antagonistic interactions within each of these parts of the mercury cycle.

Thus the understanding of mercury sources, the origin, transmission, and ecological pathways of mercury exposure, are each critical in understanding and managing mercury in the environment, as well as understanding the potentials of human exposure. A worldwide distribution of mercury sources was developed by the United Nations Environmental Program and updated for 2005 emission estimates. The results of this emission inventory are shown in **Figure 3.1**. The emissions geographic distribution reflects areas of industrialization and human population densities. This is intuitively valid for large scale industries that require significant worker populations, each of which require power generation. This allows one to understand the comparatively isolated hot-spots seen in the northeastern Russian Federation, isolated areas across Canada and Alaska, as well as South America, Africa, and Australia. Some of the remote hot-spots are locations of extraction operations for fossil fuels or metals.

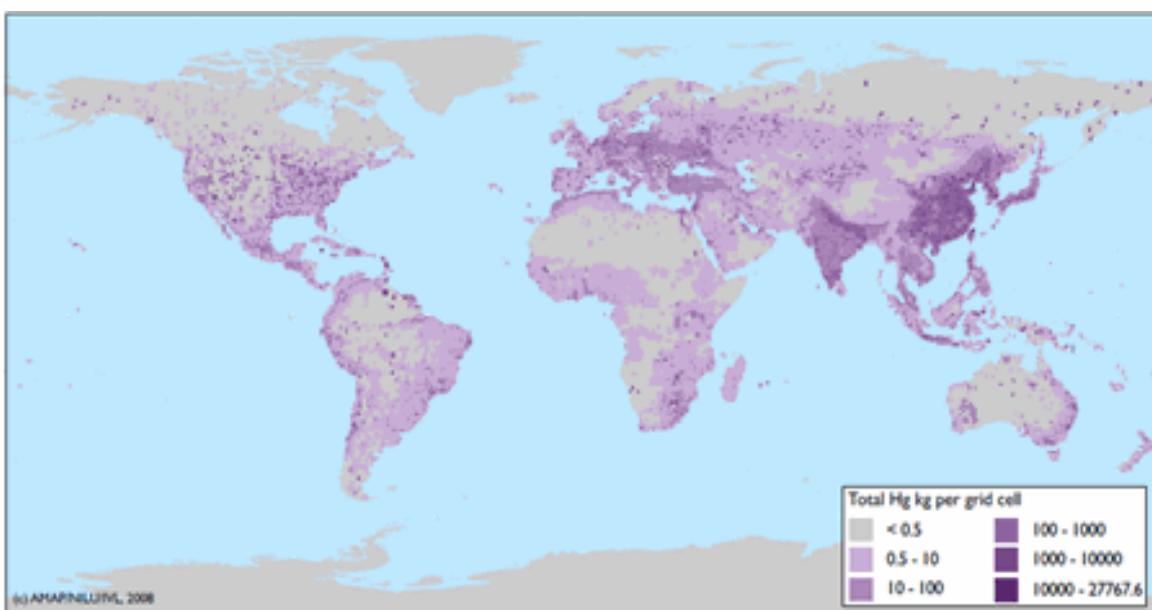


Figure 3.2 Worldwide Distribution of Mercury Emissions (United Nations Environment Program Global Atmospheric Mercury Assessment: Sources, Emissions and Transport, 2008, using 2005 data, as presented by the Arctic Monitoring and Assessment Program Secretariat)

Note: The following discussion of natural and anthropogenic does not provide, nor is intended to provide, an inventory of loads. The numbers provided are for illustrative purposes of relative loads of certain source types, to combine into total loads by category would be invalid.

3.2 Natural Sources

Natural sources of mercury are those that occur as part of natural systems external to anthropogenic actions. The natural sources emit mercury mostly as gaseous Hg^0 . Major natural sources include geothermal activity, such as volcanoes and geothermal vents. Volcanoes and geothermal vents occur both on land and within oceans, with subsequent

emissions from oceans. Both locations eventually result in mercury entering human environs. Ocean volcanoes and geothermal vents emit mercury into the water column, mercury is then mixed with waters, moving via currents and advection, mixing and cycling, eventually reaching surface waters, as well as entering food webs. Ocean surface waters are sources of mercury to the atmosphere through emissions, and re-emissions of mercury that has deposited from the atmosphere or been loaded from surface water inflows. Land volcanoes and geothermal vents directly emit mercury to the atmosphere. Ocean emissions are estimated as 1000 Mg Hg/yr (range 400-1,300 Mg Hg/yr). The annual emissions from volcanoes and geothermal venting /passive gassing is estimated as an annual average of 30 Mg Hg/yr, and emissions from active eruptions, which depends upon the level of activity, are estimated at 800 Mg Hg/yr. Other geothermal activities (vents, hot springs, convective transport) emit approximately 60 Mg Hg/yr (Varekamp and Buseck, 1986).

Soils, high in metals, are also a source of mercury emissions to the atmosphere in some limited areas. One such area is the high desert plateaus of the United States in Nevada, California, Wyoming, Colorado, and other western states. The emissions from western soils has been estimated to be up to 40 Mg annually, and globally this is estimated at 400 Mg Hg/yr (Gustin, 2008). Mercury emissions, predominantly in the form of re-emissions, from vegetation depend upon several factors, including vegetation's original mercury uptake from the atmosphere, levels of atmospheric deposition to foliage and mercury uptake from roots (Rae et al. 2002); however, the proximity of vegetation to natural or anthropogenic sources (hot spots or contaminated sites) may increase its mercury content (Lodenius, 2003). Recent studies show that most of the mercury found in foliage tissue originates from the atmosphere, so vegetation sources can largely be thought of as temporary storage and re-emission sources for both natural and anthropogenic origins, as well as primary vectors for mercury combining with organic matter and entering food webs. Fires can be sources of re-emission releasing Hg contained in plant materials **Figure 3.2.** shows the global natural emissions.

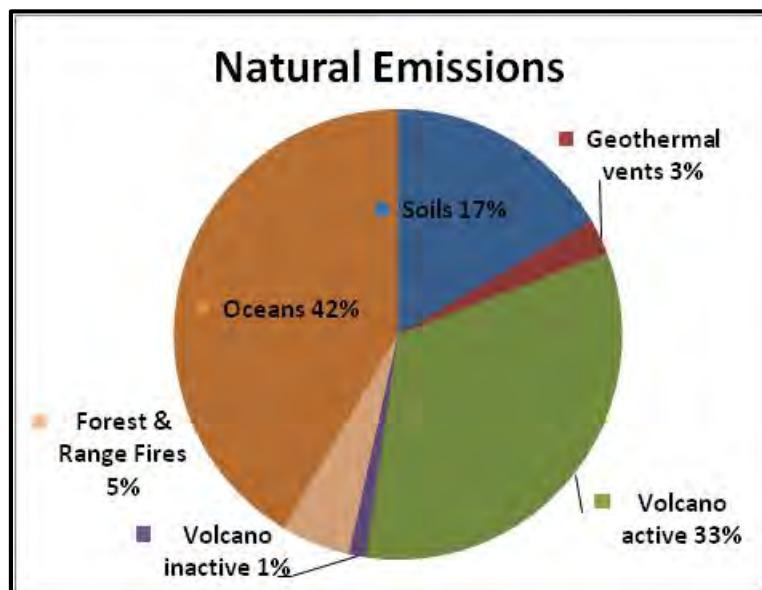


Figure 3.3. Global Natural Emissions (Derived from UNEP, 2008)

3.3 Anthropogenic Sources

3.3.1 Global Sources

There is significant uncertainty in the estimates of mercury cycling at the global scale. This uncertainty is due to the difficulty in measuring natural emissions, which are often remotely located as well as difficulty in measuring all anthropogenic sources. Natural sources bring variability in location of measures and issues of measuring this variability, for example variance in measures of ocean emissions in the Antarctic Ocean versus southern Pacific Ocean versus Arctic Ocean, the sheer expanse and impacts of upwelling, seasonal currents, adds error to estimates. Estimates in anthropogenic sources can also vary significantly due to differences in means of measures, and missing measures in much of the developing world. Lacking direct measures requires the application of estimates in the characteristics of the source then to apply an estimated, or averaged, emission for a category. For example, the amount of mercury being emitted from electric power production in China is influenced by and requires estimates of the type of electric generating unit, its operating history and efficiency, the fuel source, and the installation, operation and efficiency of any control equipment. What is known is that there are significant uncertainties, and global estimates may be off by a factor of two.

Approximately 70% of atmospheric Hg emissions are derived from either direct or re-emitted anthropogenic sources. (Lamborg et al., 2002; Mason & Sheu, 2002; Pirrone, 2010).

Anthropogenic emission sources primarily emit Hg in any of three forms: elemental mercury (Hg^0), gas-phase inorganic (RGM) and particulate HgP. Anthropogenic sources are either large scale point sources that can be estimated individually such as fossil-fueled boilers, or "diffuse" area sources that are typically small and too numerous to treat individually, such as oil-fueled residential heating systems or vehicle emissions (broadly referred to as mobile sources). There are some nonindustrial anthropogenic sources such as mercury released annually to the atmosphere by uncontrolled coal-bed fires which have regional significance loading, e.g. 32 Mg Hg/yr (Pirrone et al., 2010). Important sources of Hg to the environment include electric utilities, incinerators, industrial manufacturing, wastewater treatment plants, mining, and improper disposal of consumer products (e.g., batteries, fluorescent light bulbs, Hg switches). Mercury in batteries has almost been eliminated in consumer products in the Western Hemisphere, but remains a concern in Asia. **Figure 3.3** shows the geographic distribution of relative contributions of mercury from different regions.

Anthropogenic primary sources (initial emissions not counting re-emission from anthropogenic sources) are estimated to account for 2320 Mg of mercury emitted annually. The major source categories of anthropogenic emissions are from fossil-fuel fired power plants (45% global loads), artisanal small scale gold mining (18% global loads), cement production (10% global loads), waste incineration and landfills (7% global loads), product use (4% global loads) industrial gold production (6% global loads), and other mineral mining (10% global loads) (Pirrone et al., 2010). **Figure 3.4** shows the relative contributions from different types of human sources.

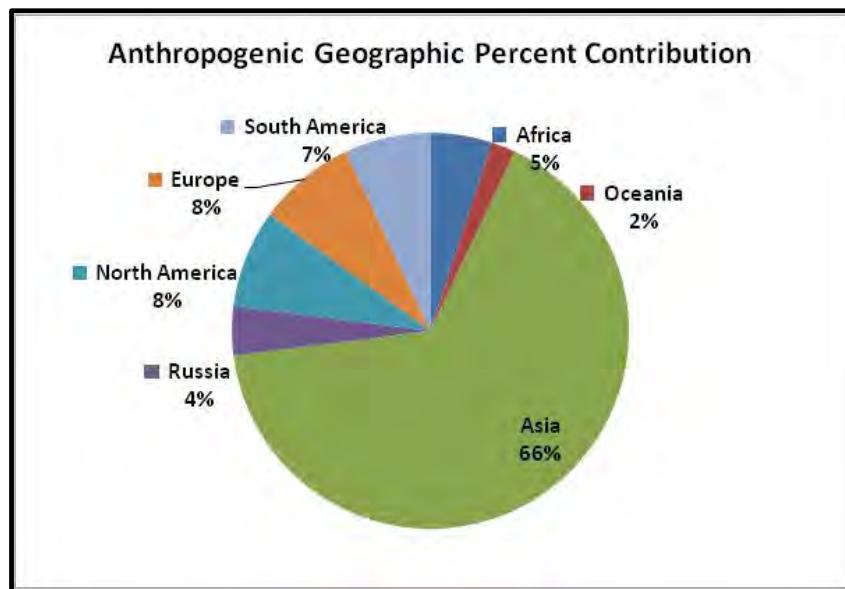


Figure 3.3 Anthropogenic Geographic Percent Contributions

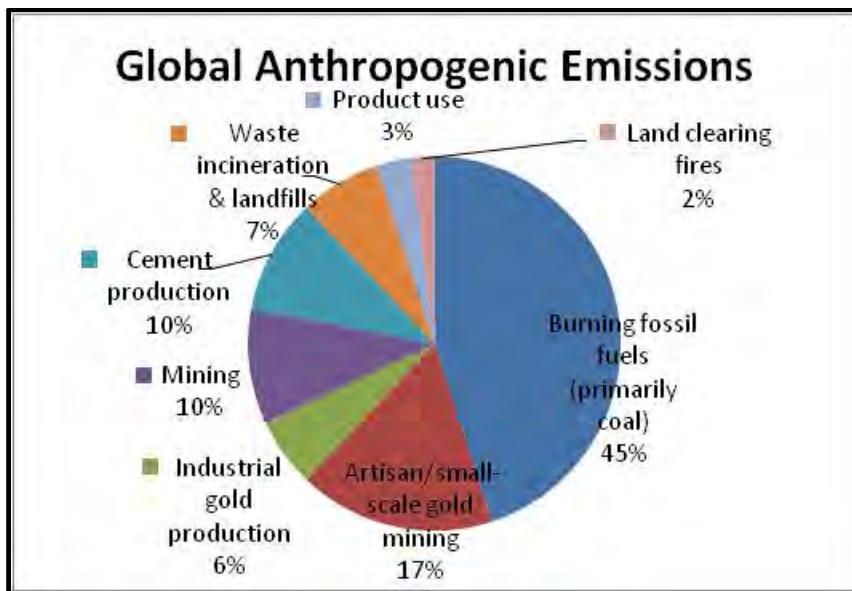


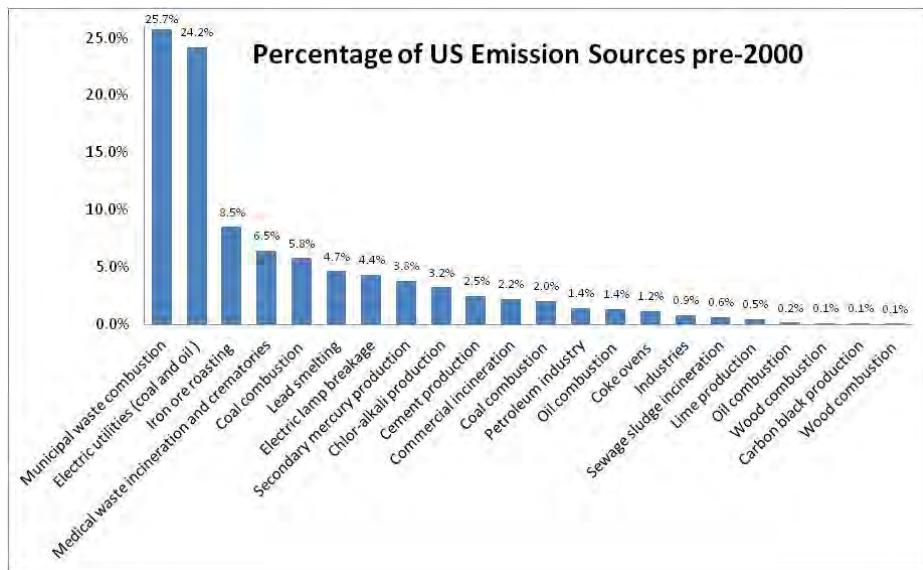
Figure 3.4 Global Anthropogenic Sources

As part of the Mercury TMDL Project, Florida contacted and participated in development of global, North American, United States, and Florida air emission inventories for use within project modeling efforts. These emission inventories are for the base atmospheric loading during the modeling year of 2009. The accuracy of emission estimates improved with resolution, as information on specific Florida sources known there direct interactions with permitting and specifics of forest fires: size, heat intensity, fuel loads, tree age, and duff composition.

3.3.2 Sources in the United States

The US EPA estimates that ~45% of all mercury deposition within the continental U.S. comes from U.S. sources. Coal-burning power plants are the largest anthropogenic source of mercury emissions in the United States, accounting for over 50 percent of all domestic human-caused mercury emissions (Source: 2005 National Emissions Inventory). The US EPA estimated about 25% of U.S. emissions from coal-burning power plants within the contiguous US are deposited within the contiguous U.S. The other 75% enters the global cycle. Estimates from other large US sources are cement ~18%, industrial boilers ~7%, burning hazardous waste ~4%, and electric arc furnaces used in steelmaking ~7%, each is the relative to total of US emissions.

US emissions have decreased significantly since the early 1990s with emissions controls, and source controls being implemented, primarily in response to implementation of US EPA NO_x and SO₂ emissions standards. These controls had synergistic effects of reducing Hg emissions. These changes resulted from implementation of more emission controls undertaken in response to changes in the Clean Air Act starting in the late 1990s. **Figure 3.5** shows relative mercury emissions in the US as of the late 1990s. Specific controls implemented at national, and state scales such as in Florida, have dramatically reduced municipal waste incineration emissions from both control of mercury entering the waste stream and implementation of emission control technologies that remove mercury.

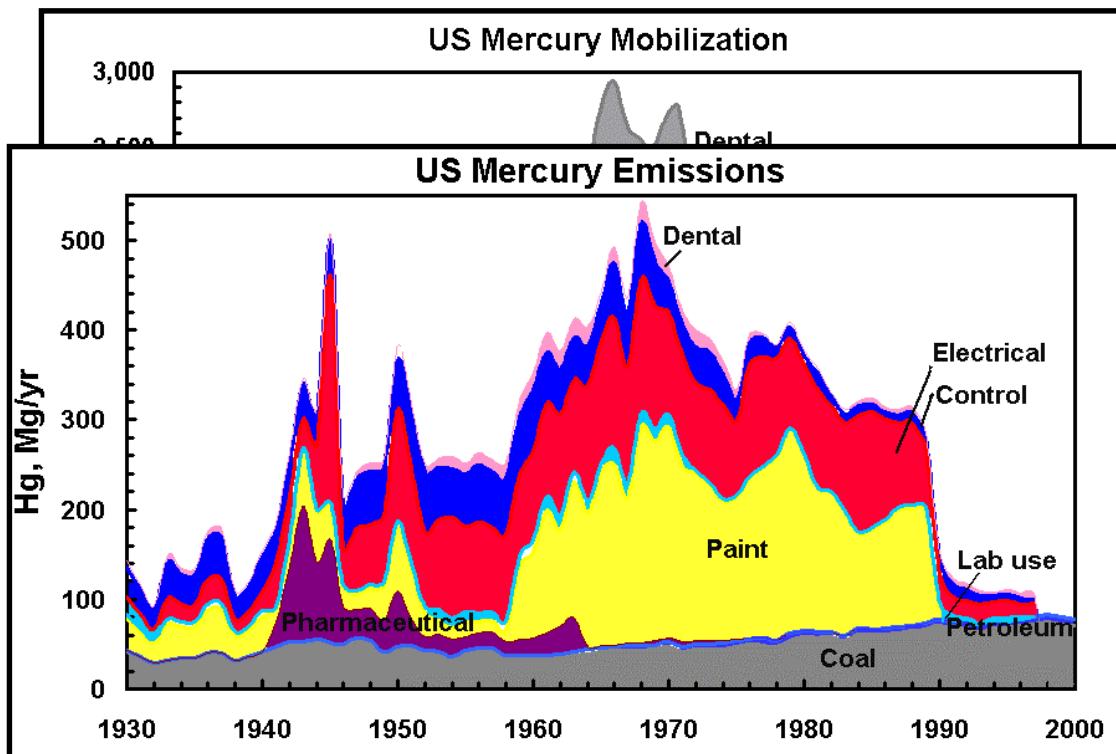


Figure

Percentage of US Emission Sources

3.5

This trend in reductions of mercury sources in the US is further illustrated in **Figures 3.6** and **3.7**, which presents changes both in total mercury and by category. One can see that mercury from certain categories – paint, pharmaceuticals, agricultural products (largely pesticides) – were predominantly eliminated by the year 2000, while the relative contribution of fossil fuels to mercury mobilization crept up slightly, the relative contribution of fossil fuels to emissions was more significant and became the overwhelming source category.



**Figure 3.6 Trend of US Mercury Mobilization in Industrial/Consumer Goods and Fuels
(Source: Husar and Husar, 2002)**

**Figure 3.7 Trend of Estimated US Mercury Emissions to the Atmosphere (Source:
Husar and Husar, 2002)**

Speciation of Anthropogenic Sources

Given that estimates for most coal-fired utilities are that they emit 50% to 70% of Hg as RGM and Hg (Table 3.1), local sources are an important component of the deposition in areas within 30-50 miles of these sources. This deposited RGM may be able to readily react with constituents as to begin entry into biological processes. An analysis of emissions and deposition in southern New Hampshire shows a local region of high deposition associated with local electric utility emissions (Evers, et al. 2007). In Florida, a study evaluated deposition patterns surrounding a coal power utility and evaluated local deposition patterns by tracking mercury isotopes in fuels sources and emission constituents unique to that source type (Sherman, et al. 2012).

Table 3.1 Examples of Mercury Speciation from Emission Sources

Source	Particulate Mercury (%)	Reactive Gaseous Mercury (%)	Elemental Mercury (%)
Coal-fired electric utilities (United States)	10	40	50
Coal-fired electric utilities (Northeast)	2	68	30
Utility oil boilers	20	30	50
Municipal waste combustors	20	58	22
Medical waste incinerators	20	75	5
Pulp and paper production	20	30	50
Chlorine production	0	5	95
Hazardous waste incinerators	22	20	58
Primary and secondary metal production	10	10	80
Municipal landfills	10	10	80

USEPA 1999, Pacyna et al. 2003, NESCAUM 2005; Driscoll et al. 2007

Recent Changes in Mercury Loading

Lake sediment studies in the Northeastern United States and Europe show Hg deposition starting to increase in the late 1800s or early 1900s. This rate increases to 2.5- to 15-times pre-industrial levels by 1970s to early 1990s. (Kamman and Engstrom, 2002). Decreases in sediment Hg deposition in the Northeast, by roughly 25% have been observed in recent years, coincident with reductions in US emissions under activities such as the Acid Rain Rule. Net global emissions remained static or increased, due to increases in Asia during this same time period. It is reasonable to correlate this reduction with controls implemented in the United States on particulate matter and sulfur dioxide emissions from electric utilities that coincidentally reduced mercury emissions, and with reductions in consumer and industrial Hg use limiting post-consumer sources. The reductions realized in some emission categories are shown in **Table 3.2**, which shows the significant reductions realized in the Municipal Waste Combustion and Medical Waste Combustion categories between 1990 and 2005.

Table 3.2. Sources of Mercury Emissions in the U.S.

Industrial Category	1990 Emission tons per year (tpy)	2005 Emission tpy	Percent Reduction
Power Plant	59	53	10%
Municipal Waste Combustors	57	2	96%
Medical Waste Incinerator	51	1	98%

3.3.3 Sources in the State of Florida

Mercury sources have changed dramatically in the last 20 years, with the advent of material controls and emissions controls. The US EPA NEI 2005 emissions year (**Table 3.3**) shows relative loads in pounds per year and relative percentage of emission categories.

Table 3.3 2005 National Emissions Inventory (NEI) - Florida (US EPA, 2005)

Source Category	Total Mercury Emissions (lbs/year)	Relative Percentage of Annual Mercury Emissions
Coal-fired electric generation	2,094	52.7%
Cement Industry	710	17.9%
Waste-to-Energy plants	692	17.4%
Oil-fired electric generation	314	7.9%
Waste water treatment plants	102	2.6%
All others	60	1.5%
Total	3,972	

Mercury, once a common constituent in batteries, has been all but eliminated from the materials and waste stream in Florida (**Figure 3.8**). Paints are another category in which mercury was once common, serving as an inhibitor to fungus, which has been eliminated. The overall trend of mercury sources has been on the decline in Florida (**Figure 3.9**).

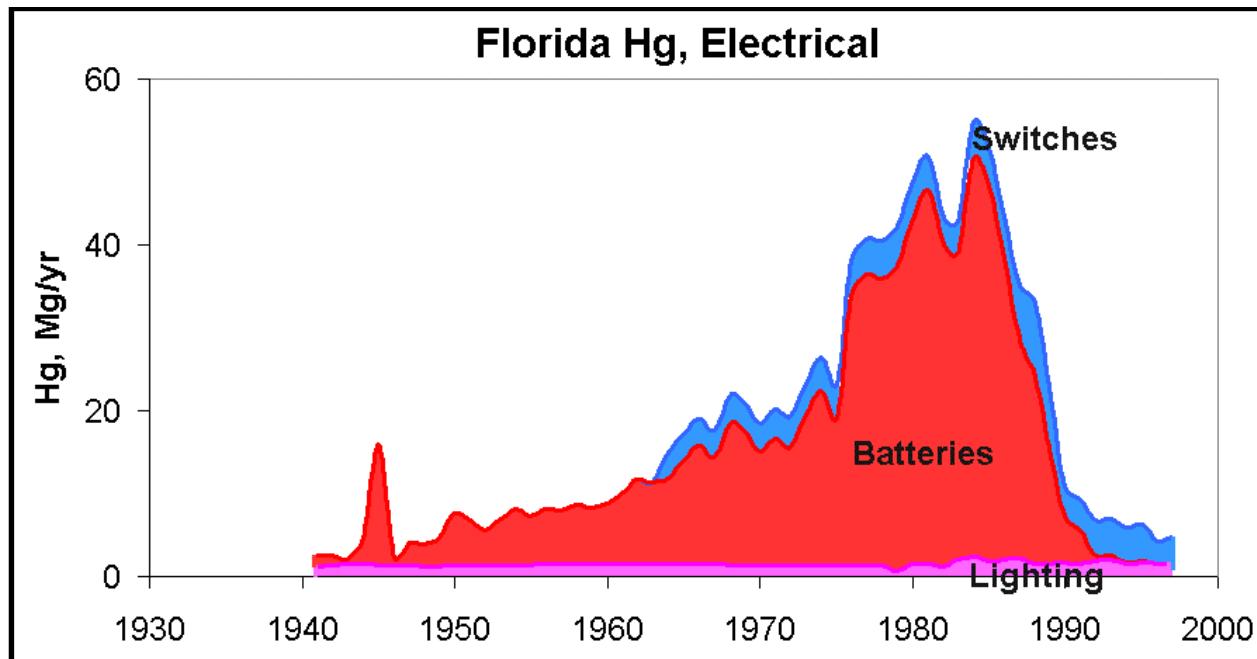


Figure 3.8 Florida mercury use in electrical devices (source Husar and Husar, 2002)

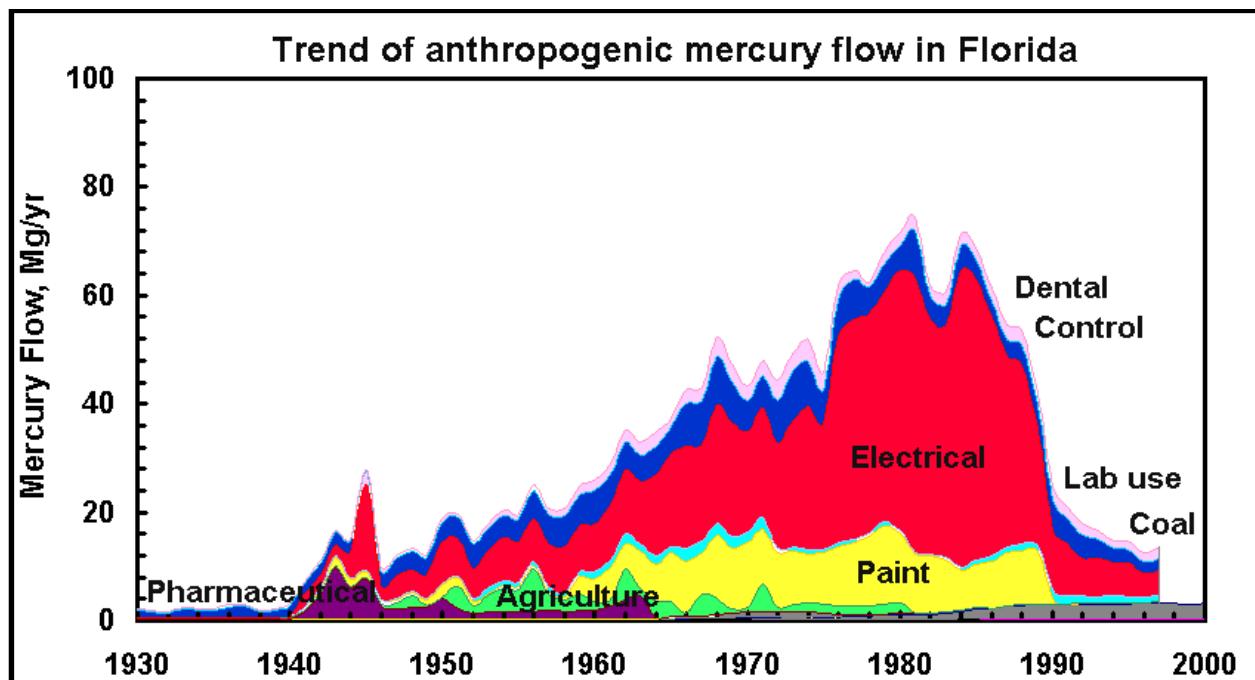


Figure 3.9 Trend of anthropogenic mercury use in Florida (Source Husar and Husar, 2002)

In the last decade even Florida's consumption of coal has been reduced because many utilities that relied on coal have constructed new facilities to take advantage of lower natural gas prices, and operated existing natural gas EGUs at higher capacity. There have been more than 10 EGUs that have been converted from fossil fuels to natural gas as the fuel sources. The emission controls for natural gas are less expensive and the amount of mercury being emitted is several orders of magnitude less.

Mobile emissions have increased (a source category not identified in Husar and Hasar 2002), which follows increases in population equating more mobile sources as well as some impacts of relative loads. These mobile sources can be an important source locally, especially due to more localized deposition associated with speciation and large constituents of HgP in diesel fuels. The fraction of municipal solid waste incineration (MSW_R) and medical waste incineration (MWI_R) have been reduced dramatically both because of emission controls required at state and federal levels, but also because of the dramatic reduction of mercury in the waste stream prior to incineration. Trends in waste incineration emissions have also been reduced (**Figure 3.10**).

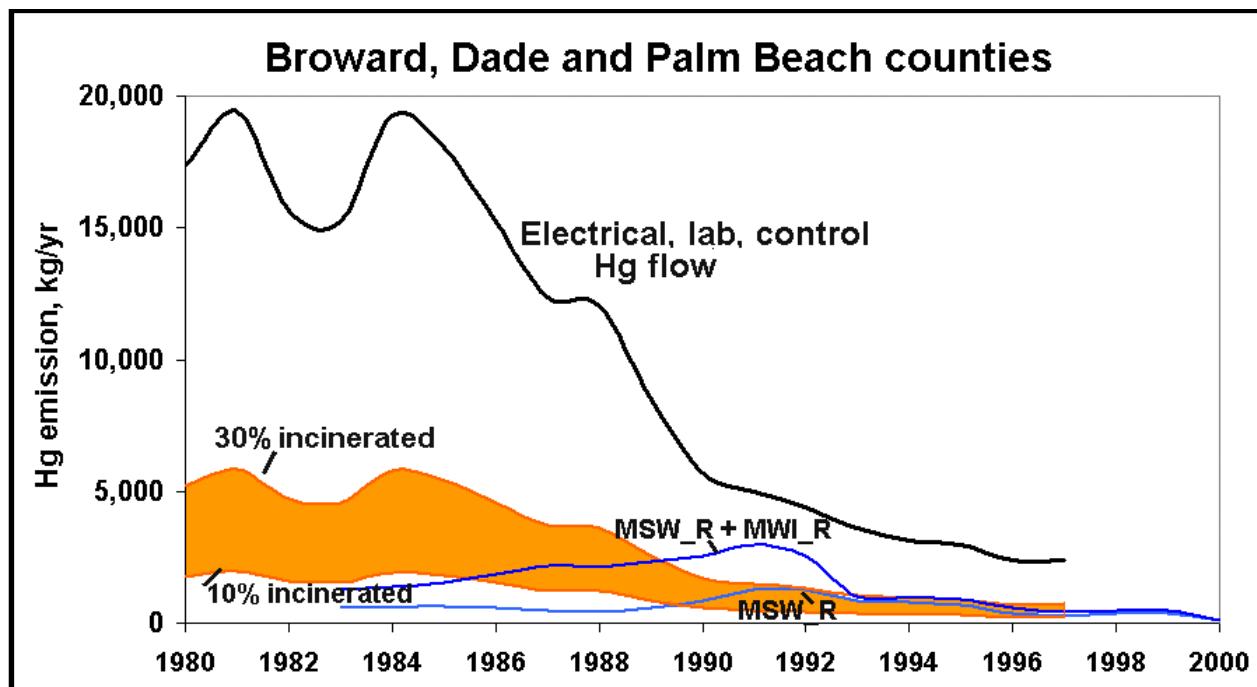


Figure 3.10 Comparison of waste incineration emissions for Broward, Dade, and Palm Beach counties (source: Husar and Husar, 2002)

Mercury emissions falling on Florida, do not follow the trends that the sources of mercury from within Florida have followed in the last 20+ years. Figure 3.11 illustrates trends in mercury wet deposition observed at the Mercury Deposition Network (MDN) site located in Everglades National Park. Within each month's display a trending up of deposition can be observed for 2002-2007. **Figure 3.11**, shows the trends for all of the previous MDN sites in Florida, which show a flattening of deposition loads. However, the variability and spatial distribution of the data, along with the impact of increased global source emissions in the last 5 years, does not allow for a trend to be evaluated.

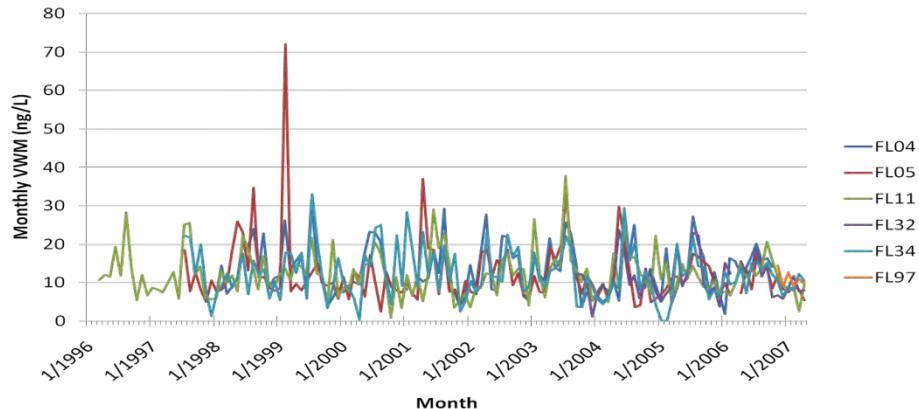


Figure 3.11 Monthly Volume-Weighted Mean Hg at Florida MDN sites

Mercury emissions from Florida sources have been in decline with the installations of emission controls on coal fired EGUs (**Table 3.4**). In several cases, the controls already implemented on coal-fired EGUs are achieving the mercury emission limits required by the pending MATS controls for mercury (**Table 3.5**) at coal-fired EGUs. The table also compares mercury emissions from 2009, a time at which only some mercury controls were fully installed and operational, with the anticipated limits under MATS being for implementation of all required controls. Also 2009 was during a significant economic slowdown when power and energy demands were reduced.

Table 3.4 Estimated Mercury Reduction Associated with the Mercury Air Toxic Standards Rule (MATS) (Source DARM, 2012)

Plant Name	Unit ID	Capacity (MW)	On Line Year	Wet/Dry Scrubber	Scrubber Online Year	NOx Comb Control	NOx Post-Comb Control	SCR Online Year	SNCR Online Year	PM Control	Approx. Hg Reduction (%)
Seminole	2	658	1984	Wet Scrubber	1984	LNBO	SCR	2009		ESPC	75
Seminole	1	658	1984	Wet Scrubber	1984	LNBO	SCR	2009		ESPC	73
St. Johns River Power Park	2	626	1988	Wet Scrubber	1988	LNB	SCR	2008		ESPC	75
St. Johns River Power Park	1	626	1987	Wet Scrubber	1987	LNB	SCR	2009		ESPC	75
Stanton Energy Center	2	446	1996	Wet Scrubber	1996	LNB	SCR	1996		ESPC	86
Stanton Energy Center	1	440	1987	Wet Scrubber	1987	LNB				ESPC	57
Crystal River	1	379	1966			LNC1				ESPC	0
Crystal River	2	491	1969			LNB				ESPC	0
Crystal River	4	722	1982	Wet Scrubber	2010	LNB	SCR	2008		ESPC	90
Crystal River	5	721	1984	Wet Scrubber	2009	LNB	SCR	2009		ESPC	90
Crist	7	472	1973	Wet Scrubber	2010	LNB	SCR	2004		ESPC	76
Crist	4	78.0	1959		2010	LNB	SNCR		2006	ESPC+ESPH	76
Crist	5	78.0	1961		2010	LNB	SNCR		2006	ESPC+ESPH	76
Crist	6	302	1970	Wet Scrubber	2010	LNB+OFA	SCR	2012	2006	ESPC	76
Scholz	2	49.0	1953							ESPC	0
Scholz	1	49.0	1953							ESPC	0
Lansing Smith	2	195	1967			LNC3	SNCR		2005	ESPC+ESPH	0
Lansing Smith	1	162	1965			LNB	SNCR		2005	ESPC+ESPH	0
Big Bend	BB03	364	1976	Wet Scrubber	1995	LNB	SCR	2009		ESPC	87
Big Bend	BB01	391	1970	Wet Scrubber	1999	LNB	SCR	2009		ESPC	87
Big Bend	BB04	447	1985	Wet Scrubber	1985	LNB	SCR	2007		ESPC	87

Plant Name	Unit ID	Capacity (MW)	On Line Year	Wet/Dry Scrubber	Scrubber Online Year	NOx Comb Control	NOx Post-Comb Control	SCR Online Year	SNCR Online Year	PM Control	Approx. Hg Reduction (%)
Big Bend	BB02	391	1973	Wet Scrubber	1999	LNB	SCR	2009		ESPC	87
Deerhaven Generating Station	B2	228	1981	Wet Scrubber	2009	OFA	SCR	2009		ESPC	83
Northside Generating Station	2	275	2002	Dry Scrubber	2002		SNCR		2002	B	
Northside Generating Station	1	275	2002	Dry Scrubber	2002		SNCR		2002	B	
C D. McIntosh Jr	3	342	1982	Wet Scrubber	1982	LNB	SCR	2011		ESPC	75
Cedar Bay Generating LP	CBC	83.3	1994	Reagent Injection			SNCR		1994	B	
Cedar Bay Generating LP	CBB	83.3	1994	Reagent Injection			SNCR		1994	B	
Cedar Bay Generating LP	CBA	83.3	1994	Reagent Injection			SNCR		1994	B	
Indiantown Cogeneration LP	AAB0 1	330	1995	Dry Scrubber	1995	LNB+OFA	SCR	1995		B	

Table 3.5 Estimated Mercury Reduction Associated with the Mercury Air Toxic Standards Rule (MATS) (Source DARM, 2012) Repeat header next page

2009 emissions controls reflect EGU operations for the base atmospheric modeling year, and the projected CAMD MATS limits are the projected emission loads allowed based upon the CAMD heat inputs. Some EGUs had controls come online in 2009, which is not reflected in the 2009 loads.

Coal-fired Electric Generation Unit	Emissions with 2009 Controls (lbs/yr)	CAMD Heat Input (MMBtu)	CAMD MATS-limited Hg (lbs/yr)
TECO Big Bend	106.3		
Unit 1	65.5	20,504,228	24.6
Unit 2	18.7	12,866,303	15.4
Unit 3	10.9	31,424,714	37.7
Unit 4	11.2	31,965,301	38.4
LEC C.D.McIntosh	19.6		
Unit 3	19.6	19,974,895	24.0
Cedar Bay Cogen	29.0		
Unit A		7,058,495	8.5
Unit B		7,471,021	9.0
Unit C		6,849,345	8.2
GP Crist	327.2		
Unit 4	29.0	2,448,587	2.9
Unit 5	28.5	4,135,866	5.0
Unit 6	96.4	10,635,530	12.8
Unit 7	173.3	22,037,348	26.4
PE Crystal River	528.0		
Unit 1	83.0	20,859,374	25.0
Unit 2	110.0	23,734,375	28.5
Unit 4	158.0	42,114,153	50.5
Unit 5	177.0	30,288,500	36.3
GRU Deerhaven	5.3		
Unit 2	5.3	14,576,952	17.5
Indiantown Cogen	19.6		
Unit 1		15,651,993	18.8
GP Lansing Smith	150.1		
Unit 1	70.7	5,486,938	6.6
Unit 2	79.4	9,602,261	11.5
TECO Polk Power	9.0		
Unit 1	9.0	10,690,718	26.7
GP Scholz	13.6		

Coal-fired Electric Generation Unit	Emissions with 2009 Controls (lbs/yr)	CAMD Heat Input (MMBtu)	CAMD MATS-limited Hg (lbs/yr)
Unit 1	7.3	278	0.0
Unit 2	6.3	125,240	0.2
Seminole Gen. Station	54.3		
Unit 1	26.3	29,206,824	35.0
Unit 2	28.0	45,703,994	54.8
JEA SJRPP/NGS	72.0		
SJRPP Unit 1	29.7	39,932,826	47.9
SJRPP Unit 2	28.6	49,271,796	59.1
NGS Unit 1	8.6	18,222,684	5.5
NGS Unit 2	5.2	18,438,274	5.5
OUC Stanton	135.0		
Unit 1	106.5	33,123,155	39.7
Unit 2	28.4	29,156,501	35.0
TOTALS	1469.0		717.2

Many of the above referenced units installed air pollution controls in the 2009 timeframe. 2009 emissions do not necessarily represent the full operating capacity of these units. The CAMD information is based on information submitted by the utilities to the EPA Clean Air Markets Division.

Cement production is another relatively significant source of mercury emissions (**Table 3.6**). This is from the combined issues of coal being used as a fuel source in the cooking of the clinker, the mercury in the limestone which is a major raw ingredient for clinker production and also that coal ash from power utilities being a common ingredient used in cement production.

Table 3.6 2009 Florida Portland Cement Production and Estimated Mercury Emissions (source DARM, 2012)

Facility	Mercury (lb/MM ton clinker)	Mercury (Act. lb/yr)	Mercury Permitted (lb/yr)	MACT Limit (lb/MM ton clinker)	Mercury @ MACT (lb/yr)
American Cement					
Kiln No. 1(New)	111	43	122/12-month	55	21.08
CEMEX North					
Kiln No.1			No limit (~120)	55	
Kiln No.2			No limit (~120)	55	
TOTAL	0	0	~240		
CEMEX South					
Kiln No.1	154	40	262.8	55	14.32
Kiln No.2 (New)	119	73	122	55	33.73
TOTAL		113			48.05
CEMEX Miami					
Kiln No. 1	83	62	182	55	40.68
FRI					

Facility	Mercury (lb/MM ton clinker)	Mercury (Act. lb/yr)	Mercury Permitted (lb/yr)	MACT Limit (lb/MM ton clinker)	Mercury @ MACT (lb/yr)
Kiln No. 1	50	23	200	55	25.31
Kiln No.2 (New)	111	24	122	55	12.05
TOTAL		48			37.36
Sumter Cement					
Kiln No.1 (delayed)			184/12- month		
Suwannee American					
Kiln No. 1	89	53	97	55	32.55
Titan					
Kiln No.1	80	78	229/12- month	55	53.52
Totals:	Actual Hg:	395		MACT Limit Hg:	233.23

These source categories, the emissions inventory, were updated as part of the Florida Mercury TMDL project for the base case atmospheric modeling year of 2009. Florida emissions, by category, were derived and updated from the US EPA's National Emissions Inventory 2005 (US EPA NEI, 2005), as presented in **Table 3.7**. The table shows an estimated 30% and 50% reduction in coal-fired EGU and waste-to-energy plant emissions, respectively. These reductions can be attributed to new controls and adjustments to the waste stream. The table shows a reduction of ~50% by the cement industry; however, this cannot be attributed to controls and is a result of having identified a dramatically reduced level of production in response economic conditions and the slowing of the housing market. The dramatic increase shown for Gerdau-Ameristeel is a consequence of correcting errors in the NEI 2005 for accurate information on levels of production and production methodologies at this facility.

Table 3.7 2009 Mercury Emissions Inventory in Florida (DARM & UMAQL, 2011)

Source Category	2005 NEI (lbs/year)	Nominal 2009 DARM Update (lbs/year)	Relative Percentage of Annual Mercury Emissions 2009
Coal-fired electric generation	2,094	1,469	37.0%
Cement Industry	710	326	8.2%
Waste to energy plants	692	663	16.7%
Oil-fired electric generation	314	314	7.9%
Waste water treatment plants	102	102	2.6%
Medical waste incineration	4	2	0.1%
Gerdau-Ameristeel	13	250	6.3%
All others	43	43	1.1%
Total:	3,972	3,169	

3.4 Mercury Deposition and Re-Emission

Mercury deposition can be thought of broadly as occurring under two circumstances: wet and dry deposition. As the names imply wet deposition is that which occurs in precipitation events: rain, sleet, snow, and dew. Wet deposition is measured by capturing the precipitation and securing it so that the mercury cannot evaporate or sublimate from the collection. Wet deposition is especially important in Florida because of the high frequency of convection storms (thunder storms), and the large size of these weather systems in Florida. Convection storms can climb in excess of 10 miles which allows a stripping of atmospheric constituents, including mercury, from these great vertical columns, thus the wet deposition often represents the mercury in a very large volume of the atmosphere. Additionally, thunderstorms can produce winds in excess of 55 mph pulling in still more volumes of air from which the rain, or hail, strips atmospheric pollutants. Across Florida, thunderstorms are more common in inland areas by ~20%; and, across coasts to inland areas thunderstorms occur on average of 80 to 100 days per year. The scale of rain from thunderstorms often in excess of 3 inches in an hour also means that pollutants stripped from the air, and those already deposited on ground surfaces, are washed into mesic, wetland, and aquatic systems.

Dry deposition as the name implies is that which occurs external to precipitation events. Dry deposition characteristics and rates are far less studied than wet deposition. This is due to the increase in complexity of capturing and measuring this form of deposition. Prior to the Department's efforts in the mercury TMDL Project to document levels attributable to dry deposition, estimates of the relative contribution from dry deposition ranged as being 20% to being equal to wet deposition. The clear need to have accurate empirical measures for dry deposition to quantify loading of mercury deposition required state of the art science to be put in place across Florida to make dry deposition measures. Knowing only the net amount of dry deposition while being an important measure would leave so many more questions as to the nature and composition of dry deposition. The Mercury TMDL Project applied measuring methodologies that provided fine time resolution, as well as speciation of dry deposition. These provide critical data to be used toward a better understanding atmospheric chemistries and which aid in understanding mercury movement through the environment. The Department chose to measure primary atmospheric pollutants continuously such as NO_x, SO₂, O₃, CO, as well as total mercury (THg). Mercury speciation was measured at two-hour intervals continuously. These dry deposition measures were collected at the four supersites (Pensacola, Jacksonville, Tampa, and Davie) for 14-18 months from 2009 to 2010. While rates of dry deposition varied spatially and temporally across the state, it was always close to being equal to the event driven wet deposition in terms of total mercury. The dry deposition mercury speciation and continuous measures are important in understanding the specifics and dynamics of mercury cycling within Florida. Atmospheric dry mercury is stripped by forests in leaf and needle uptake as well as in resistance knocking mercury from the air to the forest floor. Atmospheric dry mercury is taken up by prairie, shrub, and wetland plants, where this may be a critical avenue of entry into food webs, and a means of having mercury bound to organic matter enter aquatic systems. This entry into plant matter may be a primary mechanism of entering biological systems and food webs.

Based upon the literature, estimates of a mean volatilization rate of Hg⁰ from soil is roughly 11 pg per square-meter per hour. This rate would reemit most of the atmospheric Hg⁰ deposition onto bare soils or hard surfaces. However, the uncertainty of this process identifies an area for additional research on Hg re-emissions. This re-emission cycle would be especially important in areas which can subsequently have deposition enter ecological systems, such as areas with significant cover of wetlands or forests, and with high levels of rainfall and daily dew deposition.

3.5 Mercury Movement in the Environment

Before we get into the detailed discussion of mercury transport in different ecosystems, we can use a general summary here to describe the major pools of mercury in natural systems and the dynamics of mercury among these pools (see Figure 2.1).

Some studies looking at the environmental fate of mercury showed high THg and MeHg concentrations locations far from identified point source emissions. What has uniformly been identified as locations where mercury is accumulating in the environment is low lying, flat areas (wetter systems, e.g., mesic and wetland systems) (Dennis et al., 2005); those areas where precipitation accumulates in landscapes. Also Total Organic Carbon (TOC) correlated well with THg and MeHg. For Florida this indicates much of the environment – flat, wet, high in mesic forest and wetland cover – is very suitable in almost all areas of the state and such cover is close to emission sources. In Washington State, a study looked at sediment profiles in three lakes of varying distance from the emission source a coal fired power plant, and found mercury profiles in sediments reflecting the emissions history of the regional source, by load and distance (Furl et al. 2011).

Mercury risks to human health, or wildlife, require exposure that occurs primarily, though not exclusively, through fish consumption. The amount of mercury that is methylated in ecosystems is only a very small fraction of the mercury that is deposited in ecosystems. Sources that deposit mercury into ecosystems, whether from emissions or direct discharge, natural or anthropogenic, are the means by which mercury becomes available to be transformed into toxic methylmercury within the ecosystems and then bioaccumulated up food chains into fish.

3.5.1 Mercury transport and fate in forest ecosystems

Studies of direct soil sequestration of Hg, immobilization of Hg in forest soil, show a correlation with the retention of organic carbon (Schwiseg, 1999). Pools of Hg in upland soils in northern temperate regions are about 7 mg per m², with higher levels reported around the globe, so this is only a reference number. The export of Hg by waters draining upland soils to surface waters is generally low. Concentrations and fluxes of Hg in soil waters, analogously to the pattern in soil, are closely related to dissolved organic carbon content. Concentrations of total Hg are highest in waters draining the upper soil, coinciding with high concentrations of DOC. The conditions optimal for this occurrence are shallow, flat systems with wet high organic soils as is predominant in Florida. Concentrations and fluxes of total Hg decrease as DOC is immobilized with depth in mineral soil (Grigal, 2002). Limited studies suggest that MeHg concentrations in upland soils and ground waters are generally low, although higher concentrations occur in upper soil waters and decrease with soil depth. Low concentrations and fluxes of MeHg in drainage waters suggest that rates of methylation are low, and freely draining upland soils are generally not important in the supply of MeHg to downstream surface waters, with the possible exception of recently harvested forests (Porvari et al., 2003).

3.5.2 Mercury in Wetlands: transport and transformation

Wetlands influence the composition and supply of different Hg species to adjacent surface waters. Wetlands are typically net sinks of total Hg and sources of MeHg (Grigal 2002). Rates of total Hg accumulation are greater in wetlands than in upland soils because of the strong association of Hg with organic matter (Grigal, 2003). Annual rates of MeHg production in wetlands are approximately 0.1 to 1 µg per m² per year (Galloway and Branfireun, 2004). The factors controlling methylation of Hg in wetlands are not completely understood, but they most likely involve the amounts and types of organic matter, water and soils chemistries, hydrologic flow paths, microbial composition, microbial locations relative to flow paths, and rates of microbial activity, as well as any limiting resource for microbial activity. Organic matter produced in wetlands forms complexes with both ionic Hg and MeHg, enhancing the transport of these Hg species to surface waters. There is debate on how these complexes in some cases enhance later consumption by single celled organisms or are perhaps incidental in consumption by first level secondary consumers. An elevated supply of DOC to downstream surface waters may stimulate conditions for mercury methylation, and limit mercury available for photodegradation and photoreduction of HgII. Concentrations of MeHg in wetland pore waters and surface waters vary seasonally, with the highest concentrations evident during the late summer, as a result of warmer temperatures, higher rates of microbial activity, and longer hydraulic residence times (Galloway and Branfireun 2004).

3.5.3 Mercury in surface waters

Freshwater ecosystems vary in how they respond to Hg pollution. Total Hg concentrations in surface waters in the Northeast vary by more than an order of magnitude across systems, from less than 0.5 to 12.7 nanograms per liter, the 5th to 95th percentile respectively (Dennis et al., 2005). Most of the Hg in surface water occurs as HgII, with MeHg ranging from 1% to 35% of total Hg. Under conditions of high total Hg loading, MeHg production can vary widely, depending on the methylation efficiency of a particular ecosystem.

Other factors controlling mercury in surface waters

Other factors, such as water chemistry, land cover and land use, and watershed disturbances, alter the transport, transformation, and bioavailability of Hg in surface waters. Acidic deposition and the associated sulfur alter the acid-base status of surface waters, thus influencing Hg transformation potentials, may influence Hg uptake by sulfur reducing bacteria (SRB), and associated bioaccumulation in fish. Sulfur chemicals are closely coupled with Hg dynamics. The solubility of Hg increases with sulfide concentrations in anoxic waters through complexation reactions, potentially increasing the pool of Hg available for methylation (Benoit et al., 2005). The relationship of mercury to acidification is also related as the required controls under Acid Rain Rules promulgated under the Clean Air Act serve to control SO₂ and NO_x emissions which directly cause acid rain which brings about surface water and soil acidification.

Watersheds with mixed agriculture and forest land cover had the highest methylation efficiency, even where these watersheds had low total Hg in sediments. Waters draining agricultural landscapes have relatively high concentrations of total Hg and MeHg due to mercury binding to organic particulates and higher methylation rates. These can also have lower concentrations in fish, due to algal "bloom dilution" associated with high phosphorus loading or elevated DOC concentrations (which stimulate methylation but limit bioaccumulation), or both (Kamann et al.,

2004). Forest harvesting has been shown to increase export of total Hg and MeHg (Porvari et al., 2003). Fire results in a complex pattern of Hg loss from watersheds. During and shortly after fire, elevated Hg losses are associated with volatilization from soils and losses from erosion, as well as increased pore water flushing (Grigal 2002). It is important to remember that while forest harvesting increases turnovers and scales by anthropogenic actions, that human initiated forest fires are reflecting natural fire ecology. Thus, forest harvesting can expose soils increasing aspects of the mercury cycle, managed fires are merely mimicking natural fire ecology and not increasing mercury loads. Deforestation efforts, especially areas without a natural fire ecology, as seen in the developing world, are a source of mercury through both the burning of above ground biomass and through the exposure, including associated tilling, of soils which readily volatilize any associated mercury. Activities that manage water levels create significant exposure-saturation patterns, especially systems such as reservoirs or soil management programs as with rice, soybeans, or sugar cane, can be sources of increased mercury emissions and increased pulses of MeHg formation. These often located in floodplains and converted wetland systems, provide areas of mercury binding to organic matter enhanced by soil management associated with planting and prime environments for methylation. In reservoir systems the littoral zone can fluctuate wetting and drying, thereby varying natural cycles of reduction and oxidation both by location and extent, enhancing the production of MeHg (Evers et al., 2007; Sorensen et al., 2005).

Habitat type also has an important influence on MeHg concentrations. Data for two-lined salamanders (*Eurycea bislineata*) identified in headwater streams have significantly higher MeHg concentrations than those in lakes (Bank et al., 2005). Larval insects in reservoirs have been shown to have THg concentrations that are 3 to 10 times higher than those in natural lakes (Tremblay et al. 1996). Crayfish (*Orconectes virilis*) in headwater streams have THg concentrations up to five times greater than those in lakes (Pennuto et al., 2005). The landscape position of each of these may explain the differences observed.

Forested regions, where wetlands are prevalent, and with low productivity surface waters, promote high concentrations of mercury in freshwater biota and thus are particularly sensitive to mercury deposition.

3.5.4 Mercury moving through organisms

Biota are exposed to MeHg primarily through the roles played by bacteria, and fish and insect consumption. The Northeastern Ecosystem Research Cooperative (NERC) data establish robust Hg exposure profiles for fish, birds, and mammals and highlight the importance of habitat type, foraging guild, trophic structure, and demographics on MeHg exposure (Evers et al., 2005). In general, THg concentrations vary by species taxonomy. As a general rule, MeHg increases with increasing trophic position. Mercury in benthic invertebrates and larval insects has been studied in northeastern lakes and reservoirs, where it was observed that even in invertebrates, increased mercury per biomass is associated with an increase in trophic level (odonates > hemipterans / coleopterans > trichopterans > dipterans / ephemeroptera) (Tremblay et al., 1996). The NERC data on Hg in over 15,000 fish show that the mean fillet THg levels in 10 of the 13 species are above EPA guideline of 0.3 µg/g and highest in top level predators such as walleye (*Sander vitreus*) and lake trout (*Salvelinus namaycush*).

Chapter 4: TMDL Approach

4.1 General Approach

To address the mercury impairment in Florida waters, the Department selected a statewide approach for mercury TMDL development, rather than a waterbody-specific TMDL approach for the following reasons. First, the predominant source of mercury leading to impaired waters in Florida is from atmospheric deposition. The majority of atmospheric mercury deposited on Florida, >95%, as well as the emission sources, comes from outside of Florida. Mercury in the atmosphere is transported across multiple watershed boundaries, where it is deposited and biologically magnified through the food web, resulting in high fish tissue concentrations. While a watershed-based TMDL approach is typical for most pollutants, the phenomenon of atmospheric transport of mercury makes a regional or statewide approach the only practical method for TMDL development. This approach is consistent with other mercury TMDL efforts supported by US EPA, including multi-state efforts. EPA recognized the sources of the mercury impairments were largely from outside the borders of individual states and issued a guidance document (USEPA, 2008), which supported the concept of addressing the problem at scales ranging from waterbody-specific, regional, statewide, or multi-state.

Second, the statewide approach will be far more cost-effective than the waterbody oriented approach. Using the IWR listing process, the Department has verified the mercury fish tissue impairment in more than 1100 water segments, as shown in **Table 1.2**. Rather than attempting to develop a mercury TMDL for each of these waterbodies, the proposed approach will focus on reducing mercury emissions statewide to benefit all Florida waterbodies, especially those susceptible to mercury bio-magnification (e.g., oligotrophic, low alkalinity systems). Although the concept of conducting this type of regional TMDL analysis is relatively novel, a similar predicate was established as part of the 1990 National Acid Precipitation Assessment Program Integrated Assessment. For that program, EPA conducted regional simulations for thousands of lakes in the Upper Midwest, the Adirondacks, and Florida to evaluate how lakes would behave in response to Clean Air Act mandated changes in sulfate emissions, which in turn were predicted to reduce acidic deposition.

Key elements that a mercury TMDL should consider were recommended by EPA (USEPA, 2008). These elements include:

- (1) Identification of waterbodies, pollutant sources
- (2) Water quality standards and TMDL target
- (3) Loading capacity – Linking water quality and pollutant sources (including point and nonpoint sources)
- (4) Conducting load and wasteload allocations to nonpoint and point sources
- (5) Establishing a margin of safety of the TMDL to address the uncertainties associated with the target development.

A technical framework was established by the Department to address the TMDL needs listed above (**Figure 4.1**). A sampling protocol was designed to measure fish tissue mercury concentrations, concentrations of total mercury, MeHg, and other biogeochemical parameters

(for both water column and sediment from lakes) that may influence the mercury dynamics in Florida waters were collected in numerous Florida streams (129) and lakes (130) that were chosen based on a stratified statistical sampling design. Historic data, including fish tissue mercury concentration data collected through the fish consumption advisory program jointly carried out by the Department of Health (DOH), Florida Fish and Wildlife Conservation Commission (FFWCC), and the Department, water chemistry data collected through Department's Integrated Water Resource Monitoring Network (IWRM) were also examined to identify the historic trend of mercury impairment in the State of Florida. These data and fish consumption data collected through the largest consumption study to date, were used to establish the statewide TMDL for mercury.

In addition, to aid with subsequent evaluations of the impacts to Florida's waters, from sources both within and outside Florida, the Department developed a technical framework designed to quantify and assess the sources and impacts of mercury from atmospheric deposition. Technical components included quantifying mercury loadings into Florida and identifying the contribution from local sources, regional sources, United States sources, and sources in other countries. In order to quantify the mercury loading into the state, predictive atmospheric models were used to simulate mercury loadings from different sources and quantify the atmospheric deposition flux. Air monitoring networks were also established to measure wet and dry depositions at several strategic locations across the State to provide measurements for model evaluation, to characterize seasonal dynamics of the air deposition, and to examine the spatial effects of major emission centers in the states. Site monitoring locations were specifically established within regions of known point source emissions, which differs significantly from MDN locations which are deliberately located away from known emission sources. This allows identification of local conditions, but also creates monitoring requirements of capturing a more variable system. The TMDL approach of assigning percent reduction to sources, has each respective mercury source be responsible only to their loading, i.e., no source is more weighted for reductions than another.

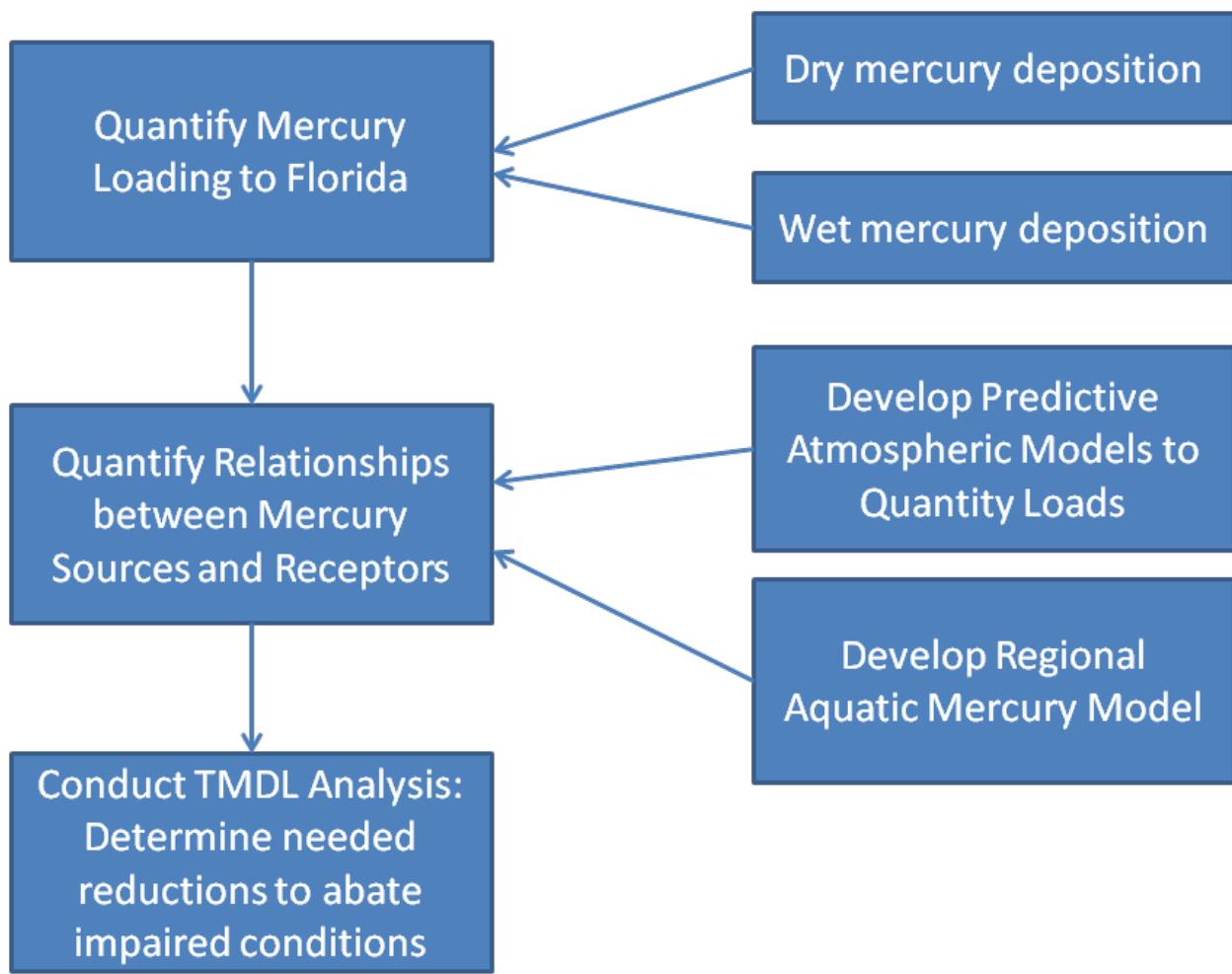


Figure 4.1 Overview of Technical Components of a Statewide Mercury TMDL Project

4.2 Mercury Atmospheric Deposition Monitoring

The Department contracted with the University of Michigan to conduct extensive seasonal field sampling activities regionally around four continuous sampling sites in Florida (Pensacola, Jacksonville, Tampa, and Davie) in the period 2008-2010. The atmospheric sampling sites were established to be able to collect wet and dry deposition data. Details of these efforts are contained in Appendix F.

Table 4.1 Initiation & End Dates of Supersite and Wet Only Site Data Collections

Site	Air & Dry Deposition Start	Air & Dry Deposition End	Wet Deposition Start	Wet Deposition End
Davie	4/3/2009	8/31/2010	2/2/2009	8/29/2010
Tampa	1/12/2009	8/31/2009	1/29/2009	8/24/2010
Jacksonville	3/9/2009	8/30/2010	3/18/2009	8/29/2010
Pensacola	10/1/2008	8/31/2010	10/7/2008	8/29/2010
Orlando			3/21/2009	8/2/2010
ENP			11/30/2008	8/30/2010

4.3 Mercury Atmospheric Modeling

The Department also contracted with the University of Michigan to perform atmospheric modeling through scaled analyses starting at a global scale with an 80 km grid and concluding at a 4 km grid scale for Florida. The details of this effort are described in Appendix F.

4.4 Mercury Aquatic Cycle Modeling

The Department also contracted with ALL to perform inferential aquatic modeling, a statistical assessment applying partition analyses for the lakes (more than 7,700 lakes greater than 4 ha in size) and stream/river reaches (more than 83,400 km of stream and riverine reaches) within Florida (see **Appendix L**).

4.5 Sampling of Fish Tissue and Collection of Chemical and Biochemical Data from the Water Column and Sediment

Developing Mercury Aquatic Models is an essential part of the statewide Mercury TMDL development for impaired Florida waters. The goal of the modeling is to establish a functional relationship between the mercury loading into receiving waters and the fish tissue mercury concentration in these waterbodies. Past studies have demonstrated that, while fish tissue mercury concentration for each individual receiving waterbody may show a linear response to the change of mercury loading into the waterbody, the fish tissue mercury concentrations across lakes and streams were dominated by biogeochemical and landscape variables other than mercury loadings (Riva-Murray et al., 2011; Liu et al., 2009; Kamman et al., 2005; Selvendiran et al., 2008). Therefore, collecting water quality and sediment samples in tandem with the

collection of fish tissue mercury concentration is required in order to develop aquatic models. These needed fish data were collected and analyzed by the Florida Fish and Wildlife Conservation Commission (FWCC) and the Department jointly through a monitoring program conducted in a period from September of 2008 through October of 2010.

In order to ensure a sufficiently broad data range and reasonably even distribution of data across the gradient of each sampled parameter for statistical analyses, sampling sites for needed parameters were chosen using a stratified random sampling design. Basically, the concentration ranges of three target variables (pH, color, and chlorophyll *a* for lakes; pH, color, and nitrate for streams) from lakes and streams included in the Department's Status Monitoring Network (SMN) were examined. The identified concentration ranges of these parameters were divided into 5 concentration intervals for each parameter, which yielded a possible 125 unique variable interval combinations (5x5x5) or sampling bins. The actual numbers of bins that were populated by at least one lake or stream reach were 101 and 95, respectively. Additional lakes and streams were sampled at random from individual bins to produce a total number of 133 lakes and 131 streams segments for the sampling.

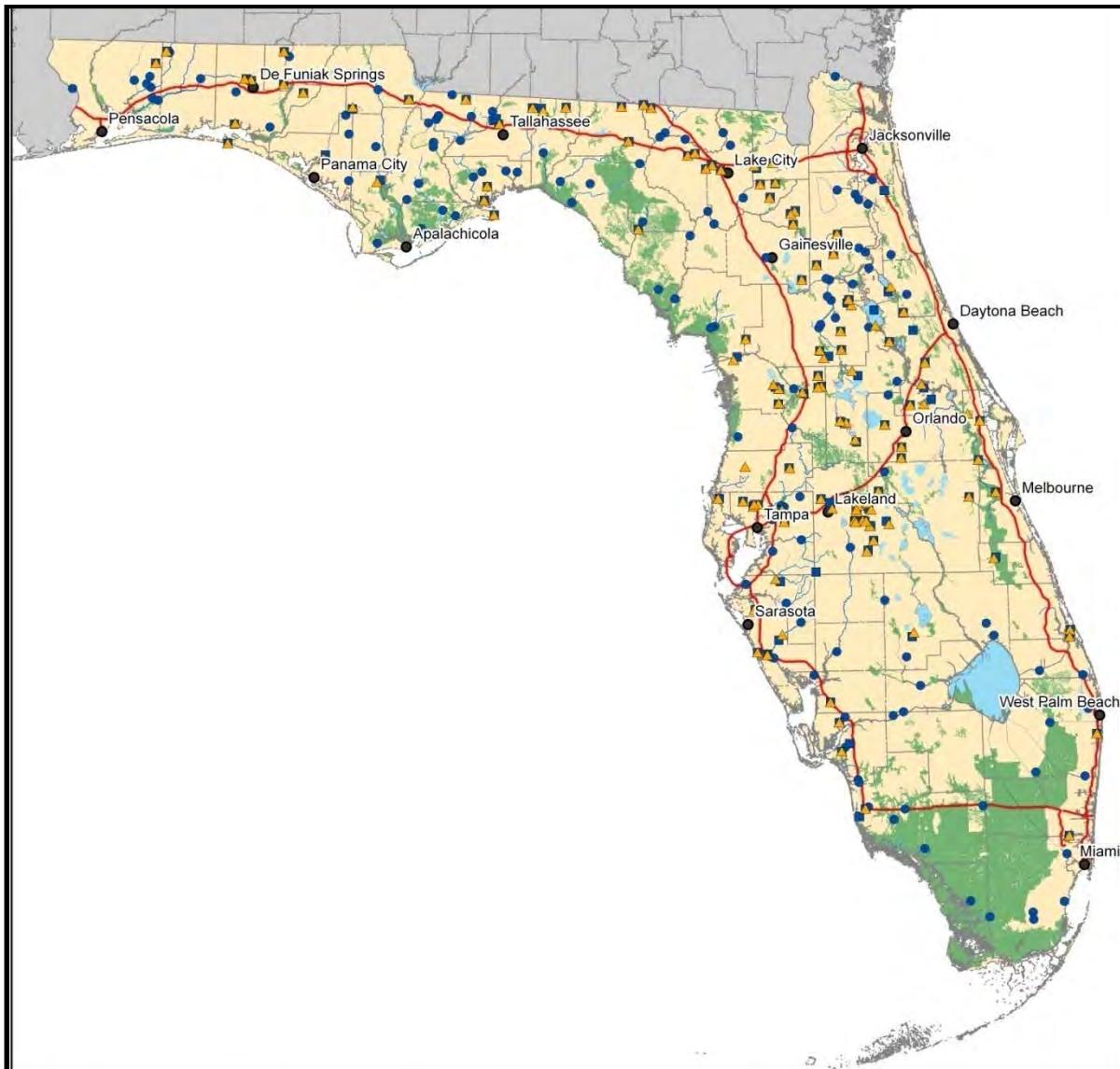
For each selected waterbody, 12 large-mouth bass (LMB) were collected for total mercury analyses. LMB were selected as representing a top level predator in systems in which they are present, thus having the greatest rates of bioaccumulation. Size of sample fish was determined by the current (FY08/09) FFWC's size regulations for black bass; however, LMB up to 2" less than the minimum size regulation up to approximately 20" were collected in order to establish robust relationship between fish tissue concentration and fish size. Where it was infeasible to collect 12 LMB, spotted sunfish (SPSU) were collected across a range of available sizes. Preliminary analyses comparing concurrently collected LMB and SPSU indicated well-correlated tissue mercury concentrations between these two fish species. These sample fish were collected by FWCC and shipped to Eustis Fisheries Research Laboratory, or other FWCC facilities for tissue sample preparation. Prepared fish tissues samples were transported to Department's Central Laboratory for total mercury analyses.

Other than fish sample collection, FWCC also collected concurrent water quality samples from the same lakes and streams where fish samples were collected. Water quality samples were collected for measurement of aqueous mercury species and ancillary water quality parameters including major ion, dissolved organic carbon (DOC), color, total suspended solid (TSS), and nutrients. Field measurements, including dissolved oxygen, conductivity, and Secchi depth, were also collected. Water quality samples collected by the FFWC were shipped via overnight courier to Department's Central Laboratory in Tallahassee for analyses.

In order to provide a complete dataset to describe factors that influence the mercury fish tissue concentrations in Florida waters, sediment sample were also collected in lakes where fish and water quality samples were collected. Lake sediment sample collections were conducted by the Department and were in parallel to the sample fish and water quality sample collection efforts made by FWCC. Sediment sample analyses were conducted by Department's Central Laboratory. These analyses focused on mercury and MeHg, metals (aluminum, arsenic, cadmium, cobalt, chromium, copper, iron, potassium, magnesium, manganese, nickel, lead, antimony, selenium, strontium, titanium, vanadium, and zinc) and nutrients.

All sample collections were conducted in the period from September of 2008 through October of 2010. Sample collections were conducted once for each selected waterbodies. **Figure 4.2**

shows the location of sampling sites. Results from sample analyses were summarized in Chapter 5 of this report. All field and laboratory procedures for collection of fish samples adhere to the guidelines established in the Comprehensive Quality Assurance Plans for Collection of Fish established for FWCC (FWC Chemistry Laboratory SOP, HGSOP 4/03) and FDEP (DEP-SOP-001/01, FS6000 General Biological Tissue Sampling). All field and laboratory procedure for collection and analysis of water samples and laboratory analysis of fish tissue samples were adhere to the requirements set forth in Department's Quality Assurance Rule, Chapter 62-160, F.A.C, including Department's Standard Operating Procedure (SOPs) for field activities (DEP-SOP-001/01).



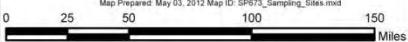
Florida Mercury TMDL Aquatic Sampling Sites		
 Map prepared by the Bureau of Watershed Restoration, D.E.P.R. This map is a DRAFT and therefore NOT legal for decision making purposes. For more information, contact Gregory White at 386-245-8110. Map prepared May 03, 2012. Map ID: 0301_Sampling_Sites.mxd 	<p>This map illustrates the locations of fish tissue and water quality sampling locations for lakes and streams as well as locations sediment were collected for the Florida Mercury TMDL.</p>	<ul style="list-style-type: none"> ▲ Sediment Collection Locations ■ Lake Water Quality & Fish Tissue ● Stream Water Quality & Fish Tissue ● Major Cities ~~~~ Interstates — Major Rivers ■ Florida Counties

Figure 4.2 Statewide Mercury TMDL Project Sampling Sites

4.6 Historic Data for Fish Tissue Mercury Concentration and Water Column Chemistry

Other than the fish tissue, water column, and sediment data collected during the 2008-2010 monitoring program, historical data collected through the fish consumption advisory program jointly carried out by the Department, FFWC, and DOH, and by the Department's Integrated Water Resource Monitoring Network (IWRMN) were also examined in order to identify the temporal trend of mercury fish tissue impairment in Florida.

Since 1983, FWCC, DOH, and the Department have been jointly conducting investigations on fish tissue mercury impairment in Florida waters. This effort primarily focuses on waterbodies and fish species that are important for fishing activities. Samples of popular fish species, such as LMB, bluegill, redear, sunfish, warmouth, spotted sunfish redbreast sunfish, black crappie, catfish, some exotics such as Oscars, butterfly peacocks, and Mayan cichlids, and over 100 salt water species such as Atlantic croaker, black grouper, dolphin, fantail mullet, gray snapper, gulf flounder, king mackerel, spotted seatrout, and yellowfin tuna, have been collected by FWCC from freshwater and marine waterbodies identified by FWCC and shipped to the Department for tissue mercury analysis. Fish consumption advisories for specific water bodies are issued by DOH if the mercury concentration found in fish is at levels that may pose a risk to human health. Advisories for mercury in Florida waters have been issued since 1989. The DOH Web site (www.doh.state.fl.us/floridafishadvice) offers regularly updated consumption advisories containing specific advice about eating fish from Florida's fresh and marine waters. These advisories are not intended to discourage fish eating but to provide guidance for choosing the right fish and also limit eating fish from waterbodies of high concern of mercury pollution. For the statewide mercury TMDL, the Department obtained fish tissue results of over 30,000 fish samples collected from more than 300 freshwater segments. Result summarizations of these data are provided in Chapter 5 of this report.

As mercury fish tissue concentrations can be influenced both by external mercury loadings into the aquatic system and biogeochemical characteristics of receiving waters, it is desirable to pair the analyses on mercury fish tissue concentration data with the analysis of water quality data. The water quality data used in these analyses were primarily retrieved from Department's IWR Database, which included data collected by Florida's Integrated Water Resource Monitoring Network (IWRM, <http://www.dep.state.fl.us/water/monitoring/index.htm>). This network was initiated in 1996 by the Department in an effort to refining its water resource monitoring and included three tiers of monitoring programs. Tier I monitoring program include status monitoring and trend monitoring. These monitoring networks primarily focus on providing the spatial and temporal water quality trend in Florida at the state level. Tier II monitoring program is watershed and waterbody oriented. It includes not only the monitoring efforts of the Department on individual waterbodies, but also collects water quality monitoring results from more than 90 other entities including other state agencies, county and local governments, universities, and voluntary groups. Water quality results from the Tier II monitoring program constitute the vast majority of the water quality data that the Department uses to conduct the IWR listing process and develop TMDLs for impaired waters. Tier III monitoring are primarily associated with the monitor activities required through the Department's regulatory permits, which is used to evaluate the effectiveness of point source discharge reductions and implementation of best management practices required by TMDLs.

Chapter 5: Monitoring Results

5.1 Fish Tissue Results

Fish tissue data were collected from 133 lakes and 131 streams in Florida in the period from September 2008 through October 2010. The fish tissue sampling focused on LMB; however, for those waterbodies in which no LMB could be collected or not enough LMB could be collected, spotted sunfish (SPSU) or spotted bass (SPB) were collected in place of LMB, using a translation between species to a common normalized fish standard. Out of the total 264 waterbodies sampled, fish samples from 90 waterbodies included SPSU samples and from 7 waterbodies included (SPB samples).

Average fish tissue concentrations were calculated for each species in each waterbody and median values of these waterbody-species average were then determined. The median tissue mercury concentration for LMB, SPSU, and SPB, based on fish samples collected in this project were 0.40 mg/Kg, 0.25 mg/Kg, and 0.68 mg/Kg, respectively. The 90th percentile fish mercury concentrations for LMB, SPSU, and SPB were 0.89 mg/Kg, 0.43mg/Kg, and 1.02 mg/Kg, respectively. **Figure 5.1** shows the distribution of fish tissue mercury concentration based on data collected from the above sampling project after the fish tissue normalization was conducted. Detailed information regarding the location of sampled waterbodies, general sampling conditions, and water chemistry of the sampled waterbodies can be found in **Appendix H** of this report.

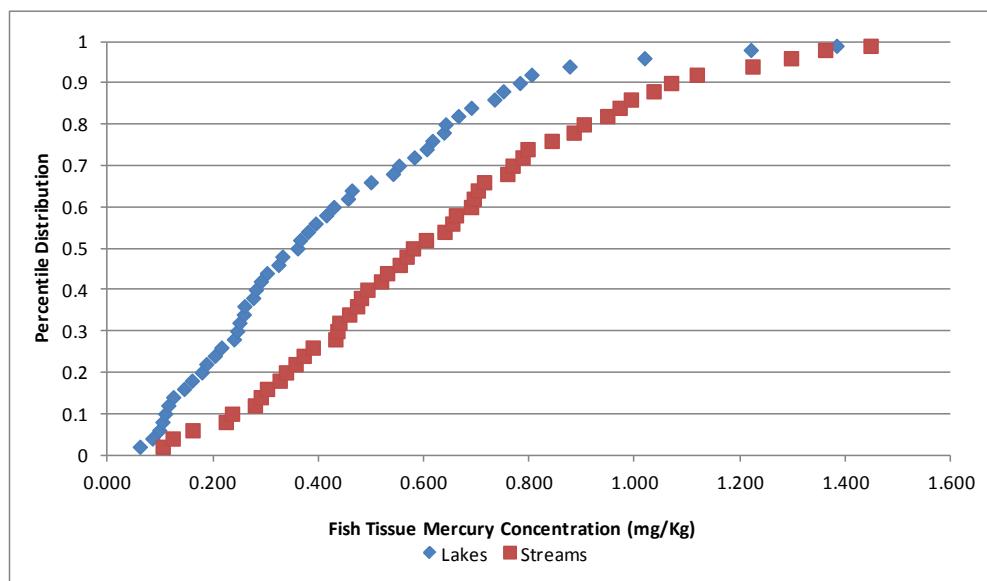


Figure 5.1 Cumulative Frequency of Fish Tissue Mercury Concentration in Lakes and Streams.

Fish tissue concentrations were also collected through the Florida fish consumption advisory program jointly carried out by FWC, DOH, and the Department since 1983. Based on the LMB data collected through the program, there appear to be a general trend of decrease in fish tissue

concentration since the early 1980s (**Figure 5.2**), although the probability that the slope of the decreasing line is zero is slightly higher than the 0.05 level .

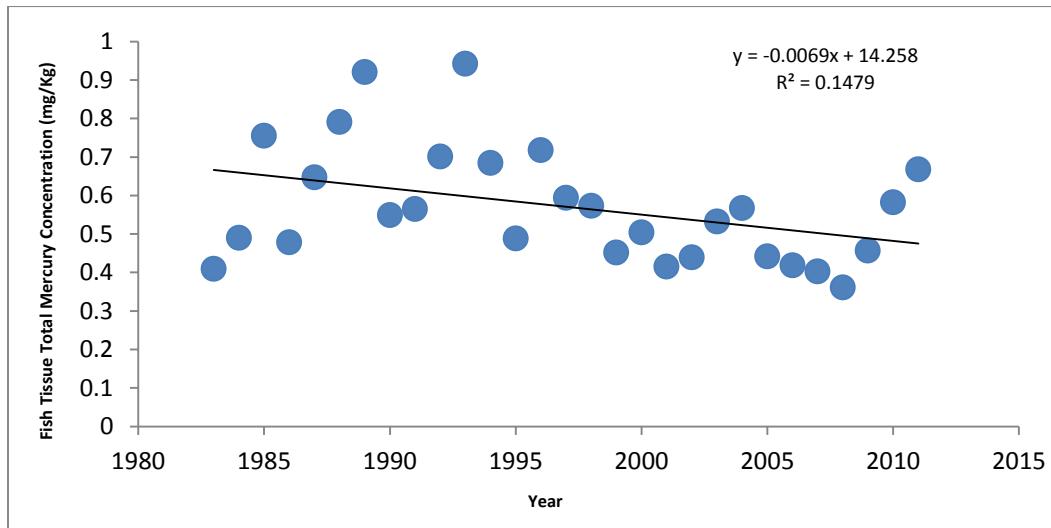
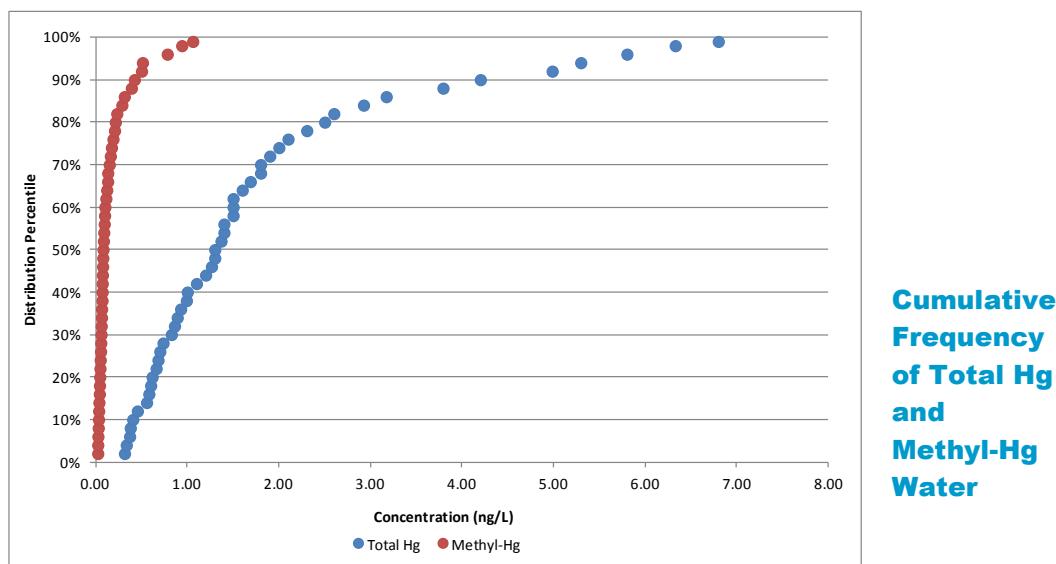


Figure 5.2 Dynamics of Fish Tissue Mercury Concentration in Florida Waters in the Period from 1983 through 2011

5.2 Total and Methylmercury, and other Water Column Parameters

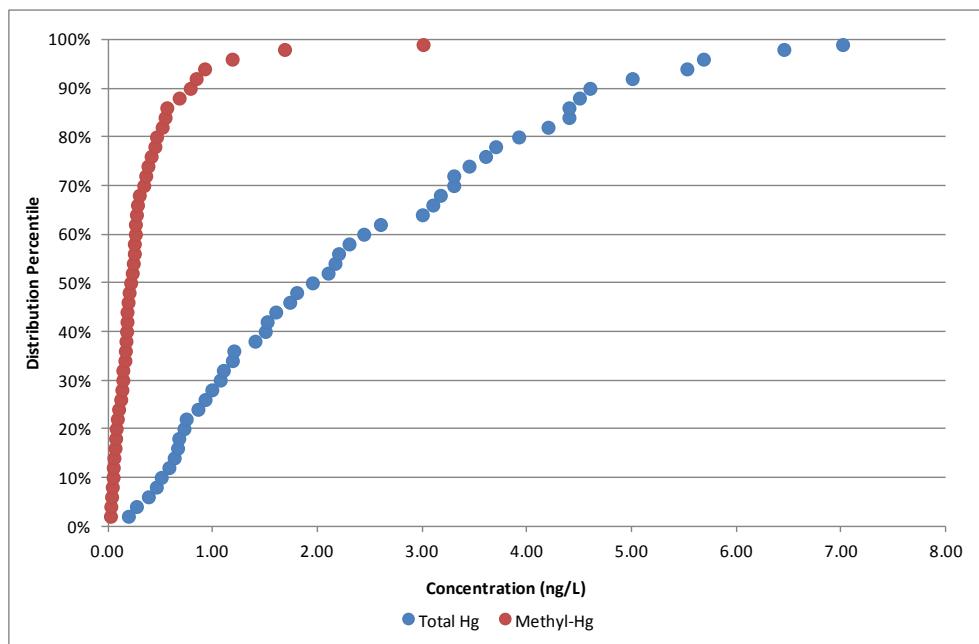
Water column samples were collected from the same waterbodies and at the same time when fish samples were collected and sent to the Department's Central Lab for analysis. These data include total mercury, MeHg, and other water quality parameters. **Figures 5.3a** and **5.3b** show the accumulative distributions of total mercury and MeHg in lakes and streams, respectively.

Figure 5.3a



Cumulative Frequency of Total Hg and Methyl-Hg in Water

Column Concentrations in Lakes



Figure

5.3b

Cumulative Frequency of Total Hg and Methyl-Hg Water Column Concentrations in Streams

The ranges of total mercury concentration in lakes and streams were fairly similar. The total mercury concentration in sampled lakes ranged from 0.22 to 7.70 ng/L. In streams, the range was 0.10 to 7.90 ng/L. However, stream total mercury concentration tended to distribute more toward the higher concentration end than the total mercury concentration in lakes. Based on **Figure 5.3a**, the 50th percentile of the lake total mercury concentration was 1.30 ng/L, which means that the total mercury concentration in about 50% of the lake was higher than 1.30 ng/L. In contrast, in more than 63% of the stream segments being sampled, the total mercury concentration was higher than 1.30 ng/L (**Figure 5.3b**). A similar trend was also observed with MeHg. The 50th percentile of the MeHg concentration in lakes was about 0.08 ng/L, which means that the methyl-mercury concentration is higher than 0.08 ng/L in about 50% of the lakes. For streams, more than 78% of the stream segments being sample had MeHg concentration higher than 0.08 ng/L.

To examine the methylation potential in streams and lakes, a ratio between MeHg and total mercury was calculated for each waterbody sampled, and the accumulative frequencies of the ratio were presented in **Figure 5.4** for both lakes and streams. Again, the overall distribution shows that, in stream segments, the ratio between MeHg and total mercury concentration tended to be higher than in lake segments. While the 50th percentile of the lake methyl to total mercury ratio was about 7%, the ratio of stream segments at the same percentile was about 12%. Except for one point at about the 99 percentile, the entire accumulative frequency curve of the stream methyl to total mercury ratio lain to the right of the lake methyl to total mercury ratio, indicating higher methyl to total mercury ratio in most stream segments sampled than in lakes.

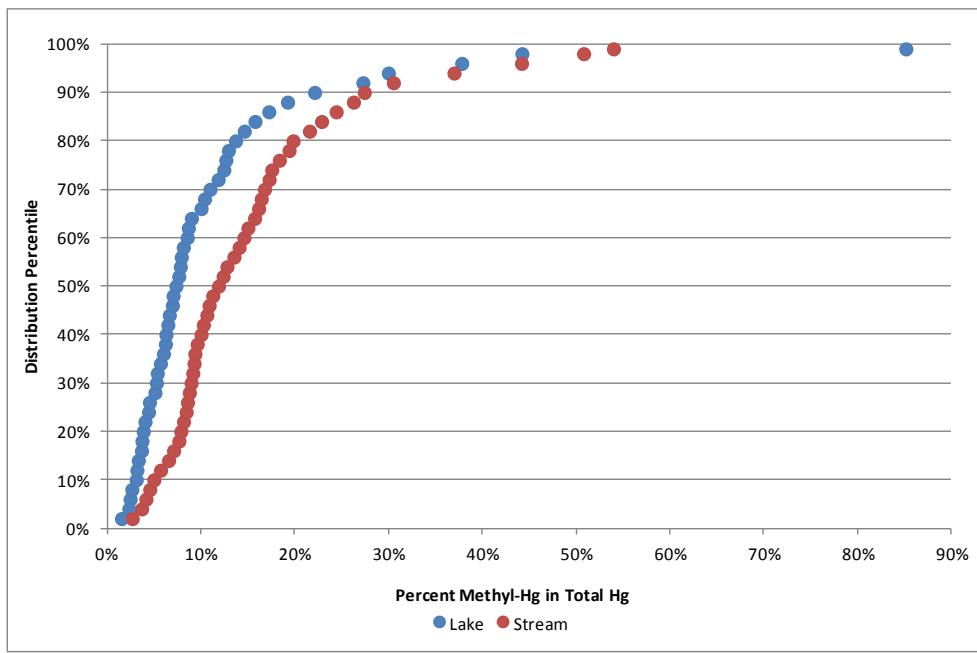


Figure 5.4 Cumulative Frequency Curve for the Methyl to Total Mercury Water Column Ratio in Lakes and Streams

Spatial distribution of total mercury, MeHg, and methyl-to-total mercury ratio in lakes and streams across the State were also examined. Detailed spatial distributions of these parameters can be found in **Appendix I**. Basically, no clear explicit spatial distribution patterns were identified from these analyses.

Statistics of other water parameters were summarized in **Table 5.1**. The raw data used to calculate these statistics can be found in **Appendix H**.

Table 5.1 Mean and Standard Deviations for all Parameters Measured or Collected in Waters Sampled for the Statewide Mercury TMDL

- = Sediment data were only collected for lake sampling locations

Parameter	Lakes		Streams	
	Mean	Standard Deviation	Mean	Standard Deviation
Alkalinity (mg/L)	37.50	44.58	90.13	80.89
Field Measurements				
Sample Depth	0.89	0.27	0.76	0.28
Secchi Depth	1.35	0.92	1.15	0.74
Site Depth	3.46	2.19	1.96	1.48
DO (mg/L)	7.52	2.10	5.88	2.48
pH	7.03	1.37	6.74	1.15
Specific Conductance ($\mu\text{mhos}/\text{cm}$)	307.04	733.83	487.32	1185.85
Temperature ($^{\circ}\text{C}$)	23.41	6.40	21.90	4.56
Redox (mvolt)	247.81	133.75	250.34	137.83

Parameter	Lakes		Streams	
	Mean	Standard Deviation	Mean	Standard Deviation
Major Ions				
Calcium (mg/L)	19.14	21.22	40.17	35.19
Chloride (mg/L)	58.81	215.07	79.48	336.51
Magnesium (mg/L)	7.02	15.57	10.79	27.15
Potassium (mg/L)	3.99	5.72	3.32	7.80
Sodium (mg/L)	32.48	120.72	49.53	215.91
Sulfate (mg/L)	25.03	47.12	29.07	55.74
Trophic Status Parameters				
Carbon- Organic (mg/L)	13.43	10.09	16.57	14.65
Ammonia (N) (mg/L)	0.06	0.21	0.04	0.05
Nitrogen- Total Kjeldahl (mg/L)	1.23	0.90	0.85	0.57
NNOx (mg/L)	0.05	0.13	0.26	0.45
Phosphorus- Total (mg/L)	0.06	0.09	0.12	0.20
Chlorophyll a (ug/L)	18.78	36.33	4.32	11.54
Chlorophyll a- uncorrected (ug/L)	20.87	39.31	5.15	13.67
Pheophytin (ug/L)	2.61	5.64	1.28	3.40
Water Clarity Parameters				
Color (PCU)	90.49	111.92	147.27	149.84
TSS (mg/L)	7.83	10.89	6.12	4.79

5.3 Sediment Mercury

Sediment total mercury, MeHg, and other sediment parameters were also collected for the 133 lakes. **Figure 5.5** shows the accumulative frequencies of sediment total and MeHg concentrations. **Figure 5.6** shows the accumulative frequency of sediment methyl to total mercury ratio.

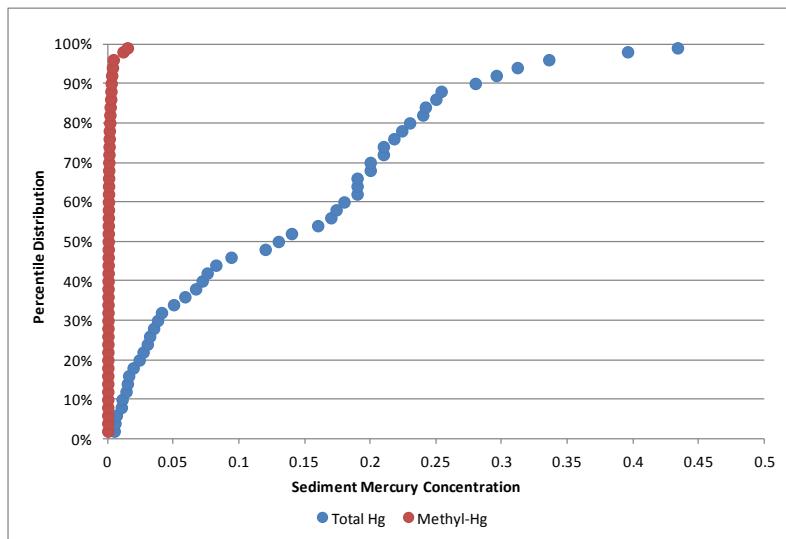


Figure 5.5 Cumulative Frequency of Sediment Total and MeHg Concentration

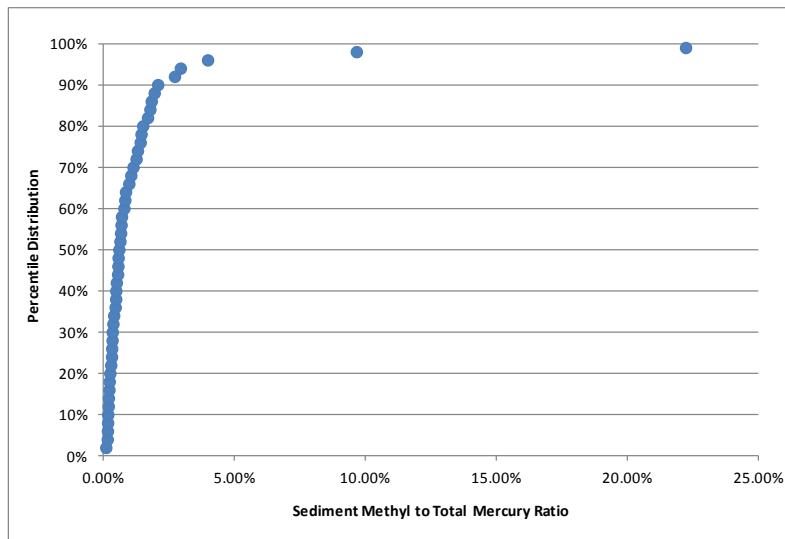


Figure 5.6 Cumulative Frequency of Sediment Methyl to Total Mercury Ratio

Compared to the water column methyl-to-total mercury ratio, which mostly fell in the range from 1% to 40%, the sediment methyl to total mercury ratio was significantly lower. It mostly fell in the range from 0.02% to 5%.

Statistics of other sediment parameters were summarized in **Table 5.2**. The raw data used to calculate these statistics can be found in **Appendix H**.

Table 5.2 Statistics Summary of Other Sediment Parameters (mg/kg)

Parameter	Mean	Standard Deviation
Al	19126.79	20204.63
Cr	28.28	27.34
Fe	8489.10	9354.47
Mg	1898.84	2453.72
Mn	82.37	103.47
Ni	9.78	8.52
K	1361.12	1559.38
Sr	158.88	280.10
Ti	1859.05	1622.37
V	28.35	27.64
Zn	51.58	118.80
Sb	0.99	3.54
As	4.41	3.59
Cd	0.52	0.55
Cu	78.40	651.48
Pb	26.96	22.87
Se	2.24	1.78

Parameter	Mean	Standard Deviation
Org C	16.30	15.66
Tot C	17.13	15.43
TKN	11587.91	11330.35
TP	1284.14	1684.14

Chapter 6. Model Results

6.1 Summary of Atmospheric Modeling Results

The deterministic atmospheric modeling performed as part of the Statewide Mercury TMDL Project analyzed various scales from global (80km resolution) to Florida region (4km resolution). The resolution of the modeling became more finite as the models scaled down to Florida. The model scales went from an 80km grid for the global domain, to 56 km for the North American domain, to 12 km for the Southeastern US domain, to a 4km domain for Florida. This 4km domain is the most resolute statewide modeling performed to date by any entity world-wide. As part of the development of the deterministic atmospheric model, meteorological models at the same domains had to be developed to handle the transport of atmospheric constituents. To provide load inputs into each scale of the model emissions inventories were developed with increasing specificity such that for Florida all individual major emission sources were specifically updated to current controls and operating levels for the 2009 base model year.

The deterministic atmospheric chemistry modeling, meteorological modeling, and emissions processing were all performed through publically available, public domain, models (see **Appendix F**). These models were enhanced through resolution of bug fixes, discovered when applying the models at the varying scales, as well as coding. All bug fixes were documented in the revised coding as well as being posted to the information boards publically maintained by the respective agencies managing this public domain software (this coding has been supplied to entities that have requested it, such as groups representing coal fired power industry in Florida). All enhancements were posted to the website for the models, and included in subsequent versioning. One pioneering enhancement in this effort was the implementation of a tagging scheme by which emission source categories could be tracked as to identify the source of deposition onto Florida. The source categories tracked in the atmospheric model are:

- Florida electric coal fueled
- Florida electric oil fueled
- Florida waste-to-energy
- Florida other sources grouped
- Alabama sources
- Georgia sources
- Mississippi sources
- Louisiana sources
- Texas sources
- Other US sources
- Global sources coming into USA
- Deposition re-emission

Another modeling effort is referred to as Inferential Dry Deposition Modeling. This allows an extrapolation of measured monitoring data to Florida statewide. This effort looks at conditions of land cover, such as forests or urbanized areas, meteorology, and their affects on how mercury gets deposited onto land surfaces. This enhances estimates of dry deposition.

A third atmospheric modeling effort examines the source types that are depositing at the atmospheric monitoring locations. This effort uses two different public domain statistical analysis packages to identify chemical constituents in atmospheric deposition that best explain the variation in the deposition measured. These models are EPA's PMF (USEPA, 2007) and Unmix (USEPA, 2007). Each of these through different algorithms, and PMF allowing the added use of uncertainty, perform partition analyses that use the full suite of constituents measured. The partition analyses provide arrays of constituent combinations that best represent the variability in constituents measured. Based upon the mix of constituents, and their relative amounts in a given array one can relate these to established profiles of source emissions. For additional information and results please see [Appendix F](#).

6.2 Overview Inferential Aquatic Modeling

The inferential aquatic modeling performed as part of the Statewide Mercury TMDL project sought to identify rigorous relationships between fish tissue THg, water quality measures, sediment quality measures, and modeled atmospheric deposition. These assessments were made through a wide range of statistical analyses applying parametric and nonparametric approaches, graph analyses, neural network analyses, fuzzy logic, and partition analyses. The data sets used were those collected for the 133 lakes and 131 streams, as well as expanding this data set with an additional 100 measures from historic fish tissue and water quality measures that were collected. The expanded fish tissue data were supplied by Ted Lange of FWC, and the water quality data were pulled from the SMN data. The added data were selected because near coincidence in time of fish tissue and water quality measures and these being in close time frame to the data collected as part of Statewide Mercury TMDL Project. For additional information and results please see [Appendix L](#).

Chapter 7: TMDL Target Setting

7.1 Setting a Reduction Target Based on Mercury in Fish Tissue

7.1.1 Reduction Target for Fish Consumption by Humans

In Florida, waters are identified as impaired based upon The Florida Department of Health (FDH) fish consumption advisories that evaluate mercury concentrations in fish tissue (62-303.470). FDH is the lead state agency for providing fish consumption advisories, which are published periodically to alert Floridians about possible contamination issues linked to fish caught in Florida's waters. A series of "Quick Facts" and the advisories can be viewed at: <http://www.myfloridaeh.com/medicine/fishconsumptionadvisories/index.html>. FDH provides general and specific guidelines that discuss the benefits and risks of eating fresh water and marine fish species, balancing the recommendation to eat sufficient fish (so as to benefit from the vitamins and omega-3 fatty acids) against the risk of consuming too much fish of the wrong species. FDH provides detailed warnings for specific fish species in many of Florida's lakes and streams, including advice on portion size for women of childbearing age, young children, and the general population. FDH also provides guidance on consumption of some marine species, which are locally caught. Included in the warnings are waters exhibiting excessive levels of saxitoxin (generally limited to puffer fish in waters on the central east coast of Florida), pesticides, and mercury in fish tissue. While the former should be avoided entirely, the FDH provides clear guidance on the quantities and frequency for consuming fish with elevated levels of mercury for nearly 400 fresh waterbodies, as well as for all of Florida's coastal waters and many of its estuaries.

The Department works cooperatively with FDH, the Department of Agriculture and Consumer Services, and the Florida Fish and Wildlife Conservation Commission to gather and assess the data and information needed to produce the fish consumption advisories discussed previously. Based on the advisory levels issued by the FDH for the general population, the DEP develops periodic updates for its lists of impaired waterbodies. Over the last decade, the listing threshold for impairment has been updated to reflect new science, going from 0.5 mg/Kg to 0.3 mg/Kg of mercury in fish tissue. The result is over 1100 waterbody segments (both fresh and marine waters) have been verified as impaired for excessive levels of mercury in fish for one or more species in each listed waterbody (unlike the DoH, the DEP may evaluate and list multiple segments within a single large lake or long river). It is important to note that there are significant natural levels of mercury in the environment, including emissions from volcanoes, soils, ocean emissions, and forest fires around the globe. Based on the impacts of this class of emissions, several species (e.g., shark or orange roughy) known to have high levels of mercury in their tissue would still have excessively high levels, even if all anthropogenic releases of mercury to the environment were stopped. Florida fish species will benefit from this TMDL by having lower amounts of mercury being deposited in the environment, which will result in lower levels of mercury in fish. Fish species that are just above the 0.3 ppm threshold, such as warmouth and shoal bass, or just above the 0.1 ppm threshold redear sunfish, channel catfish, bluegill, white catfish, others (**Figure 7.1**), may be brought below consumption guidelines in more of Florida's waters. The issue of protection is human health, thus the target is based upon fish consumption, which is the primary basis of human exposure to mercury.

The ultimate objective of reducing mercury is to prevent risks to public health. This requires additional holistic analyses of dietary habits of Floridians and the expected resulting mercury levels within those populations from consuming a variety of fish species with differing mercury concentrations.

Two approaches to setting a mercury fish tissue target are being presented. First, to more clearly present the estimated level of risk associated to Florida's primary high risk population (i.e., women of child-bearing age), we examined the data distributions for a wide range of women's body weights combined with the actual likelihood of exposure to mercury based on the likelihood of eating those fish species consumed in Florida. This uses the identified reference dose and exposure for limiting risk. This would cover fish consumption across Florida from marine and fresh water, thus representing all aquatic systems. The second approach describes work that has been done to broadly assess Florida fresh waters (thereby supporting the statewide approach to setting the TMDL) using the Largemouth Bass (*Micropterus salmoides*) as the primary indicator species. In both cases, the concentrations of mercury in fish tissue, the natural and anthropogenic fractions are ultimately divided as to identify where human controls, reductions in mercury loads, will limit exposure.

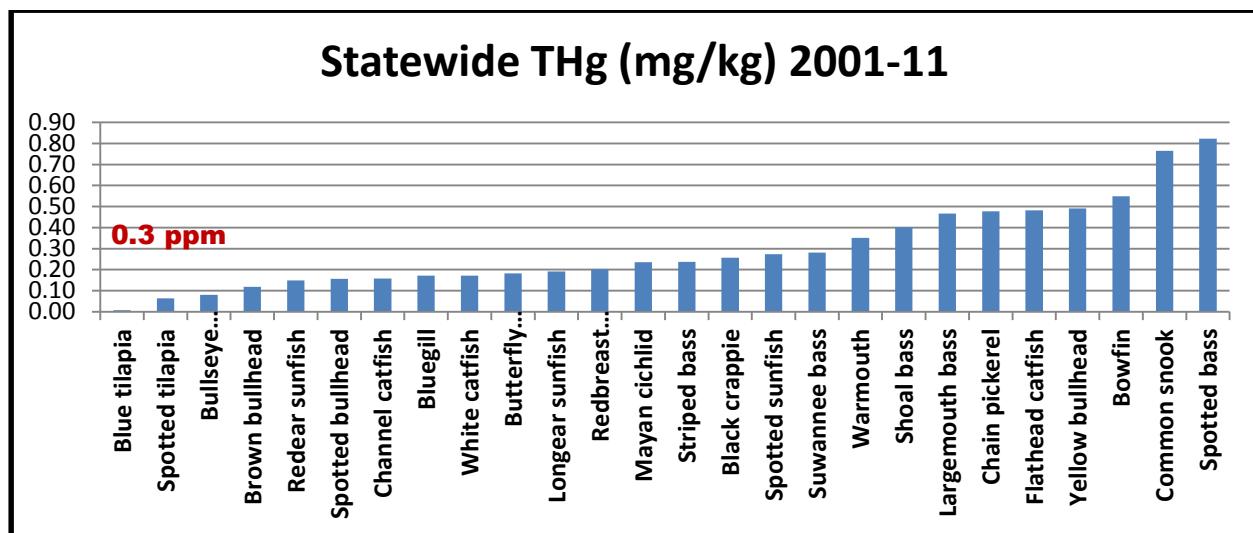


Figure 7.1. Tissue Mercury Concentrations for Florida Fish

Both of Florida's approaches to setting a statewide Total Maximum Daily Load to address high levels of mercury in fish tissues are dependent upon several assumptions, identified below:

- 1) The fraction of mercury being emitted to the atmosphere that comes from natural sources (and cannot be abated) is 30%.
- 2) Mercury concentrations in fish tissue increase with trophic level, age, and size of the fish.
- 3) The use of a larger top trophic level fish (LMB) in the TMDL analysis is a conservative approach, as lower trophic levels will have bioaccumulated less mercury, as will smaller fish.

- 4) The FDoH mercury concentration in fish tissue set to 0.3 mg/Kg is protective of the general population of people consuming fish, and a concentration of 0.1 mg/Kg is protective of young children and women of childbearing age.
- 5) There is a long-term linear relationship between mercury being emitted and deposited on the land and water with the concentrations of mercury in the water column.
- 6) Almost all mercury in fish tissue is in the form of MeHg, and represents greater than 95% of the mercury in most fish species (Bloom, 1992)

7.1.1.1 Market Basket Approach:

Human health risks are broadly defined through the equation:

$$Toxin * Exposure = Risk$$

For mercury, it is the methylmercury in fish tissue, represented by the total mercury in fish tissue, that is, the toxin. As with all toxins, a level at which harm can be identified is set at a threshold value and is influenced by the conditions of exposure. In the case of ingested toxin, there are not only the amount consumed and level of toxin therein, but also effects that have to do with age, sex, size, development status, among others. Each of these attributes has variations across fish species and human population. The variations can be represented by distributions, which encompass the population. For example, weights can range from the thin to heavy, with a curve representing the percentage of individuals at each weight. An analysis may be made by randomly selecting from this distribution to assign a weight for a risk analysis. This distribution can similarly be done for the other factors influencing exposure. Then iterating a model many times, randomly selecting from representative distributions would produce a representative of impacts and responses of a population.

Floridians eat a variety of fish including multiple species from in-state waters, out-of-state waters, marine waters and shellfish. All of which have different concentrations of mercury. This market basket approach accounts for different consumption patterns based on a Florida-specific survey (Degner 1994). Risks were calculated based on consumption patterns among women of childbearing age reported by Degner and species-specific arithmetic mean methyl mercury tissue concentrations. Rather than simply evaluating overall total fish consumption, this approach analyzed species/item specific consumption patterns. Because a substantial database of tissue contamination levels exists for methyl mercury, including Florida species, out-of-state species and internationally obtained species (estimate are that >85% of fish consumed come from outside US waters), this market basket approach accurately characterizes exposure risks to the seafood consuming population.

The Degner survey provides a robust dataset of Floridians' seafood consumption patterns, including individual species or seafood items, which were broken out into sub-populations, such as women of childbearing age. The survey was initiated in 1993 and concluded in 1994 as a state-wide telephone survey of 8,000 households stratified by county. Counties were stratified proportionally by population as reported by the 1990 Census. For adults, information on the amount of fish consumed both at-home and away-from-home during a 7-day period was collected from a randomly selected adult within the household surveyed. A 7-day recall method was chosen since other studies have shown a high degree of accuracy between 7-day food records and a subject's ability to recall consumption of foods, particularly those either commonly

or rarely eaten (Degner *et al.*, 1994). Survey data represented 7-day consumption patterns for Floridians. This data set is still used as a primary data source in making estimates of fish consumption for regional to national levels.

Probabilistic risk assessment techniques are well suited for quantitatively estimating the range of risks present among different individuals exposed to methyl mercury in fish tissue. Monte-Carlo simulation using Crystal Ball Fusion Edition (Release 11.1) software was selected as the probabilistic approach for the methyl mercury risk analysis. Probabilistic risk assessment utilizes input distributions, rather than point estimates, to better represent the variability that exists within a population; that is, instead of using one value for body weight and fish consumption, the entire range of possible values (a probability density function) was used. This probabilistic approach more accurately reflects actual populations and results in a better assessment of risk than does a simple deterministic approach. This approach follows EPA's position "that such probabilistic analysis techniques as Monte Carlo analysis, given adequate supporting data and credible assumptions, can be viable statistical tools for analyzing variability and uncertainty in risk assessments" (EPA, 1997), and guidelines therein.

A Monte Carlo analysis was selected as the approach to best determine trends of exposure and necessary mercury levels to protect women of childbearing years. A Monte Carlo analysis iterates results based upon distributions of possible values (e.g., fish consumed, mercury concentration, weight), randomly selecting from these distributions to perform a deterministic computation of mercury exposure. The Monte Carlo process repeats the analysis a set number of times, herein 10,000 time, and then aggregates the results of the individual calculations, into probability distribution that be used to select predictive values (e.g, mean, median, 90th percentile) of risk to the target population.

Distributions for fish consumption rates were taken from the Degner survey, which provided 7-day consumption data for 2,761 women of childbearing age (18-49). To convert weekly consumption data from the survey to daily average consumption rates needed for the risk calculations, probability distribution functions were fit to the consumption data for each individual species or food item. Probability distribution functions were successfully fit to survey data for 14 of the most commonly consumed species. These 14 species accounted for 73.4% of the total consumption. Robust probability functions could not confidently be fit to the survey results for the remaining 42 less commonly consumed species due to the small numbers of survey participants who reported consuming these species. Therefore, an overall total consumption curve was fit to proportionally assign consumption rates for the 42 less frequently consumed species. Probability distribution functions were generated based on survey results for consumers to assign fish type consumed, combined with an assumed probability that a woman would eat fish/seafood on any given week. Species that individually accounted for less than 1.0% of the total survey consumption were aggregated into two groups: a) other Florida species; and b) other non-Florida species. In total, the other Florida and other non-Florida species groups accounted for 8.0 and 5.6%, respectively, of the total reported consumption.

The number of women reporting consuming a particular food item, divided by the total number of respondents (2,761) was assumed to represent the probability of consuming that item during any given week of the year. This calculation of consumption probability (*cp*) assumes that the decision to eat seafood in any one week is a random process that is represented by the survey data. For example, 21% of women of childbearing age reported consuming canned tuna during the survey, which in the current application is assumed to equate to a 21% probability (*cp*) that a

women would choose to eat canned tuna during any given week of the year. Given the fact that the survey included a large sample of people, randomly selected throughout Florida, the data are representative of the consumption and non-consumption patterns of the target population.

Best fit probability distribution functions (lognormal) were applied to the 7-day consumption data (consumers only) for each species/item. The 7-day probability functions were fit directly from the survey data, for example **Figure 7.2** illustrates the function for canned tuna. An analysis was applied to simulate 52 weeks of consumption. The analysis procedure is summarized by **Figure 7.3**. During any week a women either consumed, or did not consume an item based on the consumption probability (*cp*). For weeks that a woman consumed fish, the amount consumed was assigned based on the 7-day fitted probability function. The weekly consumption rate was assigned a value of zero for weeks that a woman did not eat fish. The total annual consumption was summed and divided by 364⁶ to arrive at an average daily consumption rate. The analysis was run for 10,000 iterations and probability distributions were fit to the resulting data. A lognormal distribution (location=21.11, $\mu=5.36$, $\sigma=0.85$; **Figure 7.2**) was fit to consumer canned tuna data. Monte-Carlo analysis was applied, based on the above assumptions, to simulate total 52 week canned tuna consumption, which resulted in a fitted lognormal probability distribution function (Location=-4.90, Mean=9.81, Std. Dev.=3.86, **Figure 7.4**).

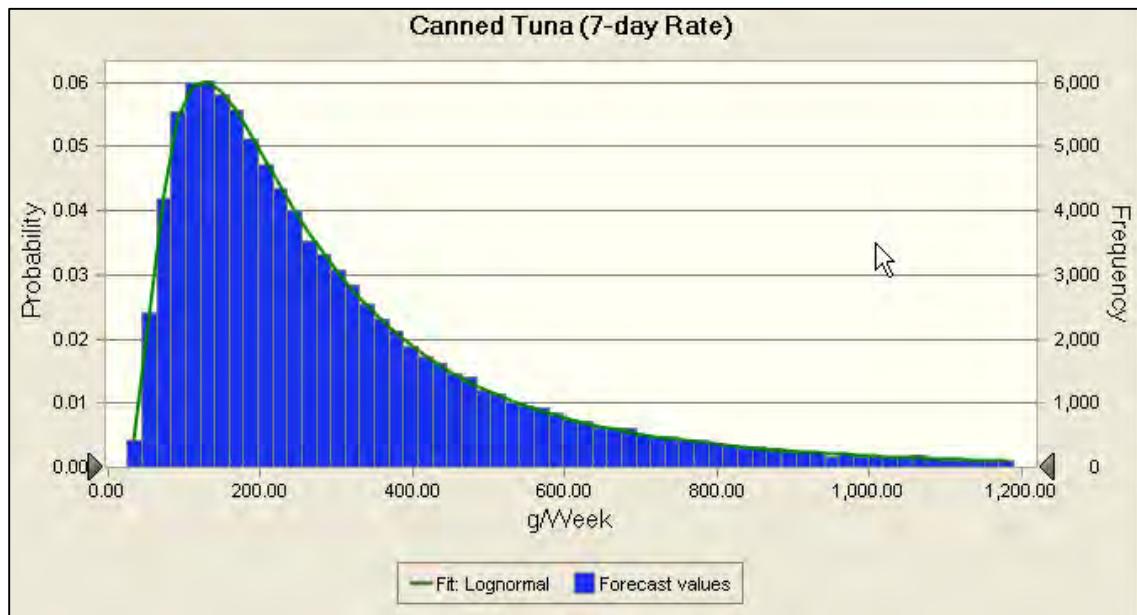


Figure 7.2. Women of childbearing age 7-day consumption rate (grams per week) lognormal distribution (location=21.11, $\mu=5.36$, $\sigma=0.85$) for canned tuna.

⁶ 7 days multiplied by 52 weeks equals 364 days

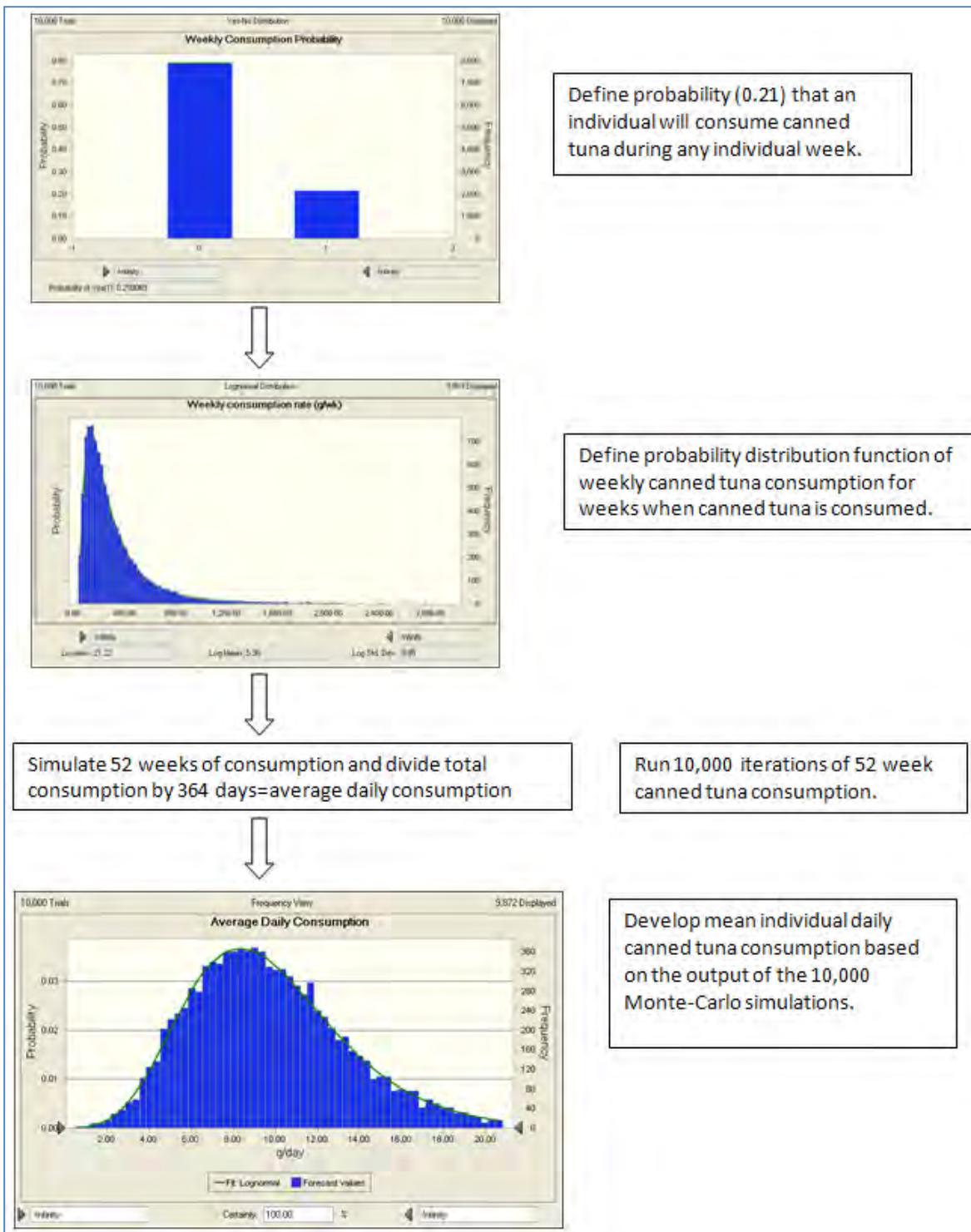


Figure 7.3 Example (canned tuna) process followed to generate species/item specific and total seafood consumption rates for women of childbearing age.

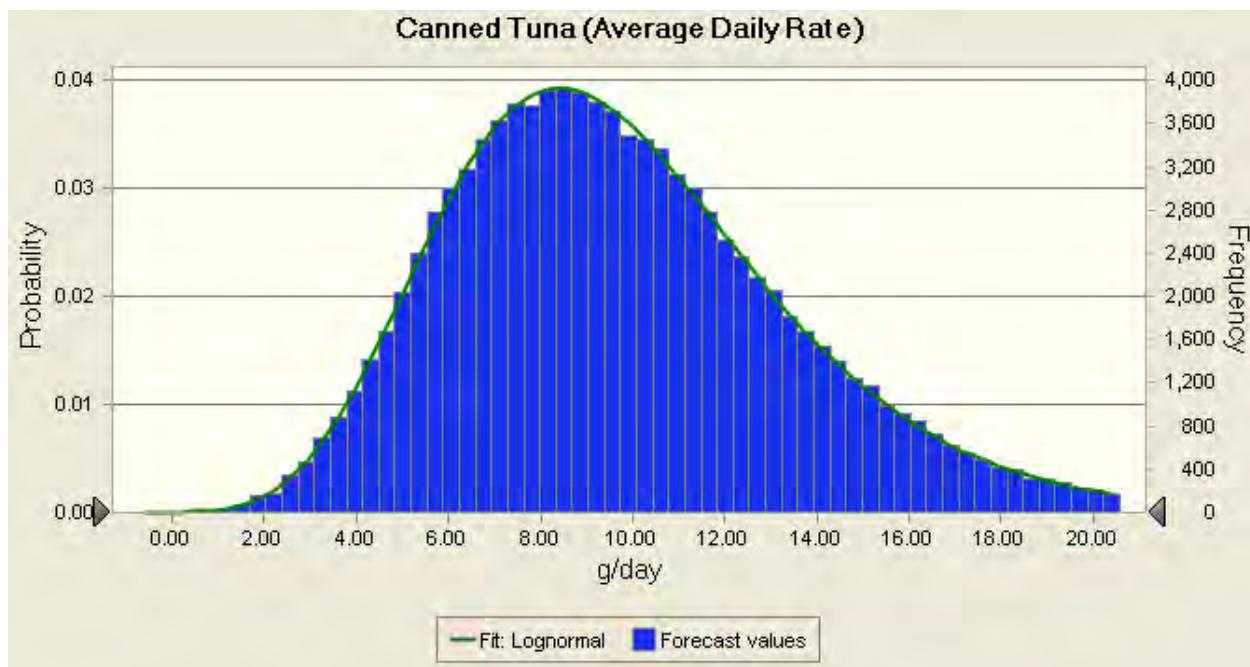


Figure 7.4. Average daily (g/day) canned tuna consumption rate distribution for women of childbearing age. The distribution was developed based on simulating 52 weeks of consumption for 10,000 individuals and developing a composite distribution from the simulated individual daily average consumption rates. Average daily individual consumption was calculated as the sum across all 52 weeks divided by 364.

As described above, species/item specific consumption rate probability density functions were developed for canned tuna, shrimp, flounder, grouper, freshwater catfish, bread fish fillets, dolphin, stone crab claws, salmon, crab meat, oysters and scallops. Additionally, a probability distribution function was developed for total fish consumption. Consumption rates for the 42 occasionally consumed items were assigned proportionally based on the total fish consumption distribution function (**Figure 7.5**); that is, the simulated total consumption rate was multiplied by the percent total consumption rate for the given species (**Table 7.1**). For example, a woman whose simulated total consumption rate was 53 g/day would be assigned a seatrout consumption rate of 0.76 g/day ($53 \text{ g/day} \times 0.0144$). Species that individually accounted for less than 1% of the total consumption, for women of childbearing age, were aggregated into either other Florida seafood or other non-Florida seafood, based on whether the species occurred within Florida waters. Consumption rates for the aggregated other Florida and other non-Florida species were assigned proportionally based on the total consumption distribution. As in the previous example, a woman whose total consumption rate was 53 g/day would be assigned other Florida seafood and other non-Florida seafood consumption rates of 4.24(8% total) and 2.99 (5.65% total) g/day, respectively.

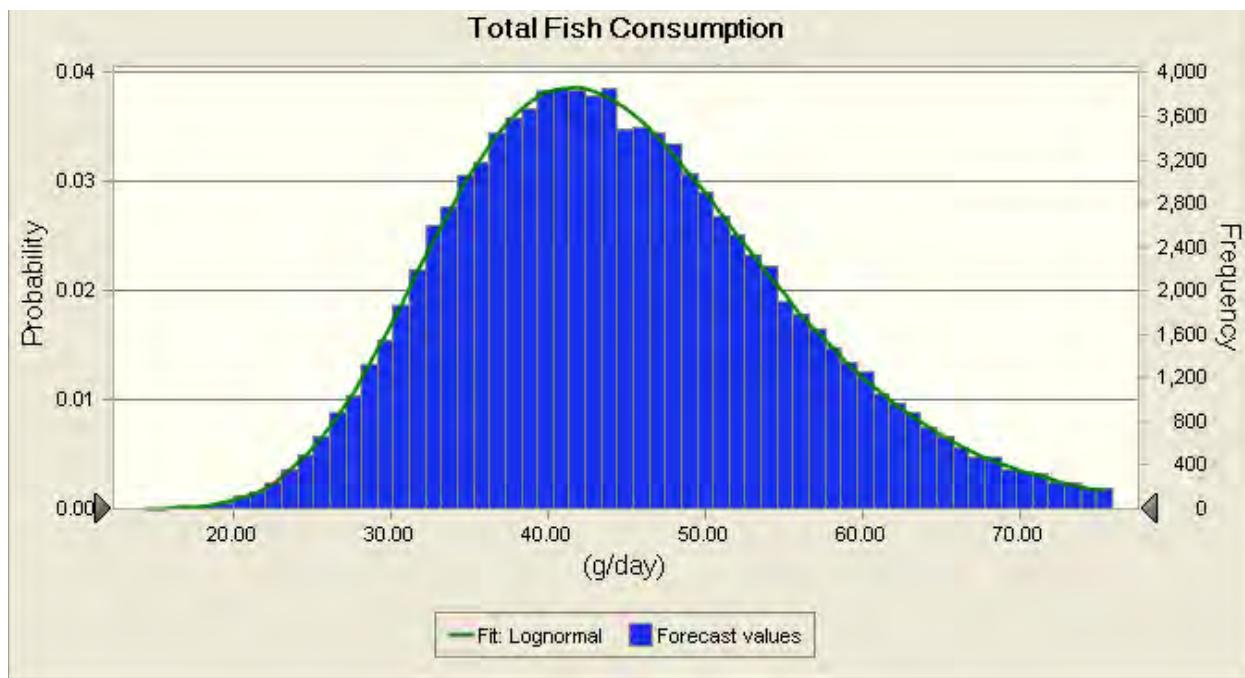


Figure 7.5. Average daily (g/day) total consumption distribution for women of childbearing age.

Mean species specific tissue total mercury contamination levels were assigned to each species/item based on the best available data (**Table 7.1**). A distributional approach for characterizing tissue concentrations was considered, but not pursued based on the assumption that individual consumer exposure from any individual species would tend towards the mean concentration over the long-term. If mercury distributions had been included then the program would have randomly selected both species specific consumption rates and mercury contamination levels for each individual iteration with mercury exposures calculated as the product of the consumption rate and mercury contaminate level on a species basis. The species specific consumption rate assigned for each iteration really represents a long-term average daily consumption for that individual. The mercury contamination level should likewise reflect the long-term average level of mercury the individual is exposed to through consumption of the given species. Use of mercury contamination distributions would have assigned some individuals high contamination levels, which is equivalent to assuming that the particular individual's exposure typically is at that level; however, exposure varies over time and by meal. For example, canned light chunk tuna mercury levels can range from 0.0 to 0.54 mg/kg with a mean of 0.11 mg/kg. It is highly unlikely that an individual who consumes tuna on a regular basis will always select (*i.e.*, randomly pull from a store self) either the most or least contaminated cans of tuna, but will rather experience variation over time in exposure levels, such that the long-term exposure will tend towards a mean value. The species specific arithmetic mean values represent the best estimates of long-term exposures; therefore, consumption weighted mean tissue total mercury concentrations were calculated and used for the other categories of Florida and non-Florida seafood (**Tables 7.2 and 7.3**). Note: a more complex model incorporating variation in mercury content could be constructed, but such a

model would require significantly more iterations as well as simulation of long-term individual exposure variation over a year or more.

Table 7.1 List of market basket species, consumption probability distribution function or proportion (for occasionally consumed items) and mean Hg tissue concentration. Probability distribution functions are listed in Appendix J. Consumption rates for the remaining items were assigned based on proportion of the total consumption distribution (lognormal distribution).

Florida Species	Species	Percent Total Consumption	Mean Total Mercury (mg/kg)	Consumption Rate
N	Canned tuna	24.00%	0.228	Distribution
Y	Shrimp	9.97%	0.016	Distribution
Y	Flounder	6.09%	0.115	Distribution
Y	Snapper	5.92%	0.389	Distribution
Y	Grouper	5.85%	0.489	Distribution
Y	Freshwater catfish	4.20%	0.016	Distribution
N	Breaded fish fillets	4.01%	0.010	Distribution
N	Fish sticks	3.34%	0.010	Proportion of total
Y	Mullet	3.13%	0.046	Proportion of total
Y	Dolphin	2.53%	0.133	Distribution
Y	Stone crab claws	2.45%	0.101	Distribution
Y	Clams	2.23%	0.016	Distribution
N	Salmon	2.09%	0.021	Distribution
Y	Crab meat	1.91%	0.101	Distribution
Y	Oysters	1.85%	0.011	Distribution
N	Fresh tuna	1.61%	0.463	Proportion of total
Y	Seatrout	1.44%	0.315	Proportion of total
Y	Panfish	1.34%	0.204	Proportion of total
N	Sardines	1.30%	0.013	Proportion of total
Y	Scallops	1.07%	0.003	Distribution
Y	Other FL Seafood	8.00%	0.428	Proportion of total
N	Other Non-FL Seafood	5.65%	0.328	Proportion of total

(sources of average mercury: FWRI –Adams et al., 2003, FDA; Sunderland, 2012)

Table 7.2 Summary of calculation of consumption weighted mean total mercury tissue concentration for the other Florida seafood category. Total consumption was calculated as the total Degner survey reported consumption for women of childbearing age.

Species	Mean Hg (mg/kg)	Total Consumption (kg)	Mean Hg · Consumption	Source
Amberjack	0.441	1305.6	576.19	FMRI
Blue crab	0.101	7288.4	734.02	FDA
King mackerel	1.153	1906.3	2198.54	FMRI
Mackerel	0.381	6988.4	2661.96	FMRI
Marine catfish	0.422	454.7	191.68	FDA/FMRI
Pompano	0.441	772.4	340.89	FMRI
Red drum	0.196	4510.9	885.26	FMRI
Salad shrimp	0.016	2918.1	47.58	FDA
Sheepshead	0.183	909.5	166.30	FMRI
Snook	0.374	893.9	334.59	FMRI
Whitefish	0.103	2303.8	237.46	FDA
Largemouth bass	0.470	7664.9	3602.50	Lange
Lobster tails	0.167	8084.8	1348.82	FDA
Shark	1.185	8389.4	9942.42	FDA/FMRI
Total		54391.1	23268.22	
Weighted mean			0.428	

Table 7.3 Summary of calculation of consumption weighted mean total mercury tissue concentration for the other non-Florida seafood category. Total

consumption was calculated as the total Degner survey reported consumption for women of childbearing age.

Species	Mean Hg (mg/kg)	Total Consumption (mg/kg)	Mean Hg · Consumption	Source
Bluefish	0.561	505.3	283.64	FDA/FMRI
Halibut	0.232	365.8	84.93	FDA
Mussels	0.030	2306.4	69.19	Sunderland
Sea bass	0.218	480.7	104.98	FDA/FMRI
Swordfish	1.088	6828.6	7426.10	FDA
Whole lobster	0.167	7496.0	1250.59	FDA
Cod	0.113	6663.7	751.19	FDA
Haddock	0.057	1336.1	76.54	FDA
Imitation crab meat	0.010	6813.1	65.15	FDA
Orange Roughy	0.569	2710.0	1543.22	FDA
Total		35505.5	11655.55	
Weight mean			0.328	

Total methylmercury exposure (dose) was calculated as the summed exposures for each item where the exposure of an individual item was calculated as the species specific consumption rate (kg/day) multiplied by the species/item specific mean total mercury contamination level (mg/kg, **Equation 1**). This use of total mercury, as normally measured, as surrogate for methylmercury adds a margin of safety as total mercury is always greater the methylmercury fraction. A distribution of exposures, based on 10,000 iterations, was generated for each scenario evaluated. Each individual iteration randomly selected a body weight, a total consumption rate, and seafood item specific consumption rates from the corresponding probability density functions (**Appendix J**).

Exposure to mercury from the consumption of contaminated fish and seafood items is calculated as a function of consumption rate and the level of contamination present with the fish:

$$Hg\ Exposure = \sum_{i=1}^n FC_i \times TRC_i \quad \text{Equation 1}$$

where,

FC_i = Consumption of the i^{th} species in kg/day, and

TRC_i = Tissue residual concentration (mg Hg/kg) of the i^{th} species. For the Florida market basket analysis, total residual concentration of the i^{th} species were based on the mean tissue concentration for each species.

The Hg exposure was divided by the body weight (kg) to calculate the weight adjusted dose (mg Hg/kg·day). For example, a woman of childbearing age consumes fish and other seafood items at the rates listed in **Table 7.4**. Her exposure to mercury from each item consumed is calculated by multiplying the consumption rate by the mercury contaminant concentration for the species. Her total exposure is calculated as the sum of the exposures from all species (**Equation 1**). The woman's mercury dose is calculated as the total exposure to mercury by her body weight (**Equation 2**). The example woman weighs 63 kg, thus her dose is 0.13 mg Hg/kg·day. The dose is compared to the reference dose (RfD) of 0.10 µg Hg/kg·day, leading to the conclusion that the woman exceeds the reference dose.

$$Dose \left(\frac{\text{mg Hg}}{\text{kg} \cdot \text{day}} \right) = \frac{\text{Hg Exposure}}{\text{Body Weight (kg)}} \times 1000 \quad \text{Equation 2}$$

Table 7.4. Example calculation of mercury exposure and dose

Species	FC_i (Consumption Rate, kg/day)	TRC_i (Tissue Hg Concentration, mg Hg/kg)	Hg Exposure (THg) (mg Hg/day)
Canned tuna	0.0092	0.228	0.0021
Shrimp	0.0037	0.016	0.000060
Flounder	0.0013	0.115	0.00015
Snapper	0.0037	0.389	0.00144
Grouper	0.0025	0.489	0.00120
Freshwater catfish	0.0010	0.016	0.00002
Breaded fish fillets	0.00020	0.010	0.0000019
Fish sticks	0.0015	0.010	0.000014
Mullet	0.0014	0.046	0.000063
Dolphin	0.0010	0.133	0.00014
Stone crab claws	0.00046	0.101	0.000046
Clams	0.00097	0.016	0.000015
Salmon	0.0016	0.021	0.000034
Crab meat	0.0008	0.101	0.000081
Oysters	0.00071	0.011	0.000008
Fresh tuna	0.00071	0.463	0.00033
Seatrout	0.00063	0.315	0.00020
Panfish	0.00059	0.204	0.00012
Sardines	0.0006	0.013	0.0000075
Scallops	0.0004	0.003	0.0000015
Other FL Seafood	0.0035	0.428	0.0015
Other non-FL Seafood	0.0025	0.328	0.00081
Total Exposure (mg Hg/day)			0.00832
Dose (µg Hg/kg·day)			0.132

Monte Carlo analysis conducts repeated random samplings from a population or distribution to compute a range of outcomes based on variability in the input variables. In the case of the mercury market basket analysis repeated samplings were conducted from the distributions of species specific consumption rates (FC_i) and body weights for women of childbearing age (BW_j), where BW_j is the body weight in kilograms for the j^{th} woman. Mercury doses were calculated for each randomly selected combination of body weight (BW_j) and fish consumptions (FC_i), resulting in a distribution of mercury doses for Florida women of childbearing age. The distributions used in the analysis are summarized in **Appendix J**. All Monte Carlo analyses were conducted for 10,000 iterations. DEP evaluated the sensitivity of the analysis (exposure distribution) to the number of iterations. Analyses conducted using 50,000 and 100,000 did not produce significantly different results at the mean, 90th, or even 95th percentile of the exposure distribution. It was therefore determined that 10,000 iterations were sufficient to provide a stable solution to the problem.

An analysis of baseline or current conditions (current mean methylmercury contamination levels) suggested that there is a 51.5% certainty that the target population (women of childbearing age) is at or below the protective reference dose of 0.1 $\mu\text{g}/\text{kg}\cdot\text{day}$ (**Figure 7.6**). This level of certainty indicates that a significant portion of the population could exceed the reference dose and may be at risk of adverse health effects. The analysis shows that women of childbearing age are under-protected at the existing mercury contamination levels in fish they consume.

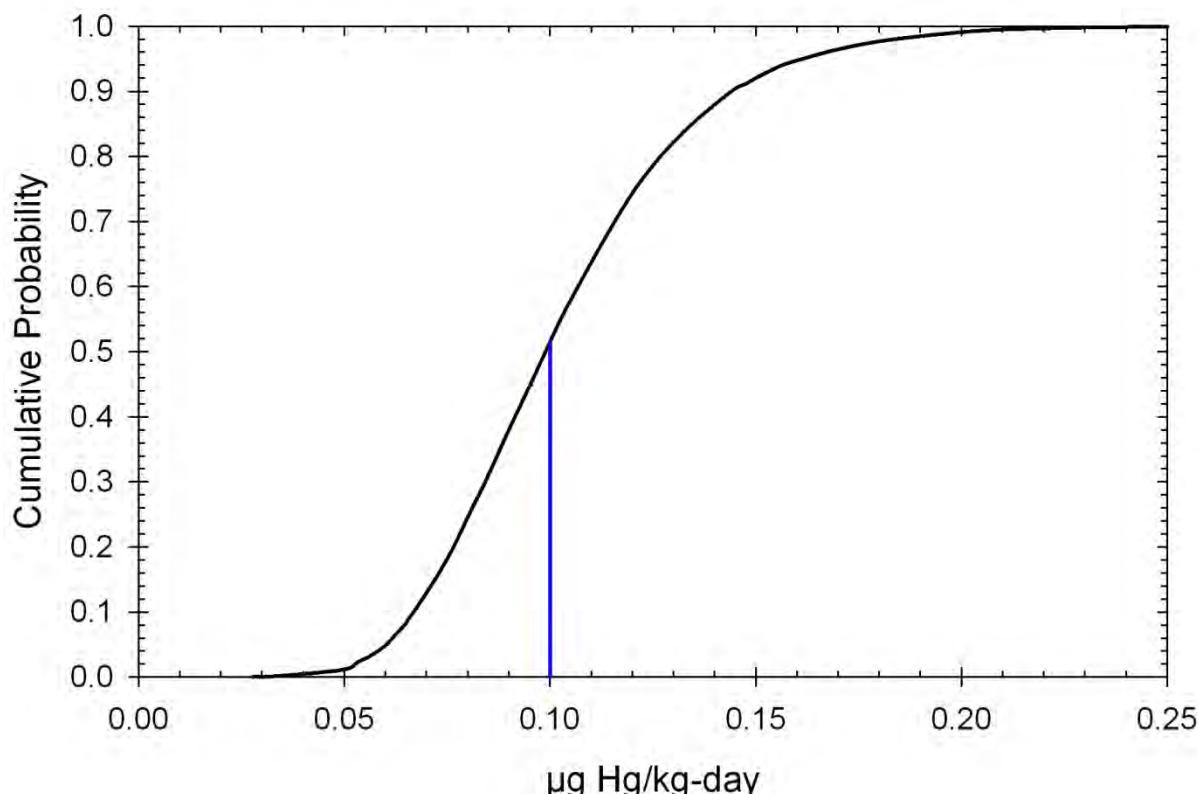


Figure 7.6 Baseline scenario cumulative probability distribution of methyl mercury dose for women of childbearing age based on the market basket analysis.

The Monte Carlo simulator was next used to evaluate the effect of reducing Florida fish contamination levels on the dose distribution. This analysis involved iteratively reducing the tissue residual concentration (TRC_i) for Florida species by a constant percentage and running the Monte Carlo analysis of body weights and consumption rates until a 90% certainty of not exceeding the reference dose was achieved. The randomly sampling was conducted in the same manner as was done for the baseline analysis. This analysis found that Florida fish levels would need to be reduced to 40% of current levels (i.e., 60% reduction) to achieve the protective target certainty level (Figure 7.7). Under the Florida species 60 percent reduction scenario the previous example 63 kg woman from Table 7.4 would now receive a dose of only 0.084 µg Hg/kg-day, which is below the RfD (Table 7.5). This 60% reduction in total sources is equivalent to an 86% reduction in anthropogenic sources given that natural background deposition accounts for 30% of the deposition. These results are supported by the Department's independent study (Sunderland et al., 2012) looking at fish consumption and exposure for Gulf of Mexico residents, which using a larger list of species consumed (N=32) and applying a similar probabilistic approach, found similar exposures, and thus similar reductions in anthropogenic sources being required to reduce exposure.

Table 7.5. Mercury exposure and dose for the example women from Table 7.4. The example woman weighs 63 kg and consumes fish and seafood items according to the patterns listed in FC_i column below. Mercury exposures were calculated based on the FL species reduction scenario tissue concentration levels.

Florida Species	Species	FC _i (Consumption Rate, kg/day)	Baseline TRC _i (Tissue Hg Concentration, mg Hg/kg)	FL Species Reduction Scenario TRC _i (Tissue Hg Concentration, mg Hg/kg)	Hg Exposure (mg Hg/day)
N	Canned tuna	0.0092	0.228	0.228	0.0021
Y	Shrimp	0.0037	0.016	0.007	0.000024
Y	Flounder	0.0013	0.115	0.046	0.000059
Y	Snapper	0.0037	0.389	0.156	0.00058
Y	Grouper	0.0025	0.489	0.196	0.00048
Y	Freshwater catfish	0.0010	0.016	0.006	0.0000064
N	Breaded fish fillets	0.00020	0.010	0.010	0.0000019
N	Fish sticks	0.0015	0.010	0.010	0.000014
Y	Mullet	0.0014	0.046	0.018	0.000025
Y	Dolphin	0.0010	0.133	0.053	0.000055

Florida Species	Species	FC_i (Consumption Rate, kg/day)	<i>Baseline TRC_i</i> (Tissue Hg Concentration, mg Hg/kg)	<i>FL Species Reduction Scenario TRC_i</i> (Tissue Hg Concentration, mg Hg/kg)	Hg Exposure (mg Hg/day)
Y	Stone crab claws	0.00046	0.101	0.040	0.000019
Y	Clams	0.00097	0.016	0.006	0.0000061
N	Salmon	0.0016	0.021	0.021	0.000034
Y	Crab meat	0.0008	0.101	0.040	0.000032
Y	Oysters	0.00071	0.011	0.005	0.0000032
N	Fresh tuna	0.00071	0.463	0.463	0.00033
Y	Seatrout	0.00063	0.315	0.126	0.000079
Y	Panfish	0.00059	0.204	0.082	0.000048
N	Sardines	0.0006	0.013	0.013	0.0000075
Y	Scallops	0.0004	0.003	0.001	0.00000061
Y	Other FL Seafood	0.0035	0.428	0.171	0.00060
N	Other Non-FL Seafood	0.0025	0.328	0.328	0.00081
Total Exposure (mg Hg/day)					0.00530
Dose ($\mu\text{g Hg/kg}\cdot\text{day}$)					0.084

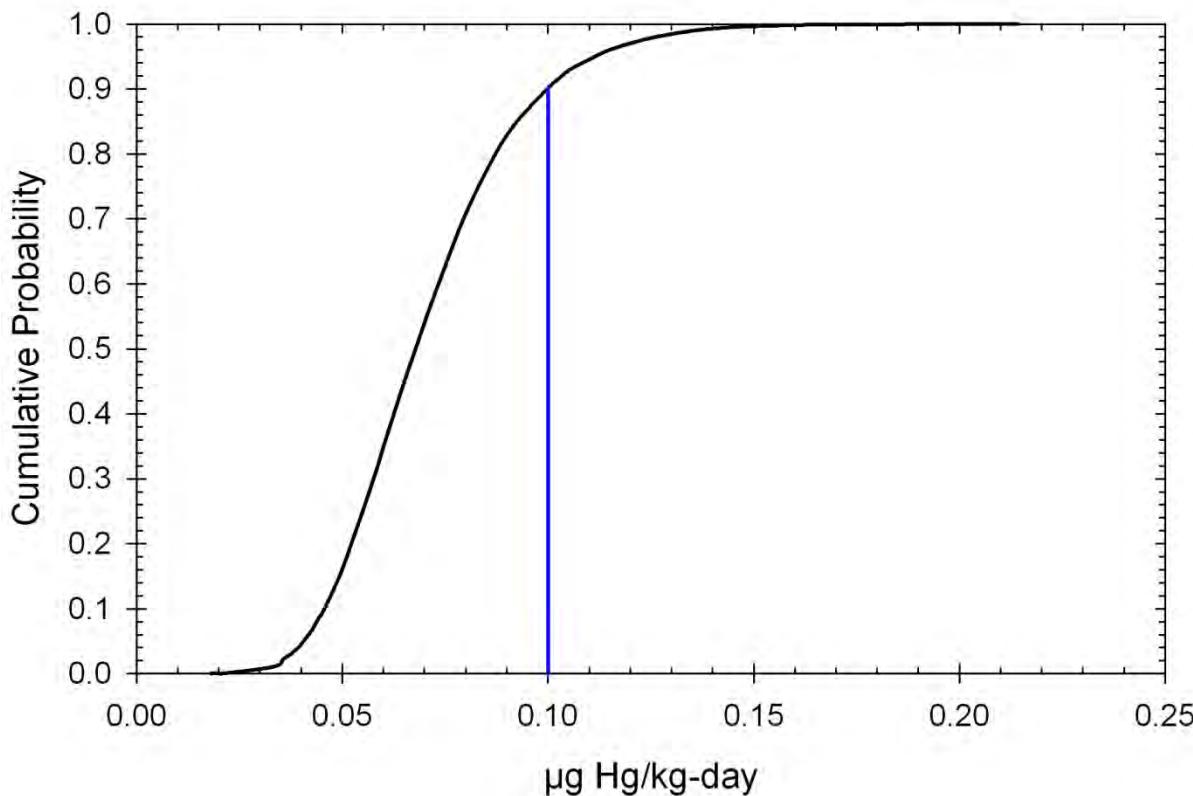


Figure 7.7 Sixty percent reduction in Florida species methyl mercury scenario cumulative probability distribution of methyl mercury dose for women of childbearing age based on the market basket analysis.

The 60% reduction and 90% certainty assume no change in non-Florida species; however, U.S. EPA and other states are simultaneously seeking mercury source reductions. Therefore, it is highly likely that reductions in non-Florida seafood will occur and result in even greater certainty of achieving the reference dose. Furthermore, 403.067(6), F.S., requires the Department to consider the extent to which nonattainment of water quality standards is caused by pollution sources outside of Florida when allocating TMDLs. DEP ran a series of scenarios assuming reduction in non-Florida species to maximum target contamination levels ranging from 0.1 mg/kg to 0.3 mg/kg. Under these scenarios, the mean methyl mercury level for any species above the maximum target level was reduced to the target level. For example, mean canned tuna is currently at 0.228 mg/kg. Under the 0.1 mg/kg scenario the assumed contamination level was reduced to 0.1 mg/kg. The non-Florida species reduction scenarios were applied in addition to an assumed 60% reduction in Florida species. The analysis showed that reductions below 0.2 mg/kg in non-Florida species substantially increased the certainty (**Table 7.4**) that the protective reference dose will be achieved. Specifically, reductions in non-Florida species to 0.15 mg/kg or less will result in a greater than 99% certainty.

Table 7.6 Summary of baseline (current condition) and reduction scenario methyl mercury exposure risks. Certainty represents the confidence that the population is at or below the reference dose (0.1 µg/kg·day). Reduction scenarios were run by reducing fish tissue concentrations by a reductions factor (i.e., RF*species mean concentration) necessary to achieve 90 percent certainty assuming no reduction in non-Florida species. Additional scenarios were run under the assumptions that non-Florida species are reduced to levels ranging from ≤0.10 to 0.3 mg/kg.

Florida Species Percent Reduction	Non-FL Species Max. mg/kg	Certainty
Baseline	Baseline	51.50
60	Baseline	90.18
60	0.300	91.96
60	0.275	93.07
60	0.250	92.80
60	0.225	94.52
60	0.200	96.63
60	0.175	98.35
60	0.150	99.39
60	0.125	99.79
60	0.100	99.92

7.1.1.2 Using Largemouth Bass:

A second line of evidence for setting a TMDL reduction target is to assess the data gathered statewide for top trophic level predators that live in most of Florida's waterbodies and are consumed by humans. For marine species, Snapper and Grouper represent the highest consumed, top trophic level species that exist in Florida waters. Largemouth bass (LMB) represents the highest consumed, top trophic level species that exist in Florida's freshwater lakes and streams. The average mercury concentration of these species is relatively equivalent. Because the State has much more data for LMB, we will focus on that species as a surrogate for the statewide (fresh and marine) TMDL targeting. Beginning in 1983, and under contract with the Florida Fish and Wildlife Conservation Commission, the DEP has been provided with 31,159 fish tissue samples, mostly targeting Largemouth Bass (LMB). For the purposes of setting this Total Maximum Daily Load, a stratified-randomized sampling approach was designed and implemented for the period 2008-2010, also focusing on LMB. While the DEP has mercury data for many fish species, a reduction target based on a high trophic level predator (such as LMB) will be protective of all the other lower trophic level feeders. As was not the case with the fish tissue data collected prior to 2008, a specific suite of water chemistry was also collected to aid in our assessment of the potential causes of methylation in Florida's fresh surface waters. Having these paired water quality data also allowed us to calculate a "Bioaccumulation Factor" for each waterbody, and from these values, an average statewide BAF was determined.

Previously, other states, and groups of states, have established statewide (or regional) TMDLs for mercury as a way to efficiently address widespread fish consumption advisories. New Jersey recently (2009) had approved a TMDL for 122 waterbodies listed as impaired for mercury in fish tissue, with sources that were tied to air emissions (TMDL for Mercury Impairments Based in Concentration in Fish Tissue Caused Mainly by Air Deposition to Address 122 HUC 14s Statewide, NJDEP, 2010). As was done in the TMDLs for New Jersey, and by applying the assumption of a linear relationship between mercury in the environment to that in fish tissue, the needed reduction in mercury deposition can be calculated. Specifically in Florida, if the required reduction is based on the 90th percentile concentration of mercury in LMB measured over the designated study period (i.e., a value of 0.74 mg/Kg for the period 2008-2010) and compared to the desired fish tissue target of 0.3 mg/Kg for the general population, a reduction of 85% of anthropogenic sources contributing to Florida's mercury burden would have to be achieved.

7.2 Reduction Target for Fish Consumption by Wildlife

Wildlife may be at risk of mercury exposure from consumption of fish with elevated levels of mercury. The greatest risk is for piscivorous species. In the Mercury Report to Congress, a value of 0.077 ppm was deemed as being protective of Trophic Level-3 wildlife consumers and 0.346 for Trophic Level-4 wildlife consumers. For this analysis, the more protective value of 0.077 is used herein to evaluate necessary reductions in mercury sources for the protection of wildlife. The Department focused its evaluation on Wood Storks (*Mycteria americana*), and Great Blue Herons (GBH, *Ardea herodias*) as the primary though not exclusive focus. White Ibis (*Eudocimus albus*), and other smaller wading birds such as Tricolor Herons (*Egretta tricolor*), Little Blue Herons (*Egretta caerulea*), and others, were also considered but as the smaller wading birds are primarily feeding on Trophic Level-2 prey items, it is considered that if the target value of 0.077 is achieved for wood storks and GBH, then lower trophic levels would similarly be protected. This setting of reduction targets based upon a higher trophic level follows guidelines of USEPA, and approaches used in promulgated mercury TMDLs. Based upon the monitoring performed for the Statewide Mercury TMDL project (see **Chapter 5** and **Appendix H**) an evaluation by system type of stream/river, lakes/ponds, and Everglades, the Everglades has the highest levels of mercury as observed in LMB (**Figure 7.8**).

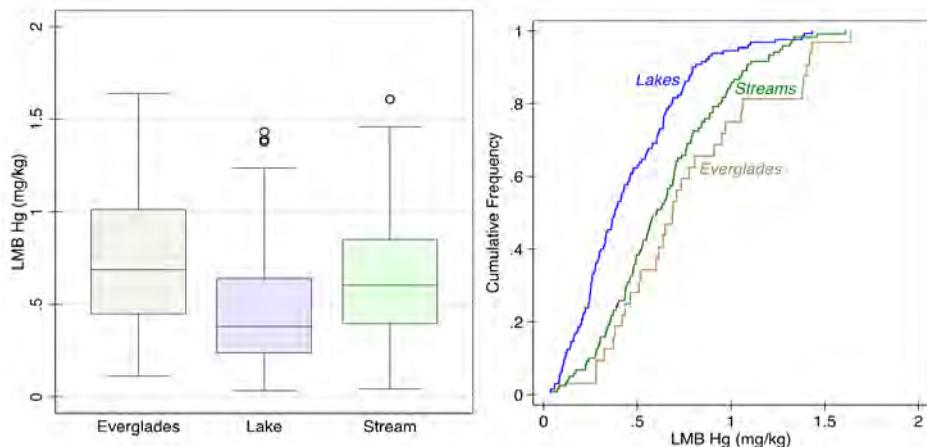


Figure 7.8 Box plot (left) and cumulative frequency distribution plot (right) comparing standardized (15 inch length) largemouth bass (LMB) total mercury concentrations in fish tissue collected in the Everglades measured from 2008–2010. Box plots represent median and 25th, and 75th percentiles; whiskers represent 10th and 90th percentiles; and points are outliers. Sample numbers are as follows: Everglades = 32, Florida lakes = 130, and streams = 120 (Axelrad, D., et al., 2012)

Thus, assessing trophic level-3 fish in the Everglades, as may be consumed by Wood Storks and GBH, provides a margin of protection to other system types across the state. The Everglades Protection Area has numerous wood stork rookeries (Figure 7.9), and GBH rookery and loafing areas are ubiquitous across the region.

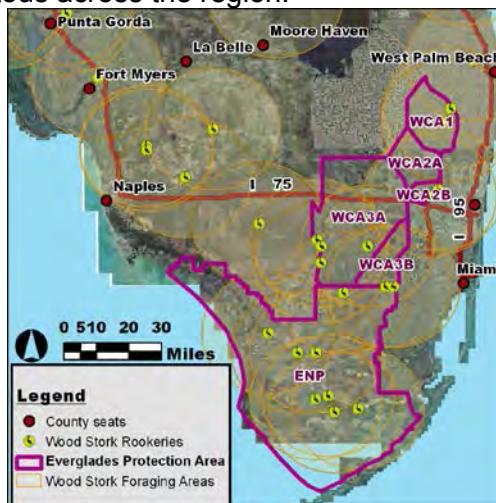


Figure 7.9 Wood Stork Rookeries and Foraging Areas in Everglades Protection Area

Wood stork rookeries are provided as the foraging region of wood storks are known to be most limited of the two demonstration species. Foraging for wood storks during late phases of the nesting season track well with water drawdowns in forage areas (thereby concentrating food species). This provides concentrations that allow easier capture of smaller individuals relative to level of effort. Fish size consumed is normally 1-6 inches in length.

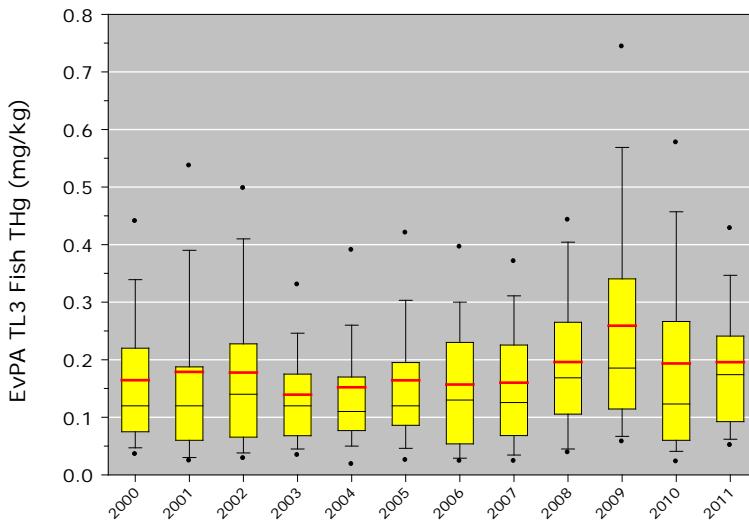


Figure 7.10 Mercury in TL3 fish (bluegill, redear sunfish, and spotted sunfish) collected from 25 locations in the Everglades Protection Area from 2000 to 2011. Data include the median (black horizontal line), mean (red horizontal line), 25-75th percentiles in yellow, 10-90th percentiles as whiskers, and 5-95th percentiles as points.

The mean mercury level in TL3 fish across the Everglades Protection Area is 0.176 mg/kg ($N = 1,966$). This number is used analogously to the average mercury values used in fish species in the Market Basket approach presented earlier as to evaluating fish consumption risk in the at risk population of women of childbearing age and young children. The margins of safety inherent in the use of the average for wading bird consumption include: diets are not exclusively fish, diets are skewed toward fish smaller than those collected for measuring THg in fillets, and whole fish values for mercury are typically lower than fillet-only values (Bevelhimer et al., 1997). The latter is true due to limited concentration of mercury in bones, as compared to other metals such as arsenic, as well as limited sequestration in organs.

Applying the more conservative percent reduction, i.e., higher value, as determined in the anthropogenic exposure evaluations, of 60%, the respective reduction in TL3 fish would result in an expected level of:

$$0.176 \text{ mg/kg} * 0.60 \text{ (percent reduction)} = 0.070 \text{ mg/kg}$$

Concerns for individual hot spots within the Everglades Protection Area are at times raised relative to wildlife exposure through fish consumption. However, in terms of practical application when one considers foraging patterns, that “hot spots” are being driven as coincident with single sampling events, and that hot spot locations do not remain stationary across time – further indicating that these location representations are sampling artifacts -, hot spots are not deemed to be an established control point for exposure. If one were to consider a single hot spot location then this would have to be visited repeatedly, with the same elevated level being experienced by the same bird at each feeding. For GBH and other wading birds there is not same focus on common forage location that there is for wood storks. GBH breeding adults range as much as 30 km from the colony, and typically range 6.5 km (Butler, 1992), areas much

larger than “hot spots.” Other large charismatic species such as Great Egrets (*Ardea alba*) forage primarily on nekton, crustaceans, and other aquatic invertebrates (Kushlan, 2000). The size of other wading birds limits opportunity to feed on larger fish that are of a size and age to have accumulated elevated levels of mercury. The Everglades marsh limits fish foraging to wading birds. The potential of visiting a hot spot is the same as any other single location in the landscape. The above factors combine to limit risks of “hot spots” for non-wood storks. For wood storks, the focus on location is coincident with water level drawdowns concentrating prey fish, and primary fish consumed being smaller fish. The wider area upon which fish population concentration is based during draw downs eliminates point measures of hot spots, as well as increases concentration of small prey items, i.e., more small fish are comprising the diet during drawdowns. Thus, the depressional areas in which wood storks forage later in nesting season represent much larger areas of recruitment of prey items as a consequence of lower water levels concentrating regional prey distributions. Thus, the hot spot phenomena, as a basis of elevated exposure, is also moot for wood storks.

7.3 Demonstration of Protection of Water Quality Standards

The Department of Environmental Protection is charged with developing Total Maximum Daily Loads that demonstrate the expected reductions, when achieved, will result in attainment of its water quality standards. As the DEP currently lacks a mercury in fish tissue criterion, evidence must be provided to show that the fish tissue target established under this TMDL will be protective of the water quality criteria found in Chapter 62-302.530(41), Florida Administrative Code. Using the fish tissue mercury concentration and ambient methylmercury and total mercury concentration data collected from 264 Florida streams and lakes in the period from 2008 through 2010, the Department concluded, based on a Monte Carlo analysis, that, once the 0.3 mg/Kg fish tissue concentration target is achieved, there is a 95 percent probability that the ambient total mercury concentration in freshwater systems in the State of Florida would be lower than the 12 ng/L ambient total mercury criteria for freshwater systems. This demonstrates with a high confidence level that the statewide mercury TMDL will be protective of the ambient water quality criteria. The same mercury load reduction will also be protective of Florida marine waters, which has a total mercury ambient target of 25 ng/L. Detailed descriptions on the analysis can be found in **Appendix M**.

Chapter 8: Determination of the TMDL

8.1 Expression and Allocation of the TMDL

The objective of a TMDL is to provide a basis for allocating acceptable loads among all of the known pollutant sources in a watershed so that appropriate control measures can be implemented and water quality standards achieved. A TMDL is expressed as the sum of all point source loads (wasteload allocations, or WLAs), nonpoint source loads (load allocations, or LAs), and an appropriate margin of safety (MOS), which takes into account any uncertainty concerning the relationship between effluent limitations and water quality:

$$\text{TMDL} = \sum \square \text{WLAs} + \sum \square \text{LAs} + \text{MOS}$$

As discussed earlier, the WLA is broken out into separate subcategories for wastewater discharges and stormwater discharges regulated under the NPDES Program:

$$\text{TMDL} \cong \sum \square \text{WLAs}_{\text{wastewater}} + \sum \square \text{WLAs}_{\text{NPDES Stormwater}} + \sum \square \text{LAs} + \text{MOS}$$

It should be noted that the various components of the revised TMDL equation may not sum up to the value of the TMDL because (a) the WLA for NPDES stormwater is typically based on the percent reduction needed for nonpoint sources and is also accounted for within the LA, and (b) TMDL components can be expressed in different units (for example, the WLA for stormwater is typically expressed as a percent reduction, and the WLA for wastewater is typically expressed as mass per day).

WLAs for stormwater discharges are typically expressed as “percent reduction” because it is very difficult to quantify the loads from MS4s (given the numerous discharge points) and to distinguish loads from MS4s from other nonpoint sources (given the nature of stormwater transport). The sources of mercury in a stormwater collection system are from wet and dry deposition, and atmospheric deposition is considered a component of the nonpoint source load allocation.

This approach is consistent with federal regulations (40 CFR § 130.2(l)), which state that TMDLs can be expressed in terms of mass per time (e.g., pounds per day), toxicity, or other appropriate measure. Florida’s statewide TMDL for mercury is expressed in terms of a percent reduction, and represents the maximum daily load Florida’s lakes, streams, estuaries, and coastal waters can assimilate without exceeding the water quality criteria for mercury (**Table 8.1**).

8.2 Load Allocation

A reduction in mercury of 86 percent is needed from nonpoint sources contributing to all of the fresh and marine waters in Florida to address our water quality limited segments and to protect public health. As this reduction is expressed as a percent, the value is applicable over any time period, and thereby meets EPA’s requirement that TMDLs must be expressed as a “daily” value. It should be noted that the LA includes loading from stormwater discharges regulated by the Department and the water management districts that are not part of the NPDES Stormwater Program (see **Appendix K**). As the predominant nonpoint source of mercury to Florida’s waters arrives via atmospheric deposition, from sources both within and outside of Florida, specific allocations cannot be made at this time. This 86 percent reduction is needed both within and

outside of Florida and does not preclude consideration of reductions already being achieved by Florida sources as identified in Chapter 9. Reductions, as deemed necessary and practicable (recognizing technological, fiscal, and legal constraints) will be assigned during the subsequent TMDL implementation phase, described more completely in Chapter 9.

Table 8.1 TMDL Components for Mercury in Florida's Fresh Water Lakes, Streams, and Estuarine and Coastal Waters

This is a six-column table. Column 1 lists the parameter, Column 2 lists the TMDL, Column 3 lists the WLA for wastewater, Column 4 lists the WLA for NPDES stormwater, Column 5 lists the LA (percent reduction), and Column 6 lists the MOS.

Parameter	TMDL (% reduction)	WLA for Wastewater (Kg/year)	WLA for NPDES Stormwater	LA (% reduction)	MOS
Mercury	86	23 kg*	**	86	Implicit

* Based on all readily available data, the Department estimated the current permitted mercury load being discharged to waters of the state. This value represents less than 0.5 % of the total mercury load from point and nonpoint sources in Florida. Mercury minimization is expected for major facilities.

** NPDES MS4 Permits may require reductions to meet the TMDL goal if sources of mercury under the direct control of a MS4 permittee or co-permittee are found to exist.

8.3 Wasteload Allocation

8.3.1 NPDES Wastewater Discharges

The WLA for the statewide mercury TMDL is established as 23 kg/year. This value translates to 0.063 Kg/day. Consistent with the findings of other approved TMDLs established on a regional, statewide, or multi-state basis, Florida has determined that the mercury contribution from NPDES-permitted point source discharges are minor relative to the loads being deposited on Florida's land and waters (fresh and marine) from atmospheric deposition.

In Florida, the existing point source load for the entire state has been estimated as being approximately 0.5 % of the total mercury loading to the land and waters of the state. According to EPA's *Guidance for Implementing the January 2001 Methylmercury Water Quality Criterion* (EPA, 2010), point source discharges are considered a small contribution if the loading or cumulative loading of all point sources to the receiving water are expected to account for a small or negligible portion of the total mercury loadings. **Table 8.2** provides a summary of the fraction the proposed Wasteload Allocation for NPDES permitted facilities versus the existing total mercury load for Florida and how those values compared to statewide or regional mercury TMDLs approved elsewhere in the United States. The Department anticipates that the significant decreases in mercury loading to Florida's waters have been and will continue to be associated with reductions in atmospheric emissions from anthropogenic sources within and outside of Florida.

Table 8.2 TMDL Comparison of Wasteload Allocations for Mercury as a Percentage of Total Mercury Load for Florida and Other State or Regional TMDLs

State or Region	Total Mercury Load	Wasteload Allocation	WLA/Total Load (%)
Minnesota	2781 Kg/yr	11 Kg/yr	0.40
Northeastern States	6,651 Kg/yr	38 Kg/yr	0.57
New Jersey	601 Kg/yr	6.8 Kg/yr	1.13
Florida	4,793 Kg/yr	23 Kg/yr	0.48

Once this TMDL is in effect, any new requirements will generally be evaluated and addressed in the renewal of existing NPDES permits for point sources, if not earlier through a reopen clause. The need for compliance schedules to meet the TMDL requirements may be established in a BMAP and/or in NPDES permits or an associated Administrative Order. In cases where there are sufficient data to determine whether the NPDES discharger has quantifiable concentrations of mercury, NPDES permits except domestic facilities discharging less than 1 MGD will include a set of additional conditions for implementation of a mercury minimization program to ensure that point sources are discharging the minimum amount of mercury practicable. For domestic facilities with quantifiable concentrations of mercury and discharging greater than 1 MGD, a mercury minimization plan shall include annually the identification of dental operations, hospitals and educational facilities (i.e., Universities and K-12 schools) within their service area; the production or adoption of best management practices (BMPs) for the appropriate industries as applicable; and promulgation of the BMP program. This option will meet the applicable federal regulatory guidance and requirements (EPA, 2010).

All of the NPDES-permitted domestic wastewater facilities were assessed using data available the WAQR database (as of July 2012) and the combined permitted flows were calculated. The result of combining the permitted flows from domestic facilities (1353 MGD) with those for the industrial facilities (785 MGD) yielded a total of 2138 MGD. In addition, the permitted industrial wastewater flows were also calculated, but with two caveats. First, not all of the industrial facilities have permit limits for flow. Second, for power plants that use once-through cooling water, those volumes were calculated separately from the total for other industrial sources. It is also presumed that "Intake Credits" can be provided for any mercury that is passing through the facility via once-through cooling water. However, other waste streams (e.g., discharges from coal ash storage facilities or ponds) are not excluded from subsequent investigations, whose findings may be addressed in mercury minimization plans.

8.3.2 NPDES Stormwater Discharges

The WLA for stormwater discharges with an MS4 permit has been determined to be generally not applicable. Any MS4 permittee is only responsible for reducing the anthropogenic loads associated with stormwater outfalls that it owns or otherwise has responsible control over, and it is not responsible for reducing other nonpoint source loads in its jurisdiction. Therefore, as the mercury levels that may be present in stormwater are a result of nonpoint sources linked to atmospheric deposition, no reductions are required of the MS4 permittees in Florida. However, if through the course of monitoring or in light of other information becoming available, local

sources of mercury under the control of the MS4 permittee or a co-permittee are found to exist, the permit holder will be subject to implementing necessary controls to reduce mercury loads associated with those local sources, so as to meet the requirement of this TMDL.

8.4 Margin of Safety

There are multiple lines of evidence to support the use of an implicit margin of safety in this TMDL. Consistent with the recommendations of the Allocation Technical Advisory Committee (Department, 2001), an implicit MOS was used in the development of this TMDL. Included in this implicit MOS is the assumption that all of the mercury in fish tissue is in the form of MeHg (the harmful fraction) and it is not. As discussed in Section 2.2, the application of a multifold increase in setting of the reference dose for MeHg is another significant component of the Margin of Safety (MOS). As noted previously, compared to other fish species, Largemouth Bass have higher overall tissue MeHg concentration because their position in the food chain dictates a longer food chain length for bioaccumulation. Use of Largemouth Bass for the TMDL target development provides another margin of safety to the TMDL as all other fish living at lower trophic levels will also benefit.

Chapter 9: Ongoing Activities and Implementation

Plan Development

9.1 Implementation Plan Development

Following the adoption of this TMDL by rule and adoption or approval by EPA, the Department will determine the best course of action regarding its implementation. The TMDL alone does not create new legal authorities and the LA and WLA discussed herein are enforceable to the extent independent legal authorities exist under state law. In general and depending on the pollutant(s) causing the waterbody impairment and the significance of the waterbody, the Department will select the best course of action leading to the development of a plan to restore the waterbody. Agency actions to implement this TMDL are subject to Section 403.067, Florida Statutes as well as the notice and hearing processes of Chapter 120 of the Florida Statutes. Implementation can be accomplished cooperatively with stakeholders by creating a Basin Management Action Plan, referred to as the BMAP. BMAPs are one mechanism through which TMDLs are implemented in Florida (see Subsection 403.067[7], F.S.).

If the Department determines that a BMAP is needed to support the implementation of this TMDL, a BMAP will be developed through a transparent, stakeholder-driven process intended to result in a plan that is cost-effective and technically feasible, and that meets the restoration needs of the applicable waterbodies. Once adopted by order of the Department Secretary, BMAPs are enforceable through wastewater and municipal stormwater permits for point sources and through BMP implementation for nonpoint sources.

However, in some basins and for some parameters the development of a BMAP is not the most efficient way to restore a waterbody such that it meets its designated uses. This is because some impairments result from the cumulative effects of a multitude of potential sources, both natural and anthropogenic. The Department can rely on existing permitting programs, local or industry initiatives, or a combination of both as a more cost-effective and simplified approach to identify the actions needed for restoration activities, while still meeting the requirements of Subsection 403.067(7), F.S.

9.2 Ongoing Mercury Reduction Activities in Florida

An important element of implementation planning is consideration of mercury reductions already in place or in progress as well as the cost effectiveness of minimization efforts. Global anthropogenic emissions of mercury are the source of the vast majority of mercury deposition in Florida. Thus, Florida's achievement of the TMDL is dependent upon not only out-of-state but out-of-country mercury emission reductions. Florida sources are, however, implementing mercury reduction efforts that must be taken into account. On the point source side, many NPDES Industrial and Domestic Permitted Sources are already regulated for mercury and it is anticipated EPA will be revising its effluent limitation guidelines to further limit discharges of metals from some source categories. On the non-point source side, as discussed previously, there has been a significant reduction in air emissions of mercury from Florida facilities. In

addition, there are also numerous, ongoing waste reduction efforts being implemented to reduce mercury from Florida's waste stream.

Mercury Waste Reduction Strategies in Florida

Florida is a recognized leader among states in managing mercury waste and reducing its use in products. Florida's statutes and rules governing mercury predate federal regulations and helped drive national policy.

DEP Waste Management Program involvement is characterized with the following activities which are also described with more detail below. The list starts with programs currently having the most potential or actual impact on reducing mercury in Florida's environment.

- Reducing mercury from batteries through legislation
 - Promoting recycling of mercury containing lamps and devices through regulation and education
 - Helping operators safely use drum top crushers according to regulation for volume reduction of spent fluorescent lamps
 - Recycling mercury from homeowners and Conditionally Exempt Small Quantity Generators through Florida's Household Hazardous Waste program
 - Providing a convenient mercury recycling agreement for state and municipal agencies
 - Innovatively reducing mercury use in hospitals,
 - Providing mercury thermometer exchange programs,
 - Adopting the Thermostat Recycling Corporation (TRC) program and leading in the nation in recycling mercury thermostats,
 - Participating in the national End of Life Vehicle Solutions (ELVS) program for auto mercury
 - Creating a mercury amalgam management BMP brochure,
 - Requiring recycling of mercury-containing lamps and devices in the Green Lodging program,
 - Requiring recycling of bilge pump switches in the Clean Marina program,
 - Recommending removal of mercury-containing lamps and devices from buildings prior to demolition,
 - Developing beneficial reuse of fluorescent lamp glass generated through recycling
 - Providing data on metal loading in ash and leachate from ash disposal
- Federal legislation has also helped reduce mercury waste in Florida. Florida has adopted the Universal Waste Rule to help manage waste mercury and ensure its proper recycling. The federal ban on sale of mercury fever thermometers has helped eliminate one of the largest sources of mercury in the home.

Regulations and Statutes

Chapter 62-737, Florida Administrative Code, titled “The Management of Spent Mercury-Containing Lamps and Devices Destined for Recycling” details requirements for recycling and has contributed to better management of mercury waste in Florida. Statutory authority for the environmentally sound management of mercury-containing lamps and devices, elimination of mercury in packaging, and elimination of mercury from batteries sold in Florida (Sections 403.7186, 403.7191, and 403.7192, Florida Statutes, respectively) have been important components of proper mercury waste management in Florida. Rules and Statutes pertaining to mercury can be found at: <http://www.dep.state.fl.us/waste/categories/mercury/pages/laws.htm>. Regulations from other states have also helped mercury waste management in Florida. An example is the strict labeling regulations adopted in some New England states. Product manufacturers have used labeling on products sold nation-wide as a result which helps show Florida consumers what products contain mercury and should be recycled.

Reduction of Mercury from Batteries

Legislation [403.7192, Florida Statutes] sets limitations on the mercury content of alkaline-manganese/zinc-carbon batteries and button batteries; prohibits sale of button-shaped batteries with a mercury electrode; and establishes a disposal ban and take back requirements for other batteries with a mercury electrode. This has resulted in a reduction of mercury in municipal solid waste and a concomitant reduction in mercury content in sentinel species, primarily freshwater fish and wading birds.

Mercury-Containing Lamps Recycling

No report on mercury management in Florida would be complete without discussing how lamps are recycled. Florida currently has one permitted mercury reclamation/recovery facility, one permitted mercury recovery facility, and a third mercury recovery facility in the permitting process. This means we have the ability to recycle our mercury in-state and keep recycling costs lower for our regulated community. Handler/transporter businesses register with the Department to provide more transparency in their operations.

Drum Top Crushers for Fluorescent Lamps

Another aspect of lamp recycling in Florida is the use of drum top crushers (DTC) for fluorescent lamps. These devices can be used for recycling a generator’s lamps on site. The ease of operation and convenience make them a popular method of lamp management in Florida, and facilities with storage issues find them particularly appealing. A 2010 interpretation of 62-737.400(6)(b), F.A.C., resulted in an additional use memo that allows a DTC to be put on a truck and taken to the generator’s site. At least one company is using this to recycle the copious numbers of lamps generated at tanning salons, a class of generators that have historically not recycled their lamps. The memo and other information about drum top crushers is here: <http://www.dep.state.fl.us/waste/categories/mercury/pages/drum-top.htm>

Household Hazardous Waste Program

The Department’s strong state-wide Household Hazardous Waste program has been an important contributor to the recycling of mercury statewide. Thermometers, fluorescent lamps, thermostats, other mercury containing devices and even bottles of elemental mercury have been properly recycled and kept out of the waste stream. The HHW web pages are here: <http://www.dep.state.fl.us/waste/categories/hazardous/pages/household.htm>.

Recycling Agreement for State and Municipal Government Entities

The Florida Department of Management Services has provided a State Purchasing Agreement for municipal and state government facilities to recycle their mercury-containing lamps and devices at a competitive price. The State Purchasing Agreement that is renewed annually can be viewed here: <http://www.dep.state.fl.us/waste/categories/mercury/pages/contract.htm>.

Hospital Mercury Reduction Program

Starting in 1998, various hospitals were visited and received recycling information and, more importantly, information on alternatives to mercury-containing devices. Presentations at conferences for hospital waste management personnel also helped disseminate this information. Hospitals learned how to store and recycle their mercury-containing lamps and devices. Perhaps the most important component was a strong push to eliminate the use of mercury sphygmomanometers. Working with the national programs Hospitals for a Healthy Environment and Healthcare Without Harm brought additional resources to Florida's hospitals. The Department also worked with Florida's Department of Health to write a letter banning the use of mercury sphygmomanometers in Florida's health clinics, resulting in the recycling of these devices as they have been replaced with mercury-free alternatives. Two reports on the medical program can be found here:

http://www.dep.state.fl.us/waste/categories/mercury/pages/medical_facilities.htm.

Staff continues to work with Hospitals for a Healthy Environment as a reviewer and judge for their "Making Medicine Mercury Free" annual national awards program.

Thermometer Exchange Programs

The Department's Pollution Prevention efforts helped develop more mercury awareness by holding and participating in mercury thermometer exchange programs in various parts of the state and also through programs during Earth Day celebrations. These collection programs were an important step that preceded the federal ban on sale of mercury fever thermometers for home use.

Thermostat Recycling Corporation Participation in Florida

Thermostat Recycling Corporation is a national product stewardship program. Member heating, ventilation and air conditioning (HVAC) contractors and wholesalers can use the program to send mercury thermostats for recycling at no cost. Since its inception, Florida has led the country in number of participating wholesalers and in thermostats recycled. Recently many of our Household Hazardous Waste programs have also become TRC members, broadening the reach of the program. The website for the national program is <http://www.thermostat-recycle.org/pages/the-program>

Automotive Mercury Recycling

A small amount of mercury has historically been used in automobiles. Small ampoules are used in tilt switches in anti-lock brake systems (ABS), trunk lighting systems and sometimes in hood lighting systems. Although they have been engineered out of most vehicles, millions of vehicles are still in operation with these switches intact. As they aged, the majority of them were being sent to scrap yards with the mercury still in the vehicle until a national program was set up in 2000 to capture these small ampoules for recycling. ELVs (End of Life Vehicle Solutions) even provided a bounty for the switches until their funds expired. This program has helped keep tons of elemental mercury out of the waste stream nationwide. Florida has collected at least 318.15 pounds of mercury from over 145,000 switches to date. More information is available at <http://www.elvsolutions.org/>.

Dental Amalgam Management Guidance

In 2000, Florida DEP developed and printed a brochure, “Best Management Practices for Scrap Dental Amalgam.” By partnering with the Florida Department of Health, Florida Department of Transportation and the Occupational Safety and Health Administration (OSHA), the Department ensured that this guidance included proper management solutions that were acceptable by all agencies affected. This guidance includes a recommendation for Florida dentists to install amalgam separators to eliminate the greatest portion of the mercury generated in a dental operatory. The Department maintains its dialogue with the Florida Dental Association to ensure the most up-to-date regulatory information is available to their member dentists. The brochure can be downloaded from here:

http://www.dep.state.fl.us/waste/categories/mercury/pages/medical_facilities.htm.

Green Lodging Program

The Green Lodging program has been instrumental in creating a database of hotels and motels across Florida that have adopted green practices. With several hundred designated facilities to date, this program has helped establish proper recycling programs for mercury-containing lamps and devices. The program website is here: <http://www.dep.state.fl.us/greenlodging/default.htm>

Clean Marina Program

The Clean Marina program includes recycling mercury bilge pump switches in their “Clean Marina Action Plan Guidebook.” Keeping this source of mercury from being dumped in our waterways is important. There are other smaller sources of mercury on boats and at marinas that also require proper management like mercury containing lamps and thermostats. Visit their web site here: <http://www.dep.state.fl.us/cleanmarina/>

Deconstruction and Demolition Guidance

Deconstruction and demolition of existing structures is on-going. A booklet, “Recommended Management Practices for the Removal of Hazardous Materials from Buildings Prior to Demolition” includes information on identifying and properly managing mercury-containing components that should be recycled. See the booklet here:

http://www.dep.state.fl.us/waste/quick_topics/publications/shw/hazardous/fact/c&dwaste.pdf

Beneficial Reuse for Fluorescent Lamp Glass Generated Through Recycling

The Department will start using fluorescent lamp glass (FLG) as a substitute for a percentage of the washed sand aggregate in flowable fill used to remediate contaminated petroleum sites in north Florida. This glass, generated by mercury processors while recycling fluorescent lamps, has traditionally been difficult to recycle and the current disposal method has primarily been as daily cover at landfills. There is a potential demand for 50,000-75,000 tons/year of FLG for this innovative program, exceeding the current estimates of FLG supply in Florida.

Mercury in Waste-to-Energy Plant Ash Database

In Florida, the ash generated from solid waste combustors (Waste to Energy, WTE) that primarily receive and burn solid waste collected from residential, commercial and industrial sources is regulated under 62-701 of the Florida Administrative Code (F.A.C.). Under Chapter 62-701, F.A.C., any WTE ash disposed of in Florida must be placed in disposal units that have either a composite liner or a double liner and the leachate from these lined units must be properly managed. In addition, if not addressed in another Department permit or certification,

WTE facilities must obtain waste processing facility solid waste permits to address management of the incoming solid waste stream and the ash generated by the combustion process. These permits ensure the ash is then properly disposed of or recycled.

Ash residue may only be recycled or disposed of in a landfill. If the ash is recycled, the recycler must demonstrate that processed ash residue or products using ash residue will not endanger human health or the environment. Exposure risks to be considered include, but are not limited to, inhalation, ingestion, skin contact, and migration to soil, surface and ground water. If the ash is disposed of it may only be placed or deposited in a lined landfill with a leachate collection and removal system and liner system that complies with the most protective liner requirements detailed in chapter 62-701, F.A.C.

In order to inform the public and regulated community of the metals loading in ash and leachate from ash disposal, the Department has developed a web-based tool that allows the user to query historical data on the level of metal contamination present in WTE ash for each ash generating facility in Florida. While as of December 8, 2011 this data is no longer required (the ash rule, Chapter 62-702, was repealed), the Department believes the previously compiled data is still representative of WTE ash and leachate in Florida. The results of the historical chemical analysis of ash from WTE facilities located in Florida are presented in the form of automated reports that can be found at the following web address:

http://www.dep.state.fl.us/waste/ash/wte_rptfrm.asp

9.3 Considerations in Wasteload Allocation

Mercury contributions from point sources in Florida are estimated to be 23 kilograms (50.5 pounds) per year. This contribution is insignificant when compared with nonpoint source contributions from the state, nation and around the world. In addition, NPDES Industrial and Domestic permitted sources are already regulated for mercury and it is anticipated EPA will be revising its effluent limitation guidelines to further limit discharges of metals from some source categories. As Florida point sources are such an insignificant portion of Florida's mercury loading when compared with nonpoint sources, it is not appropriate or necessary to assign specific allocations as part of this TMDL. NPDES Sources may be required through their permit to determine if their facility adds to the mercury load or if the presence of mercury is due solely to facility pass-through or because of storm water conveyance. Facilities that do not add to the mercury load will not need to have a permit condition to address mercury in their effluent; whereas facilities that do add to the mercury load may receive an effluent limit and will be required to meet the limit or develop and implement a waste minimization plan if one is not already in place. In light of the foregoing, this TMDL will not require specific allocations or require reductions from point source discharges; however, cost-effective mercury minimization programs will ensure mercury discharges from point sources, in total, will not exceed the WLA.

9.4 Considerations in Load Allocation

As stated previously, global anthropogenic emissions of mercury are the source of the vast majority of mercury deposition in Florida. Florida sources, however, are implementing significant mercury reduction efforts. Mercury emissions in Florida have decreased over the past 20-25 years due to air pollution emission reductions required by the federal Clean Air Act

and Florida's rules implementing the federal Clean Air Act. In light of or anticipation of these rules, many of Florida's industries have installed sophisticated mercury controls resulting in dramatic emission reductions. In 1988, Florida's anthropogenic mercury emissions were approximately 70-75 megagrams (165,300 - 154,300 pounds) and by 1997, these emissions were approximately 14 megagrams (30,800 pounds) per year (see Figure 3.9). Based upon emissions estimates for 2009, Florida's mercury emissions decreased to 3,169 pounds (see Table 3.7). This represents a significant and dramatic reduction in mercury air emissions.

More specifically, the mercury emission reductions in the waste-to-energy and coal-fired electric utility industries have been dramatic over the last two decades. These reductions are discussed in much more detail in Chapter 3 of this document. As indicated in Table 3.4, many of Florida's coal fired electric utilities have installed control equipment that is reducing mercury emissions from this industry. Based upon the progress in reducing mercury emissions from coal-fired electric utilities in Florida and the fact that global anthropogenic emissions of mercury account for the vast majority of mercury deposition in Florida, this TMDL will not require additional reductions of mercury air emissions from existing coal-fired electric utilities in Florida. In addition, the Department will not be opening or revising federal, Clean Air Act permits as part of the Clean Water Act's TMDL program.

The Department notes that implementation of other Clean Air Act programs such as Best Available Retrofit Technology (BART) and Maximum Achievable Control Technology (MACT) for the power industry likely will result in still further reductions in mercury emissions in Florida over the next several years. EPA estimates that its utility MACT rule, which became effective in April 2012, will result in approximately a 90% reduction in mercury emissions from coal-fired electric utilities based on pre-controlled emissions. There are also additional emissions reductions anticipated under EPA's MACT rule for cement plants.

EPA anticipates that by 2013, the cement MACT rule will reduce mercury emissions from the Portland cement industry in the United States by 92% based on projected 2013 emissions. Due to lower mercury-containing raw materials in Florida, it is anticipated that the cement MACT will result in a somewhat lower percent reduction in mercury emissions- closer to 50%. It has been noted that the 50% anticipated reduction is less than the identified 86% target established by the TMDL. While this is true, when the environmental risk is global in nature, it is important to consider possible environmental impacts associated with possible off-shoring of cement production to ensure a positive environmental outcome is achieved.

As recently as 2004, Florida imported approximately 45% of its Portland cement. Because of the high demand during the 2004-2005 timeframe, Florida's cement facilities expanded their production capacities and added new kilns with best available control technologies for air emissions. With the recent economic downturn resulting in decreased shipping costs, fleet availability and available terminal space, off-shoring of cement production may be a concern.⁷

Studies have been conducted to determine the net environmental costs or benefits if additional regulations in the United States cause a shift in cement production to countries with less restrictive environmental requirements. Several have concluded that the shifting of cement production to less restrictive countries will significantly reduce or eliminate the environmental benefits ascribed to EPA's cement MACT rule and may actually lead to additional mercury

⁷ See http://www.cox.smu.edu/c/document_library/get_file?p_l_id=68463&folderId=229433&name=DLFE-3104.pdf; http://www.cement.org/newsroom/Kings_College/Kings_College_Study.pdf;

emissions globally.⁸ This is due to less-efficient kiln designs and less-restrictive emissions requirements in other countries that may assume any off-shored cement production. Based upon the foregoing and the fact that EPA has established a maximum achievable technology standard for mercury for the cement industry, this TMDL will not require additional reductions of mercury air emissions from existing cement facilities in Florida.

Achievement of this TMDL is dependent upon reduction of global mercury sources. As discussed further in Appendix L, computer modeling estimates of the fractional contributions of Florida sources to Florida's lakes and rivers/streams was generally below 5% with only ~4% of the sites having contributions in excess of 10%. Based upon this effort, it appears that eliminating the fraction of atmospheric Hg loadings to Florida lakes and streams/rivers was predicted to be quite small, with (weighted) reductions averaging about 0.01 and 0.02 mg/kg for large and small lakes, respectively and about 0.01 and 0.02 mg/kg for rivers and streams, respectively.

9.5 Identification of Impaired Waters

Another impact that this TMDL may have is on the Department's Impaired Waters Rule (IWR) listing process. The IWR listing is a continuous process that rotates through the State's 52 hydrologic basins to identify water segments impaired for various pollutants. Mercury fish tissue impairment will continuously be one of the parameters that the IWR listing will cover. After this TMDL becomes effective, if new water segments are listed for mercury fish tissue impairment, the Department will examine possible sources of mercury that may have resulted in the listing. Unless the Department finds that the new listing is caused by conditions that are not covered in this TMDL (e.g. local emission or effluent sources that are not covered by this TMDL), the Department will consider the listing is covered by this TMDL and, therefore, no new TMDL will be developed.

⁸ Id.

References

- Adams, D. H., McMichael Jr., R. H., & Henderson, G. E. (2003). Mercury Levels in Marine And Estuarine Fishes of Florida 1989-2001. *Florida Fish and Wildlife Conservation Commission, 2nd ed*(rev 57), 57pp. (Available at: http://research.myfwc.com/publications/publication_info.asp?id=43959)
- Arizona Department of Environmental Quality. (2010). Lake Mary Regional TMDL For Mercury in Fish Tissue Upper Lake Mary, Lower Lake Mary, Soldiers Lake, Soldiers Annex Lake, and Lower Long Lake, Little Colorado River Watershed, Coconino County, http://www.azdeq.gov/environ/water/assessment/download/Lake_Mary_Region_Draft-6-16-2010.pdf
- Arkansas Water Division - Water Quality Planning Branch, varying years, <<http://www.adeq.state.ar.us/water/tmdl/>>
- Axelrad, D. et al. (2012) Draft South Florida Environmental Report. Florida Department of Environmental Protection.
- Bank, M. S., Loftin, C. S., & Jung, R. E. (2005). Mercury Bioaccumulation in Northern Two-lined Salamanders from Streams in the Northeastern United States. *Ecotoxicology*, 14, 181-191
- Becker, D. S., & Bigham, G. N. (1995). Distribution of mercury in the aquatic food web of Onondaga Lake, New York. *Water, Air, and Soil Pollution*, 80, 563-571
- Benoit, J. M., Gilmour, C. C., Heyes, A., Mason, R. P., & Miller, C. L. (2003). Geochemical and Biological Controls over Methylmercury production and degradation in aquatic ecosystems. From: *Biogeochemistry of Environmentally Important Trace Elements*, 262-297
- Bergan, T., Gallardo, L., & Rodhe, H. (1999). Mercury in the global troposphere: a three-dimensional model study. *Atmospheric Environment*, 33, 1575-1585
- Bergquist, B. A., & Blum, J. D. (2007). Mass-Dependent and -Independent Fractionation of Hg Isotopes by Photoreduction in Aquatic Systems. *Science*, 318(417), 417-420
- Bevelhimer, M.S., Beauchamp, J.J. Sample, B.E. and Southworth G.R. (1997) Estimation of Whole Fish Contaminant Concentration from Fish Fillet Data. US Department of Energy
- Bigler, W.J., Ware, F., Savage, T., King, S., & Hartwig, C.. (1985). Heavy Metals in Fish and Clams from the Chipola and Santa Fe Rivers of North Florida. *Florida Academy of Science*
- Biswas, A., Blum, J. D., Bergquist, B. A., Keeler, G. J., & Xie, Z. (2008). Natural mercury isotope variation in coal deposits and organic soils. *Environmental Science & Technology*, 42(22), 8303-8309.
- Bloom, N. S. (1992). On the Chemical Form of Mercury in edible fish and marine invertebrate tissue. *Canadian Journal of Fisheries and Aquatic Sciences*, 49, 1010-1017.
- Blum, J. D., & Berquist, B. A. (2007). Reporting of variations in the natural isotopic composition of mercury. *Journal of Analytical and Bioanalytical Chemistry*, 388, 353-359.
- Brandon, A., Cunningham, M., & Onorato, D. (2009). Spatial and Temporal Patterns in Mercury Concentrations in Blood and Hair of Florida Panthers (*Puma concolor coryi*): 1978-2008. *SETAC North America 30th Annual Meeting, Abstract*, 304
- Bullock Jr., O. R., & Brehme, K. A. (2002). Atmospheric mercury simulation using the CMAQ model: formulation description and analysis of wet deposition results. *Atmospheric Environment*, 36, 2135-2146
- Butler, R.W. 1992. Great Blue Heron (*Ardea herodias*). p. 1-19. In A. Poole, P. Stettenheim and F. Gill (ed.) *The Birds of North America*, No. 25. The Birds of North America, Inc., Philadelphia, PA, USA.

- Chasar, L. C., Scudder, B. C., Stewart, A. R., Bell, A. H., & Aiken, G. R. (2009). Mercury Cycling in Stream Ecosystems. 3. Trophic Dynamics and Methylmercury Bioaccumulation. *Environmental Science & Technology*, 43(8), 2733-2739
- Corrales, J., Naja, G. M., Dziuba, C., Rivero, R. G., & Orem, W. H. (2011). Sulfate threshold target to control methylmercury levels in wetland ecosystems. *The Science of the Total Environment*, 409, 2156-2162
- Degner, R. L., Adams, C. M., Moss, S. D., & Mack, S. K. (1994). Per Capita Fish and Shellfish Consumption in Florida. *Florida Dept of Environmental Protection, Contract WM-475*, 1-110 (available at: <http://www.fred.ifas.ufl.edu/agmarketing/pubs/1990s/Fish%20&%20shellfish%20consumption.pdf>)
- Delany, M. F., Bell, J. U., & Sundlof, S. F. (1988). Concentrations of contaminants in the muscle of the American Alligator in Florida. *Wildlife Diseases*, 24(1), 62-66
- Dennis, I. F., Clair, T. A., Driscoll, C. T., Kamman, N. C., Chalmers, A. T., Shanley, J., Norton, S. A., et al. (2005). Distribution Patterns of Mercury in Lakes and Rivers of Northeastern North America. *Ecotoxicology*, 14, 113-123
- Driscoll, C. T., Han, Y. J., Chen, C. Y., Evers, D. C., Lambert, K. F., Holsen, T. M., Kamman, N. C., et al. (2007). Mercury Contamination in Forest and Freshwater Ecosystems in the Northeastern United States. *Bioscience*, 57(1), 17-28
- Duncan B. N., Martin, R.V., Staudt, A., Yevich, R., and Logan, J.A. (2003), Interannual and seasonal variability of biomass burning emission constrained by satellite observations, *Journal of Geophysical Research Atmospheres*, 108, 4040,
- Dvonch, J. T., Graney, J. R., Keeler, G. J., & Stevens, R. K. (1999). Use of Elemental Tracers to Source Apportion Mercury in South Florida Precipitation. *Environmental Science & Technology*, 33, 4522-4527
- Dvonch, J. T., Graney, J. R., Marsik, F. J., Keeler, G. J., & Stevens, R. K. (1998). An investigation of source-receptor relationships for mercury in south Florida using event precipitation data. *The Science of the Total Environment*, 213, 95-108.
- Dvonch, J. T., Keeler, G. J., & Marsik, F. J. (2005). The Influence of Meteorological Conditions on the Wet Deposition of Mercury in Southern Florida. *Applied Meteorology*, 44, 1421-1435
- Evers, D. C., Burgess, N. M., Champoux, L., Hoskins, B., Major, A., Goodale, W. M., Taylor, R. J., et al. (2005). Patterns and Interpretation of Mercury Exposure in Freshwater Avian Communities in Northeastern North America. *Ecotoxicology*, 14, 193-221
- Evers, D. C., Han, Y. J., Driscoll, C. T., Kamman, N. C., Goodale, M. W., Lambert, K. F., Holsen, T. M., et al. (2007). Biological Mercury Hotspots in the Northeastern United States and Southeastern Canada. *Bioscience*, 57(1), 29-43
- Evers, D. C., Jackson, A. K., Tear, T. H., & Osborne, C. E. (2012). Hidden Risk: Mercury in Terrestrial Ecosystems of the Northeast. *Biodiversity Research Institute, BRI Report*, 1-33
- Facemire, C. F., Gross, T. S., & Guillette, L. J. (1995). Reproductive Impairment in the Florida Panther: Nature or Nurture? *Environmental Health Perspectives*, 103(4), 79-86.
- Farmer, T. M., Wright, R. A., & DeVries, D. R. (2010). Mercury Concentration in Two Estuarine Fish Populations across a Seasonal Salinity Gradient. *Transaction of the American Fisheries Society*, 139, 1896-1912.
- FDA Food and Drug Administration, (2011) Mercury Levels in Commercial Fish and Shellfish 1990-2010. <http://www.fda.gov/food/foodsafety/product-specificinformation/seafood/foodbornepathogenscontaminants/methylmercury/ucm115644.htm>

- Fish and Wildlife Research Institute (FWRI), Florida Fish and Wildlife Conservation Commission (FWC),
<http://myfwc.com/research/>
- Fish base, <<http://www.fishbase.org>>
- Florida Department of Environmental Protection. (2001). TMDL Allocation Technical Advisory Committee (ATAC) (available at: <http://www.dep.state.fl.us/water/tmdl/background.htm#atac>)
- Florida Department of Health. (2011) Fish Consumption Advisories.
<http://www.doh.state.fl.us/floridafishadvice/2011%20Advisories.pdf>
- Florida Fish and Wildlife Conservation Commission. (2010). Annual Report on the Research and Management of Florida Panthers: 2009-2010. *Fish and Wildlife Research Institute & Division of Habitat and Species Conservation, Naples, Florida, USA*, 2009-2010. (available at: http://www.floridapanthernet.org/images/field_notes/FWC_Panther_Annual_Report_2009_2010.pdf)
- Frederick, P. C. (2000). Mercury contamination and its effects in the Everglades ecosystem. *Reviews in Toxicology*, 3, 213-255
- Frederick, P. C., & Jayasena, N. (2010). Altered pairing behaviour and reproductive success in white ibises exposed to environmentally relevant concentrations of methylmercury. *Proceedings of the Royal Society*, 1-7
- Frederick, P. C., Hylton, B., Heath, J. A., & Spalding, M. G. (2004). A historical record of mercury contamination in Southern Florida (USA) as inferred from avian feather tissue. *Environmental Toxicology and Chemistry*, 23(6), 1474-1478
- Furl, C. V., & Meredith, C. A. (2011). Mercury Accumulation in Sediment Cores from Three Washington State Lakes: Evidence for Local Deposition from a Coal-Fired Power Plant. *Environmental Contamination and Toxicology*, 60, 26–33.
- FTN Associates, Ltd. (2002). TMDLs for Segments Listed for Mercury in Fish Tissue for the Ouachita River Basin, and Bayou Bartholomew, Arkansas and Louisiana to Columbia. Prepared for USEPA Region VI, Dallas, TX. Approved December 18, 2002. (available at: http://www.epa.gov/waters/tmdldocs/ouarbbartg_f.pdf)
- FTN Associates, Ltd. (2002). TMDLs for Segments Listed for Mercury in Fish Tissue for Selected Arkansas Watersheds. Prepared for US EPA Region VI, Dallas, TX. Approved December 10, 2002. http://www.epa.gov/waters/tmdldocs/3_hginfish_f.pdf
- Furl, C. V., & Meredith, C. A. (2011). Mercury Accumulation in Sediment Cores from Three Washington State Lakes: Evidence for Local Deposition from a Coal-Fired Power Plant. *Environmental Contamination and Toxicology*, 60, 26-33.
- Galloway, M.E., & Branfireun, B.A. (2004), Mercury dynamics of a temperate forested wetland, *Science of the Total Environment*, 325(1–3), 239-254
- Gordon, G. E. (1988). Receptor models. *Environmental Science & Technology*, 22(10), 1132-42
- Grandjean, P., Satoh, H., Murata, K., & Eto, K. (2010). Adverse Effects of Methyl mercury: Environmental Health Research Implications. *Environmental Health*, 118(8), 1137-1145.
- Granier, C., Guenther, A., Lamarque, J.-F., Mieville, A., Muller, J., Olivier, J., & Orlando, J. J. (2005). POET, a database of surface emissions of ozone precursors, available at: (available at: <http://accent.aero.jussieu.fr/POET.php>)
- Griffith, G. E., Canfield Jr., D. E., Horsburgh, C. A., & Omernik, J. M. (1997). Lake Regions of Florida. *U.S. Environmental Protection Agency*, R-97(127), 1-88 (available at: http://plants.ifas.ufl.edu/education/misc_pdfs/Lake_regions.pdf)
- Grigal, D. F. (2002). Inputs and outputs of mercury from terrestrial watersheds: a review. *Environmental Reviews*, 10, 1-39

- Grigal, D. F. (2003). Mercury Sequestration in Forests and Peatlands: A Review. *Journal of Environmental Quality*, 32, 393-405
- Gustin, M S., (2008) An update on the natural sources and sinks of atmospheric mercury, *Applied Geochemistry*, 23, 482-493
- Gustin, M. S. (2003) Are mercury emissions from geologic sources significant? A status report, *Science of the Total Environment*, 304(1-3), 153-167
- Gustin, M. S., Lindberg M. S., Austin, K., Coolbaugh, M., Vette, A., Zhang, H. (2000), Assessing the contribution of natural sources to regional atmospheric mercury budgets, *Science of the Total Environment*, 259(1-3), 61-71
- Gustin, M. S., Lindberg, S. E., & Weisberg, P. J. (2008). An update on the natural sources and sinks of atmospheric mercury. *Applied Geochemistry*, 23, 482-493
- Hill W. R., Stewart A. J., Napolitano G. E. (1996). Mercury speciation and bioaccumulation in lotic primary producers and primary consumers. *Canadian Journal of Fisheries and Aquatic Sciences*. 53: 812-819.
- Holmes, C. D., Jacob, D. J., Mason, R. P., & Jaffe, D. A. (2009). Sources and deposition of reactive gaseous mercury in the marine atmosphere. *Atmospheric Environment*, 43, 2278-2285.
- Hopke, P. K., Ito, K., Mar, T., Christensen, W. F., Eatough, D. J., Henry, R. C., Kim, E., et al. (2006). PM source apportionment and health effects: 1. Intercomparison of source apportionment results. *Journal of Exposure Science and Environmental Epidemiology*, 16, 275-286.
- Hord, L. J., Jennings, M., & Brunell, A. (1990). Mercury Contamination of Florida Alligators. *Crocodiles: Proceedings of the 10th Working Meeting of the Crocodile Specialist Group, IUCN - The World Conservation Union, Gland Switzerland*, 1, 1-15.
- Hoyer, M. V., Burke, J., & Keeler, G. J. (1995). Atmospheric Sources, Transport and Deposition of Mercury in Michigan: Two Years of Event Precipitation. *Water, Air, and Soil Pollution*, 80, 199-208
- Husar, J. D., & Husar, R. B. (2002). Trends of Anthropogenic Mercury Mass Flows and Emissions in Florida. *FDEP Final Report, PO# S3700 303975*, 1-74.
- Jaeglé, L., Strode, S. A., Selin, N. E., Jacob, D. J. (2009), The Geos-Chem model, *Mercury Fate and Transport in the Global Atmosphere, Chapter 18*, 533-545
- Jung, G., Hedgecock, I. M., & Pirrone, N. (2009). The ECHMERIT Model. *Mercury Fate and Transport in the Global Atmosphere, Chapter 19*, 547-569
- Kamman, N. C., & Engstrom, D. R. (2002). Historical and present fluxes of mercury to Vermont and New Hampshire lakes inferred from 210Pb dated sediment cores. *Atmospheric Environment*, 36, 1599-1609
- Kamman, N. C., Burgess, N. M., Driscoll, C. T., Simonin, H. A., Goodale, W., Linehan, J., Estabrook, R., et al. (2005). Mercury in Freshwater Fish of Northeast North America: A Geographic Perspective Based on Fish Tissue Monitoring Databases. *Ecotoxicology*, 14, 163-180.
- Kamman, N. C., Lorey, P. M., Driscoll, C. T., Estabrook, R., Major, A., Pientka, B., & Glassford, E. (2003). Assessment of mercury in waters, sediments, and biota of New Hampshire and Vermont lakes, USA, sampled using a geographically randomized design. *Environmental Science & Technology*, 23(5), 1172-1186
- Kannan, K., Smith, R. G., Lee, R. F., Windom, H. L., Heitmuller, P. T., Macauley, J. M., & Summers, J. K. (1998). Distribution of Total Mercury and Methyl Mercury in Water, Sediment, and Fish from South Florida Estuaries. *Environmental Science & Technology*, 34, 109-118.
- Karouna-Renier, N. K., Rao, K. R., Lanza, J. J., Rivers, S. D., Wilson, P. A., Hodges, D. K., Levine, K. E., et al. (2008). Mercury levels and fish consumption practices in women of child-bearing age in the Florida Panhandle. *Environmental Research*, 108, 320-326

- Keeler, G. J., Landis, M. S., Norris, G. A., Christianson, E. M., & Dvonch, J. T. (2006). Sources of Mercury Wet Deposition in Eastern Ohio, USA. *Environmental Science & Technology*, 40(19), 5874-5881
- Knightes, C. D., Sunderland, E. M., Barber, M. C., Johnston, J. M., & Ambrose Jr., R. B. (2009). Application of Ecosystem-scale Fate and Bioaccumulation models to predict fish mercury response times to changes in atmospheric deposition. *Environmental Toxicology and Chemistry*, 28(4), 881-893.
- Kushlan, J. A. 2000. Heron feeding habitat conservation. p. 219–235. In J. A. Kushlan and H. Hafner (eds.) *Heron Conservation*. Academic Press, London, UK.
- Lamborg, C. H., Fitzgerald, W. F. (2002). Modern and historic atmospheric mercury fluxes in both hemispheres: global and regional mercury cycling implications, *Global Biogeochemical Cycles*, 16: 1104-1114
- Landis, M. S., & Keeler, G. J. (1997). Critical Evaluation of a Modified Automatic Wet-Only Precipitation Collector for Mercury and Trace Element Determinations. *Environmental Science & Technology*, 31, 2610-2615.
- Landis, M. S., & Keeler, G. J. (2002). Atmospheric Mercury Deposition to Lake Michigan during the Lake Michigan Mass Balance Study. *Environmental Science & Technology*, 36, 4518-4524
- Lange, T. (2006). Trends in Mercury in Everglades Fish. *Report from FFWCC to FDEP*. 11 pp
- Lindberg, S. E., Bullock Jr., O. R., Ebinghaus, R., Engstrom, D. R., Feng, X., Fitzgerald, W. F., Pirrone, N., et al. (2007). A synthesis of progress and uncertainties in attributing the sources of mercury in deposition. *Ambio*, 36(1), 19-33.
- Liu, B., Keeler, G. J., Dvonch, J. T., Barres, J. A., Lynam, M. M., Marsik, F. J., & Morgan, J. T. (2007). Temporal variability of mercury speciation in urban air. *Atmospheric Environment*, 41, 1911-1923.
- Lodenius, M., & Tulisalo, E. (2003). Exchange of mercury between atmosphere and vegetation under contaminated conditions. *The Science of the Total Environment*, 304, 169-174
- Lohman, K., Seigneur, C., Gustin, M. S., & Lindberg, S. E. (2008). Sensitivity of the global atmospheric cycle of mercury to emissions. *Applied Geochemistry*, 23, 454-466.
- Lyman, S. N., Gustin, M. S., Prestbo, E. M., & Marsik, F. J. (2007). Estimation of Dry Deposition of Atmospheric Mercury in Nevada by Direct and Indirect Methods. *Environmental Science & Technology*, 41(6), 1970-1976.
- Lynam, M. M., & Keeler, G. J. (2005). Automated Speciated Mercury Measurements in Michigan. *Environmental Science & Technology*, 39(23), 9253-9262.
- Marsik F. J., Keeler, G. J., Dvonch, J. T., Sillman S., Pollman, C., Pirrone, N., Hedgecock, I., Jung G. & Schürmann, G. (2011) Monthly Inferential Modeled Estimates of Mercury Dry Deposition. *Report to Florida Department of Environmental Protection*. 1-12
- Marsik F. J., Keeler, G. J., Dvonch, J. T., Sillman S., Pollman, C., Pirrone, N., Hedgecock, I., Jung G. & Schürmann, G. (2010) Project Deliverable of Subtask 5.1.1: Global Chemical Modeling, Deliverable #3. *Report to Florida Department of Environmental Protection*. 1-3
- Mason, R. P., & Sheu, G.-R. (2002). Role of the ocean in the global mercury cycle. *Global Biogeochemical Cycles*, 16(4), 14-40.
- Mason, R. P., & Sullivan, K. A. (1997). Mercury in Lake Michigan. *Environmental Science & Technology*, 31(3), 942-947.
- Mason, R. P., Fitzgerald, W. F., & Morel, F. M. M. (1994). The biogeochemical cycling of elemental mercury: Anthropogenic influences. *Geochimica et Cosmochimica Acta*, 58(15), 3191-3198.
- Mason, R. P., Heyes, D., & Sveinsdottir, A. (2006). Methylmercury Concentrations in Fish from Tidal Waters of The Chesapeake Bay. *Environmental Science & Technology*, 51, 425-437

- May K, Stoeppeler, M, & Reisinger, K. (1987). Studies on the ratio total mercury / methylmercury in the aquatic food chain. *Toxicological & Environmental Chemistry*. 13(3-4), 153-159.
- Mergler, D., Anderson, H. A., Chan, L. H. M., Mahaffey, K. R., Murray, M. W., Sakamoto, M., & Stern, A. H. (2007). Methylmercury Exposure and Health Effects in Humans: A Worldwide Concern. *AMBIOS*, 36(1), 3-11.
- Miles, C. J., Moye, H. A., Phlips, E. J. & Sargent, B., (2001), Partitioning of Monomethylmercury between Freshwater Algae and Water. *Environmental Science & Technology*, 35(21), 4277-4282
- Miller, G. E., Grant, P. M., Kishore, R., Steinkruger, F. J., Rowland, F. S., & Guinn, V. P. (1972). Mercury Concentrations in Museum Specimens of Tuna and Swordfish Mercury Concentrations in. *Advancement Of Science*, 175(4026), 1121-1122.
- Minnesota Pollution Control Agency (MPCA), (2007) *Minnesota Statewide Mercury Total Maximum Daily Load*. Prepared by Minnesota Pollution Control Agency. Approved 2007. (available at: <http://www.pca.state.mn.us/index.php/water/water-types-and-programs/minnesotas-impaired-waters-and-tmdls/phosphorus-and-mercury-issues/statewide-mercury-tmdl-pollutant-reduction-plan.html?menuid=&redirect=1>)
- Nair, U., Wu, Y., Walters, J., Jansen, J., & Edgerton, E. S. (2012). Diurnal and seasonal variation of mercury species at coastal-suburban, urban, and rural sites in the southeastern United States. *Atmospheric Environment*, 47, 499-508.
- Nam DH, Yates D, Ardapple P, Evers DC, Schmerfeld J, Basu N. (2012). Elevated mercury exposure and neurochemical alterations in little brown bats (*Myotis lucifugus*) from a site with historical mercury contamination. *Ecotoxicology*, 21(4) 1094-1101
- National Research Council. (2000). Toxicological Effects of Methylmercury. *Committee on the Toxicological Effects of Methylmercury*, 1-364. (available at: <http://www.nap.edu/openbook.php?isbn=0309071402>)
- NEIWPCC, (2007) *Northeast Regional Mercury Total Maximum Daily Load*. Northeast states and the New England Interstate Water Pollution Control Commission (NEIWPCC). 1-113 (available at: <http://www.epa.gov/region1/eco/tmdl/pdfs/ne/tmdl-Hg-approval-doc.pdf>)
- NESCAUM. (2005). Inventory of Anthropogenic Mercury Emissions in the Northeast. *NESCAUM Report*, 1-40. (available at: <http://www.nescaum.org/documents/inventory-of-anthropogenic-mercury-emissions-in-the-northeast/>)
- New Jersey DEP, (2009) Total Maximum Daily Load for Mercury Impairments Based on Concentration in Fish Tissue Caused Mainly by Air Deposition to Address 122 Water Segments (HUC 14s) Statewide. Prepared by New Jersey Department of Environmental Protection. Approved 2009. (available at: http://www.nj.gov/dep/wms/bear/TMDL%20HG%20document%20final%20version%209-09_formated%20for%20web%20posting%20js.pdf)
- Newman, J., Zillioux, E. J., Rich, E., Liang, L., & Newman, C. (2004). Historical and Other Patterns of Monomethyl and Inorganic Mercury in the Florida Panther (*Puma concolor coryi*). *Environmental Contamination and Toxicology*, 48, 75-80.
- Odum, H. T. (1972). An Energy Circuit Language for Ecological and Social Systems: Its Physical Basis. *Systems analysis and simulation in ecology*, 2, 139-211.
- Ogden, J. C., Robertson, W. B., Davis, G. E., and Schmidt, T. W., (1974) Pesticides, polychlorinated biphenyls and heavy metals in upper food chain levels, Everglades National Park and vicinity: U.S. Natl. Park Service PB-231 359
- Osborne, C. E., Evers, D. C., Duron, M., Schoch, N., Yates, D., Buck, D., Lane, O. P., et al. (2011). Mercury Contamination within Terrestrial Ecosystems in New England and Mid-Atlantic States: Profiles of Soil, Invertebrates, Songbirds, and Bats. *Biodiversity Research Institute*, BRI-2011-0, 1-100

- Paatero, P. (1997). Least squares formulation of robust non-negative factor analysis. *Chemometrics and Intelligent Laboratory Systems*, 37, 23-35.
- Pacyna J, Pacyna E, Steenhuisen F, & Wilson S. (2003). Mapping 1995 global anthropogenic emissions of mercury, *Atmospheric Environment*, 37(S1): S- 109-S-117
- Pacyna, E. G., Pacyna, J. M., Steenhuisen, F., & Wilson, S. (2006). Global anthropogenic mercury emission inventory for 2000. *Atmospheric Environment*, 40, 4048-4063.
- Pennuto, C. M., Lane, O. P., Evers, D. C., Taylor, R. J., & Loukmas, J. (2005). Mercury in the Northern Crayfish, *Orconectes virilis* (Hagen), in New England, USA. *Ecotoxicology*, 14, 149-162.
- Pirrone N. , Mason R. P., eds; (2009), Mercury Fate and Transport in the Global Atmosphere (Springer, Dordrecht, The Netherlands)
- Pirrone, N., Allegraini, I., Keeler, G. J., Nriagu, J. O., Rossmann, R, & Robbins, J. A. (1998). Historical atmospheric mercury emissions and depositions in North America compared to mercury accumulations in sedimentary records. *Atmospheric Environment*, 32, 929–940
- Pirrone, N., Cinnirella, S., Feng, X., Finkelman, R. B., Friedli, H. R., Leaner, J. J., Mason, R. P., et al. (2010). Global mercury emissions to the atmosphere from anthropogenic and natural sources. *Atmospheric Chemistry and Physics*, 10, 5951-5964.
- Porcella, D. B., Watras, C. J., & Bloom, N. S., (1992), Mercury species in lake water. In: The deposition and fate of trace metals in our environment, General technical report NC-150. 127-138
- Portier, K. M., Um, Y., Degner, R. L., Mack, S. K., & Adams, C. M. (1995). Statistical Analysis of Florida Per Capita Fish and Shellfish Consumption Data. *Florida Agricultural Market Research Center, IR* 95-1, 1-185 (available at: <http://www.fred.ifas.ufl.edu/agmarketing/pubs/1990s/Fish%20&%20Shellfish%20statistical%20analysis.pdf>)
- Porvari, P., Verta, M., Munthe, J., & Haapanen, M., (2003). Forestry practices increase mercury and methylmercury output from boreal forest catchments. *Environmental Science and Technology* 37, 2389-2393
- Rea, A. W., Lindberg, S. E., Scherbatskoy, T., & Keeler, G. J. (2002). Mercury accumulation in foliage over time in two northern mixed-hardwood forests. *Water, Air, and Soil Pollution*, 133, 49-67.
- Riva-Murray, K., Chasar, L. C., Bradley, P. M., Burns, D. A., Brigham, M. E., Smith, M. J., & Abrahamsen, T. A. (2011). Spatial patterns of mercury in macroinvertebrates and fishes from streams of two contrasting forested landscapes in the eastern United States. *Ecotoxicology*, 20, 1530-1542.
- Roeckner, E., Arpe, K., Bengtsson, L., Christoph, M., Claussen, M., Dümenil, L., Esch, M., Giorgetta, M., Schlese, U., & Schulzweida, U., (1996) The atmospheric general circulation model ECHAM4: Model description and simulation of present-day climate. Max Planck Institut für Meteorologie, Report No. 218, Hamburg, Germany, 90 pp.
- Roelke, M.E., Schultz, D.P., Facemire, C.F., Sundlof, S.F. & Royals, H.E. (1991). Mercury Contamination in Florida Panthers. Prepared by the Technical Subcommittee of the Florida Panther Interagency Committee.
- Roman, H. A., Walsh, T. L., Dewailly, E., Guallar, E., Hattis, D., Marien, K., Schwartz, J., et al. (2011). Evaluation of the Cardiovascular Effects of Methylmercury Exposures: Current Evidence Supports Development of a Dose-Response Function for Regulatory Benefits Analysis. *Environmental Health Perspectives*, 119(5), 607-614.
- Rumbold, D. G., Lange, T. R., Axelrad, D. M., & Atkeson, T. D. (2008). Ecological risk of methylmercury in Everglades National Park, Florida, USA. *Ecotoxicology*, 17, 632-641.
- Scheuhammer, A. M., Meyer, M. L., Sandheinrich, M. B., & Murray, M. W. (2007). Effects of Environmental Methylmercury on the Health of Wild Birds. Mammals. and Fish. *Ambio*, 36(1), 12-18

- Schwersig D, Ilgen G, & Matzner E. (1999). Mercury and methylmercury in upland and wetland acid forest soils of a watershed in NE-Bavaria, Germany. *Water, Air, and Soil Pollution*, 113, 141-154
- Selin, N. E. (2009). Global Biogeochemical Cycling of Mercury: A Review. *Annual Review of Environment and Resources*, 34, 43-63.
- Selin, N. E., Jacob, D. J., Park, R. J., Yantosca, R. M., Strode, S. A., Jaegle, L., & Jaffe, D. A. (2007). Chemical Cycling and deposition of atmospheric mercury: Global constraints from observations. *Journal of Geophysical Research*, 112(D02308), 1-14
- Selin, N. E., Jacob, D. J., Yantosca, R. M., Strode, S. A., Jaegle, L., & Sunderland, E. M. (2008). Global 3-D land-ocean-atmosphere model for mercury: Present-day versus preindustrial cycles and anthropogenic enrichment factors for deposition. *Global Biogeochemical Cycles*, 22, 1-13.
- Selvendiran, P., Driscoll, C. T., Bushey, J. T., & Montesdeoca, M. R. (2008). Wetland influence on mercury fate and transport in a temperate forested watershed. *Environmental Pollution*, 154, 46-55
- Sherman, L. S., Blum, J. D., Keeler, G. J., Demers, J. D., & Dvonch, J. T. (2012). Investigation of Local Mercury Deposition from a Coal-Fired Power Plant Using Mercury Isotopes. *Environmental Science & Technology*, 46(1), 382-390.
- Sillman, S., Marsik, F. J., Al-Wali, K. I., Keeler, G. J., & Landis, M. S. (2007). Reactive mercury in the troposphere: Model formation and results for Florida, the northeastern United States, and the Atlantic Ocean. *Journal of Geophysical Research*, 112(D23), D23305
- Skamarock, W. C., & Klemp, J. B. (2008). A time-split nonhydrostatic atmospheric model for weather research and forecasting applications. *Journal of Computational Physics*, 227, 3465-3485.
- Sorensen, J. A., Kallemeijn, L. W., & Sydor, M., (2005). Relationship between mercury accumulation in young-of-the-year yellow perch and water-level fluctuations. *Environmental Science and Technology*, 39, 9237-9243.
- St. Louis, V. L., Rudd, J. W. M., Kelly, C. A., Beaty, K. G., & Bloom, N. S. (1994). Importance of Wetlands as Sources of Methylmercury to Boreal Forest Ecosystems. *Canadian Journal of fisheries and aquatic sciences*, 51(5), 1065-1076.
- State of Oregon, (2006). Willamette Basins TMDL Report, Chapter 3 Willamette Basin Mercury TMDL, (available at: <http://www.deq.state.or.us/wq/tmdls/willamette.htm>)
- Stern, A. H. (2005). A review of the studies of the cardiovascular health effects of methylmercury with consideration of their suitability for risk assessment. *Environmental Research*, 98, 133-142.
- Strode, S. A., Jaegle, L., Selin, N. E., Jacob, D. J., Park, R. J., Yantosca, R. M., Mason, R. P., et al. (2007). Air-sea exchange in the global mercury cycle. *Global Biogeochemical Cycles*, 21(GB107), 1-12.
- Sunderland, E. M., Kriens, D., & Von Stackelberg, K., (2012), Pilot Analysis of Gulf of Mexico State Residents' Methylmercury Exposures from Commercial and Locally Caught Fish, *Report to: Florida Department of Environmental Protection*. 1-39.
- Sveinsdottir, A. Y., & Mason, R. P. (2005). Factors Controlling Mercury and Methylmercury Concentrations in Largemouth Bass (*Micropterus salmoides*) and Other Fish from Maryland Reservoirs. *Environ Sci Technol*, 49, 528-545.
- Tremblay, A, Lucotte, M., & Rheault I., (1996), Methylmercury in a benthic food web of two hydroelectric reservoirs and a natural lake of northern Quebec (Canada), *Water, Air, and Soil Pollution* 91, 255-269
- Tremblay, A., & Lucotte, M. (1997), Accumulation of total mercury and methyl mercury in insect larvae of hydroelectric reservoirs, *Canadian Journal of Fisheries and Aquatic Sciences*, 54, 832-841.

- U.S. Environmental Protection Agency. (2007). EPA Unmix 6.0 Fundamentals & User Guide. *U.S. Environmental Protection Agency, EPA/600/R-07/089*, 1-97 (available at: <http://www.epa.gov/heasd/products/unmix/unmix-6-user-manual.pdf>)
- Ugarte, C. A., Rice, K. G., & Donnelly, M. A. (2005). Variation of total mercury concentrations in pig frogs (*Rana grylio*) across the Florida Everglades , USA. *The Science of the Total Environment*, 345, 51 - 59.
- United Nations Environment Programme (UNEP). (2008). The Global Atmospheric Mercury Assessment: Sources, Emissions and Transport (PDF), Geneva (available at: http://www.chem.unep.ch/mercury/Atmospheric_Emissions/UNEP%20SUMMARY%20REPORT%20-%20CORRECTED%20May09%20%20final%20for%20WEB%202008.pdf)
- US Environmental Protection Agency & State of Louisiana. (2001). Mercury TMDLs for Subsegments within Mermentau and Vermillion-Teche River Basins, (available at: <http://www.epa.gov/waters/tmdldocs/ACF11AE.pdf>)
- US Environmental Protection Agency (2001). Fish tissue criterion for methylmercury to protect human health document, EPA-823-R-01-001, Office of Water, Washington, DC. (available at: <http://www.epa.gov/waterscience/criteria/methylmercury/document.html>)
- US Environmental Protection Agency (2005). 2005 National Emissions Inventory Data & Documentation. (available at: <http://www.epa.gov/ttnchie1/net/2005inventory.html>)
- US Environmental Protection Agency (2008) TMDLs Where Mercury Loadings Are Predominantly From Air Deposition; http://water.epa.gov/lawsregs/lawsguidance/cwa/tmdl/mercury/upload/2008_10_01_tmdl_pdf_document_mercury_tmdl_elements.pdf
- US Environmental Protection Agency. (1997), Panel: Firestone, Michael; Barry, Timothy; Bennett, David; Chang, Steven; Callahan, Michael; Barnes, Donald; Wood,.; Knott William P.; Steven M. EPA Technical Panel, Guiding Principles for Monte Carlo Analysis; Risk Assessment Forum, U.S. Environmental Protection Agency
- US Environmental Protection Agency. (1999). Control of Mercury Emissions from Coal-Fired Utility Boilers. *U.S. Environmental Protection Agency*, 1-15. (available at: <http://www.epa.gov/ttn/atw/utility/hgwhitepaperfinal.pdf>)
- US Environmental Protection Agency. (2007) EPA Positive Matrix Factorization (PMF) 3.0 Fundamentals & User Guide. ORD contract 68-W-04-005. http://www.epa.gov/heasd/products/pmf/EPA%20PMF%203.0%20User%20Guide%20v16_092208_final.pdf
- US Environmental Protection Agency. 1997. Mercury Study Report to Congress, vols. 1-8. Washington (DC): Office of Air Quality Planning and Standards and Office of Research and Development. Report no. EPA-4521R-97-005. (available at: <http://www.epa.gov/hg/report.htm>)
- Varekamp, J. C., & Buseck, P. R. (1986). Global mercury flux from volcanic and geothermal sources. *Applied Geochemistry*, 1(1), 65-73
- Vo, A.-T. E., Bank, M. S., Shine, J. P., & Edwards, S. V. (2011). Temporal increase in organic mercury in an endangered pelagic seabird assessed by century-old museum specimens. *Proceedings of the National Academy of Sciences*, 108(18), 7466-7471 (available at: <http://www.pnas.org/content/108/18/7466.full>)
- Ward, D. M., Nislow, K. H., & Folt, C. L. (2010). Bioaccumulation syndrome: identifying factors that make some stream food webs prone to elevated mercury bioaccumulation. *Annals of the New York Academy of Sciences*, 1195, 62-83.
- Watras CJ, & Bloom NS. (1992). Mercury and methylmercury in individual zooplankton: implication for bioaccumulation. *Limnology and Oceanography*, 31, 1313-18

- Wesely, M. L., & Hicks, B. B. (1977). Some Factors that Affect the Deposition Rates of Sulfur Dioxide and Similar Gases on Vegetation. *Journal of the Air Pollution Control Association*, 27(11), 1110-1116
- Wolfe, M. F., Schwarzbach, S. E., & Sulaiman, R. A. (1998). Effects of Mercury on Wildlife: A Comprehensive Review. *Environmental Toxicology and Chemistry*, 17(2), 146-160
- Xu, X., Yang, X., Miller, D. R., Helble, J. J., & Carley, R. J., (1999), Formulation of bi-directional air-surface exchange of elemental mercury, *Atmospheric Environment*, 33(27) 4345-4355

FLORIDA DEPARTMENT OF ENVIRONMENTAL PROTECTION

Division of Environmental Assessment and Restoration
Bureau of Watershed Restoration

Mercury TMDL for the State of Florida

Appendix A:

Complete USEPA's 1998 303(d) Consent Decree List for Florida Waterbodies (freshwater and marine) Requiring Mercury TMDLs.

Watershed Evaluation and TMDL Section



May 22, 2012

Appendices

Appendix A: Complete USEPA's 1998 303(d) Consent Decree List for Florida Waterbodies (freshwater and marine) Requiring Mercury TMDLs. Waterbodies are presented in ascending order by group name.

*Note: The initial list used data from stations listed in the Department's 1996 305(b) report. The report used best available information at the time to generally characterize the quality of Florida's waters. Some of the delineations of waterbody areas and locations of sampling stations for the 1998 303(d) list were inaccurate due to metadata limitations at that time. With the primary goal of providing more accurate assessments, the Department has revised the delineations over time. EPA has labeled the redrawing of WBID boundaries "resegmentation," as the original stations corresponded to specific WBID areas or segments. Resegmented WBIDs are those WBIDs that have been altered from the initial 1998 303(d) Consent Decree or previous cycle boundaries. As a result of the resegmentation process for the different group basins, WBIDs may have been changed.

Group Name	Basin Rotation Group	WBID*	Marine Waterbodies		Waterbody Type
			Water Segment		
Charlotte Harbor	Group 2	2065F	Matlacha Pass		Estuary
Choctawhatchee-St. Andrews	Group 3	778C	Choctawhatchee Bay		Estuary
Indian River Lagoon	Group 5	2963A	Indian River Above Sebastian Inlet		Estuary
Indian River Lagoon	Group 5	2963B	Indian River Above Melbourne Crossway		Estuary
Indian River Lagoon	Group 5	2963C	Indian River Above Melbourne Crossway		Estuary
Indian River Lagoon	Group 5	2963D	Indian River Above 520 Crossway		Estuary
Indian River Lagoon	Group 5	3057B	Banana River Above 520 Crossway		Estuary
Indian River Lagoon	Group 5	5003C	South Indian River		Estuary
Indian River Lagoon	Group 5	5003D	South Indian River		Estuary
Nassau - St. Marys	Group 4	2097A	St. Marys River Above Intercoastal Waterway		Estuary
Nassau - St. Marys	Group 4	2097B	St. Marys River		Estuary
Perdido	Group 5	462A	Perdido River		Estuary
Sarasota Bay - Peace - Myakka	Group 3	1991C	Myakka River		Estuary
Sarasota Bay - Peace - Myakka	Group 3	2056A	Peace River Lower Estuary		Estuary
Sarasota Bay - Peace - Myakka	Group 3	2056B	Peace River Mid Estuary		Estuary
St. Lucie - Loxahatchee	Group 4	3194	North St.Lucie		Estuary
Tampa Bay	Group 1	1558C	Tampa Bay Upper		Estuary
Tampa Bay	Group 1	1558D	Hillsborough Bay Lower		Estuary
Tampa Bay	Group 1	1558E	Hillsborough Bay Upper		Estuary
Tampa Bay	Group 1	1558F	Old Tampa Bay Lower		Estuary
Tampa Bay	Group 1	1558G	Old Tampa Bay		Estuary
Tampa Bay	Group 1	1558H	Old Tampa Bay		Estuary
Tampa Bay	Group 1	1558I	Old Tampa Bay		Estuary
Tampa Bay	Group 1	1584B	McKay Bay		Estuary

Tampa Bay	Group 1	1778	Cockroach Bay	Estuary
Tampa Bay	Group 1	1797B	Bishops Harbor	Estuary

Freshwater Waterbodies				
Group Name	Basin Rotation Group	WBID*	Water Segment	Waterbody Type
Choctawhatchee-St. Andrews	Group 3	553A	Deer Point Lake	Lake
Kissimmee River	Group 4	3172	East Lake Tohopekaliga	Lake
Kissimmee River	Group 4	3173A	Lake Tohopekaliga North	Lake
Kissimmee River	Group 4	3173C	Lake Tohopekaliga South	Lake
Kissimmee River	Group 4	3180A	Lake Cypress	Lake
Kissimmee River	Group 4	3183B	Lake Kissimmee Mid	Lake
Kissimmee River	Group 4	3183E	Lake Kissimmee South	Lake
Ochlockonee - St.Marks	Group 1	791L	Lake Miccosukee	Lake
Ocklawaha	Group 1	2740B	Lake Ocklawaha	Lake
Suwannee	Group 1	3605F	Altho Drainage	Lake
Upper St. Johns	Group 3	28931	Sawgrass Lake	Lake
Upper St. Johns	Group 3	2893K	Lake Poinsett	Lake
Upper St. Johns	Group 3	2893Q	Lake Helen Blazes	Lake
Apalachicola-Chipola	Group 2	1109A	Equiloxic Creek	Stream
Apalachicola-Chipola	Group 2	1251	Crooked River	Stream
Apalachicola-Chipola	Group 2	51A	Chipola River (Dead Lakes)	Stream
Choctawhatchee-St. Andrews	Group 3	49	Choctawhatchee River	Stream
Choctawhatchee-St. Andrews	Group 3	49F	Choctawhatchee River	Stream
Everglades	Group 5	3238	West Palm Beach Canal	Stream
Everglades	Group 5	3248	North New River Canal	Stream
Everglades	Group 5	3251	S-3	Stream
Everglades	Group 5	3252	Wca1 Center Sector	Stream
Everglades	Group 5	3254	Hillsboro Canal	Stream
Everglades	Group 5	3260	S-8	Stream
Everglades	Group 5	3263	S-7	Stream
Everglades	Group 5	3265	WCA2a East Sector	Stream
Everglades	Group 5	3268	WCA3a Center Sector	Stream
Everglades	Group 5	3278	WCA3b	Stream
Everglades	Group 1	3289	Everglades National Park Shark Slough	Stream
Everglades West Coast	Group 1	3261B	Tamiami Canal	Stream
Everglades West Coast	Group 5	3266	L-28 Interceptor	Stream
Kissimmee River	Group 4	3183A	Lake Kissimmee North	Stream
Lake Worth Lagoon - Palm Beach Coast	Group 4	3233	L-8	Stream
Middle St. Johns	Group 3	2991A	Econlockhatchee River	Stream
Nassau - St. Marys	Group 4	2097I	St Marys River	Stream

Freshwater Waterbodies				
Group Name	Basin Rotation Group	WBID*	Water Segment	Waterbody Type
Nassau - St. Marys	Group 4	2097K	St. Marys River North Prong	Stream
Nassau - St. Marys	Group 4	2106	Little St. Marys River	Stream
Nassau - St. Marys	Group 4	2211	Middle Prong St. Marys	Stream
Ochlockonee - St.Marks	Group 1	1297A	Ochlockonee River	Stream
Ochlockonee - St.Marks	Group 1	1297E	Ochlockonee River	Stream
Ochlockonee - St.Marks	Group 1	1297F	Ochlockonee River	Stream
Ocklawaha	Group 1	2740A	Oklawaha River Above St. Johns River	Stream
Ocklawaha	Group 1	2740C	Oklawaha River Above Lake Oklawaha	Stream
Ocklawaha	Group 1	2740D	Oklawaha Riv Above Daisy	Stream
Pensacola	Group 4	10C	Escambia River	Stream
Pensacola	Group 4	10D	Escambia River	Stream
Pensacola	Group 4	10E	Escambia River	Stream
Pensacola	Group 4	10F	Escambia River	Stream
Pensacola	Group 4	24A	Blackwater River	Stream
Pensacola	Group 4	24D	Blackwater River	Stream
Pensacola	Group 4	30	Yellow River	Stream
Pensacola	Group 4	30A	Yellow River	Stream
Perdido	Group 5	462B	Perdido River	Stream
Perdido	Group 5	462C	Perdido River	Stream
Sarasota Bay - Peace - Myakka	Group 3	1539	Peace Creek Drain Canal	Stream
Sarasota Bay - Peace - Myakka	Group 3	1623C	Peace River Above Joshua Creek	Stream
Sarasota Bay - Peace - Myakka	Group 3	1623D	Peace River Above Charlie Creek	Stream
Sarasota Bay - Peace - Myakka	Group 3	1623E	Peace River Above Oak Creek	Stream
Sarasota Bay - Peace - Myakka	Group 3	1623H	Peace River Above Payne Creek	Stream
Sarasota Bay - Peace - Myakka	Group 3	1623J	Peace River Above Bowlegs Creekk	Stream
Southeast Coast - Biscayne Bay	Group 4	3284	Snake Creek Canal West	Stream
Southeast Coast - Biscayne Bay	Group 5	3303	C-111	Stream
Springs Coast	Group 5	1440	Anclote River	Stream
St. Lucie - Loxahatchee	Group 4	3234	C-18	Stream
Suwannee	Group 1	3315	Withlacoochee River	Stream
Suwannee	Group 1	3473B	Fenholloway Below Pulp	Stream
Suwannee	Group 1	3605A	Santa Fe River	Stream
Tampa Bay Tributaries	Group 2	1443A	Hillsborough River	Stream
Tampa Bay Tributaries	Group 2	1443B	Hillsborough River	Stream
Tampa Bay Tributaries	Group 2	1443D	Hillsborough River	Stream
Tampa Bay Tributaries	Group 2	1443E	Hillsborough River	Stream

Freshwater Waterbodies				
Group Name	Basin Rotation Group	WBID*	Water Segment	Waterbody Type
Upper St. Johns	Group 3	2893I	St. Johns River Above Puzzle Lake	Stream
Upper St. Johns	Group 3	2893L	St. Johns River Above Lake Poinsett	Stream
Upper St. Johns	Group 3	2893N	St. Johns River Above Lake Winder	Stream
Upper St. Johns	Group 3	2893P	St. Johns River Above Lake Washington	Stream
Upper St. Johns	Group 3	2893X	St. Johns River Above Sawgrass Lake	Stream



Florida Department of Environmental Protection
Division of Water Resource Management
Bureau of Watershed Management
2600 Blair Stone Road, Mail Station 3565
Tallahassee, Florida 32399-2400
(850) 245-8561
www2.dep.state.fl.us/water/

FLORIDA DEPARTMENT OF ENVIRONMENTAL PROTECTION

Division of Environmental Assessment and Restoration
Bureau of Watershed Restoration

Mercury TMDL for the State of Florida

Appendix B

Complete list of Florida Water Segments
Verified as Impaired for Mercury (In Fish Tissue)

Watershed Evaluation and TMDL Section



August 23, 2012

Appendices

Table B-1: Complete list of Florida freshwaters verified as impaired for mercury (in fish tissue). List presented includes WBIDs from the most recently completed cycle of the basin rotation (Cycle 2). Waterbodies are presented in ascending order by Basin Name and Waterbody Type.

¹Case Number assigned to each WBID when verified lists are adopted by an order signed by FDEP Secretary

²Assessment cycle (1 or 2) during which conditions of the State's waters are evaluated

³FDEP has divided the surface waters of the State into five groups to facilitate the identification of impaired waters

⁴WBID number at the time of assessment. Subject to change if WBIDs are modified as new and better information becomes available.

OGC Case Number ¹	Cycle ²	Group ³	Basin	WBID ⁴	Water Segment Name	Waterbody Type
09-1678	2	2	Apalachicola - Chipola	51A	Dead Lake	Lake
03-2385	1	2	Apalachicola - Chipola	926A1	Lake Mystic	Lake
10-0475	2	3	Choctawhatchee - St. Andrew	210A	Double Pond	Lake
10-0472	2	3	Choctawhatchee - St. Andrew	283	Lake Juniper	Lake
10-0544	2	3	Choctawhatchee - St. Andrew	553A	Deerpoint Lake	Lake
10-0476	2	3	Choctawhatchee - St. Andrew	61A	Sand Hammock Pond	Lake
09-1024	1	5	Everglades	3289X	Everglades Lakes	Lake
09-2719	2	1	Everglades West Coast	3259Z	Little Hickory Bay	Lake
06-0532	1	4	Kissimmee River	1472B	Lake Hatchineha	Lake
10-3138	2	4	Kissimmee River	1480	Lake Marion	Lake
10-3142	2	4	Kissimmee River	1573A	Tiger Lake	Lake
10-3145	2	4	Kissimmee River	1663	Crooked Lake	Lake
06-0508	1	4	Kissimmee River	1685A	Lake Arbuckle	Lake
06-0502	1	4	Kissimmee River	1706	Lake Clinch	Lake
06-0503	1	4	Kissimmee River	1730B	Livingston Lake	Lake
06-0506	1	4	Kissimmee River	1842	Lake Sebring	Lake
10-3156	2	4	Kissimmee River	1856B	Lake Istokpoga	Lake
06-0516	1	4	Kissimmee River	1860B	Lake Josphine	Lake
06-0517	1	4	Kissimmee River	1938A	Lake June in Winter	Lake
06-0518	1	4	Kissimmee River	1938C	Lake Placid	Lake
10-3159	2	4	Kissimmee River	1938H	Lake Annie	Lake
10-3177	2	4	Kissimmee River	3169C	Big Sand Lake	Lake
06-0545	1	4	Kissimmee River	3170B	Lake Russell	Lake
10-3188	2	4	Kissimmee River	3170H	Lake Sheen	Lake
06-0549	1	4	Kissimmee River	3170Q	Lake Butler	Lake
10-3193	2	4	Kissimmee River	3170S	Down Lake	Lake
10-3194	2	4	Kissimmee River	3170T	Lake Bessie	Lake
10-3195	2	4	Kissimmee River	3170W	Lake Louise	Lake
10-3196	2	4	Kissimmee River	3170Y	Lake Tibet Butler	Lake
10-3197	2	4	Kissimmee River	3171	Lake Hart	Lake
06-0551	1	4	Kissimmee River	3171A	Lake Mary Jane	Lake
06-0527	1	4	Kissimmee River	3172	East Lake Tohopekaliga	Lake

OGC Case Number¹	Cycle²	Group³	Basin	WBID⁴	Water Segment Name	Waterbody Type
06-0553	1	4	Kissimmee River	3173A	Lake Tohopekaliga	Lake
06-0529	1	4	Kissimmee River	3176	Alligator Lake	Lake
10-3201	2	4	Kissimmee River	3177	Lake Gentry	Lake
06-0554	1	4	Kissimmee River	3177A	Brick Lake	Lake
06-0555	1	4	Kissimmee River	3180A	Lake Cypress	Lake
06-0557	1	4	Kissimmee River	3183B	Lake Kissimmee (Mid) (Include Previous 3183E And 3183A)	Lake
09-2078	2	1	Lake Okeechobee	3212A	Lake Okeechobee	Lake
09-2078	2	1	Lake Okeechobee	3212B	Lake Okeechobee	Lake
09-2078	2	1	Lake Okeechobee	3212C	Lake Okeechobee	Lake
09-2078	2	1	Lake Okeechobee	3212D	Lake Okeechobee	Lake
09-2078	2	1	Lake Okeechobee	3212E	Lake Okeechobee	Lake
09-2078	2	1	Lake Okeechobee	3212F	Lake Okeechobee	Lake
09-2078	2	1	Lake Okeechobee	3212G	Lake Okeechobee	Lake
09-2078	2	1	Lake Okeechobee	3212H	Lake Okeechobee	Lake
09-2078	2	1	Lake Okeechobee	3212I	Lake Okeechobee	Lake
09-2579	2	2	Lower St. Johns	2213G	St. Johns River Above Doctors Lake	Lake
09-2580	2	2	Lower St. Johns	2213H	Stj Riv Ab Julington C	Lake
09-2581	2	2	Lower St. Johns	2213I	St. Johns River Above Black Creek	Lake
09-2582	2	2	Lower St. Johns	2213J	St. Johns River Above Palmo Creek	Lake
09-2583	2	2	Lower St. Johns	2213K	St. Johns River Above Tocoi	Lake
09-2584	2	2	Lower St. Johns	2213L	St. Johns River Above Federal Point	Lake
09-2635	2	2	Lower St. Johns	2541	Georges Lake	Lake
09-2642	2	2	Lower St. Johns	2575	Cue Lake	Lake
03-2533	1	2	Lower St. Johns	2575Q	Cue Lake	Lake
09-2560	2	2	Lower St. Johns	2606B	Crescent Lake	Lake
09-2561	2	2	Lower St. Johns	2615A	Dead Lake	Lake
09-2607	2	2	Lower St. Johns	2617A	Lake Broward	Lake
09-2562	2	2	Lower St. Johns	2630B	Lake Disston	Lake
09-2616	2	2	Lower St. Johns	2671A	Lake Daugharty	Lake
03-2556	1	2	Middle St. Johns	2892	Lake Margaret	Lake
09-2197	2	2	Middle St. Johns	2893A	Lake George	Lake
09-2235	2	2	Middle St. Johns	2893D	Lake Monroe	Lake
09-2174	2	2	Middle St. Johns	2893H	Mullet Lake	Lake
09-2175	2	2	Middle St. Johns	2893J	Mud Lake	Lake
09-2230	2	2	Middle St. Johns	2894	Lake Delancey	Lake
09-2231	2	2	Middle St. Johns	2899B	Lake Kerr	Lake
03-2570	1	2	Middle St. Johns	2905C	Wildcat Lake	Lake
03-2571	1	2	Middle St. Johns	2916B	Grasshopper Lake	Lake
09-2172	2	2	Middle St. Johns	2917	Boyd Lake	Lake
09-2248	2	2	Middle St. Johns	2921	Lake Woodruff	Lake
09-2249	2	2	Middle St. Johns	2921C	Lake Dexter	Lake
09-2178	2	2	Middle St. Johns	2925A	Lake Ashby	Lake

OGC Case Number¹	Cycle²	Group³	Basin	WBID⁴	Water Segment Name	Waterbody Type
09-2251	2	2	Middle St. Johns	2929B	Lake Norris	Lake
09-2252	2	2	Middle St. Johns	2929C	Lake Dorr	Lake
09-2238	2	2	Middle St. Johns	2954	Konomac Lake Reservoir	Lake
09-2261	2	2	Middle St. Johns	2961	Lake Sylvan	Lake
03-2582	1	2	Middle St. Johns	2964A	Lake Harney	Lake
09-2266	2	2	Middle St. Johns	3004A	Bear Lake	Lake
03-2629	1	2	Middle St. Johns	3011C	Lake Lucien	Lake
09-2192	2	2	Middle St. Johns	3036	Lake Frederica	Lake
06-0579	1	4	Nassau - St. Marys	2339	Ocean Pond	Lake
09-1997	2	1	Ochlockonee - St. Marks	1297C	Lake Talquin	Lake
09-1997	2	1	Ochlockonee - St. Marks	1297D	Lake Talquin	Lake
09-1997	2	1	Ochlockonee - St. Marks	889A	Moore Lake	Lake
09-2036	2	1	Ocklawaha	2723A	Cowpen Lake	Lake
09-2055	2	1	Ocklawaha	2740B	Lake Ocklawaha	Lake
09-2063	2	1	Ocklawaha	2771A	Lake Eaton	Lake
09-2064	2	1	Ocklawaha	2779A	Mill Dam Lake	Lake
09-2065	2	1	Ocklawaha	2782C	Lake Bryant	Lake
09-2020	2	1	Ocklawaha	2785A	Smith Lake	Lake
09-2004	2	1	Ocklawaha	2797A	Ella Lake	Lake
09-2005	2	1	Ocklawaha	2803A	Holly Lake	Lake
09-2047	2	1	Ocklawaha	2839A	Lake Minneola	Lake
09-2048	2	1	Ocklawaha	2839D	Lake Cherry	Lake
09-2051	2	1	Ocklawaha	2839M	Lake Louisa	Lake
09-2052	2	1	Ocklawaha	2839N	Lake Minnehaha	Lake
09-1999	2	1	Ocklawaha	2873C	Johns Lake	Lake
10-3043	2	4	Pensacola	10EA	Woodbine Springs Lake	Lake
12-0037	2	5	Perdido	784	Tee And Wicker Lakes	Lake
10-0238	2	3	Sarasota Bay - Peace - Myakka	15041	Lake Hamilton	Lake
10-0252	2	3	Sarasota Bay - Peace - Myakka	1539P	Lake Dexter	Lake
10-0273	2	3	Sarasota Bay - Peace - Myakka	1677C	Lake Buffum	Lake
10-0095	2	3	Sarasota Bay - Peace - Myakka	1981	Lake Myakka (Lower Segment)	Lake
10-0097	2	3	Sarasota Bay - Peace - Myakka	1981C	Lake Myakka (Upper Segment)	Lake
09-1919	2	1	Suwannee	3321A	Lake Octahatchee	Lake
09-1920	2	1	Suwannee	3322A	Lake Cherry	Lake
09-1877	2	1	Suwannee	3593A	Lake Crosby	Lake
09-1879	2	1	Suwannee	3598D	Lake Sampson	Lake
09-1925	2	1	Suwannee	3605G	Santa Fe Lake	Lake
09-1925	2	1	Suwannee	3605H	Lake Althro	Lake
09-1885	2	1	Suwannee	3635A	Hampton Lake	Lake
03-2266	1	2	Tampa Bay Tributaries	1443E1	Hillsborough Reservoir	Lake
05-1295	1	3	Upper St. Johns	28931	Sawgrass Lake	Lake
10-0292	2	3	Upper St. Johns	28932	Lake Cone at Seminole	Lake

OGC Case Number¹	Cycle²	Group³	Basin	WBID⁴	Water Segment Name	Waterbody Type
10-0283	2	3	Upper St. Johns	2893K	Lake Poinsett	Lake
10-0305	2	3	Upper St. Johns	2893O	Lake Washington	Lake
10-0313	2	3	Upper St. Johns	2893Q	Lake Helen Blazes	Lake
10-0274	2	3	Upper St. Johns	2893V	Blue Cypress Lake	Lake
10-0290	2	3	Upper St. Johns	2893Y	Lake Winder	Lake
10-0296	2	3	Upper St. Johns	2964B	Puzzle Lake	Lake
10-0298	2	3	Upper St. Johns	2964C	Ruth Lake	Lake
10-0300	2	3	Upper St. Johns	2966A	Buck Lake	Lake
10-0301	2	3	Upper St. Johns	3008A	Fox Lake	Lake
10-0302	2	3	Upper St. Johns	3008B	South Lake	Lake
10-3230	2	4	Withlacoochee	1329B	Lake Rousseau	Lake
10-3225	2	4	Withlacoochee	1347	Lake Okahumpka	Lake
09-2587	2	2	Lower St. Johns	2213Q	Green Cove Springs	Spring
09-1997	2	1	Ochlockonee - St. Marks	1006X	Wakulla Springs	Spring
09-1997	2	1	Ochlockonee - St. Marks	793X	Newport Spring	Spring
09-1997	2	1	Ochlockonee - St. Marks	793Y	St Marks Spring	Spring
09-1997	2	1	Ochlockonee - St. Marks	793Z	Horn Spring	Spring
12-0536	2	5	Springs Coast	1341B	Cedar Cove Spring	Spring
12-0538	2	5	Springs Coast	1341C	Hunter Spring	Spring
12-0540	2	5	Springs Coast	1341D	House Spring	Spring
12-0542	2	5	Springs Coast	1341E	Crystal Spring	Spring
12-0543	2	5	Springs Coast	1341F	Idiots Delight Spring	Spring
12-0545	2	5	Springs Coast	1341G	Tarpon Spring	Spring
12-0547	2	5	Springs Coast	1341H	Crescent Drive Spring	Spring
12-0528	2	5	Springs Coast	1348Z	Chassahowitzka Springs	Spring
09-1923	2	1	Suwannee	3310Z	Nutall Rise Spring	Spring
09-1928	2	1	Suwannee	3315Z	Madison Blue Spring	Spring
09-1926	2	1	Suwannee	3341W	Lime Run Sink	Spring
09-1921	2	1	Suwannee	3341X	Alapaha River Rise	Spring
09-1926	2	1	Suwannee	3341Y	Suwannee Springs	Spring
09-1924	2	1	Suwannee	3422K	Guaranto Spring	Spring
09-1924	2	1	Suwannee	3422M	Turtle Spring	Spring
09-1924	2	1	Suwannee	3422N	Hart Springs	Spring
09-1924	2	1	Suwannee	3422R	Manatee Springs	Spring
09-1924	2	1	Suwannee	3422S	Fanning Springs	Spring
09-1925	2	1	Suwannee	3605P	Siphon Creek Rise (Gil	Spring
09-1925	2	1	Suwannee	3605Q	Ala 112971	Spring
09-1925	2	1	Suwannee	3605R	Santa Fe Rise	Spring
09-1925	2	1	Suwannee	3605S	Devils Ear	Spring
09-1925	2	1	Suwannee	3605T	Columbia Springs	Spring
09-1925	2	1	Suwannee	3605U	Col 61981 (Spring)	Spring
09-1925	2	1	Suwannee	3605W	Poe Spring	Spring
09-1925	2	1	Suwannee	3605X	Blue Spring Gilchrist	Spring
09-1925	2	1	Suwannee	3605Y	Ginnie Spring	Spring
09-1925	2	1	Suwannee	3605Z	Trail Springs	Spring
09-1656	2	2	Apalachicola - Chipola	1109A	Equiloxic Creek	Stream

OGC Case Number¹	Cycle²	Group³	Basin	WBID⁴	Water Segment Name	Waterbody Type
09-1684	2	2	Apalachicola - Chipola	1251	Crooked River	Stream
09-1659	2	2	Apalachicola - Chipola	375A	Apalachicola River	Stream
09-1660	2	2	Apalachicola - Chipola	375B	Apalachicola River	Stream
09-1661	2	2	Apalachicola - Chipola	375C	Apalachicola River	Stream
09-1662	2	2	Apalachicola - Chipola	375D	Apalachicola River	Stream
09-1663	2	2	Apalachicola - Chipola	375E	Apalachicola River	Stream
09-1664	2	2	Apalachicola - Chipola	375F	Apalachicola River	Stream
09-1665	2	2	Apalachicola - Chipola	375G	Apalachicola River	Stream
09-1666	2	2	Apalachicola - Chipola	375H	Apalachicola River	Stream
09-1670	2	2	Apalachicola - Chipola	51	Chipola River	Stream
09-1679	2	2	Apalachicola - Chipola	51B	Chipola River	Stream
09-1680	2	2	Apalachicola - Chipola	51C	Chipola River	Stream
09-1681	2	2	Apalachicola - Chipola	51D	Chipola River	Stream
09-1682	2	2	Apalachicola - Chipola	51E	Chipola River	Stream
09-1649	2	2	Apalachicola - Chipola	728	Sweetwater Creek	Stream
09-1650	2	2	Apalachicola - Chipola	735	Upper Sweetwater Creek	Stream
05-1138	1	3	Choctawhatchee - St. Andrew	49	Choctawhatchee River	Stream
05-1138	1	3	Choctawhatchee - St. Andrew	49A	Choctawhatchee River	Stream
05-1138	1	3	Choctawhatchee - St. Andrew	49B	Choctawhatchee River	Stream
05-1138	1	3	Choctawhatchee - St. Andrew	49C	Choctawhatchee River	Stream
05-1138	1	3	Choctawhatchee - St. Andrew	49D	Choctawhatchee River	Stream
05-1138	1	3	Choctawhatchee - St. Andrew	49E	Choctawhatchee River	Stream
05-1138	1	3	Choctawhatchee - St. Andrew	49F	Choctawhatchee River	Stream
09-1029	1	5	Everglades	3252	Wca 1 (Central Sector)	Stream
09-1029	1	5	Everglades	3252B	Wca 1 (North Sector)	Stream
09-1029	1	5	Everglades	3252D	Wca 1 (West Sector)	Stream
09-1029	1	5	Everglades	3252E	Wca 1 (South Sector)	Stream
09-1029	1	5	Everglades	3252G	Wca 1 (East Sector)	Stream
09-1010	1	5	Everglades	3252H	Loxahatchee West Sector	Stream
09-1015	1	5	Everglades	3260B	Holey Land	Stream
09-1018	1	5	Everglades	3263	S-7	Stream
09-1019	1	5	Everglades	3263A	Holey Land	Stream
12-0381	2	5	Everglades	3265F	WCA 2A (West Sector)	Stream
12-0382	2	5	Everglades	3265G	WCA 2A (Central Sector)	Stream
12-0383	2	5	Everglades	3265H	WCA 2A (Central Sector)	Stream
12-0384	2	5	Everglades	3268F	WCA 3 L-67	Stream
12-0385	2	5	Everglades	3268G	WCA 3A (West Sector)	Stream
12-0386	2	5	Everglades	3268H	WCA 3A (East Sector)	Stream
12-0387	2	5	Everglades	3268I	WCA 3A (Central Sector)	Stream
12-0388	2	5	Everglades	3268J	WCA 3B	Stream
09-1031	1	5	Everglades	3272	Conservation Area 2B	Stream

OGC Case Number¹	Cycle²	Group³	Basin	WBID⁴	Water Segment Name	Waterbody Type
09-1023	1	5	Everglades	3289	Shark Slough (Everglades National Park)	Stream
09-1023	1	5	Everglades	3289B	Huston River	Stream
09-1023	1	5	Everglades	3289F	Charley Creek	Stream
09-1023	1	5	Everglades	3289J	L-67 Culvert Us-41 (Everglades National Park)	Stream
09-1023	1	5	Everglades	3289K	Taylor Slough (Everglades National Park)	Stream
09-1023	1	5	Everglades	3289R	Shark Slough A (Everglades National Park)	Stream
09-2719	2	1	Everglades West Coast	3258F	Oak Creek	Stream
09-2719	2	1	Everglades West Coast	3259A	Cocohatchee River	Stream
09-2719	2	1	Everglades West Coast	3259I	Camp Keais	Stream
09-2719	2	1	Everglades West Coast	3261B	Tamiami Canal	Stream
09-2719	2	1	Everglades West Coast	3261C	Barron River Canal	Stream
09-2719	2	1	Everglades West Coast	3266A	C-139 Annex Basin (L3 Canal)	Stream
09-2719	2	1	Everglades West Coast	3278I	Faka Union (South Segment)	Stream
09-2719	2	1	Everglades West Coast	3278M	L-28 Tieback	Stream
10-3086	2	4	Fisheating Creek	3201A1	Fisheating Creek	Stream
10-3203	2	4	Kissimmee River	3186A	Kissimmee River	Stream
10-3212	2	4	Kissimmee River	3202	Kissimmee River	Stream
10-3214	2	4	Kissimmee River	3209	Kissimmee River	Stream
10-0089	2	3	Lake Worth Lagoon - Palm Beach Coast	3233A	L-8	Stream
09-1029	1	5	Lake Worth Lagoon - Palm Beach Coast	3252C	Acme (North Sector)	Stream
09-1029	1	5	Lake Worth Lagoon - Palm Beach Coast	3252F	Acme (South Sector)	Stream
09-2585	2	2	Lower St. Johns	2213M	St. Johns River Above Rice Creek	Stream
09-2586	2	2	Lower St. Johns	2213N	St. Johns River Above Dunns Creek	Stream
09-2194	2	2	Middle St. Johns	2213O	St. Johns River Above Ocklawaha River	Stream
09-2198	2	2	Middle St. Johns	2893A1	St. Johns River Below Lake George	Stream
09-2199	2	2	Middle St. Johns	2893A2	St. Johns River Above Lake George	Stream
09-2201	2	2	Middle St. Johns	2893A3	Lake George Leftover	Stream
09-2245	2	2	Middle St. Johns	2893B	St. Johns River Above Lake Woodruff	Stream
09-2234	2	2	Middle St. Johns	2893C	St. Johns River Above Wekiva River	Stream
09-2236	2	2	Middle St. Johns	2893E	St. Johns River Above Lake Monroe	Stream
09-2173	2	2	Middle St. Johns	2893F	St. Johns River Above Lake Jesup	Stream
09-2246	2	2	Middle St. Johns	2893Z	St. Johns River Below Lake Dexter (St. Johns River Above Lake George)	Stream
09-2250	2	2	Middle St. Johns	2921D	Lake Woodruff Outlet	Stream

OGC Case Number¹	Cycle²	Group³	Basin	WBID⁴	Water Segment Name	Waterbody Type
09-2255	2	2	Middle St. Johns	2956	Wekiva River	Stream
09-2256	2	2	Middle St. Johns	2956A	Wekiva River	Stream
09-2258	2	2	Middle St. Johns	2956B	Lower Wekiva River	Stream
09-2259	2	2	Middle St. Johns	2956C	Wekiwa Spring	Stream
09-2183	2	2	Middle St. Johns	2964	St. Johns River Above Lake Harney (Underhill Slough)	Stream
09-2184	2	2	Middle St. Johns	2964A1	Lake Harney Outlet	Stream
09-2185	2	2	Middle St. Johns	2991	Econlockhatchee River	Stream
09-2186	2	2	Middle St. Johns	2991A	Econlockhatchee River	Stream
06-0577	1	4	Nassau - St. Marys	2097D	St. Marys River	Stream
06-0577	1	4	Nassau - St. Marys	2097E	St. Marys River	Stream
06-0577	1	4	Nassau - St. Marys	2097F	St. Marys River	Stream
06-0577	1	4	Nassau - St. Marys	2097G	St. Marys River	Stream
06-0577	1	4	Nassau - St. Marys	2097H	St. Marys River	Stream
06-0577	1	4	Nassau - St. Marys	2097I	St. Marys River	Stream
06-0577	1	4	Nassau - St. Marys	2097J	St. Marys River	Stream
06-0577	1	4	Nassau - St. Marys	2097K	St. Marys River	Stream
10-3133	2	4	Nassau - St. Marys	2211	Middle Prong St Marys River	Stream
10-3134	2	4	Nassau - St. Marys	2247	St Marys River (South Prong)	Stream
09-1997	2	1	Ochlockonee - St. Marks	1006	Wakulla River	Stream
09-1997	2	1	Ochlockonee - St. Marks	1006V	Wakulla River Below Highway 98 Bridge	Stream
09-1997	2	1	Ochlockonee - St. Marks	1006W	Wakulla River Between Bridges	Stream
09-1997	2	1	Ochlockonee - St. Marks	1038	Sopchopy River (West Branch)	Stream
09-1997	2	1	Ochlockonee - St. Marks	1038B	Sopchopy River (East Branch)	Stream
09-1997	2	1	Ochlockonee - St. Marks	1241	Crooked River	Stream
09-1997	2	1	Ochlockonee - St. Marks	1248B	Ochlockonee Bay	Stream
09-1997	2	1	Ochlockonee - St. Marks	1248C	Ochlockonee Bay	Stream
09-1997	2	1	Ochlockonee - St. Marks	1297A	Ochlockonee River	Stream
09-1997	2	1	Ochlockonee - St. Marks	1297B	Ochlockonee River	Stream
09-1997	2	1	Ochlockonee - St. Marks	1297E	Ochlockonee River	Stream
09-1997	2	1	Ochlockonee - St. Marks	1297F	Ochlockonee River	Stream
09-1997	2	1	Ochlockonee - St. Marks	1297G	Ochlockonee River	Stream
09-1997	2	1	Ochlockonee - St. Marks	442	Lake Iamonia Outlet	Stream
09-1997	2	1	Ochlockonee - St. Marks	793B	St Marks River	Stream
09-1997	2	1	Ochlockonee - St. Marks	889	Moore Lake Drain	Stream
09-1997	2	1	Ochlockonee - St. Marks	998	Sopchopy River	Stream
09-2054	2	1	Ocklawaha	2740A	Ocklawaha River Above Stjohns River	Stream
09-2057	2	1	Ocklawaha	2740C	Ocklawaha River Above Lake Ocklawaha	Stream
09-2017	2	1	Ocklawaha	2740D	Ocklawaha River Above Daisy	Stream
09-2002	2	1	Ocklawaha	2740F	Ocklawaha River/Sunnyhill	Stream
06-0580	1	4	Ocklawaha	2827	Wolf Branch	Stream
06-0587	1	4	Pensacola	10A	Escambia River	Stream
06-0587	1	4	Pensacola	10B	Escambia River	Stream
06-0587	1	4	Pensacola	10C	Escambia River	Stream

OGC Case Number¹	Cycle²	Group³	Basin	WBID⁴	Water Segment Name	Waterbody Type
06-0587	1	4	Pensacola	10D	Escambia River	Stream
06-0587	1	4	Pensacola	10E	Escambia River	Stream
06-0587	1	4	Pensacola	10G	Escambia River	Stream
06-0582	1	4	Pensacola	24	Blackwater River	Stream
06-0586	1	4	Pensacola	24A	Blackwater River	Stream
10-3039	2	4	Pensacola	24AA	Blackwater River (Freshwater Segment)	Stream
06-0586	1	4	Pensacola	24B	Blackwater River	Stream
06-0586	1	4	Pensacola	24C	Blackwater River	Stream
06-0586	1	4	Pensacola	24D	Blackwater River	Stream
06-0622	1	4	Pensacola	30	Yellow River	Stream
06-0622	1	4	Pensacola	30A	Yellow River	Stream
06-0622	1	4	Pensacola	30B	Yellow River	Stream
06-0622	1	4	Pensacola	30C	Yellow River	Stream
06-0622	1	4	Pensacola	30D	Yellow River	Stream
06-0622	1	4	Pensacola	30E	Yellow River	Stream
09-0977	1	5	Perdido	2F	Perdido River	Stream
09-0980	1	5	Perdido	72	Direct Runoff to Stream	Stream
09-0980	1	5	Perdido	72D	Direct Runoff to Stream	Stream
09-0980	1	5	Perdido	72E	Direct Runoff to Stream	Stream
09-0980	1	5	Perdido	72F	Direct Runoff to Stream	Stream
10-0249	2	3	Sarasota Bay - Peace - Myakka	1539	Peace Creek Drainage Canal	Stream
10-0150	2	3	Sarasota Bay - Peace - Myakka	1623B	Peace River Above Horse Creek	Stream
10-0152	2	3	Sarasota Bay - Peace - Myakka	1623C	Peace River Above Joshua Creek	Stream
10-0153	2	3	Sarasota Bay - Peace - Myakka	1623D	Peace River Above Charlie Creek	Stream
10-0154	2	3	Sarasota Bay - Peace - Myakka	1623E	Peace River Above Oak Creek	Stream
05-1241	1	3	Sarasota Bay - Peace - Myakka	1623F	Peace River Above Troublesome	Stream
10-0156	2	3	Sarasota Bay - Peace - Myakka	1623G	Peace River Above Little Charlie Creek	Stream
10-0263	2	3	Sarasota Bay - Peace - Myakka	1623H	Peace River Above Payne Creek	Stream
10-0264	2	3	Sarasota Bay - Peace - Myakka	1623I	Peace River Above Whidden Creek	Stream
10-0267	2	3	Sarasota Bay - Peace - Myakka	1623J	Peace River Above Bowlegs Creek	Stream
10-0212	2	3	Sarasota Bay - Peace - Myakka	1869B	Myakka River (Upper Segment)	Stream
10-0213	2	3	Sarasota Bay - Peace - Myakka	1869C	Myakka River (Upper Segment)	Stream
10-0214	2	3	Sarasota Bay - Peace - Myakka	1877A	Myakka River (Upper Segment)	Stream
10-0215	2	3	Sarasota Bay - Peace - Myakka	1877B	Myakka River (Upper Segment)	Stream

OGC Case Number¹	Cycle²	Group³	Basin	WBID⁴	Water Segment Name	Waterbody Type
10-0091	2	3	Sarasota Bay - Peace - Myakka	1877C	Myakka River (North Fork)	Stream
10-0094	2	3	Sarasota Bay - Peace - Myakka	1972	Myakka River at Clay Gully	Stream
10-0096	2	3	Sarasota Bay - Peace - Myakka	1981B	Myakka River	Stream
10-0104	2	3	Sarasota Bay - Peace - Myakka	1991D	Myakka River	Stream
10-2856	2	4	Southeast Coast - Biscayne Bay	3286	C-4/Tamiami Canal	Stream
10-2866	2	4	Southeast Coast - Biscayne Bay	3286B	C-4/Tamiami Canal (West)	Stream
10-2861	2	4	Southeast Coast - Biscayne Bay	3290	C-6/Miami Canal	Stream
10-2873	2	4	Southeast Coast - Biscayne Bay	3301	C-111	Stream
10-2874	2	4	Southeast Coast - Biscayne Bay	3303	C-111 (South)	Stream
12-0498	2	5	Springs Coast	1440F	Anclote River Freshwater Segment	Stream
09-1721	2	2	St. Lucie - Loxahatchee	3228	Pai Mar	Stream
09-1723	2	2	St. Lucie - Loxahatchee	3234	C-18	Stream
09-1923	2	1	Suwannee	3310	Aucilla River	Stream
09-1923	2	1	Suwannee	3310A	Aucilla River	Stream
09-1923	2	1	Suwannee	3310B	Aucilla River	Stream
09-1923	2	1	Suwannee	3310C	Aucilla River	Stream
09-1928	2	1	Suwannee	3315	Withlacoochee River	Stream
09-1799	2	1	Suwannee	3324	Alapaha River	Stream
09-1800	2	1	Suwannee	3324A	Alapaha River	Stream
09-1926	2	1	Suwannee	3341	Suwannee River (Upper)	Stream
09-1926	2	1	Suwannee	3341A	Suwannee River (Upper)	Stream
09-1926	2	1	Suwannee	3341B	Suwannee River (Upper)	Stream
09-1926	2	1	Suwannee	3341C	Suwannee River (Upper)	Stream
09-1805	2	1	Suwannee	3402	Econfina River	Stream
09-1924	2	1	Suwannee	3422	Suwannee River (Lower)	Stream
02-1282	1	1	Suwannee	3422A	Suwannee River (Lower)	Stream
09-1826	2	1	Suwannee	3422B	Suwannee River (Lower)	Stream
09-1828	2	1	Suwannee	3422J	Branford Spring	Stream
09-1830	2	1	Suwannee	3422P	Mearson Spring	Stream
09-1831	2	1	Suwannee	3422Q	Ellaville Spring	Stream
09-1833	2	1	Suwannee	3422T	Troy Spring	Stream
09-1835	2	1	Suwannee	3422U	Royal Spring	Stream
09-1836	2	1	Suwannee	3422V	Convict Spring	Stream
09-1837	2	1	Suwannee	3422W	Running Spring	Stream
09-1838	2	1	Suwannee	3422X	Telford Spring	Stream
09-1839	2	1	Suwannee	3422Y	Charles Spring	Stream
09-1841	2	1	Suwannee	3422Z	Falmouth Spring	Stream
09-1923	2	1	Suwannee	3424A	Aucilla River	Stream

OGC Case Number¹	Cycle²	Group³	Basin	WBID⁴	Water Segment Name	Waterbody Type
09-1923	2	1	Suwannee	3505A	Aucilla River	Stream
09-1846	2	1	Suwannee	3528Z	Lafayette Blue Springs	Stream
09-1886	2	1	Suwannee	3573	Steinhatchee River	Stream
09-1889	2	1	Suwannee	3573A	Steinhatchee River	Stream
09-1892	2	1	Suwannee	3573B	Steinhatchee River	Stream
09-1894	2	1	Suwannee	3573X	Steinhatchee Rise	Stream
09-1895	2	1	Suwannee	3573Z	Steinhatchee Spring	Stream
09-1925	2	1	Suwannee	3605	Santa Fe River	Stream
09-1925	2	1	Suwannee	3605A	Santa Fe River	Stream
09-1925	2	1	Suwannee	3605B	Santa Fe River	Stream
09-1925	2	1	Suwannee	3605C	Santa Fe River	Stream
09-1925	2	1	Suwannee	3605D	Santa Fe River	Stream
09-1925	2	1	Suwannee	3605E	Santa Fe River	Stream
09-1925	2	1	Suwannee	3605F	Altho Drainage	Stream
09-1927	2	1	Suwannee	3699	Waccasassa River	Stream
09-1927	2	1	Suwannee	3699A	Waccasassa River	Stream
09-2512	2	1	Tampa Bay	1620	Direct Runoff to Bay	Stream
03-2255	1	2	Tampa Bay Tributaries	1443A	Hillsborough River	Stream
03-2256	1	2	Tampa Bay Tributaries	1443B	Hillsborough River	Stream
03-2257	1	2	Tampa Bay Tributaries	1443C	Hillsborough River	Stream
03-2259	1	2	Tampa Bay Tributaries	1443D	Hillsborough River	Stream
03-2267	1	2	Tampa Bay Tributaries	1443E2	Hillsborough River	Stream
09-2327	2	2	Tampa Bay Tributaries	1742A	Little Manatee River	Stream
09-2328	2	2	Tampa Bay Tributaries	1742B	Little Manatee River (North Fork)	Stream
09-2339	2	2	Tampa Bay Tributaries	1790	Little Manatee River (South Fork)	Stream
10-0325	2	3	Upper St. Johns	28935	St Johns River Above Puzzle Lake (South Segment)	Stream
10-0282	2	3	Upper St. Johns	28936	St Johns River Above East of Lake Washington	Stream
10-0294	2	3	Upper St. Johns	2893I	St Johns River Above Puzzle Lake	Stream
10-0285	2	3	Upper St. Johns	2893K1	Lake Poinsett Outlet	Stream
10-0286	2	3	Upper St. Johns	2893L	St Johns River Above Lake Poinsett	Stream
10-0287	2	3	Upper St. Johns	2893N	St Johns River Above Lake Winder	Stream
10-0311	2	3	Upper St. Johns	2893P	St Johns River Above Lake Washington	Stream
10-0315	2	3	Upper St. Johns	2893X	St Johns River Above Sawgrass Lake	Stream
10-0297	2	3	Upper St. Johns	2964B1	Puzzle Lake Drain	Stream
10-3231	2	4	Withlacoochee	1329B1	Lake Rousseau Drain	Stream
10-3232	2	4	Withlacoochee	1329C	Withlacoochee River	Stream
10-3233	2	4	Withlacoochee	1329D	Withlacoochee River	Stream
10-3244	2	4	Withlacoochee	1329E	Withlacoochee River	Stream
10-3245	2	4	Withlacoochee	1329F	Withlacoochee River	Stream
10-3246	2	4	Withlacoochee	1329G	Withlacoochee River	Stream
10-3235	2	4	Withlacoochee	1337	Withlacoochee River	Stream

OGC Case Number¹	Cycle²	Group³	Basin	WBID⁴	Water Segment Name	Waterbody Type
10-3236	2	4	Withlacoochee	1337A	Bypass Channel	Stream

Table - B2: Complete list of marine Florida waterbodies verified as impaired for mercury (in fish tissue). List presented includes WBIDs from the most recently completed cycle of the basin rotation (Cycle 2). Waterbodies are presented in ascending order by Basin Name and Waterbody Type.

¹Case Number assigned to each WBID when verified lists are adopted by an order signed by FDEP Secretary

²Assessment Cycle (1 or 2) during which conditions of the State's waters are evaluated

³FDEP has divided the surface waters of the State into five groups to facilitate the identification of impaired waters

⁴WBID number at the time of assessment. Subject to change if WBIDs are modified as new and better information becomes available.

OGC Case Number¹	Cycle²	Group³	Basin	WBID⁴	Water Segment Name	Waterbody Type
09-1638	2	2	Apalachicola - Chipola	1274C	Direct Runoff to Bay	Coastal
09-1627	2	2	Apalachicola - Chipola	8018	Gulf of Mexico (Franklin County; Gulf County)	Coastal
09-1643	2	2	Apalachicola - Chipola	8019	Gulf of Mexico (Franklin County)	Coastal
09-1628	2	2	Apalachicola - Chipola	8020	Gulf of Mexico (Franklin County; St. George Island)	Coastal
09-1629	2	2	Apalachicola - Chipola	8021	Gulf of Mexico (Franklin County; St. George Island)	Coastal
09-1630	2	2	Apalachicola - Chipola	8022	Gulf of Mexico (Franklin County; Dog Island)	Coastal
09-1631	2	2	Apalachicola - Chipola	8023	Gulf of Mexico (Franklin County; Dog Island)	Coastal
09-1694	2	2	Apalachicola - Chipola	8024	Gulf of Mexico (Franklin County; Alligator Harbor)	Coastal
03-2408	1	2	Charlotte Harbor	8054	Gulf of Mexico (Charlotte County; Sarasota County)	Coastal
03-2408	1	2	Charlotte Harbor	8055	Gulf of Mexico (Charlotte County; Charlotte Harbor)	Coastal
03-2408	1	2	Charlotte Harbor	8056	Gulf of Mexico (Lee County; Captiva Island)	Coastal
09-1795	2	2	Charlotte Harbor	8057	Gulf of Mexico (Lee County: Captiva Island)	Coastal
09-1796	2	2	Charlotte Harbor	8058	Gulf of Mexico (Lee County: Sanibel Island)	Coastal
09-1798	2	2	Charlotte Harbor	8059	Gulf of Mexico (Lee County: Sanibel Island)	Coastal
05-1160	1	3	Choctawhatchee - St. Andrew	8008	Gulf of Mexico (Okaloosa County)	Coastal
05-1160	1	3	Choctawhatchee - St. Andrew	8009	Gulf of Mexico (Walton County)	Coastal
05-1160	1	3	Choctawhatchee - St. Andrew	8010	Gulf of Mexico (Walton County)	Coastal
05-1160	1	3	Choctawhatchee - St. Andrew	8011	Gulf of Mexico (Walton County)	Coastal
05-1160	1	3	Choctawhatchee - St. Andrew	8012	Gulf of Mexico (Bay County)	Coastal
05-1160	1	3	Choctawhatchee - St. Andrew	8013	Gulf of Mexico (Bay County)	Coastal
05-1160	1	3	Choctawhatchee - St. Andrew	8014	Gulf of Mexico (Bay County; St Andrew Bay)	Coastal
05-1160	1	3	Choctawhatchee - St. Andrew	8015	Gulf of Mexico (Bay County; St Andrew Bay)	Coastal

OGC Case Number¹	Cycle²	Group³	Basin	WBID⁴	Water Segment Name	Waterbody Type
05-1160	1	3	Choctawhatchee - St. Andrew	8016	Gulf of Mexico (Gulf County; St Joseph Peninsula)	Coastal
05-1160	1	3	Choctawhatchee - St. Andrew	8017	Gulf of Mexico (Gulf County; St Joseph Peninsula)	Coastal
09-1032	1	5	Everglades	8066	Gulf of Mexico (Everglades National Park)	Coastal
09-1032	1	5	Everglades	8067	Gulf of Mexico (Everglades National Park)	Coastal
09-1032	1	5	Everglades	8068	Gulf of Mexico (Everglades National Park)	Coastal
09-1032	1	5	Everglades	8069	Gulf of Mexico (Everglades National Park; Cape Sable)	Coastal
09-1032	1	5	Everglades	8070	Gulf of Mexico (Everglades National Park; Cape Sable)	Coastal
09-2719	2	1	Everglades West Coast	8060	Gulf of Mexico (Lee County; Estero Bay)	Coastal
09-2719	2	1	Everglades West Coast	8061	Gulf of Mexico (Lee County)	Coastal
09-2719	2	1	Everglades West Coast	8062	Gulf of Mexico (Collier County)	Coastal
09-2719	2	1	Everglades West Coast	8063	Gulf of Mexico (Collier County; Rookery Bay-Naples)	Coastal
09-2719	2	1	Everglades West Coast	8064	Gulf of Mexico (Collier County; Marco Island)	Coastal
09-2719	2	1	Everglades West Coast	8065	Gulf of Mexico (Monroe County; Collier County)	Coastal
09-0968	1	5	Florida Keys	6006A	South Key Largo	Coastal
09-0968	1	5	Florida Keys	6006B	Middle Key Largo	Coastal
09-0968	1	5	Florida Keys	6006C	North Key Largo	Coastal
09-0968	1	5	Florida Keys	6009	Plantation Key	Coastal
09-0968	1	5	Florida Keys	6010	Long Key	Coastal
09-0968	1	5	Florida Keys	6011A	Vaca Key	Coastal
09-0968	1	5	Florida Keys	6011C	Grassey Key	Coastal
09-0968	1	5	Florida Keys	6012A	Big Pine Key	Coastal
09-0968	1	5	Florida Keys	6012C	No Name Key	Coastal
09-0968	1	5	Florida Keys	6012D	Long Beach	Coastal
09-0968	1	5	Florida Keys	6012E	Big Torch Key	Coastal
09-0968	1	5	Florida Keys	6013A	Saddlebunch Keys	Coastal
09-0968	1	5	Florida Keys	6013B	Sugarloaf	Coastal
09-0968	1	5	Florida Keys	6013C	Cudjoe Key	Coastal
09-0968	1	5	Florida Keys	6013D	Little Knockemdown Key	Coastal
09-0968	1	5	Florida Keys	6014A	Key West	Coastal
09-0968	1	5	Florida Keys	6014B	Stock Island	Coastal
09-0968	1	5	Florida Keys	6014C	Us Naval Air Station Key West	Coastal
09-0968	1	5	Florida Keys	6016	Duck Key	Coastal
09-0968	1	5	Florida Keys	6017	Upper Matecumbe Key	Coastal
09-0968	1	5	Florida Keys	6018	Bahia Honda State Park	Coastal
09-0968	1	5	Florida Keys	6019	Lower Matecumbe Key	Coastal
09-0968	1	5	Florida Keys	8071	Florida Bay (Everglades National Park; Flamingo)	Coastal
09-0968	1	5	Florida Keys	8072	Dry Tortugas	Coastal

OGC Case Number¹	Cycle²	Group³	Basin	WBID⁴	Water Segment Name	Waterbody Type
09-0968	1	5	Florida Keys	8073	Key West And Outlying Islands	Coastal
09-0968	1	5	Florida Keys	8074	Gulf of Mexico (Monroe County; Key West-Cudjoe Key)	Coastal
09-0968	1	5	Florida Keys	8075	Gulf of Mexico (Monroe County; Bahia Honda-Cudjoe Key)	Coastal
09-0968	1	5	Florida Keys	8076	Gulf of Mexico (Monroe County; Marathon)	Coastal
09-0968	1	5	Florida Keys	8077	Florida Bay (Middle Keys)	Coastal
09-0968	1	5	Florida Keys	8078	Florida Bay (Upper Keys)	Coastal
09-0968	1	5	Florida Keys	8079	Atlantic Ocean (Monroe County; Cudjoe Key-Key West)	Coastal
09-0968	1	5	Florida Keys	8080	Atlantic Ocean (Monroe County; Bahia Honda-Cudjoe Key)	Coastal
09-0968	1	5	Florida Keys	8081	Atlantic Ocean (Monroe County; Marathon)	Coastal
09-0968	1	5	Florida Keys	8082	Atlantic Ocean (Monroe County; Marathon)	Coastal
09-0968	1	5	Florida Keys	8083	Atlantic Ocean (Monroe County; Long Key)	Coastal
09-0968	1	5	Florida Keys	8084	Atlantic Ocean (Monroe County; Islamorada)	Coastal
09-0968	1	5	Florida Keys	8085	Atlantic Ocean (Monroe County; Islamorada)	Coastal
09-0968	1	5	Florida Keys	8086	Atlantic Ocean (Monroe County; Key Largo-Tavernier)	Coastal
09-0968	1	5	Florida Keys	8087	Atlantic Ocean (Monroe County; Key Largo)	Coastal
09-1272	1	5	Indian River Lagoon	8105	Atlantic Ocean (Indian River County)	Coastal
09-1272	1	5	Indian River Lagoon	8106	Atlantic Ocean (Indian River County; Sebastian Inlet)	Coastal
09-1272	1	5	Indian River Lagoon	8107	Atlantic Ocean (Brevard County; Sebastian Inlet)	Coastal
09-1272	1	5	Indian River Lagoon	8108	Atlantic Ocean (Brevard County)	Coastal
09-1272	1	5	Indian River Lagoon	8109	Atlantic Ocean (Brevard County)	Coastal
09-1272	1	5	Indian River Lagoon	8110	Atlantic Ocean (Brevard County)	Coastal
09-1272	1	5	Indian River Lagoon	8111	Atlantic Ocean (Brevard County; Cape Canaveral)	Coastal
09-1272	1	5	Indian River Lagoon	8112	Atlantic Ocean (Brevard County)	Coastal
09-1272	1	5	Indian River Lagoon	8113	Atlantic Ocean (Brevard County)	Coastal
09-1272	1	5	Indian River Lagoon	8114	Atlantic Ocean (Volusia County)	Coastal
09-1272	1	5	Indian River Lagoon	8115	Atlantic Ocean (Volusia County)	Coastal
09-1272	1	5	Indian River Lagoon	8116	Atlantic Ocean (Volusia County; Ponce Inlet)	Coastal
05-1175	1	3	Lake Worth Lagoon - Palm Beach Coast	8096	Atlantic Ocean (Palm Beach County/Broward County)	Coastal
05-1175	1	3	Lake Worth Lagoon - Palm Beach Coast	8097	Atlantic Ocean (Palm Beach County)	Coastal
05-1175	1	3	Lake Worth Lagoon - Palm Beach Coast	8098	Atlantic Ocean (Palm Beach County)	Coastal

OGC Case Number¹	Cycle²	Group³	Basin	WBID⁴	Water Segment Name	Waterbody Type
05-1175	1	3	Lake Worth Lagoon - Palm Beach Coast	8099	Atlantic Ocean (Palm Beach County)	Coastal
05-1175	1	3	Lake Worth Lagoon - Palm Beach Coast	8100	Atlantic Ocean (Palm Beach County; Lake Worth Inlet)	Coastal
09-2566	2	2	Lower St. Johns	8126	Atlantic Ocean (St. Johns River; Duval County)	Coastal
10-3132	2	4	Nassau - St. Marys	8127	Atlantic Ocean (St Johns River; Duval County)	Coastal
06-0580	1	4	Nassau - St. Marys	8128	Atlantic Ocean (Nassau County)	Coastal
06-0580	1	4	Nassau - St. Marys	8129	Atlantic Ocean (St Mary'S River; Nassau County)	Coastal
09-1997	2	1	Ochlockonee - St. Marks	8025	Gulf of Mexico (Franklin County; Ochlockonee Bay)	Coastal
09-1997	2	1	Ochlockonee - St. Marks	8026	Gulf of Mexico (Wakulla County; Apalachee Bay)	Coastal
09-1997	2	1	Ochlockonee - St. Marks	8027	Gulf of Mexico (Wakulla County; St Marks River)	Coastal
09-1997	2	1	Ochlockonee - St. Marks	8028	Gulf of Mexico (Jefferson County; Wakulla County)	Coastal
06-0623	1	4	Pensacola	8002	Gulf of Mexico (Escambia County; Pensacola Bay)	Coastal
06-0623	1	4	Pensacola	8003	Gulf of Mexico (Escambia County; Santa Rosa Island)	Coastal
06-0623	1	4	Pensacola	8004	Gulf of Mexico (Escambia County; Santa Rosa Island)	Coastal
06-0623	1	4	Pensacola	8005	Gulf of Mexico (Santa Rosa County; Santa Rosa Island)	Coastal
06-0623	1	4	Pensacola	8006	Gulf of Mexico (Okaloosa County; Santa Rosa County)	Coastal
06-0623	1	4	Pensacola	8007	Gulf of Mexico (Okaloosa County; Choctawhatchee Bay)	Coastal
09-0969	1	5	Perdido	8001	Gulf of Mexico (Escambia County; Perdido Bay)	Coastal
05-1282	1	3	Sarasota Bay - Peace - Myakka	8050	Gulf of Mexico (Manatee County; Sarasota Bay)	Coastal
05-1282	1	3	Sarasota Bay - Peace - Myakka	8051	Gulf of Mexico (Sarasota County; Siesta Key)	Coastal
05-1282	1	3	Sarasota Bay - Peace - Myakka	8052	Gulf of Mexico (Sarasota County)	Coastal
05-1282	1	3	Sarasota Bay - Peace - Myakka	8053	Gulf of Mexico (Sarasota County; Venice Inlet)	Coastal
06-0657	1	4	Southeast Coast - Biscayne Bay	8088	Atlantic Ocean (Monroe County; Key Largo North)	Coastal
06-0657	1	4	Southeast Coast - Biscayne Bay	8089	Atlantic Ocean (Miami-Dade County; Elliot Key)	Coastal
06-0657	1	4	Southeast Coast - Biscayne Bay	8090	Atlantic Ocean (Miami-Dade County; Biscayne Bay)	Coastal
06-0657	1	4	Southeast Coast - Biscayne Bay	8091	Atlantic Ocean (Miami-Dade County; Biscayne Bay)	Coastal
06-0657	1	4	Southeast Coast - Biscayne Bay	8092	Atlantic Ocean (Miami-Dade County; Port of Miami)	Coastal
06-0657	1	4	Southeast Coast - Biscayne Bay	8093	Atlantic Ocean (Miami-Dade County; North Dade Inlet)	Coastal

OGC Case Number¹	Cycle²	Group³	Basin	WBID⁴	Water Segment Name	Waterbody Type
06-0657	1	4	Southeast Coast - Biscayne Bay	8094	Atlantic Ocean (Broward County; Port Everglades)	Coastal
06-0657	1	4	Southeast Coast - Biscayne Bay	8095	Atlantic Ocean (Broward County)	Coastal
09-1099	1	5	Springs Coast	8039	Gulf of Mexico (Citrus County; Crystal River)	Coastal
09-1099	1	5	Springs Coast	8040	Gulf of Mexico (Citrus County)	Coastal
12-0532	2	5	Springs Coast	8041A	Gulf of Mexico (Citrus County)	Coastal
12-0533	2	5	Springs Coast	8041B	Gulf of Mexico (Hernando County)	Coastal
09-1099	1	5	Springs Coast	8042	Gulf of Mexico (Hernando County)	Coastal
09-1099	1	5	Springs Coast	8043	Gulf of Mexico (Pasco County; Hernando County)	Coastal
09-1099	1	5	Springs Coast	8044	Gulf of Mexico (Pasco County; Port Richey)	Coastal
09-1099	1	5	Springs Coast	8045C	Gulf of Mexico (Pinellas County; Pasco County)	Coastal
09-1099	1	5	Springs Coast	8045D	St. Joseph Sound	Coastal
09-1099	1	5	Springs Coast	8046	Gulf of Mexico (Pinellas County)	Coastal
09-1099	1	5	Springs Coast	8047	Gulf of Mexico (Pinellas County)	Coastal
09-1099	1	5	Springs Coast	8048	Gulf of Mexico (Pinellas County)	Coastal
12-0573	2	2	St. Lucie - Loxahatchee	8101	Atlantic Ocean (Martin County/Palm Beach County)	Coastal
12-0574	2	2	St. Lucie - Loxahatchee	8102	Atlantic Ocean (Martin County; St Lucie Inlet)	Coastal
09-1929	2	1	Suwannee	8029	Gulf of Mexico (Taylor County; Econfina River)	Coastal
09-1929	2	1	Suwannee	8030	Gulf of Mexico (Taylor County; Fenholloway River)	Coastal
09-1929	2	1	Suwannee	8031	Gulf of Mexico (Taylor County)	Coastal
09-1929	2	1	Suwannee	8032	Gulf of Mexico (Taylor County)	Coastal
09-1929	2	1	Suwannee	8033	Gulf of Mexico (Taylor County; Steinhatchee River)	Coastal
09-1929	2	1	Suwannee	8034	Gulf of Mexico (Dixie County)	Coastal
09-1929	2	1	Suwannee	8035	Gulf of Mexico (Dixie County)	Coastal
09-1929	2	1	Suwannee	8037	Gulf of Mexico (Levy County; Cedar Key)	Coastal
09-1929	2	1	Suwannee	8038	Gulf of Mexico (Levy County; Withlacoochee River)	Coastal
09-2512	2	1	Tampa Bay	8049	Gulf of Mexico (Manatee County; Hillsborough County)	Coastal
09-1195	1	5	Upper East Coast	8117	Atlantic Ocean (Volusia County)	Coastal
09-1195	1	5	Upper East Coast	8118	Atlantic Ocean (Volusia County)	Coastal
09-1195	1	5	Upper East Coast	8119	Atlantic Ocean (Flagler County)	Coastal
09-1195	1	5	Upper East Coast	8120	Atlantic Ocean (Flagler County)	Coastal
09-1195	1	5	Upper East Coast	8121	Atlantic Ocean (St Johns County; Matanzas Inlet)	Coastal
09-1195	1	5	Upper East Coast	8122	Atlantic Ocean (St Johns County)	Coastal
09-1195	1	5	Upper East Coast	8123	Atlantic Ocean (St Johns County; St Augustine Inlet)	Coastal

OGC Case Number¹	Cycle²	Group³	Basin	WBID⁴	Water Segment Name	Waterbody Type
09-1195	1	5	Upper East Coast	8124	Atlantic Ocean (St Johns County)	Coastal
09-1195	1	5	Upper East Coast	8125	Atlantic Ocean (St Johns County)	Coastal
09-1695	2	2	Apalachicola - Chipola	1034A	New River	Estuary
09-1654	2	2	Apalachicola - Chipola	1228	Bird Bay	Estuary
09-1685	2	2	Apalachicola - Chipola	1256	Alligator Harbor	Estuary
09-1617	2	2	Apalachicola - Chipola	1266	St. George Sound	Estuary
09-1619	2	2	Apalachicola - Chipola	1274	Apalachicola Bay	Estuary
09-1634	2	2	Apalachicola - Chipola	1274A	East Bay	Estuary
09-1635	2	2	Apalachicola - Chipola	1274B	Apalachicola Bay	Estuary
09-1689	2	2	Apalachicola - Chipola	1278	East Bayou	Estuary
09-1691	2	2	Apalachicola - Chipola	1279	West Bayou	Estuary
09-1693	2	2	Apalachicola - Chipola	1283	Blounts Bay	Estuary
09-1620	2	2	Apalachicola - Chipola	1288	Money Bayou	Estuary
09-1622	2	2	Apalachicola - Chipola	1289	Direct Runoff to Bay	Estuary
09-1624	2	2	Apalachicola - Chipola	1291	Indian Lagoon	Estuary
09-1626	2	2	Apalachicola - Chipola	1292	Direct Runoff to Bay	Estuary
10-0406	2	3	Caloosahatchee	3240A	Caloosahatchee Estuary (Tidal Segment1)	Estuary
10-0407	2	3	Caloosahatchee	3240A1	Cape Coral (Tidal Segment)	Estuary
10-0410	2	3	Caloosahatchee	3240A4	Deep Lagoon Canal	Estuary
10-0412	2	3	Caloosahatchee	3240B	Caloosahatchee Estuary (Tidal Segment2)	Estuary
10-0414	2	3	Caloosahatchee	3240B2	Chapel Creek / Bayshore Creek (Marine Se	Estuary
10-0416	2	3	Caloosahatchee	3240E	Yellow Fever Creek	Estuary
10-0405	2	3	Caloosahatchee	3240E1	Hancock Creek	Estuary
10-0417	2	3	Caloosahatchee	3240I	Manuel Branch	Estuary
10-0424	2	3	Caloosahatchee	3240J	Billy Creek	Estuary
09-1748	2	2	Charlotte Harbor	1983A	Lemon Bay	Estuary
09-1750	2	2	Charlotte Harbor	1983B	Lemon Bay	Estuary
09-1751	2	2	Charlotte Harbor	2021	Direct Runoff to Bay	Estuary
09-1752	2	2	Charlotte Harbor	2030	Alligator Creek Tidal	Estuary
09-1756	2	2	Charlotte Harbor	2039	Forked Creek	Estuary
09-1760	2	2	Charlotte Harbor	2042	Direct Runoff to Bay	Estuary
09-1764	2	2	Charlotte Harbor	2049	Gottfried Creek	Estuary
09-1765	2	2	Charlotte Harbor	2051	Direct Runoff to Bay	Estuary
09-1766	2	2	Charlotte Harbor	2052	Rock Creek	Estuary
03-2396	1	2	Charlotte Harbor	2065A	Charlotte Harbor Upper	Estuary
03-2397	1	2	Charlotte Harbor	2065B	Charlotte Harbor Mid	Estuary
03-2400	1	2	Charlotte Harbor	2065C	Charlotte Harbor Mid	Estuary
03-2401	1	2	Charlotte Harbor	2065D	Charlotte Harbor Lower	Estuary
09-1779	2	2	Charlotte Harbor	2065E	Pine Island Sound (Upper Segment)	Estuary
09-1780	2	2	Charlotte Harbor	2065F	Matlacha Pass	Estuary
09-1781	2	2	Charlotte Harbor	2065G	Pine Island Sound Lowr	Estuary
09-1782	2	2	Charlotte Harbor	2065H	San Carlos Bay	Estuary
09-1767	2	2	Charlotte Harbor	2067	Oyster Creek	Estuary

OGC Case Number¹	Cycle²	Group³	Basin	WBID⁴	Water Segment Name	Waterbody Type
09-1768	2	2	Charlotte Harbor	2068	Buck Creek	Estuary
09-1770	2	2	Charlotte Harbor	2072	Direct Runoff to Bay	Estuary
09-1742	2	2	Charlotte Harbor	2073	Mangrove Point Canal	Estuary
09-1771	2	2	Charlotte Harbor	2075A	Manasota Key	Estuary
09-1772	2	2	Charlotte Harbor	2075B	Barrier Island	Estuary
09-1773	2	2	Charlotte Harbor	2075C	Barrier Island	Estuary
09-1774	2	2	Charlotte Harbor	2075D	Barrier Island	Estuary
09-1775	2	2	Charlotte Harbor	2076	Direct Runoff to Bay	Estuary
09-1776	2	2	Charlotte Harbor	2078A	Coral Creek	Estuary
09-1778	2	2	Charlotte Harbor	2078B	Coral Creek (East Branch)	Estuary
09-1744	2	2	Charlotte Harbor	2087	Direct Runoff to Bay	Estuary
09-1745	2	2	Charlotte Harbor	2090	Direct Runoff to Bay	Estuary
09-1746	2	2	Charlotte Harbor	2092B	Gasparilla Island	Estuary
09-1786	2	2	Charlotte Harbor	2092C	North Captiva Island	Estuary
09-1787	2	2	Charlotte Harbor	2092D	Captiva Island	Estuary
09-1789	2	2	Charlotte Harbor	2092E	Pine Island	Estuary
09-1793	2	2	Charlotte Harbor	3240O	Punta Rasa Cove	Estuary
09-1794	2	2	Charlotte Harbor	3240S	South Urban Cape Coral	Estuary
10-0478	2	3	Choctawhatchee - St. Andrew	1008	Direct Runoff to Bay	Estuary
10-0479	2	3	Choctawhatchee - St. Andrew	1026	Alligator Bayou	Estuary
10-0480	2	3	Choctawhatchee - St. Andrew	1040	Direct Runoff to Gulf	Estuary
10-0481	2	3	Choctawhatchee - St. Andrew	1043	Direct Runoff to Bay	Estuary
10-0482	2	3	Choctawhatchee - St. Andrew	1057	Newman Bayou	Estuary
10-0532	2	3	Choctawhatchee - St. Andrew	1061A	West Bay	Estuary
10-0534	2	3	Choctawhatchee - St. Andrew	1061B	St Andrews Bay (North Segment)	Estuary
10-0535	2	3	Choctawhatchee - St. Andrew	1061C	St Andrews Bay (Middle Segment)	Estuary
10-0536	2	3	Choctawhatchee - St. Andrew	1061D	East Bay (West Segment)	Estuary
10-0537	2	3	Choctawhatchee - St. Andrew	1061E	St Andrews Bay (Mouth)	Estuary
10-0538	2	3	Choctawhatchee - St. Andrew	1061F	East Bay (East Segment)	Estuary
10-0540	2	3	Choctawhatchee - St. Andrew	1061G	North Bay (North Segment1)	Estuary
10-0541	2	3	Choctawhatchee - St. Andrew	1061H	North Bay (North Segment2)	Estuary
10-0485	2	3	Choctawhatchee - St. Andrew	1084	Direct Runoff to Bay	Estuary
10-0486	2	3	Choctawhatchee - St. Andrew	1086	Mill Bayou	Estuary
10-0488	2	3	Choctawhatchee - St. Andrew	1088	Beatty Bayou	Estuary

OGC Case Number¹	Cycle²	Group³	Basin	WBID⁴	Water Segment Name	Waterbody Type
10-0489	2	3	Choctawhatchee - St. Andrew	1092	Basin Bayou	Estuary
10-0490	2	3	Choctawhatchee - St. Andrew	1098	Goose Bayou (Upper Segment)	Estuary
10-0491	2	3	Choctawhatchee - St. Andrew	1099	Botheration Bayou	Estuary
10-0492	2	3	Choctawhatchee - St. Andrew	1105	Harrison Bayou	Estuary
10-0493	2	3	Choctawhatchee - St. Andrew	1106	Direct Runoff to Bay	Estuary
10-0494	2	3	Choctawhatchee - St. Andrew	1110	Calloway Bayou	Estuary
10-0497	2	3	Choctawhatchee - St. Andrew	1113	Goose Bayou	Estuary
10-0498	2	3	Choctawhatchee - St. Andrew	1114	Direct Runoff to Bay	Estuary
10-0499	2	3	Choctawhatchee - St. Andrew	1119	Unnamed Bayou	Estuary
10-0500	2	3	Choctawhatchee - St. Andrew	1120	Woodlawn Canal	Estuary
10-0502	2	3	Choctawhatchee - St. Andrew	1123	Robinson Bayou	Estuary
10-0503	2	3	Choctawhatchee - St. Andrew	1127	Laird Bayou	Estuary
10-0505	2	3	Choctawhatchee - St. Andrew	1128	Pretty Bayou	Estuary
10-0507	2	3	Choctawhatchee - St. Andrew	1131	Johnson Bayou	Estuary
10-0509	2	3	Choctawhatchee - St. Andrew	1136	Watson Bayou	Estuary
12-0595	2	3	Choctawhatchee - St. Andrew	1141B	Parker Bayou	Estuary
10-0512	2	3	Choctawhatchee - St. Andrew	1144	Massalina Bayou	Estuary
10-0514	2	3	Choctawhatchee - St. Andrew	1161	Direct Runoff to Bay	Estuary
10-0516	2	3	Choctawhatchee - St. Andrew	1170	Direct Runoff to Bay	Estuary
10-0517	2	3	Choctawhatchee - St. Andrew	1171	California Bayou	Estuary
10-0518	2	3	Choctawhatchee - St. Andrew	1172	Pitts Bay	Estuary
10-0521	2	3	Choctawhatchee - St. Andrew	1196	Fred Bayou	Estuary
10-0523	2	3	Choctawhatchee - St. Andrew	1209	Eagle Nest Bayou	Estuary
10-0524	2	3	Choctawhatchee - St. Andrew	1211	Ammo Lake Bayou	Estuary
10-0525	2	3	Choctawhatchee - St. Andrew	1212	Direct Runoff to Gulf	Estuary
10-0526	2	3	Choctawhatchee - St. Andrew	1230	Walker Bayou	Estuary

OGC Case Number¹	Cycle²	Group³	Basin	WBID⁴	Water Segment Name	Waterbody Type
10-0527	2	3	Choctawhatchee - St. Andrew	1235	Farmdale Bayou	Estuary
10-0528	2	3	Choctawhatchee - St. Andrew	1238	Panther Swamp	Estuary
10-0529	2	3	Choctawhatchee - St. Andrew	1254	Browns Bay	Estuary
10-0530	2	3	Choctawhatchee - St. Andrew	1267	St Joseph Bay	Estuary
10-0531	2	3	Choctawhatchee - St. Andrew	1270	Direct Runoff to Gulf	Estuary
10-0436	2	3	Choctawhatchee - St. Andrew	692	Boggy Bayou	Estuary
10-0439	2	3	Choctawhatchee - St. Andrew	722	Rocky Bayou	Estuary
10-0440	2	3	Choctawhatchee - St. Andrew	731	Alaqua Bayou	Estuary
10-0442	2	3	Choctawhatchee - St. Andrew	754	Poquito Bayou	Estuary
10-0443	2	3	Choctawhatchee - St. Andrew	770	Alaqua Creek Outlet	Estuary
05-1160	1	3	Choctawhatchee - St. Andrew	778A	Choctawhatchee Bay (Lower Segment)	Estuary
05-1160	1	3	Choctawhatchee - St. Andrew	778B	Choctawhatchee Bay (Middle Segment1)	Estuary
05-1160	1	3	Choctawhatchee - St. Andrew	778C	Choctawhatchee Bay (Middle Segment2)	Estuary
05-1160	1	3	Choctawhatchee - St. Andrew	778D	Choctawhatchee Bay (Upper Segment)	Estuary
10-0444	2	3	Choctawhatchee - St. Andrew	786	Garnier Bayou	Estuary
10-0445	2	3	Choctawhatchee - St. Andrew	789	Lagrange Bayou	Estuary
10-0446	2	3	Choctawhatchee - St. Andrew	843	Cinco Bayou	Estuary
10-0448	2	3	Choctawhatchee - St. Andrew	906	Joes Bayou	Estuary
10-0449	2	3	Choctawhatchee - St. Andrew	917	Indian Bayou	Estuary
10-0465	2	3	Choctawhatchee - St. Andrew	917A	Destin Harbor	Estuary
10-0450	2	3	Choctawhatchee - St. Andrew	937	Mack Bayou	Estuary
10-0451	2	3	Choctawhatchee - St. Andrew	944	Hewett Bayou	Estuary
10-0452	2	3	Choctawhatchee - St. Andrew	957	Mussett Bayou	Estuary
10-0453	2	3	Choctawhatchee - St. Andrew	972	Bowman Bayou	Estuary
10-0477	2	3	Choctawhatchee - St. Andrew	973	Crooked Creek	Estuary
10-0454	2	3	Choctawhatchee - St. Andrew	978	Little Bayou	Estuary

OGC Case Number¹	Cycle²	Group³	Basin	WBID⁴	Water Segment Name	Waterbody Type
10-0455	2	3	Choctawhatchee - St. Andrew	980	McQuage Bayou	Estuary
09-1022	1	5	Everglades	3289A	Oyster Bay	Estuary
09-1022	1	5	Everglades	3289C	Last Huston Bay	Estuary
09-1022	1	5	Everglades	3289D	Chevelier Bay	Estuary
09-1022	1	5	Everglades	3289E	Chevelier Bay	Estuary
09-1022	1	5	Everglades	3289G	Cannon Bay	Estuary
09-1022	1	5	Everglades	3289H	Lostmans Bay (Everglades National Park)	Estuary
09-1022	1	5	Everglades	3289I	Bays Near Flamingo (Everglades National Park)	Estuary
09-1022	1	5	Everglades	3289L	Alligator Bay	Estuary
09-1022	1	5	Everglades	3289M	Dads Bay	Estuary
09-1032	1	5	Everglades	3289N	Little Maderia Bay	Estuary
09-1032	1	5	Everglades	3289O	Joe Bay (West Segment)	Estuary
09-1032	1	5	Everglades	3289P	Alligator Bay	Estuary
09-1032	1	5	Everglades	3289Q	Sunday Bay	Estuary
09-1025	1	5	Everglades	3303G	Joe Bay East	Estuary
09-1026	1	5	Everglades	3303H	Davis Cove	Estuary
09-2719	2	1	Everglades West Coast	3258A	Estero Bay Wetlands	Estuary
09-2719	2	1	Everglades West Coast	3258B1	Hendry Creek (Marine Segment)	Estuary
09-2719	2	1	Everglades West Coast	3258C1	Estero Bay Drainage (Marine Segment)	Estuary
09-2719	2	1	Everglades West Coast	3258D1	Estero River (Marine Segment)	Estuary
09-2719	2	1	Everglades West Coast	3258E1	Imperial River (Marine Segment)	Estuary
09-2719	2	1	Everglades West Coast	3258H1	Spring Creek (Marine Segment)	Estuary
09-2719	2	1	Everglades West Coast	3258I	Estero Bay	Estuary
09-2719	2	1	Everglades West Coast	3258J	Hell Peckney Bay	Estuary
09-2719	2	1	Everglades West Coast	3259M	Ten Thousand Islands	Estuary
09-2719	2	1	Everglades West Coast	3278Q	Naples	Estuary
09-2719	2	1	Everglades West Coast	3278R	Naples Bay (Coastal Segment)	Estuary
09-2719	2	1	Everglades West Coast	3278U	Rookery Bay (Coastal Segment)	Estuary
12-0429	2	5	Florida Keys	6002	Manatee Bay	Estuary
12-0430	2	5	Florida Keys	6003	Barnes Sound	Estuary
12-0431	2	5	Florida Keys	6005	Long Sound	Estuary
12-0432	2	5	Florida Keys	6005A	Little Blackwater Sound	Estuary
12-0433	2	5	Florida Keys	6005B	Blackwater Sound	Estuary
12-0434	2	5	Florida Keys	6006Z	Pumpkin Key	Estuary
12-0435	2	5	Florida Keys	6011B	Key Colony	Estuary
09-1210	1	5	Indian River Lagoon	2924	Mosquito Lagoon	Estuary
12-0291	2	5	Indian River Lagoon	2924B1	Mosquito Lagoon (Shellfish Portion)	Estuary
12-0292	2	5	Indian River Lagoon	2924B2	Mosquito Lagoon	Estuary
12-0294	2	5	Indian River Lagoon	2942A	Turnbull Creek (Marine Segment)	Estuary
12-0296	2	5	Indian River Lagoon	2963B1	Indian River Above Melbourne Causeway	Estuary
12-0297	2	5	Indian River Lagoon	2963C1	Indian River Above Melbourne Causeway (Shellfish Portion)	Estuary

OGC Case Number¹	Cycle²	Group³	Basin	WBID⁴	Water Segment Name	Waterbody Type
12-0298	2	5	Indian River Lagoon	2963D1	Indian River Above 520 Causeway	Estuary
09-1240	1	5	Indian River Lagoon	2963E	Indian River Above Nasa Cswy.	Estuary
12-0299	2	5	Indian River Lagoon	2963EA	Indian River Above Nasa Causeway	Estuary
12-0300	2	5	Indian River Lagoon	2963F1	Indian River Above Max Brewer Causeway	Estuary
09-1198	1	5	Indian River Lagoon	3044A	Newfound Harbor	Estuary
09-1199	1	5	Indian River Lagoon	3044B	Sykes Creek/Barge Canal	Estuary
09-1202	1	5	Indian River Lagoon	3057A	Banana River Below 520 Cswy.	Estuary
09-1204	1	5	Indian River Lagoon	3057B	Banana River Above 520 Cswy.	Estuary
09-1207	1	5	Indian River Lagoon	3057C	Banana River Above Barge Canal	Estuary
12-0303	2	5	Indian River Lagoon	3081	Horse Creek	Estuary
09-1222	1	5	Indian River Lagoon	3082	Eau Gallie River	Estuary
09-1227	1	5	Indian River Lagoon	3085A	Crane Creek	Estuary
12-0307	2	5	Indian River Lagoon	3098A	Palm Bay And Turkey Creek (Estuarine Segment)	Estuary
12-0310	2	5	Indian River Lagoon	3098C	Residential Drains to Turkey Creek	Estuary
12-0312	2	5	Indian River Lagoon	3107A	Goat Creek (Marine Segment)	Estuary
09-1251	1	5	Indian River Lagoon	3129A	Sebastian River Above Indian River	Estuary
12-0318	2	5	Indian River Lagoon	3129B1	South Prong St. Sebastian River (Estuarine Segment)	Estuary
12-0321	2	5	Indian River Lagoon	3135A	C-54 Canal at Confluence With St. Sebastian River	Estuary
12-0325	2	5	Indian River Lagoon	5003B1	South Indian River (Below S.R. 60)	Estuary
12-0326	2	5	Indian River Lagoon	5003B2	South Indian River (Below S.R. 60 - Shelffish Portion)	Estuary
12-0327	2	5	Indian River Lagoon	5003D1	South Indian River (Near St. Sebastian River)	Estuary
10-0083	2	3	Lake Worth Lagoon - Palm Beach Coast	3226E	ICWW Above Royal Palm Bridge	Estuary
05-1175	1	3	Lake Worth Lagoon - Palm Beach Coast	3226E1	Lake Worth Lagoon (Northern Segment)	Estuary
10-0085	2	3	Lake Worth Lagoon - Palm Beach Coast	3226F	ICWW Above Pompano	Estuary
10-0087	2	3	Lake Worth Lagoon - Palm Beach Coast	3226F1	Lake Worth Lagoon (Central Segment)	Estuary
10-0088	2	3	Lake Worth Lagoon - Palm Beach Coast	3226F2	Lake Worth Lagoon (Southern Segment)	Estuary
09-2567	2	2	Lower St. Johns	2188	Clapboard Creek	Estuary
09-2568	2	2	Lower St. Johns	2191	Broward River	Estuary
09-2588	2	2	Lower St. Johns	2203A	Trout River (Lower Reach)	Estuary
09-2569	2	2	Lower St. Johns	2205A	Sisters Creek	Estuary
09-2570	2	2	Lower St. Johns	2205B	Cedar Point Creek	Estuary
09-2563	2	2	Lower St. Johns	2205C	ICWW	Estuary
09-2571	2	2	Lower St. Johns	2209	Browns Creek	Estuary
09-2572	2	2	Lower St. Johns	2213A	St. Johns River Above Mouth	Estuary
09-2573	2	2	Lower St. Johns	2213B	St. Johns River Above ICWW	Estuary

OGC Case Number¹	Cycle²	Group³	Basin	WBID⁴	Water Segment Name	Waterbody Type
09-2574	2	2	Lower St. Johns	2213C	St. Johns River Above Dames Point	Estuary
09-2575	2	2	Lower St. Johns	2213D	St. Johns River Above Trout River	Estuary
09-2576	2	2	Lower St. Johns	2213E	St. Johns River Above Warren Bridge	Estuary
09-2577	2	2	Lower St. Johns	2213F	St. Johns River Above Piney Point	Estuary
09-2589	2	2	Lower St. Johns	2228	Moncrief Creek	Estuary
09-2578	2	2	Lower St. Johns	2265A	Arlington River	Estuary
09-2564	2	2	Lower St. Johns	2283	Pablo Creek	Estuary
09-2565	2	2	Lower St. Johns	2328	Cabbage Creek	Estuary
06-0580	1	4	Nassau - St. Marys	2097A	St Marys River Above ICWW	Estuary
10-3114	2	4	Nassau - St. Marys	2097B	St Marys River	Estuary
10-3115	2	4	Nassau - St. Marys	2097C	St Marys River	Estuary
06-0580	1	4	Nassau - St. Marys	2124	Amelia River	Estuary
10-3116	2	4	Nassau - St. Marys	2127	Egans Creek	Estuary
10-3120	2	4	Nassau - St. Marys	2129	Lofton Creek	Estuary
10-3117	2	4	Nassau - St. Marys	2140	Jackson Creek	Estuary
10-3122	2	4	Nassau - St. Marys	2140A	Jackson Creek	Estuary
10-3123	2	4	Nassau - St. Marys	2148A	Nassau River	Estuary
06-0580	1	4	Nassau - St. Marys	2149	South Amelia River	Estuary
10-3125	2	4	Nassau - St. Marys	2170	Pumpkin Hill Creek	Estuary
10-3126	2	4	Nassau - St. Marys	2173	Deese Creek	Estuary
06-0580	1	4	Nassau - St. Marys	2174	Nassau Sound	Estuary
10-3128	2	4	Nassau - St. Marys	2176	Mill Branch Creek	Estuary
10-3129	2	4	Nassau - St. Marys	2179	Edwards Creek	Estuary
10-3130	2	4	Nassau - St. Marys	2198	Fort George River	Estuary
10-3131	2	4	Nassau - St. Marys	2198A	Marina Bay at Fort George	Estuary
09-1997	2	1	Ochlockonee - St. Marks	1071	Direct Runoff to Bay	Estuary
09-1997	2	1	Ochlockonee - St. Marks	1089	East River	Estuary
09-1997	2	1	Ochlockonee - St. Marks	1146	Spring Creek Drain	Estuary
09-1997	2	1	Ochlockonee - St. Marks	1176	Direct Runoff to Bay	Estuary
09-1997	2	1	Ochlockonee - St. Marks	1188	Walker Creek	Estuary
09-1997	2	1	Ochlockonee - St. Marks	1223	Dickerson Bay	Estuary
09-1997	2	1	Ochlockonee - St. Marks	1248A	Ochlockonee Bay	Estuary
09-1997	2	1	Ochlockonee - St. Marks	1255	Chaires Creek	Estuary
09-1997	2	1	Ochlockonee - St. Marks	793A	St Marks River (South Segment)	Estuary
06-0587	1	4	Pensacola	10F	Escambia River	Estuary
10-3041	2	4	Pensacola	24AB	Blackwater River (Tidal)	Estuary
10-3045	2	4	Pensacola	493B	Judges Bayou (Tidal Segment)	Estuary
10-3047	2	4	Pensacola	537	Jakes Bayou (Marine Portion)	Estuary
10-3048	2	4	Pensacola	539	Mulatto Bayou	Estuary
06-0623	1	4	Pensacola	548A	Escambia Bay (N)	Estuary
10-3049	2	4	Pensacola	548AA	Escambia Bay (North Segment)	Estuary
10-3052	2	4	Pensacola	548AC	Escambia Bay North (Shellfish)	Estuary
06-0623	1	4	Pensacola	548B	Escambia Bay (South Segment)	Estuary
06-0623	1	4	Pensacola	548C	Pensacola Bay (North Segment)	Estuary

OGC Case Number¹	Cycle²	Group³	Basin	WBID⁴	Water Segment Name	Waterbody Type
06-0623	1	4	Pensacola	548D	Pensacola Bay (Middle Segment)	Estuary
06-0623	1	4	Pensacola	548E	Pensacola Bay (Mouth)	Estuary
06-0623	1	4	Pensacola	548F	Bayou Grande	Estuary
06-0623	1	4	Pensacola	548G	Blackwater Bay	Estuary
10-3057	2	4	Pensacola	548GA	Blackwater Bay (North Segment)	Estuary
10-3060	2	4	Pensacola	548GB	Blackwater Bay (South Segment)	Estuary
06-0623	1	4	Pensacola	548H	East Bay	Estuary
10-3062	2	4	Pensacola	600	Direct Runoff to Bay	Estuary
10-3064	2	4	Pensacola	649	Indian Bayou	Estuary
10-3065	2	4	Pensacola	694	Trout Bayou	Estuary
06-0623	1	4	Pensacola	738	Texar Bayou	Estuary
10-3068	2	4	Pensacola	740	Bayou Grande	Estuary
10-3069	2	4	Pensacola	829	Direct Runoff to Bay	Estuary
10-3071	2	4	Pensacola	833A	Tom King Bayou	Estuary
10-3072	2	4	Pensacola	834	Direct Runoff to Bay	Estuary
06-0623	1	4	Pensacola	846	Bayou Chico	Estuary
10-3075	2	4	Pensacola	846C	Bayou Chico Drain	Estuary
10-3077	2	4	Pensacola	864	Williams Bayou	Estuary
10-3078	2	4	Pensacola	893	Direct Runoff to Bay	Estuary
06-0623	1	4	Pensacola	915	Santa Rosa Sound	Estuary
10-3080	2	4	Pensacola	925	Direct Runoff to Bay	Estuary
10-3081	2	4	Pensacola	930	Direct Runoff to Gulf	Estuary
09-0969	1	5	Perdido	1004	Big Lagoon	Estuary
09-0969	1	5	Perdido	1014	Direct Runoff to Bay	Estuary
09-0969	1	5	Perdido	1018	Direct Runoff to Bay	Estuary
09-0981	1	5	Perdido	462A	Perdido River	Estuary
09-0981	1	5	Perdido	462B	Perdido River	Estuary
09-0981	1	5	Perdido	462C	Perdido River	Estuary
09-0969	1	5	Perdido	797	Perdido Bay (Upper Segment)	Estuary
09-0969	1	5	Perdido	797A	Perdido Bay (Lower Segment)	Estuary
12-0041	2	5	Perdido	872B	Bridge Creek (Tidal Portion)	Estuary
12-0038	2	5	Perdido	935	Weekly Bayou	Estuary
09-0969	1	5	Perdido	945	Tarkiln Bayou	Estuary
09-0969	1	5	Perdido	974	Perdido Bay	Estuary
06-0623	1	4	Perdido	987	Bayou Garcon	Estuary
09-0969	1	5	Perdido	987	Bayou Garcon	Estuary
09-0969	1	5	Perdido	991	Direct Runoff to Bay	Estuary
10-0116	2	3	Sarasota Bay - Peace - Myakka	1623A	Peace River Above Thorton Branch	Estuary
10-0163	2	3	Sarasota Bay - Peace - Myakka	1862	Direct Runoff to Bay	Estuary
10-0164	2	3	Sarasota Bay - Peace - Myakka	1868	Direct Runoff to Bay	Estuary
05-1282	1	3	Sarasota Bay - Peace - Myakka	1883	Palma Sola Bay	Estuary
10-0168	2	3	Sarasota Bay - Peace - Myakka	1885	West Cedar Hammock	Estuary

OGC Case Number¹	Cycle²	Group³	Basin	WBID⁴	Water Segment Name	Waterbody Type
10-0169	2	3	Sarasota Bay - Peace - Myakka	1888	Direct Runoff to Bay	Estuary
10-0170	2	3	Sarasota Bay - Peace - Myakka	1896	Bowlees Creek	Estuary
10-0172	2	3	Sarasota Bay - Peace - Myakka	1916	Longboat Key	Estuary
10-0174	2	3	Sarasota Bay - Peace - Myakka	1924A	Cow Pen Slough (Tidal)	Estuary
10-0175	2	3	Sarasota Bay - Peace - Myakka	1931	Sarasota Coastal Drainage	Estuary
10-0178	2	3	Sarasota Bay - Peace - Myakka	1936	Whitaker Bayou (Tidal)	Estuary
10-0180	2	3	Sarasota Bay - Peace - Myakka	1947	Philippi Creek (Tidal)	Estuary
10-0181	2	3	Sarasota Bay - Peace - Myakka	1951	Direct Runoff to Bay	Estuary
10-0184	2	3	Sarasota Bay - Peace - Myakka	1953	Hudson Bayou Tidal	Estuary
10-0185	2	3	Sarasota Bay - Peace - Myakka	1954	Lido Key	Estuary
10-0186	2	3	Sarasota Bay - Peace - Myakka	1961	Direct Runoff to Bay	Estuary
05-1282	1	3	Sarasota Bay - Peace - Myakka	1968A	Anna Maria Sound	Estuary
05-1282	1	3	Sarasota Bay - Peace - Myakka	1968B	Sarasota Bay	Estuary
05-1282	1	3	Sarasota Bay - Peace - Myakka	1968C	Sarasota Bay	Estuary
05-1282	1	3	Sarasota Bay - Peace - Myakka	1968D	Roberts Bay	Estuary
05-1282	1	3	Sarasota Bay - Peace - Myakka	1968E	Little Sarasota Bay	Estuary
05-1282	1	3	Sarasota Bay - Peace - Myakka	1968F	Blackburn Bay	Estuary
10-0190	2	3	Sarasota Bay - Peace - Myakka	1975	Elligraw Bayou	Estuary
10-0193	2	3	Sarasota Bay - Peace - Myakka	1975A	Clowers Creek Estuary	Estuary
10-0195	2	3	Sarasota Bay - Peace - Myakka	1979	Siesta Key South	Estuary
10-0197	2	3	Sarasota Bay - Peace - Myakka	1982A	South Creek	Estuary
10-0200	2	3	Sarasota Bay - Peace - Myakka	1984	Catfish Creek (Tidal)	Estuary
10-0203	2	3	Sarasota Bay - Peace - Myakka	1984A	North Creek (Tidal)	Estuary
10-0100	2	3	Sarasota Bay - Peace - Myakka	1991A	Myakka River	Estuary
10-0102	2	3	Sarasota Bay - Peace - Myakka	1991B	Myakka River	Estuary
10-0103	2	3	Sarasota Bay - Peace - Myakka	1991C	Myakka River	Estuary

OGC Case Number¹	Cycle²	Group³	Basin	WBID⁴	Water Segment Name	Waterbody Type
10-0205	2	3	Sarasota Bay - Peace - Myakka	1992	Direct Runoff to Bay	Estuary
10-0206	2	3	Sarasota Bay - Peace - Myakka	1993	Casey Key	Estuary
05-1282	1	3	Sarasota Bay - Peace - Myakka	2002	Dona Bay	Estuary
10-0208	2	3	Sarasota Bay - Peace - Myakka	2009A	Curry Creek	Estuary
10-0209	2	3	Sarasota Bay - Peace - Myakka	2015	Hatchett Creek (Tidal)	Estuary
10-0210	2	3	Sarasota Bay - Peace - Myakka	2017	Direct Runoff to Bay	Estuary
05-1282	1	3	Sarasota Bay - Peace - Myakka	2018	Roberts Bay Venice	Estuary
10-0108	2	3	Sarasota Bay - Peace - Myakka	2026	Little Salt Creek (Warm Mineral Spring)	Estuary
10-0123	2	3	Sarasota Bay - Peace - Myakka	2041A	Shell Creek Below Hendrickson Dam	Estuary
10-0124	2	3	Sarasota Bay - Peace - Myakka	2046	Little Alligator Creek	Estuary
10-0111	2	3	Sarasota Bay - Peace - Myakka	2048A	Sam Knight Creek	Estuary
10-0133	2	3	Sarasota Bay - Peace - Myakka	2054	Myrtle Slough	Estuary
10-0115	2	3	Sarasota Bay - Peace - Myakka	2055	Tippecanoe Bay	Estuary
05-1255	1	3	Sarasota Bay - Peace - Myakka	2056A	Peace River Lower Estuary	Estuary
05-1256	1	3	Sarasota Bay - Peace - Myakka	2056B	Peace River Mid Estuary	Estuary
10-0138	2	3	Sarasota Bay - Peace - Myakka	2056C	Peace River Estuary(Upper Segment)	Estuary
10-0139	2	3	Sarasota Bay - Peace - Myakka	2056D	Alligator Bay	Estuary
10-0143	2	3	Sarasota Bay - Peace - Myakka	2060	Myakka Cutoff	Estuary
10-0145	2	3	Sarasota Bay - Peace - Myakka	2061	Direct Runoff to Stream	Estuary
10-0146	2	3	Sarasota Bay - Peace - Myakka	2064	Direct Runoff to Bay	Estuary
10-0147	2	3	Sarasota Bay - Peace - Myakka	2069	Punta Gorda Isles Canal	Estuary
10-0149	2	3	Sarasota Bay - Peace - Myakka	2070	Punta Gorda Isles 2 Canal	Estuary
06-0657	1	4	Southeast Coast - Biscayne Bay	3226G1	ICWW (Broward County Northern Segment)	Estuary
06-0657	1	4	Southeast Coast - Biscayne Bay	3226G2	ICWW (Broward County Central Segment)	Estuary
06-0657	1	4	Southeast Coast - Biscayne Bay	3226G3	ICWW (Broward County Southern Segment)	Estuary
06-0657	1	4	Southeast Coast - Biscayne Bay	3226G4	Las Olas Isles Finger Canal System	Estuary

OGC Case Number¹	Cycle²	Group³	Basin	WBID⁴	Water Segment Name	Waterbody Type
06-0657	1	4	Southeast Coast - Biscayne Bay	3226H	ICWW (Miami-Dade County)	Estuary
06-0657	1	4	Southeast Coast - Biscayne Bay	3226H1	ICWW (Miami-Dade County Northern Segment)	Estuary
06-0657	1	4	Southeast Coast - Biscayne Bay	3226H2	Haulover Inlet/Arch Creek	Estuary
06-0657	1	4	Southeast Coast - Biscayne Bay	3226H3	Port of Miami	Estuary
06-0657	1	4	Southeast Coast - Biscayne Bay	3226H4	Key Biscayne	Estuary
10-2838	2	4	Southeast Coast - Biscayne Bay	3226L	Oleta River (Upper Segment)	Estuary
10-2839	2	4	Southeast Coast - Biscayne Bay	3226M1	Arch Creek (Lower Segment)	Estuary
12-0606	2	4	Southeast Coast - Biscayne Bay	3226M2	Arch Creek (Upper Segment)	Estuary
10-2843	2	4	Southeast Coast - Biscayne Bay	3274	C-13 East (Middle River Canal)	Estuary
10-2845	2	4	Southeast Coast - Biscayne Bay	3276A	New River (North Fork)	Estuary
10-2847	2	4	Southeast Coast - Biscayne Bay	3277A	New River Canal (South)	Estuary
10-2850	2	4	Southeast Coast - Biscayne Bay	3277E	Dania Cutoff Canal	Estuary
10-2855	2	4	Southeast Coast - Biscayne Bay	3282	C-10 (Hollywood Canal)	Estuary
10-2857	2	4	Southeast Coast - Biscayne Bay	3288	C-6/Miami River	Estuary
10-2859	2	4	Southeast Coast - Biscayne Bay	3288A	Wagner Creek	Estuary
10-2860	2	4	Southeast Coast - Biscayne Bay	3288B	C-6/Miami River (Lower Segment)	Estuary
10-2862	2	4	Southeast Coast - Biscayne Bay	3291	DA-1	Estuary
10-2863	2	4	Southeast Coast - Biscayne Bay	3292A	Coral Gables Canal (East)	Estuary
10-2865	2	4	Southeast Coast - Biscayne Bay	3293B	C2/Snapper Creek (East)	Estuary
12-0607	2	4	Southeast Coast - Biscayne Bay	3294	Direct Runoff To Bay	Estuary
12-0608	2	4	Southeast Coast - Biscayne Bay	3296	Direct Runoff To Bay	Estuary
10-2869	2	4	Southeast Coast - Biscayne Bay	3298	Black Creek	Estuary
10-2870	2	4	Southeast Coast - Biscayne Bay	3298B	DA-4	Estuary
10-2871	2	4	Southeast Coast - Biscayne Bay	3298B1	Homestead Airport Outfall	Estuary
10-2872	2	4	Southeast Coast - Biscayne Bay	3298B2	Mowrey Canal Outfall	Estuary
10-2875	2	4	Southeast Coast - Biscayne Bay	3303B	C-111 (Coastal)	Estuary

OGC Case Number¹	Cycle²	Group³	Basin	WBID⁴	Water Segment Name	Waterbody Type
10-2876	2	4	Southeast Coast - Biscayne Bay	3303B1	Taylor Slough	Estuary
06-0657	1	4	Southeast Coast - Biscayne Bay	6001	Biscayne Bay	Estuary
06-0657	1	4	Southeast Coast - Biscayne Bay	6001C	Card Sound	Estuary
10-2878	2	4	Southeast Coast - Biscayne Bay	6002A	Route 1 Key A	Estuary
09-1099	1	5	Springs Coast	1339	Direct Runoff to Gulf	Estuary
12-0534	2	5	Springs Coast	1341	Crystal River	Estuary
09-1099	1	5	Springs Coast	1341I	Crystal River	Estuary
12-0550	2	5	Springs Coast	1345	Homosassa River (Brackish Portion)	Estuary
09-1099	1	5	Springs Coast	1345A	Crystal River Bay	Estuary
12-0551	2	5	Springs Coast	1345B	Game Creek	Estuary
12-0552	2	5	Springs Coast	1345F	Homosassa River (Shellfish Portion)	Estuary
12-0523	2	5	Springs Coast	1348	Direct Runoff to Gulf	Estuary
12-0554	2	5	Springs Coast	1348C	Otter Creek	Estuary
12-0525	2	5	Springs Coast	1348D	Baird Creek	Estuary
12-0530	2	5	Springs Coast	1361	Chassahowitzka River	Estuary
09-1099	1	5	Springs Coast	1373	Direct Runoff to Gulf	Estuary
09-1099	1	5	Springs Coast	1382	Weeki Wachee River	Estuary
12-0555	2	5	Springs Coast	1382A	Mud River - Salt Creek	Estuary
12-0558	2	5	Springs Coast	1389A	Jenkins Creek	Estuary
12-0559	2	5	Springs Coast	1389B	Minnow Creek	Estuary
12-0561	2	5	Springs Coast	1397	Direct Runoff to Gulf	Estuary
12-0562	2	5	Springs Coast	1409C	Pithlachascotee River Tidal	Estuary
09-1035	1	5	Springs Coast	1440	Anclote River Tidal	Estuary
12-0496	2	5	Springs Coast	1440A	Anclote River Bayou Complex (Spring Bayou)	Estuary
12-0499	2	5	Springs Coast	1450	Direct Runoff to Gulf	Estuary
09-1099	1	5	Springs Coast	1479	Direct Runoff to Gulf	Estuary
09-1099	1	5	Springs Coast	1508	Klosterman Bayou	Estuary
12-0503	2	5	Springs Coast	1512	Health Spring Drain / Boggy Bayou	Estuary
12-0505	2	5	Springs Coast	1527A	Sutherland Bayou	Estuary
09-1099	1	5	Springs Coast	1528	Clearwater Harbor South	Estuary
09-1099	1	5	Springs Coast	1528A	The Narrows	Estuary
09-1099	1	5	Springs Coast	1528B	Direct Runoff to Intercoastal Waterway	Estuary
09-1099	1	5	Springs Coast	1528C	Clearwater Harbor (North)	Estuary
09-1099	1	5	Springs Coast	1535	Direct Runoff to Gulf (Minnow Creek)	Estuary
09-1099	1	5	Springs Coast	1538	Curlew Creek Tidal	Estuary
09-1099	1	5	Springs Coast	1554	Direct Runoff to Gulf	Estuary
12-0508	2	5	Springs Coast	1556	Cedar Creek (Tidal)	Estuary
09-1099	1	5	Springs Coast	1562	Direct Runoff to Gulf	Estuary
09-1099	1	5	Springs Coast	1567	Stevenson Creek (Tidal Segment)	Estuary

OGC Case Number¹	Cycle²	Group³	Basin	WBID⁴	Water Segment Name	Waterbody Type
09-1099	1	5	Springs Coast	1618B	Long Bayou Runoff	Estuary
09-1099	1	5	Springs Coast	1618C	Long Bayou/Cross Bayou	Estuary
12-0512	2	5	Springs Coast	1633	McKay Creek (Tidal)	Estuary
09-1099	1	5	Springs Coast	1641	Cross Canal (South)	Estuary
09-1099	1	5	Springs Coast	1662	Pinellas Park Ditch No 1 (Tidal Segment)	Estuary
09-1099	1	5	Springs Coast	1668E	St Joe Creek (Tidal Segment)	Estuary
09-1099	1	5	Springs Coast	1694A	Boca Ciega Bay (Central)	Estuary
09-1099	1	5	Springs Coast	1694B	Boca Ciega Bay (North)	Estuary
09-1099	1	5	Springs Coast	1694C	Boca Ciega Bay	Estuary
09-1099	1	5	Springs Coast	1694D	Cross Bayou Drain	Estuary
09-1099	1	5	Springs Coast	1694F	Gulfport	Estuary
12-0513	2	5	Springs Coast	1701	Bear Creek	Estuary
12-0518	2	5	Springs Coast	1716C	Clam Bayou (East Drainage)	Estuary
12-0521	2	5	Springs Coast	1716D	Clam Bayou Drain (Tidal)	Estuary
09-1699	2	2	St. Lucie - Loxahatchee	3166	Moore'S Creek	Estuary
09-1726	2	2	St. Lucie - Loxahatchee	3194	St. Lucie River (North Fork)	Estuary
09-1731	2	2	St. Lucie - Loxahatchee	3194B	St. Lucie River (North Fork)	Estuary
09-1703	2	2	St. Lucie - Loxahatchee	3208	Manatee Pocket	Estuary
09-1704	2	2	St. Lucie - Loxahatchee	3208A	ICWW (Martin County)	Estuary
09-1734	2	2	St. Lucie - Loxahatchee	3210	St. Lucie River (South Fork)	Estuary
09-1738	2	2	St. Lucie - Loxahatchee	3210A	St. Lucie Canal	Estuary
09-1739	2	2	St. Lucie - Loxahatchee	3211	Bessey Creek	Estuary
09-1711	2	2	St. Lucie - Loxahatchee	3224	Jonathan Dickinson	Estuary
09-1705	2	2	St. Lucie - Loxahatchee	3226	Jupiter Inlet	Estuary
09-1715	2	2	St. Lucie - Loxahatchee	3226A	Loxahatchee River (Northwest Fork)	Estuary
09-1707	2	2	St. Lucie - Loxahatchee	3226B	ICWW (Martin County)	Estuary
09-1717	2	2	St. Lucie - Loxahatchee	3226C	Loxahatchee River (Southwest Fork)	Estuary
09-1719	2	2	St. Lucie - Loxahatchee	3226D	Loxahatchee River	Estuary
09-1906	2	1	Suwannee	1326	Sheephead Creek	Estuary
09-1929	2	1	Suwannee	1328	Direct Runoff to Gulf	Estuary
09-1929	2	1	Suwannee	1332	Direct Runoff to Gulf	Estuary
09-1929	2	1	Suwannee	3402A	Econfina River at Mouth	Estuary
09-1818	2	1	Suwannee	3422D	Lower Suwannee Estuary	Estuary
09-1929	2	1	Suwannee	3473A	Fenholloway at Mouth	Estuary
09-1929	2	1	Suwannee	3573C	Steinhatchee River	Estuary
09-1929	2	1	Suwannee	3699B	Waccasassa River	Estuary
09-1929	2	1	Suwannee	3701	Direct Runoff to Gulf	Estuary
09-1929	2	1	Suwannee	3705	Butler Creek (Lilly Creek)	Estuary
09-1929	2	1	Suwannee	3706	Amazon Creek	Estuary
09-1929	2	1	Suwannee	3707	Unnamed Drain	Estuary
09-1929	2	1	Suwannee	3708	Unnamed Drain	Estuary
09-1929	2	1	Suwannee	3709	Unnamed Drain	Estuary
09-1823	2	1	Suwannee	3717	Unnamed Drain	Estuary
09-1929	2	1	Suwannee	3718	Direct Runoff to Gulf	Estuary

OGC Case Number¹	Cycle²	Group³	Basin	WBID⁴	Water Segment Name	Waterbody Type
09-1929	2	1	Suwannee	3720	Direct Runoff to Gulf	Estuary
09-1929	2	1	Suwannee	3724	Direct Runoff to Gulf	Estuary
09-1911	2	1	Suwannee	3729	Black Point Swamp	Estuary
09-1929	2	1	Suwannee	3739	Direct Runoff to Gulf	Estuary
09-1929	2	1	Suwannee	3743	Direct Runoff to Gulf	Estuary
09-2512	2	1	Tampa Bay	1507A	Rocky Creek (Channel A)	Estuary
09-2512	2	1	Tampa Bay	1513	Double Branch	Estuary
09-2512	2	1	Tampa Bay	1530	Moccasin Creek Tidal	Estuary
09-2512	2	1	Tampa Bay	1536E	Palm River	Estuary
09-2512	2	1	Tampa Bay	1546	Mobbly Bayou	Estuary
09-2512	2	1	Tampa Bay	1557	Direct Runoff to Bay	Estuary
09-2512	2	1	Tampa Bay	1558A	Tampa Bay (Lower Segment)	Estuary
09-2512	2	1	Tampa Bay	1558B	Tampa Bay (Middle Segment)	Estuary
09-2512	2	1	Tampa Bay	1558BZ	Tampa Bay (Lower North Segment)	Estuary
09-2512	2	1	Tampa Bay	1558C	Tampa Bay (Upper Segment)	Estuary
09-2512	2	1	Tampa Bay	1558D	Hillsborough Bay (Lower)	Estuary
09-2512	2	1	Tampa Bay	1558E	Hillsborough Bay (Upper)	Estuary
09-2512	2	1	Tampa Bay	1558F	Old Tampa Bay (Lower Segment)	Estuary
09-2512	2	1	Tampa Bay	1558G	Old Tampa Bay	Estuary
09-2512	2	1	Tampa Bay	1558H	Old Tampa Bay	Estuary
09-2512	2	1	Tampa Bay	1558I	Old Tampa Bay	Estuary
09-2512	2	1	Tampa Bay	1558IA	Safety Harbor	Estuary
09-2512	2	1	Tampa Bay	1558N	Boca Ciega Bay (South)	Estuary
09-2512	2	1	Tampa Bay	1559	Direct Runoff to Bay	Estuary
09-2512	2	1	Tampa Bay	1563	Rocky Creek (Lower Segment)	Estuary
09-2512	2	1	Tampa Bay	1566	Boat Bayou	Estuary
09-2512	2	1	Tampa Bay	1569	Bishop Creek (Tidal)	Estuary
09-2512	2	1	Tampa Bay	1570A	Sweetwater Creek (Tidal Segment)	Estuary
09-2512	2	1	Tampa Bay	1572	Direct Runoff to Bay	Estuary
09-2512	2	1	Tampa Bay	1575	Mullet Creek Tidal	Estuary
09-2512	2	1	Tampa Bay	1581	Direct Runoff to Bay	Estuary
09-2512	2	1	Tampa Bay	1584A	Ybor City Drain	Estuary
09-2512	2	1	Tampa Bay	1584B	Mckay Bay	Estuary
09-2512	2	1	Tampa Bay	1584C	East Bay	Estuary
09-2512	2	1	Tampa Bay	1585	Direct Runoff to Bay	Estuary
09-2512	2	1	Tampa Bay	1593	Direct Runoff to Bay	Estuary
09-2512	2	1	Tampa Bay	1599	Uceta Yard Drain	Estuary
09-2512	2	1	Tampa Bay	1600	Direct Runoff to Bay	Estuary
09-2512	2	1	Tampa Bay	1601	Direct Runoff to Bay	Estuary
09-2512	2	1	Tampa Bay	1603	Direct Runoff to Bay	Estuary
09-2512	2	1	Tampa Bay	1604	Allen Creek (Tidal)	Estuary
09-2512	2	1	Tampa Bay	1605D	Delaney Creek (Tidal)	Estuary
09-2512	2	1	Tampa Bay	1606	Lemmon Street Ditch	Estuary
09-2512	2	1	Tampa Bay	1607	Direct Runoff to Bay	Estuary

OGC Case Number¹	Cycle²	Group³	Basin	WBID⁴	Water Segment Name	Waterbody Type
09-2512	2	1	Tampa Bay	1609	Direct Runoff to Bay	Estuary
09-2512	2	1	Tampa Bay	1612	Direct Runoff to Bay	Estuary
09-2512	2	1	Tampa Bay	1615	Unnamed Ditch	Estuary
09-2512	2	1	Tampa Bay	1625	Cross Canal (North)	Estuary
09-2512	2	1	Tampa Bay	1627B	Long Branch (Tidal)	Estuary
09-2512	2	1	Tampa Bay	1628A	Archie Creek (Tidal)	Estuary
09-2512	2	1	Tampa Bay	1632	Unnamed Canal	Estuary
09-2512	2	1	Tampa Bay	1637	Black Point Channel	Estuary
09-2512	2	1	Tampa Bay	1648	Direct Runoff to Bay	Estuary
09-2512	2	1	Tampa Bay	1654	Snug Harbor	Estuary
09-2512	2	1	Tampa Bay	1656	Direct Runoff to Bay	Estuary
09-2512	2	1	Tampa Bay	1661A	Riviera Bay	Estuary
09-2512	2	1	Tampa Bay	1661C	Riviera Bay Drainage	Estuary
09-2512	2	1	Tampa Bay	1661F	Riviera Bay Drainage	Estuary
09-2512	2	1	Tampa Bay	1661G	Papys Bayou	Estuary
09-2512	2	1	Tampa Bay	1664	Direct Runoff to Bay	Estuary
09-2512	2	1	Tampa Bay	1666A	Bullfrog Creek (Tidal Segment)	Estuary
09-2512	2	1	Tampa Bay	1676	Direct Runoff to Bay	Estuary
09-2512	2	1	Tampa Bay	1683	Smacks Bayou	Estuary
09-2512	2	1	Tampa Bay	1687	Shore Acres Drain	Estuary
09-2512	2	1	Tampa Bay	1691	Big Bend Bayou	Estuary
09-2512	2	1	Tampa Bay	1693	Big Bend Bayou	Estuary
09-2512	2	1	Tampa Bay	1700	Coffeepot Bayou	Estuary
09-2512	2	1	Tampa Bay	1708	Newman Branch	Estuary
09-2512	2	1	Tampa Bay	1709	Big Bayou -Basin W	Estuary
09-2512	2	1	Tampa Bay	1709B	Yacht Basin - Basin A	Estuary
09-2512	2	1	Tampa Bay	1709D	Little Bayou - Basin Q	Estuary
09-2512	2	1	Tampa Bay	1709E	Pinellas Point - Basin V	Estuary
09-1099	1	5	Tampa Bay	1709F	Frenchmans Creek - Basin U	Estuary
09-2512	2	1	Tampa Bay	1726	Direct Runoff to Bay	Estuary
09-2512	2	1	Tampa Bay	1731B	Salt Creek	Estuary
09-2512	2	1	Tampa Bay	1733	Direct Runoff to Bay	Estuary
09-2512	2	1	Tampa Bay	1756	Direct Runoff to Bay	Estuary
09-2512	2	1	Tampa Bay	1778	Cockroach Bay	Estuary
09-2512	2	1	Tampa Bay	1797A	Terra Ceia Bay	Estuary
09-2512	2	1	Tampa Bay	1797B	Bishops Harbor	Estuary
03-2263	1	2	Tampa Bay Tributaries	1443E	Hillsborough River	Estuary
09-2287	2	2	Tampa Bay Tributaries	1621G	Alafia River Above Hillsborough Bay	Estuary
09-2330	2	2	Tampa Bay Tributaries	1742C	Little Manatee River Tidal	Estuary
09-2336	2	2	Tampa Bay Tributaries	1779	Haynes Bayou	Estuary
09-2338	2	2	Tampa Bay Tributaries	1784	Bolster Bayou	Estuary
09-2347	2	2	Tampa Bay Tributaries	1848A	Manatee River Below Dam	Estuary
09-2349	2	2	Tampa Bay Tributaries	1848B	Manatee River Below Dam	Estuary
09-2352	2	2	Tampa Bay Tributaries	1876	Braden River Below Ward Lake	Estuary
09-2353	2	2	Tampa Bay Tributaries	1876A	Braden R Nr Gs Camp	Estuary

OGC Case Number¹	Cycle²	Group³	Basin	WBID⁴	Water Segment Name	Waterbody Type
09-2354	2	2	Tampa Bay Tributaries	1876B	Braden River Near Ellwood Park	Estuary
09-1162	1	5	Upper East Coast	2320	Guana River	Estuary
09-1108	1	5	Upper East Coast	2363A	Halifax River	Estuary
09-1111	1	5	Upper East Coast	2363B	Halifax River	Estuary
09-1112	1	5	Upper East Coast	2363C	Tomoka Basin	Estuary
09-1151	1	5	Upper East Coast	2363D	Palm Coast	Estuary
12-0111	2	5	Upper East Coast	2363EB	ICWW (St Johns County; Flagler County)	Estuary
12-0113	2	5	Upper East Coast	2363EC	ICWW (Flagler County)	Estuary
09-1157	1	5	Upper East Coast	2363F	ICWW	Estuary
09-1141	1	5	Upper East Coast	2363G	Matanzas River	Estuary
12-0114	2	5	Upper East Coast	2363G1	Matanzas River (Upper Segment)	Estuary
09-1142	1	5	Upper East Coast	2363H	St. Augustine Inlet	Estuary
12-0115	2	5	Upper East Coast	2363I1	Tolomato River	Estuary
12-0116	2	5	Upper East Coast	2363I2	Tolomato River (Shellfish Portion)	Estuary
09-1113	1	5	Upper East Coast	2363J	Palm Coast	Estuary
12-0118	2	5	Upper East Coast	2400	Smith Creek	Estuary
12-0122	2	5	Upper East Coast	2406C	Deep Creek (Marine Segment)	Estuary
09-1178	1	5	Upper East Coast	2435	Capo Creek	Estuary
12-0123	2	5	Upper East Coast	2442	Marshall Creek	Estuary
09-1182	1	5	Upper East Coast	2451	Stokes Creek	Estuary
09-1184	1	5	Upper East Coast	2457A	St. Marks Pond Estuary	Estuary
09-1186	1	5	Upper East Coast	2468	Casa Cola Creek	Estuary
09-1189	1	5	Upper East Coast	2470	Sombrero Creek	Estuary
09-1191	1	5	Upper East Coast	2477	Ximanes Creek	Estuary
09-1193	1	5	Upper East Coast	2483	Pancho Creek	Estuary
09-1194	1	5	Upper East Coast	2487	Robinson Creek	Estuary
12-0127	2	5	Upper East Coast	2491	San Sebastian River	Estuary
12-0130	2	5	Upper East Coast	2493A	Moultrie Creek Lower Segment	Estuary
12-0131	2	5	Upper East Coast	2502B	Salt Run	Estuary
12-0132	2	5	Upper East Coast	2502C	Salt Run (Shellfish Portion)	Estuary
09-1147	1	5	Upper East Coast	2510	Quarry Creek	Estuary
09-1148	1	5	Upper East Coast	2513	Unnamed Bayou	Estuary
09-1149	1	5	Upper East Coast	2519	East Creek	Estuary
09-1150	1	5	Upper East Coast	2529	San Julian Creek	Estuary
12-0133	2	5	Upper East Coast	2535A	Moses Creek (Marine Segment)	Estuary
12-0136	2	5	Upper East Coast	2550A	Unnamed Drain (Marine Segment)	Estuary
12-0138	2	5	Upper East Coast	2573	Unnamed Drain	Estuary
12-0140	2	5	Upper East Coast	2580A	Pellicer Creek	Estuary
12-0141	2	5	Upper East Coast	2580B	Pellicer Creek	Estuary
12-0143	2	5	Upper East Coast	2620	Bulow Creek	Estuary
09-1116	1	5	Upper East Coast	2634A	Tomoka River	Estuary
12-0147	2	5	Upper East Coast	2640	Unnamed Branch	Estuary
09-1118	1	5	Upper East Coast	2642	Unnamed Branch	Estuary
12-0149	2	5	Upper East Coast	2670	Halifax Canal	Estuary
12-0150	2	5	Upper East Coast	2672A	Rose Bay	Estuary

OGC Case Number¹	Cycle²	Group³	Basin	WBID⁴	Water Segment Name	Waterbody Type
09-1128	1	5	Upper East Coast	2674A	Spruce Creek	Estuary
09-1131	1	5	Upper East Coast	2674B	Strickland Bay	Estuary
09-1134	1	5	Upper East Coast	2678	Turnbull Bay	Estuary
10-3228	2	4	Withlacoochee	1329A	Cross Florida Barge Canal	Estuary



Florida Department of Environmental Protection
Division of Water Resource Management
Bureau of Watershed Management
2600 Blair Stone Road, Mail Station 3565
Tallahassee, Florida 32399-2400
(850) 245-8561
www2.dep.state.fl.us/water/

FLORIDA DEPARTMENT OF ENVIRONMENTAL PROTECTION

Division of Environmental Assessment and Restoration
Bureau of Watershed Restoration

Mercury TMDL for the State of Florida

Appendix C

Regional Maps Showing WBIDs on Department's Verified List
for Mercury Fish Tissue Impairment

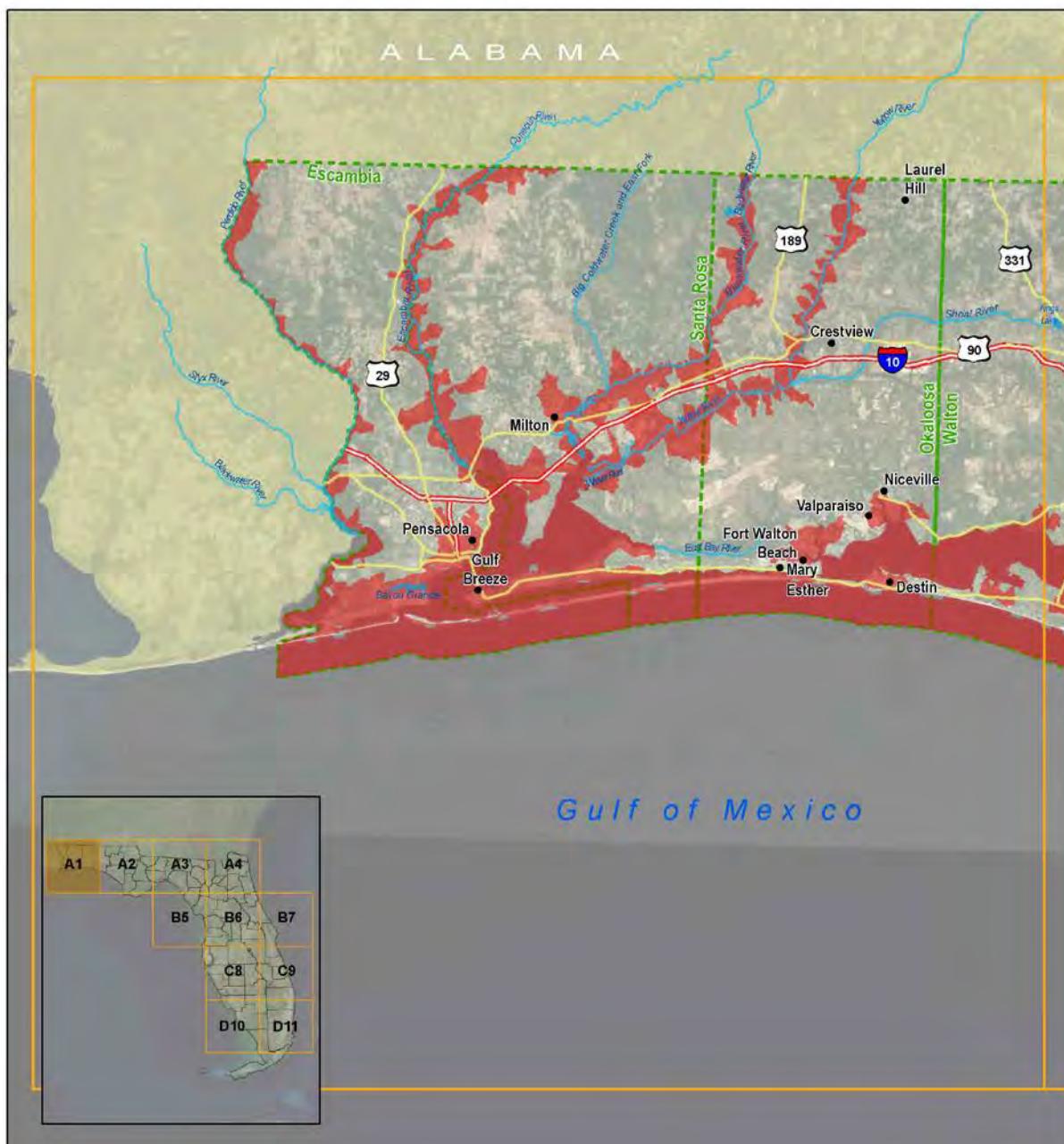
Watershed Evaluation and TMDL Section



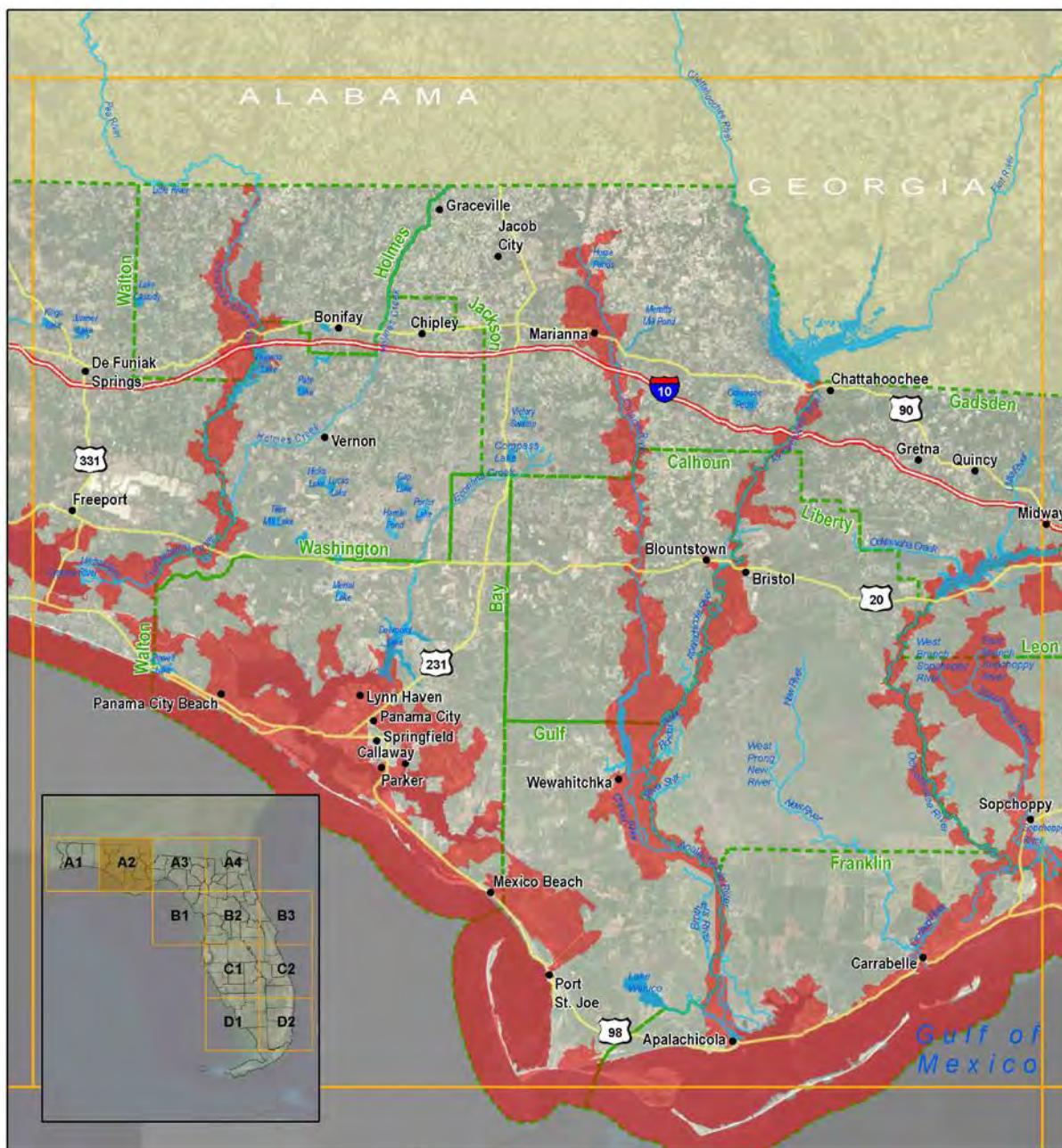
May 22, 2012

Appendices

Appendix C: Regional Maps Showing WBIDs on Department's Verified List for Mercury Fish Tissue Impairment



WBIDs (Freshwater and Marine) Impaired for Mercury (in Fish Tissue) Panhandle (West) – A1	<ul style="list-style-type: none"> Cities Interstate Primary Highways Stream/River 	<ul style="list-style-type: none"> Lake/Pond WBIDs (Freshwater and Marine) Impaired for Mercury Locator Grid Florida Counties
<small>Map prepared by the Bureau of Watershed Restoration, This map is not for legal decision making purposes. [GIS] Yesenia Escribano (850) 245-8539 [TMDL] Moira Rojas (850) 245-8460 Map ID: Hg_TMDL_Update_A1 Created: 05-14-2012</small>		



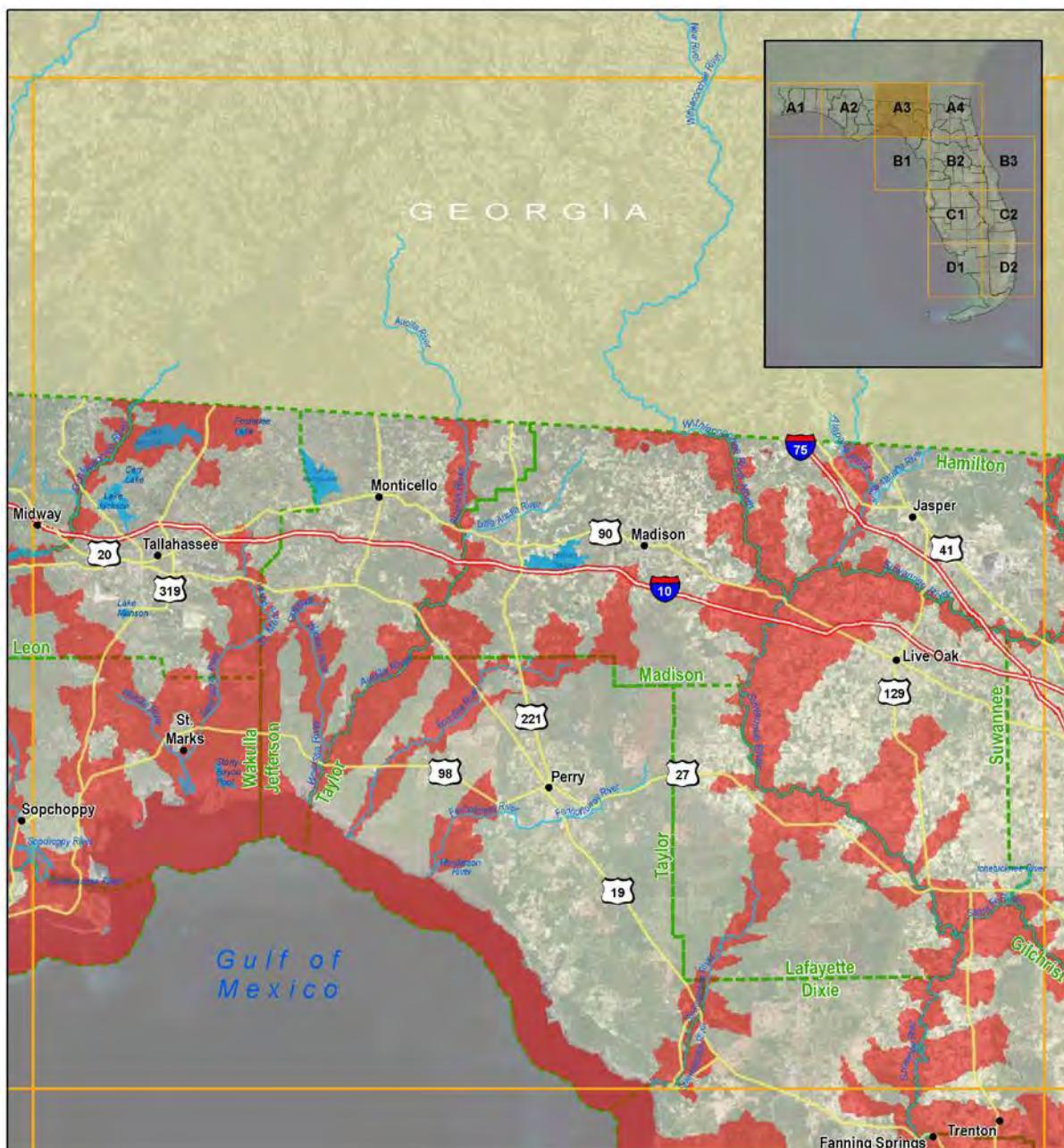
**WBIDs (Freshwater and Marine)
Impaired for Mercury (in Fish Tissue)
Panhandle (East) – A2**

Map prepared by the Bureau of Watershed Restoration,
This map is not for legal decision making purposes.
[GIS] Yesenia Escrivano (850) 245-8539
[TMDL] Moira Rojas (850) 245-8460
Map ID: Hg_TMDL_Update_A2
Created: 05-14-2012

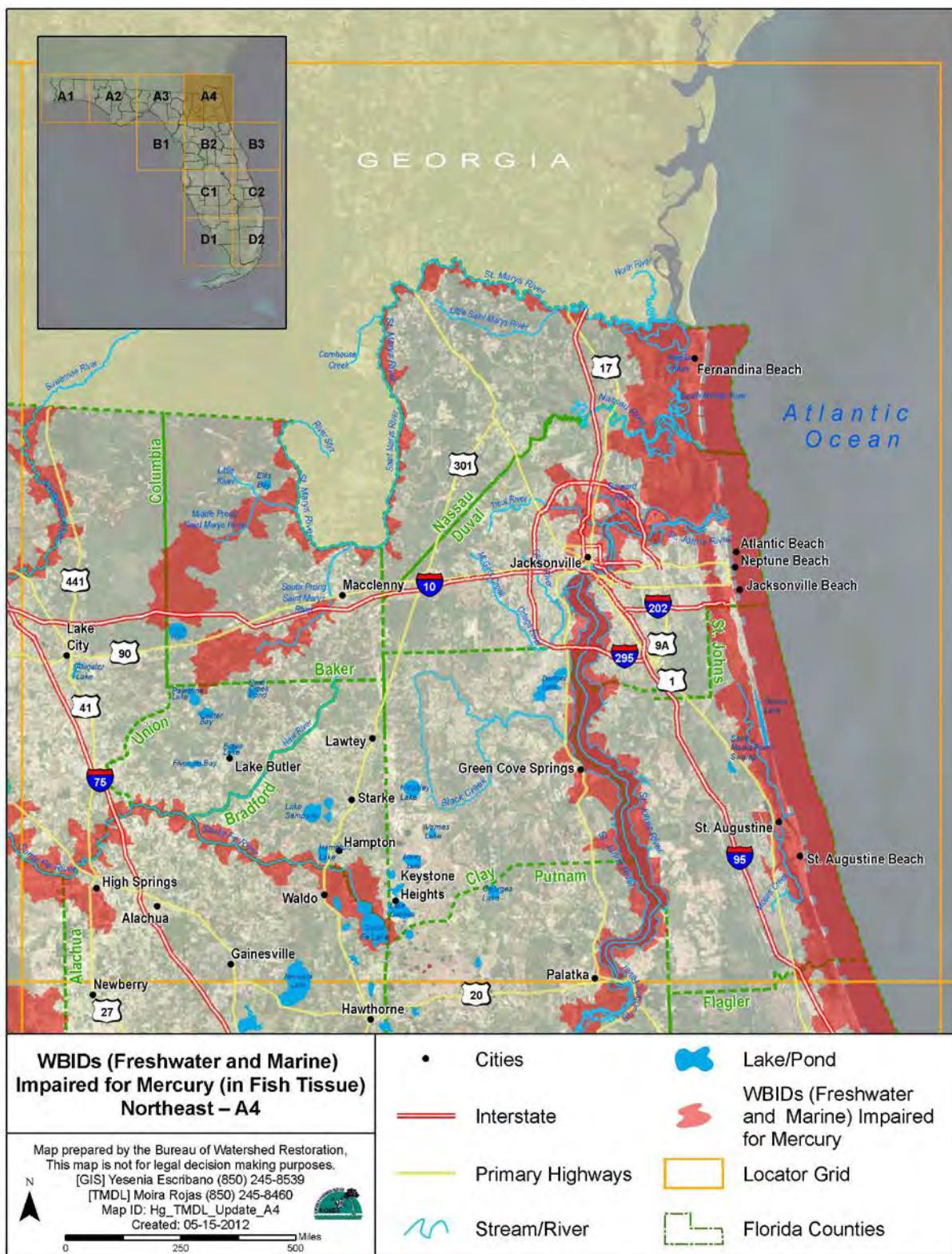


0 250 500 Miles

- Cities
- Interstate
- Primary Highways
- Stream/River
- Lake/Pond
- WBIDs (Freshwater and Marine) Impaired for Mercury
- Locator Grid
- Florida Counties

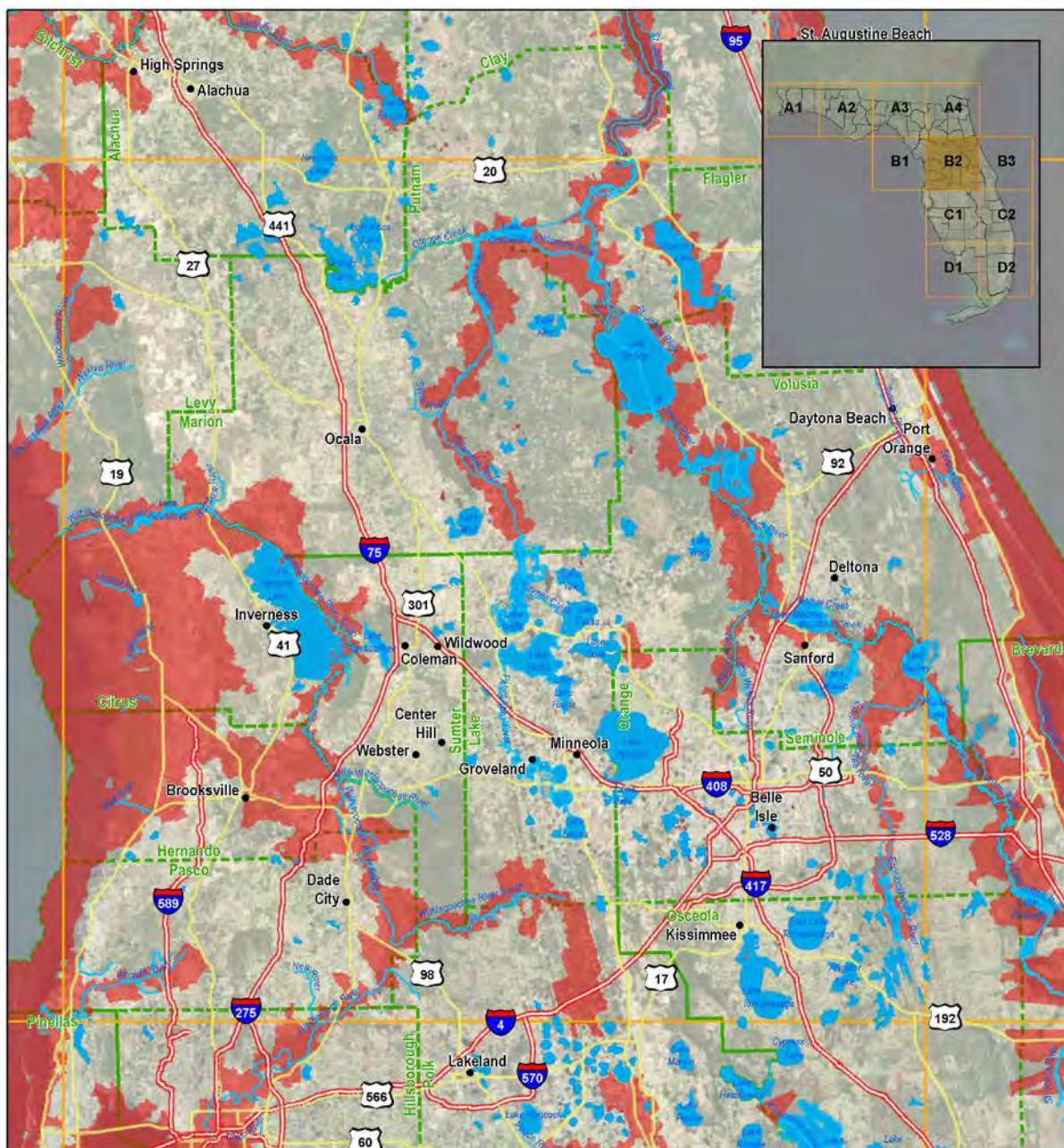


WBIDs (Freshwater and Marine) Impaired for Mercury (in Fish Tissue) Big Bend (North) – A3	<ul style="list-style-type: none"> Cities Interstate Primary Highways Stream/River 	<ul style="list-style-type: none"> Lake/Pond WBIDs (Freshwater and Marine) Impaired for Mercury Locator Grid Florida Counties
Map prepared by the Bureau of Watershed Restoration, This map is not for legal decision making purposes. [GIS] Yesenia Escrivano (850) 245-8539 [TMDL] Moira Rojas (850) 245-8460 Map ID: Hg_TMDL_Update_A3 Created: 05-14-2012	<ul style="list-style-type: none"> Interstate Primary Highways Stream/River 	<ul style="list-style-type: none"> Locator Grid Florida Counties





WBIDs (Freshwater and Marine) Impaired for Mercury (in Fish Tissue) Big Bend (South) – B1	<ul style="list-style-type: none"> Cities Interstate Primary Highways Stream/River 	<ul style="list-style-type: none"> Lake/Pond WBIDs (Freshwater and Marine) Impaired for Mercury Locator Grid Florida Counties
Map prepared by the Bureau of Watershed Restoration, This map is not for legal decision making purposes. [GIS] Yesenia Escribano (850) 245-8539 [TMDL] Moira Rojas (850) 245-8460 Map ID: Hg_TMDL_Update_B1 Created: 05-15-2012	<ul style="list-style-type: none"> Interstate Primary Highways Stream/River 	<ul style="list-style-type: none"> WBIDs (Freshwater and Marine) Impaired for Mercury Locator Grid Florida Counties



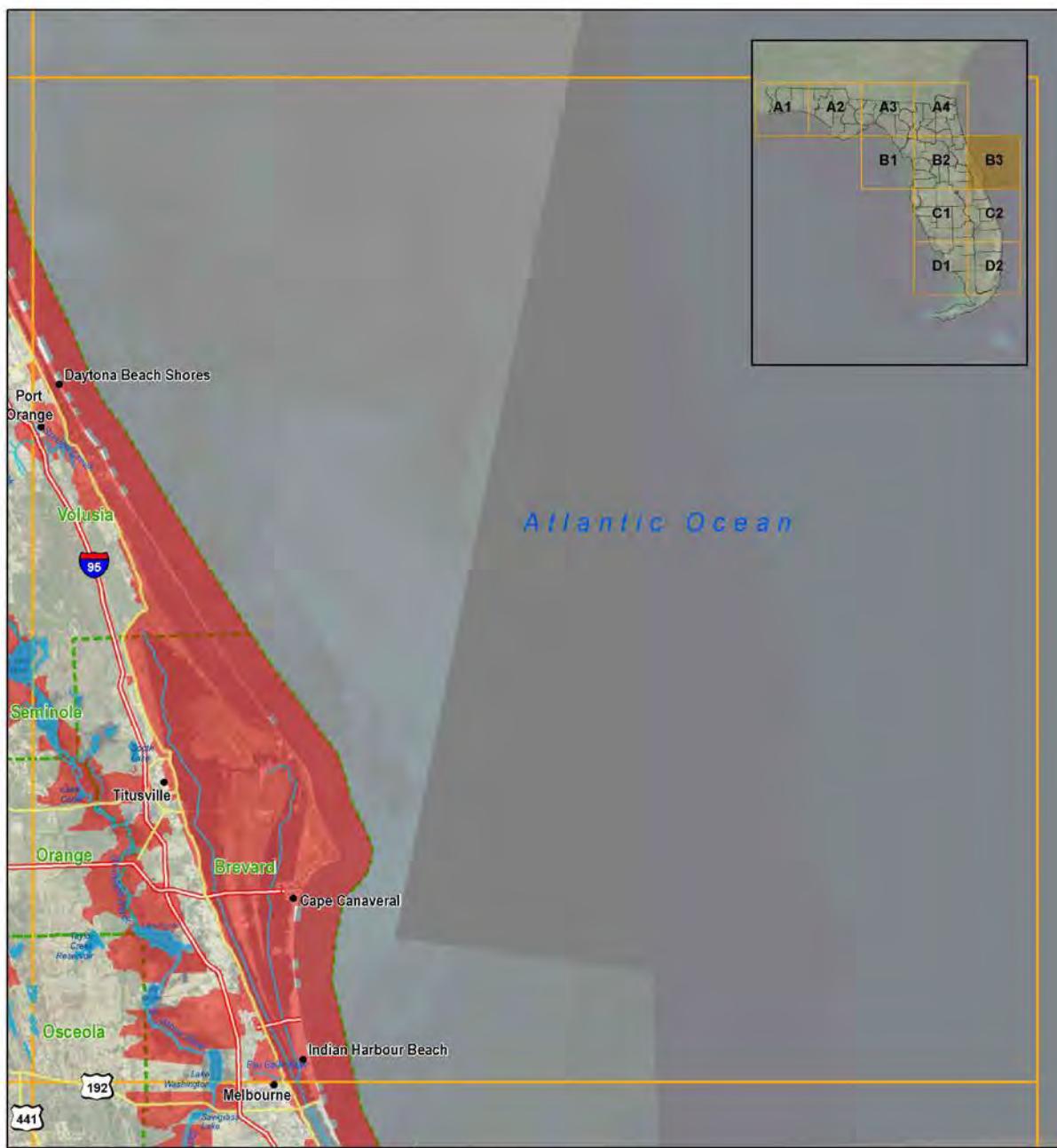
**WBIDs (Freshwater and Marine)
Impaired for Mercury (in Fish Tissue)
Central (West) – B2**

Map prepared by the Bureau of Watershed Restoration,
This map is not for legal decision making purposes.
[GIS] Yesenia Escrivano (850) 245-8539
[TMDL] Moira Rojas (850) 245-8460
Map ID: Hg_TMDL_Update_B2
Created: 05-15-2012

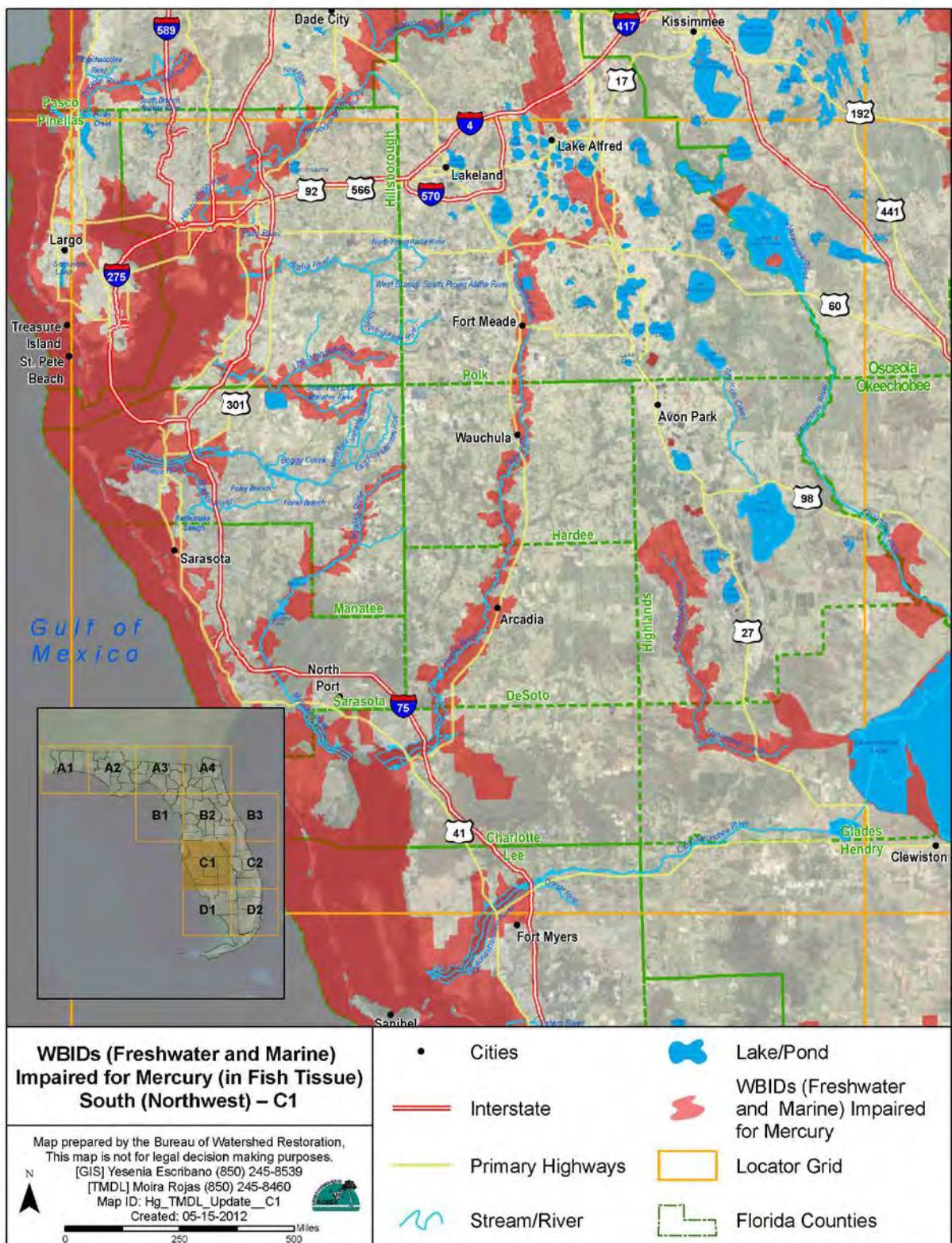


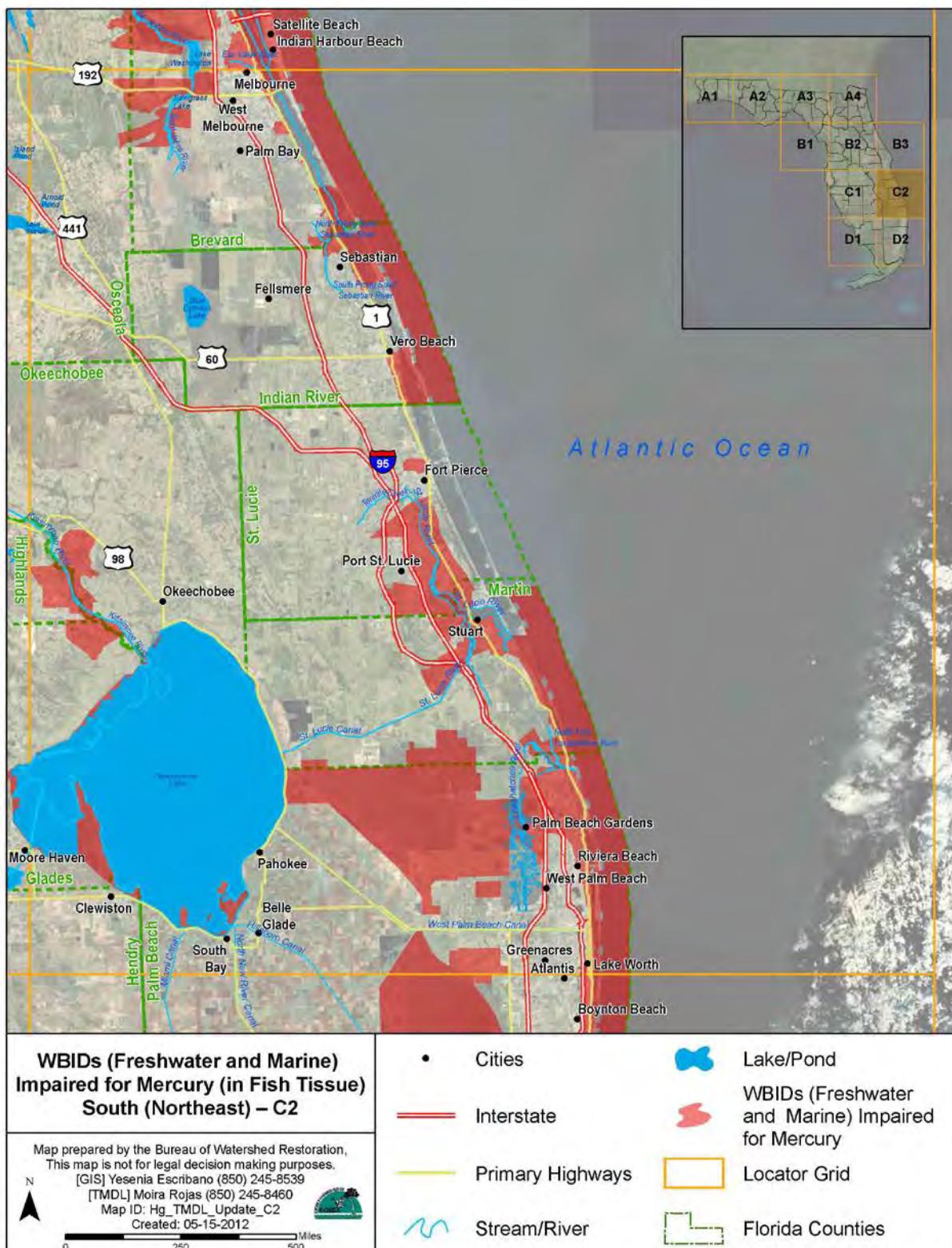
0 250 500 Miles

- Cities
- Interstate
- Primary Highways
- Stream/River
- Lake/Pond
- WBIDs (Freshwater and Marine) Impaired for Mercury
- Locator Grid
- Florida Counties



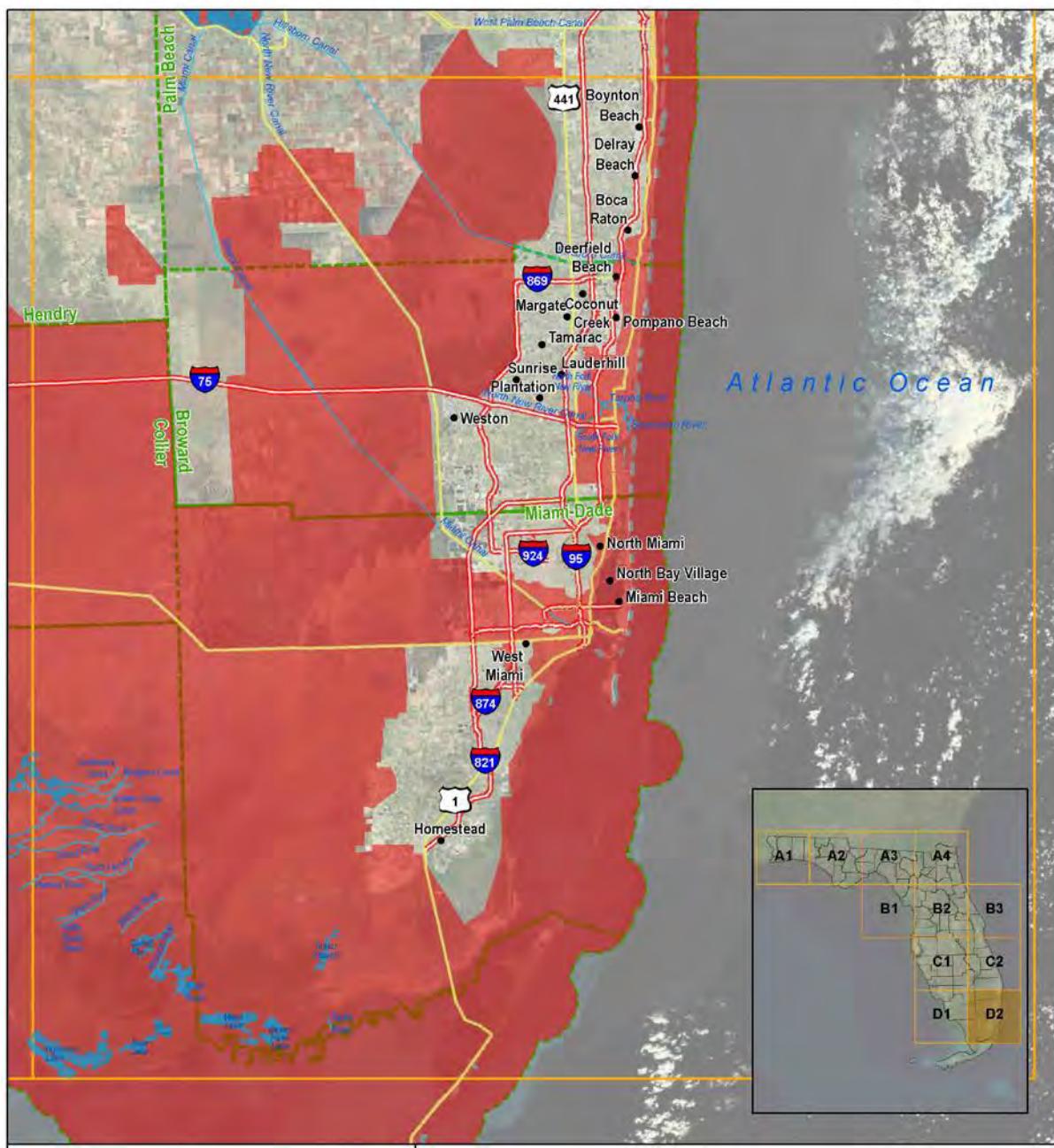
WBIDs (Freshwater and Marine) Impaired for Mercury (in Fish Tissue) Central (East) – B3	<ul style="list-style-type: none"> Cities Interstate Primary Highways Stream/River 	Lake/Pond WBIDs (Freshwater and Marine) Impaired for Mercury Locator Grid Florida Counties
Map prepared by the Bureau of Watershed Restoration, This map is not for legal decision making purposes. [GIS] Yesenia Escribano (850) 245-8539 [TMDL] Moira Rojas (850) 245-8460 Map ID: Hg_TMDL_Update_B3 Created: 05-15-2012	N 0 250 500 Miles	







WBIDs (Freshwater and Marine) Impaired for Mercury (in Fish Tissue) South (Southwest) – D1	<ul style="list-style-type: none"> • Cities — Interstate — Primary Highways ~ Stream/River
Map prepared by the Bureau of Watershed Restoration, This map is not for legal decision making purposes. [GIS] Yesenia Escribano (850) 245-8539 [TMDL] Moira Rojas (850) 245-8460 Map ID: Hg_TMDL_Update_D1 Created: 05-15-2012	<ul style="list-style-type: none"> ● Lake/Pond ■ WBIDs (Freshwater and Marine) Impaired for Mercury
N 	Locator Grid
0 250 500 Miles	Florida Counties



WBIDs (Freshwater and Marine) Impaired for Mercury (in Fish Tissue) South (Southeast) – D2	<ul style="list-style-type: none"> Cities Interstate Primary Highways Stream/River 	<ul style="list-style-type: none"> Lake/Pond WBIDs (Freshwater and Marine) Impaired for Mercury Locator Grid Florida Counties
Map prepared by the Bureau of Watershed Restoration, This map is not for legal decision making purposes. [GIS] Yesenia Escrivano (850) 245-8539 [TMDL] Moira Rojas (850) 245-8460 Map ID: Hg_TMDL_Update_D2 Created: 05-15-2012	<ul style="list-style-type: none"> Interstate Primary Highways Stream/River 	<ul style="list-style-type: none"> Locator Grid Florida Counties



Florida Department of Environmental Protection
Division of Water Resource Management
Bureau of Watershed Management
2600 Blair Stone Road, Mail Station 3565
Tallahassee, Florida 32399-2400
(850) 245-8561
www2.dep.state.fl.us/water/

FLORIDA DEPARTMENT OF ENVIRONMENTAL PROTECTION

Division of Environmental Assessment and Restoration
Bureau of Watershed Restoration

Mercury TMDL for the State of Florida

Appendix D

Mercury TMDLs of Other States That Are Waterbody Specific Or Based on Ambient Water Quality Criteria

Watershed Evaluation and TMDL Section



May 22, 2012

Appendices

Appendix D: Mercury TMDLs of Other States That Are Waterbody Specific Or Based on Ambient Water Quality Criteria

D.1. Lake Mary Regional TMDL for Mercury in Fish Tissue, Arizona

This Total Maximum Daily Load (TMDL) reflects a regional approach to fish tissue mercury contamination. Five lakes within the lower Little Colorado River watershed in northern Arizona were listed as impaired for mercury in fish tissue between 2002 and 2003. Not only are these five lakes within the same water and airsheds, they are also close to the same elevation 6,500-7,000 ft and located within similar surficial volcanic geology and soils. All five TMDL lakes were constructed between 1904 and 1954, display similar water chemistry, contain no known point sources, and share similar historical land uses. Because of these similarities, they have been treated collectively as to mercury contamination. Some differences do exist, however, most notably lake morphology, periodicity of water level (climate and water management), and fish stocking practices.

The fish species which were sampled include walleye, northern pike, largemouth bass, yellow bass, crappie, channel catfish, bluegill and rainbow trout. Many lakes in the Lake Mary region (LMR) are stocked with trout in the summer, however, the lakes are really cool-water rather than cold-water lakes, so trout populations are not likely to survive from year to year. This TMDL addresses mercury levels in all species, with a focus on walleye as the top predator species. There are two critical periods for mercury loading in this region, the monsoon season for intensity of runoff, and the spring snowmelt/runoff season for duration of runoff. The major source of mercury to the lakes in the LMR is atmospheric deposition with some mercury originating from natural geologic materials. As there are no known local atmospheric mercury sources in the LMR, it is not likely that aerial deposition can be significantly reduced in the near future through local efforts. Improvement can be made, however, by reducing soil erosion and transport of organic material from the watersheds. TMDL implementation will focus on decreasing sediment delivery to the lakes, lake level stability and fishery management. Both wet and dry aerial deposition and geologic background mercury concentration were factored into this TMDL. The TMDL model used regional wet and dry air deposition data collected at the Sycamore Canyon Mercury Deposition Network (MDN) station (AZ02). Sediment cores showed pre-impoundment levels of mercury that were later confirmed with watershed soil sampling. Four different types of models were developed and linked for this project: (1) a watershed loading model, (2) a lake hydrologic model, (3) an in-lake mercury cycling model, and (4) mercury bioaccumulation calculations. Site-specific biological accumulation factors (BAFs) were used to link model simulated water column concentrations to fish tissue concentrations. Model predictions of average mercury concentrations in adult walleye were made for various levels of anthropogenic input loads to the lakes.

In order to calculate load reductions on a lake system basis, ADEQ used the trophic level-weighted geometric mean approach described in the Guidance for Implementing the January 2001 Methyl-mercury Water Quality Criterion, (EPA, 2009). Based on trophic-level geometric mean concentrations, the following reductions in mercury loading are necessary to meet the 0.3 mg/kg mercury fish tissue standard. In Upper and Lower Lake Mary, a 25 percent reduction in

methyl-mercury and 32 percent reduction in total mercury. In Soldiers Complex, a 40 percent reduction in methyl-mercury and 46 percent reduction in total mercury.

D.2. Willamette River Basin Mercury TMDL, Oregon

In Oregon's Willamette River Basin (WRB), health advisories currently limit consumption of fish that have accumulated methyl mercury to levels posing a potential health risk for humans. Under the Clean Water Act, these advisories create the requirement for a Total Maximum Daily Load (TMDL) for mercury in the WRB.

Because methyl mercury is known to biomagnify in aquatic food webs, a biomagnification factor can be used, given a protective fish tissue criterion, to estimate total mercury concentrations in surface waters required to lower advisory mercury concentrations currently in fish in the WRB. This TMDL presents a basin-specific aquatic Food Web Biomagnification Model (FWM) that simulates inorganic (Hg^{II}) and methyl mercury (MeHg) accumulation in fish tissue and estimates WRB-specific biomagnification factors (BMF_{ME}) for resident fish species of concern to stakeholders. The model was calibrated with WRB-specific fish tissue and surface water data. Probabilistic (Monte Carlo) techniques propagate stochastic variability and uncertainty throughout the model, providing decision makers with credible range information and increased flexibility in establishing a specific mercury target level.

Ambient monitoring data gathered over the course of this study allowed Oregon DEQ to empirically estimate the relative ratio (as a percentage) of dissolved methyl mercury (DMeHg) to total mercury (THg) in the water column of the Willamette River Basin. This DMeHg:THg translator (also known as omega Ω) was used to establish water column guidance values based on units of total mercury, recognizing that it is the methylated form of mercury that is actually prone to bioaccumulation. The estimate of this translator was based on empirical data from the Willamette Basin mercury study.

A fish tissue criterion of 0.30 mg/kg (U.S. EPA methyl mercury tissue criterion), a distribution for the fraction of total mercury that is dissolved MeHg (Ω), a model estimated value for BMF_{ME} , and the following equation were used to estimate total mercury surface water target levels for each fish species.

The target level for total mercury in surface water for each fish species as,

$$TL_n = \left[\frac{TC}{BMF_{MEn} \cdot \Omega} \right] \cdot CF$$

Where:

BMF_{MEn} = MeHg biomagnification factor for the nth fish species (L/kg)

TL_n = Total mercury target level for the nth fish species (ng/L)

TC = U.S. EPA fish tissue criterion for MeHg (0.30 mg/kg)

Ω = Ratio of dissolved MeHg to total mercury in surface water (unitless)

CF = Conversion factor (1 \times 106 ng/mg)

As a result, the model predicted the probability of tissue mercury concentrations in eight fish species within the range of concentrations actually measured in these species during 25+ years of water quality monitoring.

The estimated mass of total mercury discharged from the Basin as fluvial load was estimated as a function of river flow rate at the confluence (river mile 0) and mercury concentration in unfiltered surface water samples. USGS flow data were available from five gauging stations along the mainstem of the Willamette River (USGS, 2003). An empirical relationship was developed between river flow rate and river mile by pairing measured daily mean flow rates with river mile. This relationship was then used to estimate the daily mean flow rate at sampling locations along the mainstem where daily mean flow rate data were not available for the period between 1997 and 2003. An empirical relationship was then formed between daily mean flow at river mile 0 (RM 0) and the concentration of total mercury in the mainstem. There is a moderate positive correlation between concentration and flow for total mercury; a correlation consistent with the seasonal mobilization of fine-grained particulates in the river sediment and runoff (erosion) with which mercury is associated. The estimated average annual mass load of total (unfiltered) mercury was estimated at the confluence (RM 0) as a function of concentration and flow rate. The annual output from the Basin was thus defined as the mercury discharge rate in units of kg/yr at RM 0. An average of 126.8 kg of total mercury is estimated to be discharged by the Willamette into the Columbia River each year. The estimated inputs of mercury to the Basin (128.6 kg/yr) slightly exceed the mercury mass leaving the Basin as fluvial load, suggesting that a portion of the mercury is deposited in the river bottom.

The loading capacity, presented here in units of total mercury, represents the load of total mercury (in kg/yr) deemed to be protective of the beneficial use of fish consumption. The derivation of this loading capacity relies on both the Basin-Specific Aquatic Food Web Biomagnification Model for Estimation of Mercury Target Levels and the estimate of mercury mass loads discussed above. It is assumed that a given percent reduction in mercury mass loading will result in a linear percent reduction in water column concentrations. The various processes governing mercury speciation and transformation in the Willamette River system are complex rate-dependent processes that are poorly understood and it is difficult to predict with complete certainty how the concentrations of the various species of mercury will change with decreases in total mercury loading. The basic assumption utilized in this mass balance approach, however, is that water column concentrations will decline as source contributions decrease.

The estimated annual mean rate of mercury inputs in the mainstem Willamette River System is approximately 128.5 kg/yr. According to the hypotheses outlined above, it is assumed that a given percent reduction in the mercury mass load will result in a linear percent reduction in water column concentrations. In other words, a 26.4% reduction in the loading of total mercury would eventually lead to a corresponding reduction in water column concentrations. A 26.4% reduction in the average annual load of mercury corresponds to a 33.9 kg/yr reduction in total mercury loading to the Willamette system and a loading capacity of 94.6 kg/yr. This loading capacity represents the maximum amount of total mercury that the Willamette River can absorb on an average annual basis and still meet the beneficial use of fish consumption.



Florida Department of Environmental Protection
Division of Water Resource Management
Bureau of Watershed Management
2600 Blair Stone Road, Mail Station 3565
Tallahassee, Florida 32399-2400
(850) 245-8561
www2.dep.state.fl.us/water/

FLORIDA DEPARTMENT OF ENVIRONMENTAL PROTECTION

Division of Environmental Assessment and Restoration
Bureau of Watershed Restoration

Mercury TMDL for the State of Florida

Appendix E

Impact of Mercury Pollution on Wildlife

Watershed Evaluation and TMDL Section



May 22, 2012

Appendices

Appendix E Impact of Mercury Pollution on Wildlife

E.1. American Alligator

The first report of total mercury (THg) in wild-caught American alligators (*Alligator mississippiensis*) from Florida waters was made by Ogden et al. (1974), who reported on levels in eggs collected from Shark River Slough in the ENP (the southern end of the EPA). They found concentrations of THg in alligator eggs greatly exceeded levels observed in the eggs of their estuarine counterpart, the American crocodile (*Crocodylus acutus*), collected from Florida Bay.

Measurements of THg in tail muscle from wild-caught alligators from Florida waters were first reported by Delany et al. (1988). They found that average concentrations in 32 alligators collected from eight lakes in 1984 ranged from 0.04 to 0.61 ppm. In 1989, responding to findings of elevated levels of THg in fish, the FWC collected 29 harvestable-size alligators from the WCAs and tested for THg in tail muscle. THg levels were well in excess of previous findings from non-Everglades water bodies, with a system-wide range in individual alligators of 0.46 to 3.88 ppm and an average concentration of 2.38 ppm (Hord et al., 1990).

During the same time period, the FWC obtained samples of tail muscle collected by a nuisance-alligator hunter from alligators captured in urban canals in the Fort Lauderdale area. For comparison, an additional 58 samples of tail muscle were collected from licensed meat processors from north, central, and South Florida (Hord et al., 1990). Results for nuisance alligators from the Fort Lauderdale area during May 1989 revealed a wide range of values — individual concentrations ranged from 0.17 to 2.52 ppm with an overall mean of 0.74 ppm. The results for alligators collected from meat processors from north, central, and South Florida (non-WCA locations) revealed lower THg concentrations with a range in county means of 0.13 to 0.90 ppm. The highest county mean, 0.90 ppm ($n = 1$), was from Franklin County in the panhandle, indicating that problematic levels of THg were not limited to the WCAs.

Concentrations of THg in alligator muscle collected through the 1990s clearly demonstrated THg levels exceeding the existing criteria established for the protection of human health by the FDOH and U.S. Environmental Protection Agency (USEPA, 2001a).

E.2. Florida Panther

The Florida panther (*Puma concolor coryi*) is a state and federally listed endangered species. Environmental stressors (including environmental contaminants), low genetic variability, and habitat loss have all contributed to the decline of this species. Mercury contamination has been suggested as a causative factor in the low densities, poor reproduction, and some reported deaths of panthers from portions of South Florida (Roelke et al., 1991; Facemire et al., 1995); however, factors such as prey abundance and consumption, panther diseases, genetics, and demographic issues are difficult to separate from the influence of mercury when measuring panther fitness and mortality. During a survey of various tissue, blood, and hair samples collected from 52 live and dead free-ranging panthers from 1978–1991, Roelke et al. (1991) found detectable levels of THg in all tissues as well as strong spatial gradients. Similarly, MeHg

was present in all panther hair samples collected from museum specimens dating back to the 1890s (Newman et al., 2004), with significantly higher levels observed in the 1990s than in the late 1800s.

Roelke et al. (1991) reported that the highest mercury concentrations were found in panthers from the Shark River Slough of the ENP (hair = 56.4 ppm; blood = 0.794 ppm) and the lowest concentrations were from north of Alligator Alley (hair = 1.66 ppm; blood = 0.094 ppm), which included northern Fakahatchee Strand, Florida Panther National Wildlife Refuge (FPNWR), and portions of Big Cypress National Preserve (BCNP). Differences were likely influenced by the ambient levels of mercury in the environment as well as prey selection, with panthers feeding on non-hoofed, fish-eating species [i.e., raccoons (*Procyon lotor*)] exhibiting the highest tissue THg concentrations. [Note: Animal tissue (fish, panther, etc.) are usually reported as mg/kg (ppm); blood is mg/L (ppm).]

It was noted that raccoons comprised 70 percent or more of the diet of panthers foraging within Shark River Slough. These panthers also had the highest muscle and liver THg concentrations. Panthers foraging north of Alligator Alley had lower mercury levels and fed primarily on white-tailed deer (*Odocoileus virginianus*) and feral hogs (*Sus scrofa*) — species not tied to the aquatic food web. During the late 1980s, adaptive management strategies by the FWC to modify the prey base available to panthers foraging within the Fakahatchee Strand resulted in declines in panther THg levels, as panthers transitioned from a diet dominated by raccoons to one comprised largely of deer and hogs (Roelke et al., 1991). At that time, raccoons within Fakahatchee Strand had THg values 10–100 times higher than those in deer.

From 2000–2007, the FWC gathered a total of 272 blood samples and 384 hair samples from panthers for mercury analysis. Preliminary results for these collections were reported by Brandon et al. (2009). Blood samples ($n = 158$) had measurable amounts of mercury, with concentrations ranging from 0.009 ppm to 5.3 ppm. Likewise, hair samples ($n = 321$) also had measurable concentrations of mercury, with values ranging from 0.086 ppm to 100 ppm. During this period, the panther with the highest mercury concentrations in blood and hair (from samples collected post-mortem), identified as FP 85, was first caught in the Southern Glades Wildlife Management Area in 2003 and then found dead in the ENP in 2004. The cause of death for FP 85 was listed as “unknown” (FWC, 2010).

Although average mercury concentrations in Florida panther blood and hair generally declined between study periods (1978–1991 and 2000–2007) at Big Cypress National Preserve (BCNP) south of I-75, increasing mercury levels in blood and hair were observed in recent years. Mean concentration of mercury in blood rose from 0.259 ppm ($n = 6$) in 2006 to 0.568 ppm ($n = 8$) in 2007 and more than doubled in hair from 4.518 ppm in 2006 ($n = 9$) to 10.847 ppm ($n = 13$) in 2007. This difference between years was not statistically significant for blood or hair, but because of the few animals left in the wild, any data indicating elevated panther mercury levels are cause for concern.

It is evident that the majority of the current Florida panther population occupies an area where mercury bioaccumulation in aquatic ecosystems remains a significant concern. The FWC continues to collect blood and hair samples for mercury analysis. Analyses will focus on developing a better understanding of potential influential variables contributing to mercury exposure (such as panther age and sex, and regional hydrology). Moreover, correlation analyses of mercury levels with health metrics such as body condition, blood chemistry, and reproductive success should be conducted on the expanding dataset and compared to literature-derived critical tissue concentrations to elucidate the direct and indirect effects of mercury on individuals and regional sub-populations. Finally, special consideration should be

given to regional and individual maximum exposure levels observed in panthers due to their endangered status.

E.3. Fisheating Birds

Experimental exposure of the white ibis (*Eudocimus albus*) to MeHg through diet significantly reduced reproduction. The main loss of reproduction was due to a high rate of MeHg-induced white ibis male-male pairings (up to 55 percent of males), an effect which was dose-related in two of the three study years (Frederick and Jayasena, 2008). In this study, experimental groups of 40 white ibises (even sex ratios) were exposed to 0.05, 0.1, and 0.3 mg MeHg/kg wet weight in diet from 90 days of age through three breeding seasons. No effects were found of MeHg on mass, size, survival, appetite, juvenile hormone levels, or the ability to learn to feed in novel situations. However, all of the mercury-dosed groups had significantly lower reproductive success than the control group in all years, with up to 30 percent reduction in reproductive success. The main loss of reproduction was due to nests not producing eggs, and this stemmed directly from a high rate of male-male pairings (up to 55 percent of males), an effect which was dose-related in two of the three years.

The male-male pairings showed nearly all of the characteristics of male-female pairings, including phenology, courtship, copulation, nest construction, nest attendance, mate defense, and socially monogamous behavior. Male-male pairs were often of longer duration than male-female pairings, and dosed groups all had significantly more time (pair-days) spent in male-male pairings than did the control group. In all years, the majority of the reproductive deficits in dosed groups were attributable to male-male pairing (2006: 75–85 percent, 2007: 82–100 percent, 2008: 50–100 percent). Male-male pairings were not a result of location effects, sex ratio, or constrained mating opportunities. Additionally, male-male pair bonds in all groups were formed relatively early in the breeding season at a time when there were unpaired females available in breeding condition.

Males that were dosed, and especially those that later paired with males, had significantly lower display rates than control males (Frederick and Jayasena, 2010). It seems likely that although females approached them for courtship, the displays of these males may have been substandard. Some homosexual males later formed heterosexual pair bonds in the same or subsequent seasons, and had fertile eggs in all of those situations, demonstrating that they were competent mates. Male-male pairings declined over the three breeding seasons, suggesting that birds were switching mates because of poor reproductive success.

Expression of sex steroids (estradiol and testosterone) were also affected by MeHg exposure, showing a dose-dependent response (Frederick, UF, personal communication). The pattern of altered expression was exaggerated within any group among homosexual males, suggesting that MeHg-induced changes in hormone expression affected sexual behavior such as display rates and pairing preference, and through that mechanism, reproduction was affected. While this experimental evidence strongly links hormones, mercury exposure, and behavior, the physiological mechanisms involved are unknown.

This study suggests that MeHg can function as an endocrine disruptor, resulting in altered sexual behavior and reduced reproductive success. The reduction in reproduction was not trivial — if the normal sex ratio in the wild is 1:1, the reduction in success could be up to 55 percent

(the proportion of males pairing with males in this study). In many studies, effects seen in the lab (or aviary) are exaggerated in the field because of additional stressors in the wild; it is unclear whether effects documented in the aviary would be exacerbated in the Everglades.

At minimum, the implications of this study are that MeHg exposure at ambient levels in the Greater Everglades in the early 1990s could have been enough to affect breeding behavior to the extent that measurable demographic change may have been realized. As mercury exposure declined in the late 1990s, the numbers of breeding pairs of wading birds increased by 3–5X. While some of this increase was clearly due to better hydrological conditions, hydropattern does not explain all of the increase, and mercury is an explanatory variable in nearly all models of population response during this period (Frederick and Jayasena, 2008). While these results are merely correlational, the experimental research demonstrates an effect and a mechanism by which mercury affected populations.

A risk assessment of MeHg exposure to three piscivorous wildlife species (bald eagle, (*Haliaeetus leucocephalus*); wood stork, (*Mycteria Americana*); and great egret, (*Ardea albus*)) foraging at a MeHg hot spot in northern ENP indicated the likelihood was very high, ranging from 98–100% probability, that these birds would experience exposures above the acceptable MeHg dose when foraging in northern ENP. Moreover, the likelihood that these birds would experience exposures above the lowest-observed-adverse-effect level (LOAEL) ranged from a 14% probability for the wood stork to 56% probability for the eagle. Data from this study, along with the results from several other surveys suggest that biota in ENP currently contain the highest MeHg levels in South Florida and that these levels are similar to or greater than other known MeHg hot spots in the United States (Rumbold et al., 2008)

E.4. Pig Frog

The FWC regulates harvest of amphibians and allows year round harvest of frogs for personal consumption. The pig frog (*Rana grylio*) constitutes the majority of harvest in the Everglades and Francis S Taylor Wildlife Management Area (i.e. the WCAs) (Paul Moler, FWC, Personal Communication). A study in 2005 indicated pig frogs in Everglades Water Conservation Areas (WCA) 2 and 3 have elevated levels of mercury in edible portions of leg meat that could constitute a health risk to consumers (Ugarte et al. 2005). In 2006, the FWC collected a total of 135 pig frogs for mercury analyses (Ted Lange, 2006). THg concentrations ranged from 0.005 to 0.78 ppm and the average THg concentration for all pig frogs was 0.17 ppm.

In 2008, a consumption advisory was issued by DOH for pig frogs. For the sensitive population, a limit of one meal per week from WCA 3B and one meal per month from WCA 3A was advised.

E.5. Burmese Python

The Burmese python (*Python molurus bivittatus*) is native to Southeast Asia and has been exported to the United States for the pet trade and ultimately released into the wild. These snakes thrive in the subtropical South Florida climate. Due to increases in their populations, state and federal agencies are working to control pythons. In January 2008, the FWC established a list of Reptiles of Concern (ROC) for nonnative species which includes pythons. In July 2009, a permit program was initiated to allow hunting of ROCs in FWC-managed areas.

There is concern, however, that hunters may consume the python meat, which has high concentrations of mercury.

Mercury data were collected from 24 Burmese pythons in the ENP from 2006–2009 by the U.S. Geological Survey (Krabbenhoft, unpublished data). The mean THg concentration in muscle tissue of 3.6 ppm (range: 0.14–10.75 ppm) was significantly higher than in fish and alligators within the ENP and showed no relationship to python size. Most of the mercury burden in pythons appears to be in the methylated form, with an average MeHg fraction of 80 percent in 11 co-sampled individuals (range: 67–96 percent). Analysis of the digestive tracts of captured pythons in Florida show some of the species consumed are raccoons, wading birds, and alligators (Snow et al., *in press*), which could account for the high concentrations of mercury since all of these species are fish-eating.



Florida Department of Environmental Protection
Division of Water Resource Management
Bureau of Watershed Management
2600 Blair Stone Road, Mail Station 3565
Tallahassee, Florida 32399-2400
(850) 245-8561
www2.dep.state.fl.us/water/

FLORIDA DEPARTMENT OF ENVIRONMENTAL PROTECTION

Division of Environmental Assessment and Restoration
Bureau of Watershed Restoration

Mercury TMDL for the State of Florida

Appendix F

Deterministic Atmospheric Modeling and Receptor Modeling

Watershed Evaluation and TMDL Section



July 5, 2012

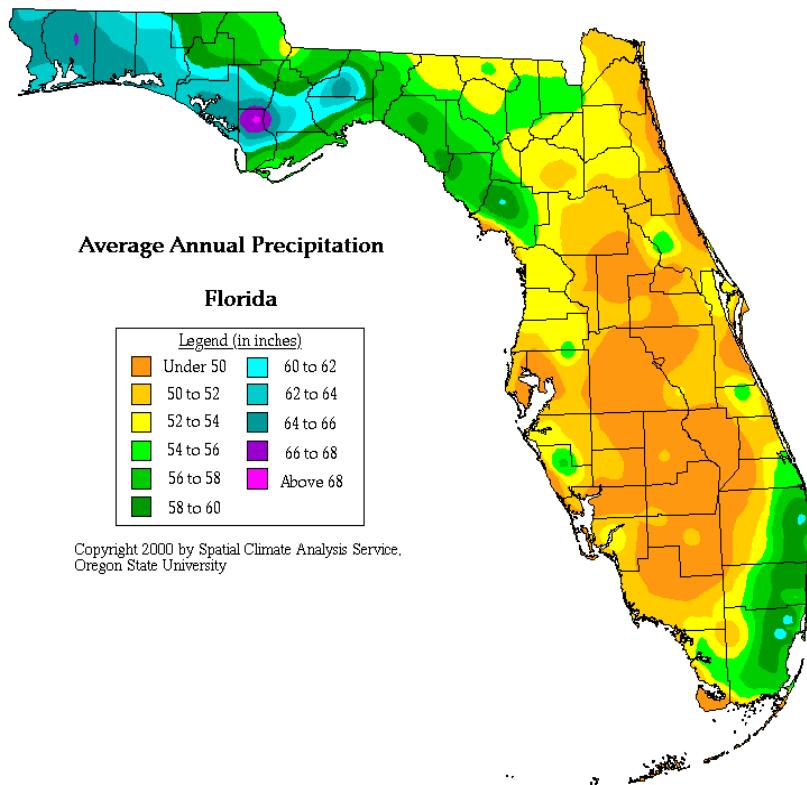
Appendix F: Atmospheric Modeling

CMAQ Model Evaluation – Draft Report

PMF Analysis of Wet Deposition Data – Draft Report

State of Florida Mercury Total Maximum Daily Load (TMDL) Project

CMAQ Model Evaluation – Draft Report



The University of Michigan Air Quality Laboratory, Ann Arbor, Michigan

June 25, 2012

CMAQ Model Evaluation

The following report synthesizes results of the Community Multiscale Air Quality (CMAQ) model evaluations conducted and reported as part of project Task Assignment 05 subtasks 5.1.1.A, 5.1.1.B, and 5.1.1.C. These include comparisons and evaluations of CMAQ output with observed (measured) ambient speciated mercury (Hg), observed mercury wet deposition, and inferentially modeled mercury dry deposition. Also included in this document are reporting on evaluations of CMAQ linearity and tagging scheme, results of which were also previously submitted as part of earlier project subtasks, as well as discussions on sensitivity to precursor emissions and applicability of model results for the TMDL project.

1. Statistics Used in Model-measurement Evaluations

The following standard performance statistics have been used to evaluate air quality models for mercury (e.g. *Bullock et al., 2009, EPA, 2008*), and have been used here.

Mean bias (in units for deposition, e.g. ug m⁻²):

$$MB = \frac{1}{N} \sum_{i=1}^N (Dm_i - Do_i)$$

where

N = number of samples

Dm_i = model value for a specific time and location

Do_i = observed value for the same time and location as the model value

Mean error (in deposition units, eg. ug m⁻²):

$$ME = \frac{1}{N} \sum_{i=1}^N |Dm_i - Do_i|$$

Normalized mean bias (relative units):

$$NMB = \frac{\sum_{i=1}^N (Dm_i - Do_i)}{\sum_{i=1}^N Do_i}$$

Normalized mean error (relative units):

$$NME = \frac{\sum_{i=1}^N |Dm_i - Do_i|}{\sum_{i=1}^N Do_i}$$

Coefficient of determination, r² (relative units):

$$r^2 = \frac{N \sum_{i=1}^N Dm_i Do_i - \sum_{i=1}^N Dm_i \sum_{i=1}^N Do_i}{N^2 \left(\sum_{i=1}^N Dm_i^2 - \left(\sum_{i=1}^N Dm_i \right)^2 \right) \left(\sum_{i=1}^N Do_i^2 - \left(\sum_{i=1}^N Do_i \right)^2 \right)}$$

2. Previous Mercury Model Evaluation Results:

Bullock et al. (2009) reported performance statistics for three different urban/regional-scale models (including CMAQ) combined with three different global-scale models, for a total of 9 comparisons. They evaluated results for a 1-year simulation for 2001 in comparison with weekly measurements of wet deposition and precipitation from the MDN network of 62 sites located throughout the U.S. (mostly in the eastern half).

They found normalized mean bias for the various model combinations ranging from -50% to +87%. There was significant variation between the three urban/regional models. CMAQ had relatively low mean bias, with values from -50% to +16% depending on the global background model. The REMSAD model tended to overpredict somewhat, with mean bias from +16% to +40%. The third regional model, TEAM, showed a major overprediction with mean bias +62% to +87%.

Normalized mean errors were 71% to 85% (CMAQ), 82% to 90% (REMSAD) and 105% to 130% (TEAM). Coefficients of determination (r^2) were relatively low for all models, ranging from 0.12 to 0.18. The relatively high mean errors and low coefficients of determination were driven largely by differences between the model and observed weekly precipitation (normalized mean error 62%, $r^2 = 0.35$).

Additionally, USEPA conducted mercury model evaluations with observed mercury wet deposition from the MDN network (USEPA, 2008). These included model results with REMSAD evaluated with three different sources of boundary conditions: CTM, GRAHM, and GEOS-CHEM.

This USEPA study utilizing REMSAD found a normalized mean bias of 60% using CTM with a normalized mean error of 66%, a normalized mean bias of 46% using GRAHM with a normalized mean error of 55%, and a normalized mean bias of 74% using GEOS-CHEM with a normalized mean error of 79%.

The performance statistics presented below for the current project differ from the previous studies in that (i) results are limited to evaluation sites in Florida, rather than for the U.S. as a whole, and (ii) the comparison is done on a monthly basis rather than weekly.

Other approaches to model evaluation:

A variety of approaches to evaluate model accuracy for mercury have been used in scientific studies. These are usually qualitative in nature rather than numerical. They include the following:

- * Evaluation of the geographical variation of wet deposition in comparison with measurements (e.g. Holmes et al., 2009, Selin and Jacob, 2008)
- * Evaluation of the vertical distribution of ambient mercury, especially above the boundary layer
- * Evaluation of the diurnal cycle of ambient mercury

Other suggested approaches include evaluation of predicted correlations between ambient Hg and other species (Hg₀ versus RGM, Hg versus sulfate and nitrate, Sillman et al., 2007) and correlations between wet deposited species and or concentrations in rainwater (Hg versus sulfate, nitrate, and/or trace metals).

3. Model-Measurement Comparisons – Mercury Wet Deposition

CMAQ wet deposition results for calendar year 2009 were compared with results from measurement sites from this TMDL project, locations of which are illustrated in Figure 1. Figure 2 shows summed annual mercury wet deposition in the CMAQ model in comparison with measured values at the 6 Florida TMDL wet deposition measurement sites. Results show generally similar magnitudes for measured and model values. The model overestimates wet deposition at Davie (DVE) and underestimates at Pensacola (OLF). Model values at the four other sites [Tampa (TPA), Orlando (UCF), Everglades National Park (ENP) and Jacksonville (JKS)] all differ from measurements by less than 20%. Geographic variations are quite consistent between model and measurements. The model shows much higher wet deposition at Davie relative to other sites and lower wet deposition at Pensacola, neither of which appears in measurements. However, both the model and measurements show higher wet deposition at the southern sites (Davie and Everglades) relative to the other sites.



Figure 1. Location of the six TMDL project routine wet deposition monitoring sites.

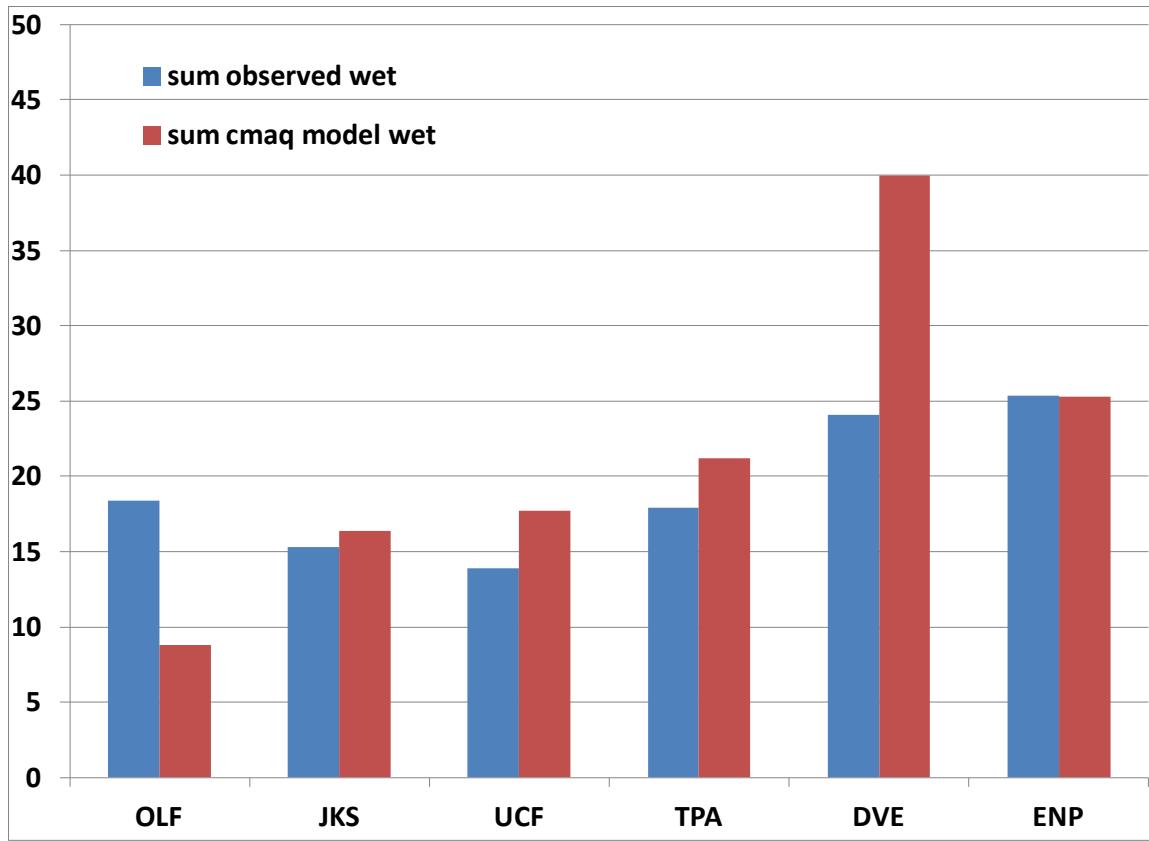


Figure 2. Summed annual (2009) mercury wet deposition ($\mu\text{g}/\text{m}^2$) in the CMAQ model in comparison with observed values at the 6 Florida TMDL wet deposition measurement sites.

Performance statistics for wet deposition evaluations, based on monthly values at each site over the 2009 year, include a normalized mean bias of 13%, and normalized mean error of 66%, and an r^2 of 0.36. While the normalized mean bias determined for this project evaluation (+13%) represents a significant improvement in performance for mercury wet deposition compared to previous studies, the determined normalized mean error and r^2 reported are very similar and quite typical of previous studies (see Section 2 above).

4. Model-Measurement Comparisons – Mercury Dry Deposition

Results of CMAQ mercury dry deposition for calendar year 2009 were evaluated with those determined using an inferential model based on surface measurements of ambient speciated mercury, meteorological and other variables (previously described and reported as part of an separate TMDL project subtask) measured at four TMDL project Supersites (Davie, Tampa, Jacksonville, and Pensacola, see Figure 1). Results of these comparisons show significant divergences between the CMAQ model and measurement-based (inferential) values. The CMAQ model dry deposition is biased low (normalized mean bias of -45%, with 51% normalized mean error over the four supersites) and the site-to-site variation tends to be different. CMAQ predicts the highest mercury dry deposition at Davie and Tampa, which likely reflect the large input from local emissions (see section below on sensitivity). CMAQ shows roughly 50% lower dry deposition for Jacksonville and Pensacola. By contrast, the inferential model shows highest dry deposition at Tampa and Pensacola, with lower deposition by 30% or more at Davie and Jacksonville. Figure 3 shows the summed annual mercury dry deposition in the CMAQ model in comparison with inferential model determined values at the 4 Florida TMDL Supersite measurement sites.

A complicating factor in this comparison is the ambiguity about the formal output for mercury dry deposition from CMAQ. The CMAQ model algorithm with bi-directional soil exchange of Hg includes release of Hg into the atmosphere from the soil as part of the dry deposition sum, so that reported dry deposition is actually the difference between direct deposition and release of Hg from soils (Jesse Bash, EPA, RTP North Carolina, personal communication, March 15, 2012). The soil release consists entirely of elemental Hg. Dry deposition of elemental mercury also differs from deposition of reactive gaseous mercury and particulate mercury in its relation to precursors. Deposition of elemental mercury is driven mainly by the global background, whereas dry deposition of reactive and particulate mercury is more sensitive to local emissions. For these reasons, and the lack of numerically quantified model-measurement based evaluations for mercury dry deposition from previous studies, it is much more difficult to contextualize the mercury dry deposition model performance compared to that presented above for mercury wet deposition. That said, this project is possibly the first to evaluate to this level of rigor the performance of CMAQ (or similar deterministic model) for mercury dry deposition compared to measurement-based approaches.

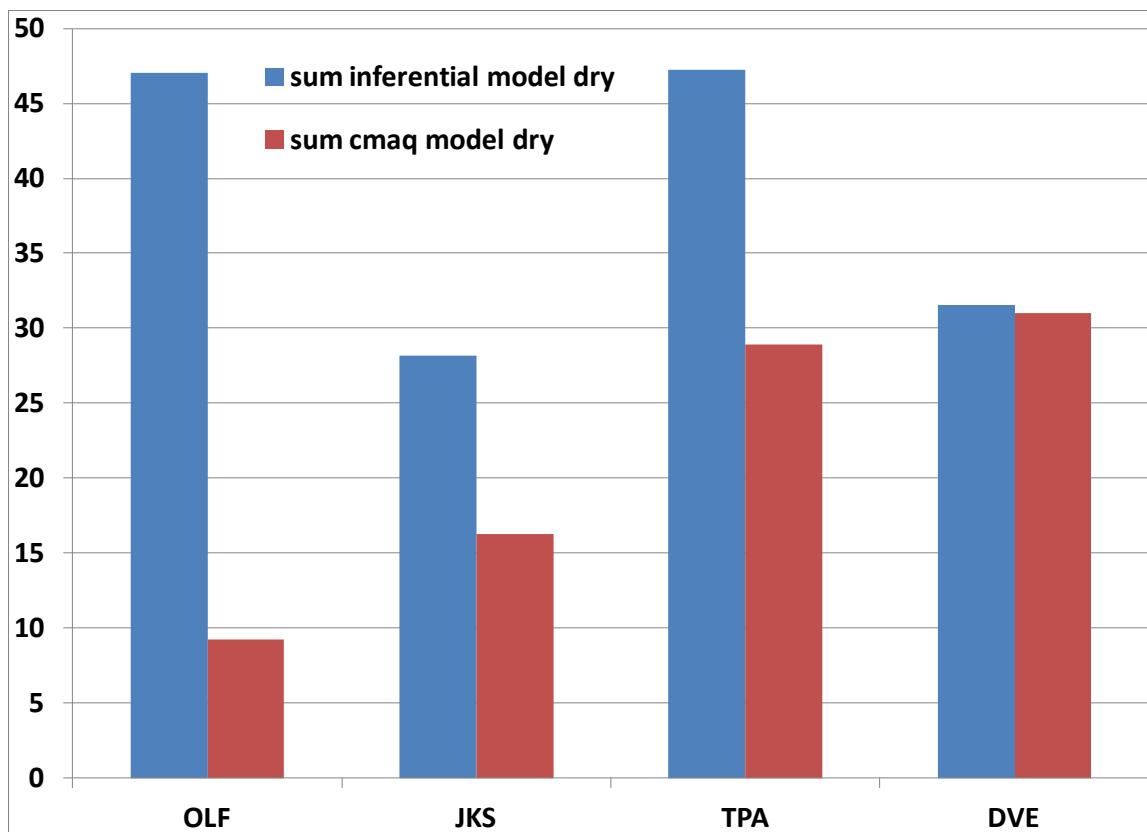


Figure 3. Summed annual (2009) mercury dry deposition ($\mu\text{g}/\text{m}^2$) in the CMAQ model in comparison with inferential model determined values for the 4 Florida TMDL Supersite measurement sites.

5. Model-Measurement Comparisons – Speciated Ambient Mercury Concentrations

Comparisons between CMAQ model results and measurements of elemental gaseous mercury (Hg_0), reactive gaseous mercury (RGM), and particulate mercury (HgP) were also conducted for calendar year 2009 for the four TMDL Supersite locations (Davie, Tampa, Jacksonville and Pensacola).

Model and measured elemental gaseous mercury show very reasonable agreement, with overall normalized mean bias of +15%, and normalized mean error of 16%. However, comparisons between model results and ambient measurements for reactive gaseous mercury and particulate mercury show large discrepancies. Model ambient concentrations are higher than measured values by factors of 10-15 for both RGM and HgP. Figure 4 shows the annual speciated ambient mercury concentrations in CMAQ in comparison with measurements from the 4 Florida TMDL Supersite measurement sites.

A distinctive feature of the measured ambient concentrations is the diurnal cycle. Measured RGM peaks during midday and declines to low values at night, with nighttime values typically lower than daytime values by a factor of 10. This strong diurnal cycle is not reproduced by the model. The RGM in the model decreases slowly at night, with the nighttime minimum just 20% below that daytime maximum. Measured particulate mercury also shows a daytime peak and nighttime minimum (lower than the daytime maximum by a factor of 3) but the nighttime decrease is not as strong as for RGM. The model also shows a diurnal cycle for HgP, but still not as strong as measured values. Elemental mercury shows less of a diurnal cycle but the measured values increase by 25% during the early morning hours (4-7am). This early morning increase does not appear in the model.

The annual cycle for reactive mercury generally shows highest values in May and in Sept-October, which correspond to the time of maximum photochemical activity in Florida. The higher reactive mercury appears in measurements and also appears in the model values.

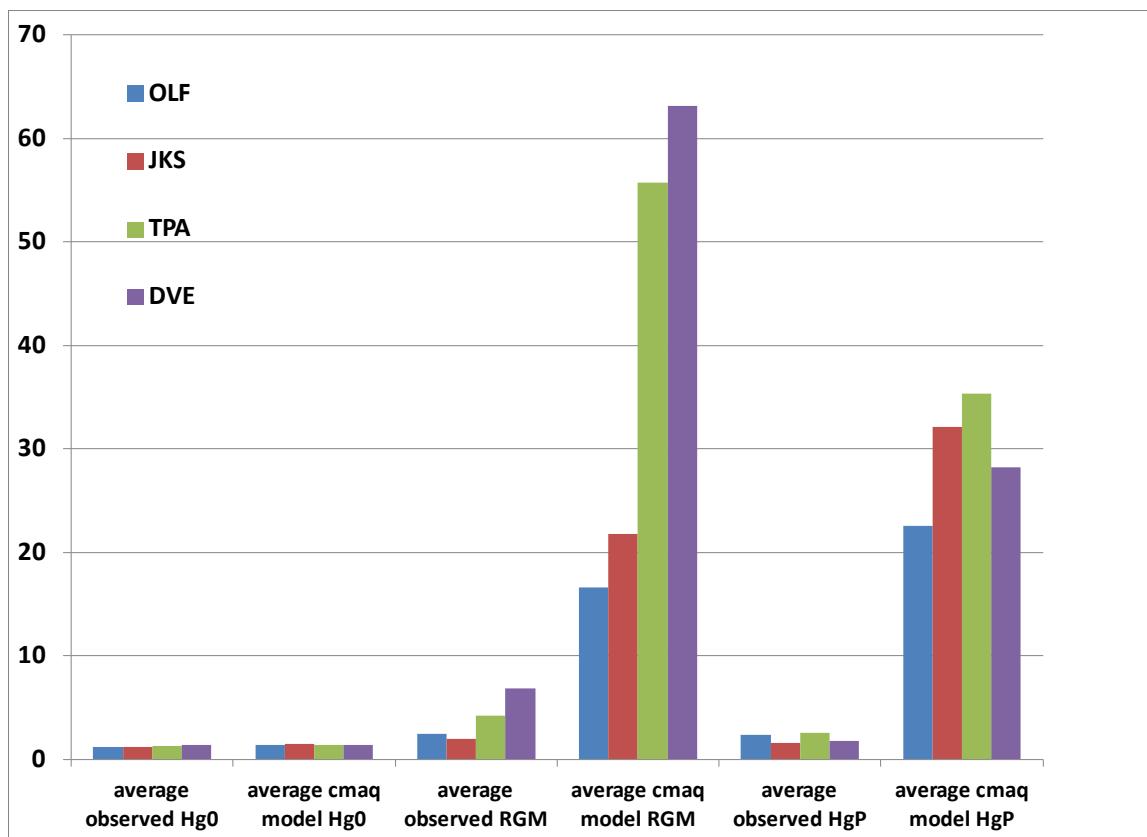


Figure 4. Annual (2009) concentrations of Hg0 (ng/m³), RGM (pg/m³), and HgP (pg/m³) in CMAQ in comparison with measurements from the 4 Florida TMDL Supersite measurement sites.

Interpretation: The strong diurnal cycle for reactive mercury combined with the seasonal peak in May and September suggest that photochemical production may have a large influence. However the very low nighttime concentrations also suggest that reactive mercury is rapidly removed at night, and that the removal process is omitted or underestimated by the model. The CMAQ model includes dry deposition of RGM with relatively high rates (2 cm s^{-1}). There is little decrease in ambient RGM in the model at Davie and other sites near emission sources because emitted RGM into the shallow nighttime boundary layer compensates for losses due to surface deposition. Consequently, dry deposition cannot explain the observed decrease in reactive mercury at night.

Possible explanations include the following:

- Rapid formation and removal of aqueous aerosols at night in association with very high humidity, fog and dew formation. This process may not be captured by the standard dry deposition representation in models.
- Conversion of reactive mercury to elemental mercury through aqueous reactions, which may be also associated with nighttime high humidity, fog and aerosol formation. Conversion from reactive mercury to elemental mercury has been suggested in association with sulfate aerosols (Seigneur et al., 2006).
- Overpredicted emissions of reactive mercury, possibly including errors in the partitioning of mercury emissions between elemental and reactive mercury.
- Overpredicted reactive mercury in the atmospheric background. However, previous comparisons between CMAQ and aircraft measurements showed relatively good agreement for RGM off the coast of Florida (Sillman et al., 2007).

Comparisons with other models:

The REMSAD simulation for the full US generally resulted in higher RGM and lower particulate mercury in comparison with CMAQ (Bullock et al., 2009a). Results from REMSAD for Florida showed surface RGM of 30-40 pg m⁻³ (annual average) and HgP 5-10 pg m⁻³. By contrast, the earlier run of CMAQ reported by Bullock et al. (2009a) found approximately 20 pg m⁻³ RGM and 20-30 pg m⁻³ HgP in Florida. These values of RGM are somewhat lower than the CMAQ results found here (40-80 pg m⁻³ RGM, 20-40 pg m⁻³ HgP), possibly because the results here are for a model run with fine horizontal resolution and in source regions. Although ambient RGM from these other models are somewhat lower than the current simulation, they still exceed measured values in Florida by a factor of 5.

Selin et al. (2009) report results from the GEOS-Chem global model and measured RGM in Florida and elsewhere. GEOS-Chem showed RGM above 100 pg m⁻³ at higher elevations (above 1 km), which are also consistent with measurements. They did not discuss surface conditions in Florida but they reported that model RGM in the southwestern U.S. (100 pg m⁻³) were much higher than measured values at the surface (6 pg m⁻³).

We conclude that the high surface concentrations of RGM and HgP in CMAQ and the contrast with much lower measured values is a result shared by the current generation of models, and is not limited to Florida.

6. Sensitivity to Precursor Emissions

The following is an overview of the factors that affect the relative influence of local emission sources versus the global background and possible assumptions in CMAQ that influence model results.

In addressing the issue of local versus global impacts it is useful to view the behavior of mercury as consisting of two separate cycles: one for emission of elemental mercury; and the other for reactive and particulate mercury.

Elemental mercury, once emitted to the atmosphere, has a lifetime in the atmosphere of approximately one year. Species with such a long atmospheric lifetime are usually widely dispersed throughout the Northern Hemisphere and throughout the troposphere, with relatively little variation in species concentrations. The resulting deposition is therefore driven primarily by global sources as opposed to local emissions. Emissions from the U.S. represent approximately 5% of total global emissions (Selin, 2009).

Reactive mercury, by contrast, has a relatively short atmospheric lifetime. Reactive gaseous mercury has a lifetime of 5-10 hours (comparable to nitrate), while particulate mercury has a lifetime of 3-5 days (comparable to sulfate). These species are both removed rapidly by both wet and dry deposition. Consequently, transport is effectively limited to 500 km for RGM and 5000 km for HgP. Removal of directly emitted reactive species is strongly linked to local sources.

It is not possible to distinguish directly emitted elemental mercury from directly emitted reactive mercury because (except in the case of dry deposition of Hg0) elemental mercury is removed from the atmosphere through conversion to reactive mercury followed by removal of reactive mercury (via wet and/or dry deposition). Measured reactive mercury therefore consists of a combination of directly emitted elemental mercury (which has been converted to reactive form) along with directly emitted reactive mercury. However, this distinction can help identify critical assumptions that affect source-receptor allocation in models.

Factors that affect local versus global source attribution in CMAQ:

- *Speciation of emissions into elemental, reactive gaseous and particulate mercury:*
Emissions of reactive and particulate mercury have a much larger local impact relative to elemental.

- *Atmospheric processes that convert reactive mercury to elemental mercury:* Several mechanisms have been proposed, including conversion in cloud water (included in CMAQ) and conversion through contact with sulfate in plumes associated with large emission sources (included in the AMSTERDAM model but not in CMAQ). Conversion to elemental mercury would reduce the impact of local emission sources.
- *Wet versus dry deposition:* Wet deposition, especially through convective precipitation (thunderstorms), involves atmospheric mixing up to a very high depth (typically 10 km or more). As such, it includes mercury from the middle and upper troposphere, which represent mainly global background sources. Dry deposition, involves mercury that is near the ground, and consequently is likely to show greater sensitivity to local (ground-based) sources.
- *Model representation of vertical transport in clouds:* The exact transport pattern in convective clouds is complex and difficult to represent in models. CMAQ uses an approximate representation in which wet deposition is removed at a uniform rate from a vertical layer extending from the surface to the cloud top. If the actual removal of mercury follows a different distribution with respect to height the impact of local versus global sources could be changed.

Sensitivity of mercury wet and dry deposition to precursor emissions of mercury were investigated for this project in two ways.

1. The original model scenario was repeated for two alternate scenarios with changed emissions: (i) a 50% reduction in mercury emitted from all Florida sources; and (ii) a 100% reduction from all Florida sources. The reduction scenarios were performed for three individual months: January, May and July 2009.
2. A tagging system was implemented that tracks mercury from 14 different source categories, including 5 Florida categories and categories representing emissions in other individual states, the rest of the U.S., soil emissions and the global background.

The tagging system, if accurate, provides much more information than the individual control runs. Tags identify the impact of emissions from a broad range of categories, whereas results from each control run provide information only about the specific reductions used in the test. The tagging results are also available for the full year rather than for the specific months of the control test.

Use of the results from both the control runs and the tagging system also critically depend on the question of ***linearity***. Conditions in the atmosphere do not always respond linearly to changes in emissions. For example: if mercury emissions in Florida are reduced by 100%, the resulting reduction in deposition is not necessarily twice as large as if mercury were reduced by only 50%. Similarly, it is not certain whether (for example) the result of a combined 60% reduction in emissions from coal-fired electricity generation along with a 30% reduction in emissions from other sources is equal to the sum of calculated reductions from each of these individually. If mercury deposition responds linearly to changes in emissions (assuming that the response to changes in elemental, reactive and particulate mercury are summed separately), then it becomes easier to infer the results of different control strategies, based on either tags for individual sources or from a small number of control scenarios.

Results here first show the response to emission changes in general (based on the more versatile tagging system as well as control runs), followed by more detailed tests for linearity and for the accuracy of tagging.

General results:

Figure 5 shows the annual mercury wet deposition partitioned into Florida and non-Florida sources, with the partition based on Florida and non-Florida tags. Results are shown for 7 sites: the four project Supersites (Davie, Tampa, Jacksonville and Pensacola), two extended sites (Everglades National Park and Orlando) and one additional site (Inglis, close to the Crystal River power plant) which is included to illustrate results in the vicinity of a largest point emission source in Florida.

Results show that wet deposition is attributed primarily to non-Florida sources, even at Crystal River. The highest Florida source attribution was at Davie and represented 25% of the total. This was followed by Crystal River (20%), Tampa (14%) and Jacksonville (11%). Florida source attribution at the other sites was 3% or less. The non-Florida source attribution consisted primarily of the global background. The amount attributed to emissions elsewhere in the U.S. were small except occasionally for locations close to state boundaries.

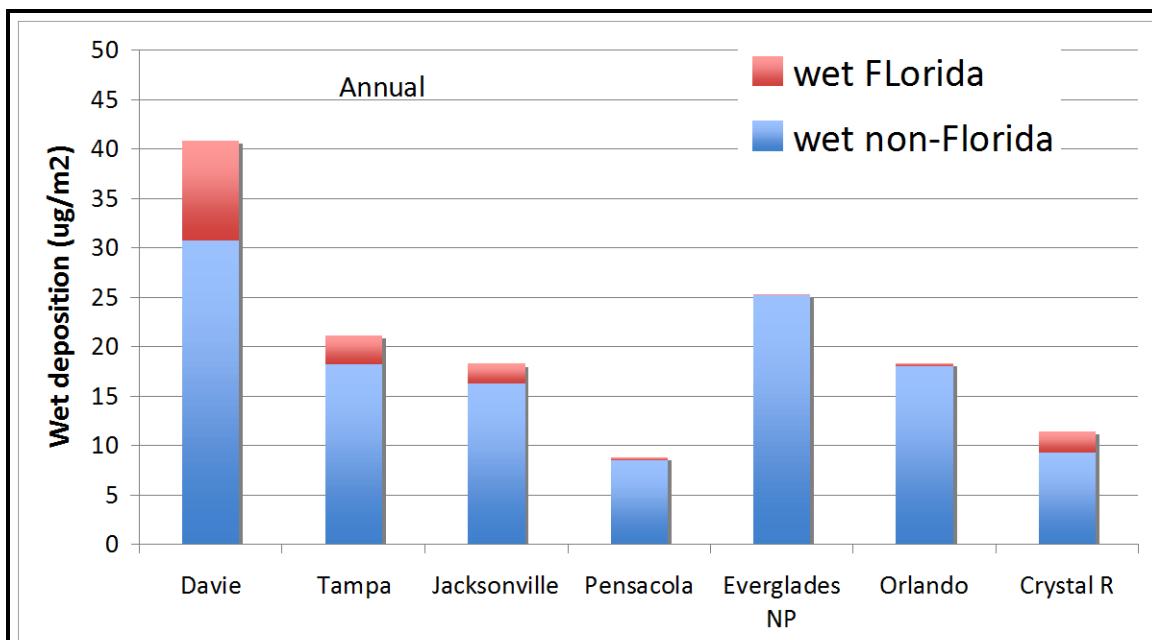


Figure 5. Annual (2009) mercury wet deposition ($\mu\text{g}/\text{m}^2$) results from CMAQ partitioned into Florida and non-Florida sources (partition based on Florida and non-Florida tags) for 7 sites.

Dry deposition, illustrated in Figure 6, shows a much larger attribution to Florida sources. The Florida source attribution accounts for more than 50% of total dry deposition at Davie and at Tampa, and approximately 30% of dry deposition at Crystal River and Jacksonville. The Florida source attribution was still relatively low elsewhere: 8% at Pensacola, 6% at Orlando and 1% at Everglades National Park. In general, CMAQ suggests that local emission sources have a large impact on local dry deposition but a much smaller impact on locations more than 100 km distant.

The variation in wet and dry deposition among sites shown in Figures 5 and 6 is also noteworthy. Dry deposition is predicted to be much higher at the sites with a large impact from Florida sources: Davie, Tampa and Crystal River. Model dry deposition for July at these sites is twice as large as dry deposition elsewhere. This enhanced dry deposition is most likely linked to the Florida source impact in the model. The site-to-site contrast provides a test for the accuracy of the model source attribution. By contrast, site-to-site variation for wet deposition does not appear to be influenced by proximity to local emission sources in the model.

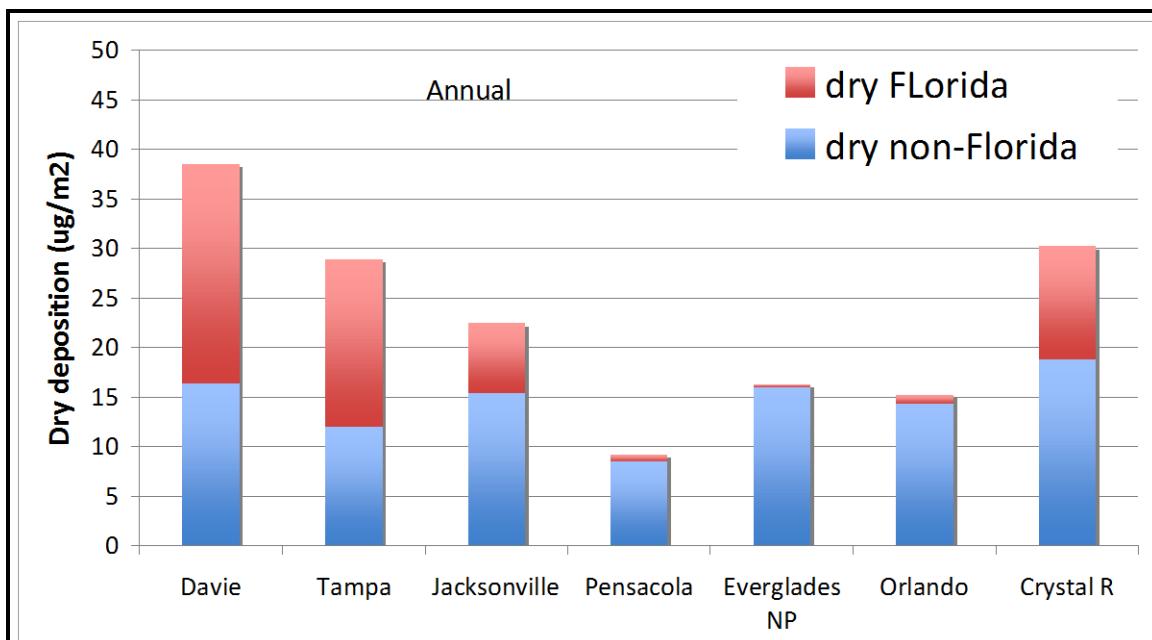


Figure 6. Annual (2009) mercury dry deposition ($\mu\text{g}/\text{m}^2$) results from CMAQ partitioned into Florida and non-Florida sources (partition based on Florida and non-Florida tags) for 7 sites.

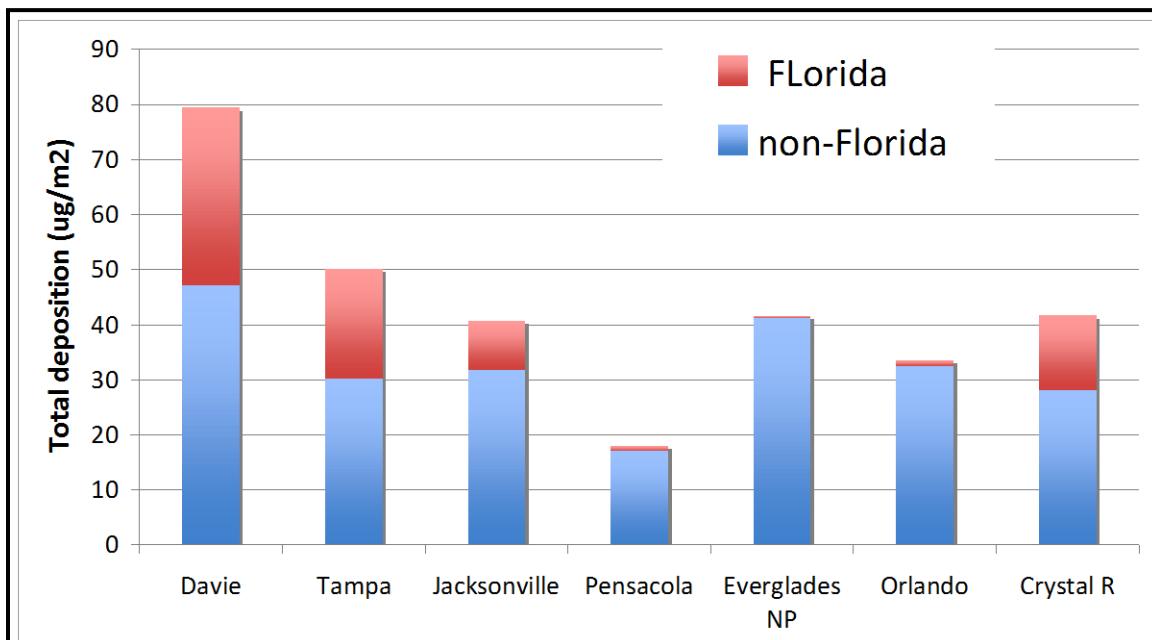


Figure 7. Annual (2009) total mercury deposition ($\mu\text{g}/\text{m}^2$) results from CMAQ partitioned into Florida and non-Florida sources (partition based on Florida and non-Florida tags) for 7 sites.

Total deposition for the year is shown in Figure 7. The Florida source attribution accounts for approximately 40% of total deposition at Davie and Tampa, 30% at Crystal River,

20% at Jacksonville, and 5% or less at the other sites. The above results are all based on the tagging methodology. Comparisons between the tags and results of control simulations are described below.

Emission reduction scenarios and tagging:

Comparisons between the tags and results of control simulations are shown in Figure 8. Here, we have calculated the CMAQ reduction in mercury wet and dry deposition associated with a 50% reduction in Florida emission sources (equal to the difference between results from the initial model scenario and the control scenario at each location). This is compared to the estimate from tagging, which is equal to the Florida tag source attribution multiplied by 50%. Results show a small degree of uncertainty, but the estimates based on tagging agree with the reduction derived from scenarios with reduced emissions to within 10% or better.

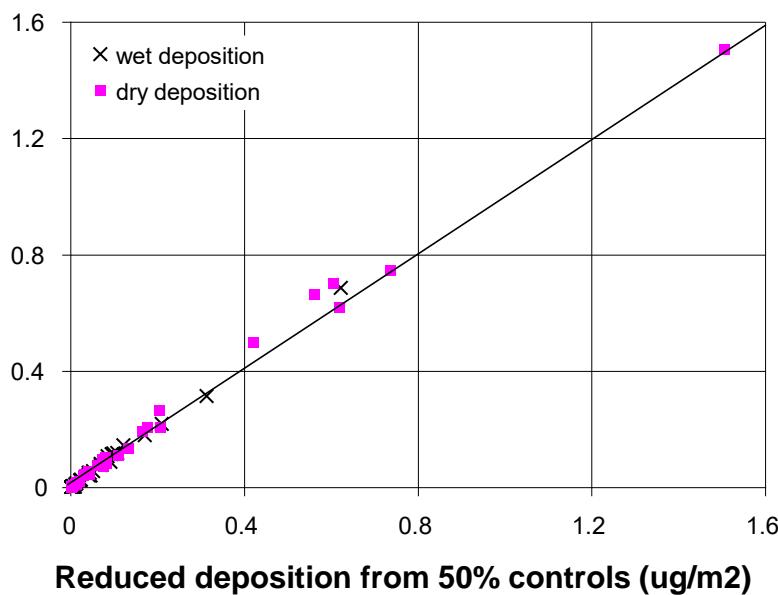


Figure 8. Calculated CMAQ reduction in mercury wet and dry deposition associated with a 50% reduction in Florida emission sources (equal to the difference between results from the initial model scenario and the control scenario at each location).

Linearity:

The question of whether the model wet and dry deposition responds in a linear way to reductions in emission rates is tested by comparing results from the 50% and 100% control scenarios.

For each scenario the reduction in deposition is calculated as the difference between deposition in the model base case and equivalent deposition in the control scenario. This method may be applied to monthly or annual sums or to results for individual days. If the model responds linearly to emissions changes, then the amount of the reduction for the scenario with 50% reduced emissions should be half as large as the reduction for the scenario for 100% reduced emissions.

Results in Figure 9 show that the model response is very close to linear. Deviations from a linear response occur for dry deposition on a few days, likely resulting from complications associated with the CMAQ bi-directional soil algorithm. These deviations are not significant in terms of monthly sums, which show deviations of less than 1% from the linear response.

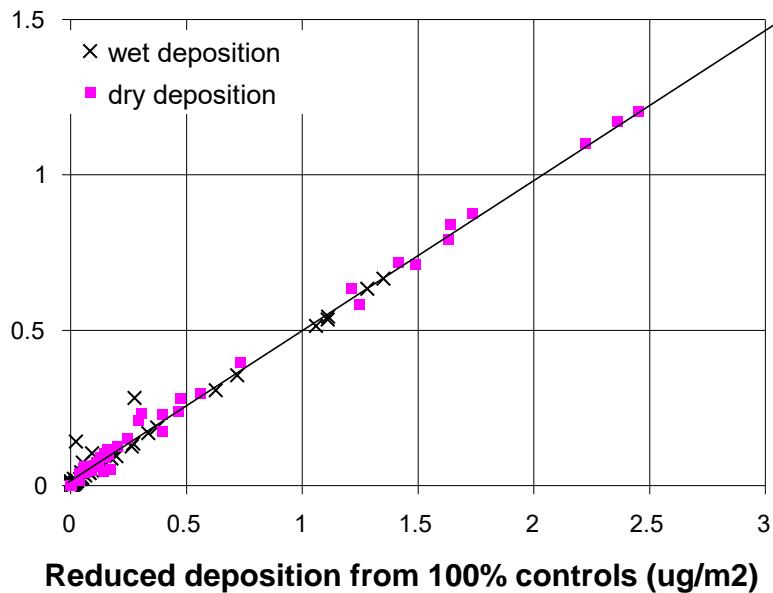


Figure 9. Linearity Tests: Reduction in Hg deposition (reduced deposition from 100% controls vs. reduction from 50% controls).

7. Sensitivity to Precursor Emissions: Conclusions and Implications from Model-Measurement Comparisons, and Applicability of CMAQ Results for TMDL Project

Results of the CMAQ evaluation of the sensitivity of mercury wet and dry deposition to Florida emissions yield the following conclusions.

CMAQ predicts the following:

- Wet deposition is attributed mainly to the global background. Impact of within Florida emissions are generally 10% or less.
- Florida emissions have a significant impact on dry deposition of Hg. At some locations more than 50% of dry deposition is attributed to Florida sources.
- The impact of Florida sources on dry deposition is mostly in locations close to the emission sources. The impact on rural areas more than 100 km distant is 20% or less.
- Dry deposition is predicted to be similar in magnitude to wet deposition, so that close to 50% of total deposition of mercury consists of dry deposition

Model-measurement comparisons provide an evaluation of CMAQ accuracy in general. In terms of ambient speciated mercury, CMAQ compared very well with gaseous elemental mercury, but significantly overestimated levels of reactive gaseous mercury and particulate mercury. These results are consistent with those presented as part of previous studies, and suggest that continued development and refinement of CMAQ and other similar models are needed to improve upon the models ability to better reflect observations based on measurements.

Model comparisons with measured mercury wet deposition are in good agreement, and for this project represent some of the best agreement observed when compared to previous studies. Model comparisons for mercury dry deposition compare less well than for wet deposition. However, a lack of any previous studies comparing these results for dry deposition somewhat complicates our ability to contextualize the dry deposition comparative results. One way to better contextualize and evaluate the CMAQ model deposition results is to compare total (wet + dry) deposition. When combined, CMAQ model results still compare well with total deposition based on measurements at the four project Supersites. Performance statistics for total mercury deposition evaluations, based on monthly values at each site over the 2009 year, include a normalized mean bias of 26%, and normalized mean error of 46%. These results are shown in a positive light even when compared to the wet-only deposition evaluations from

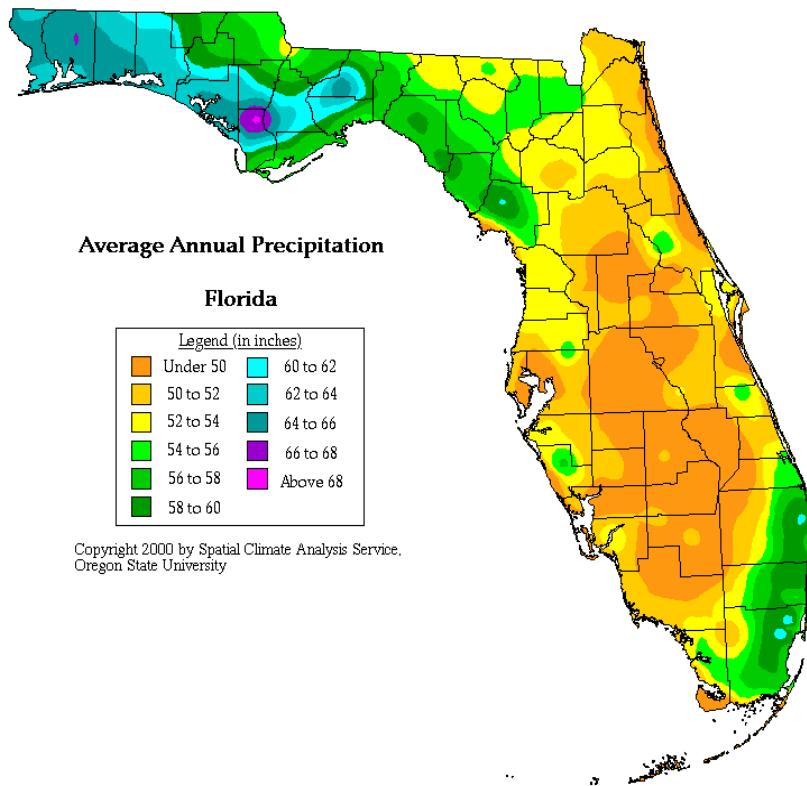
previous studies. Since total mercury deposition is the primary CMAQ output data that serves as input to the TMDL aquatic model, it can be concluded based on the performance statistics here that the CMAQ results are reasonably reflective of deposition observations from measurements, and appropriate for use in this TMDL project.

8. References

- Bullock, O. R., Jr., et al. (2008), The North American Mercury Model Intercomparison Study (NAMMIS): Study description and model-to-model comparisons, *J. Geophys. Res.*, 113, D17310, doi:10.1029/2008JD009803.
- Bullock, O. R., Jr., et al. (2009), An analysis of simulated wet deposition of mercury from the North American Mercury Model Intercomparison Study, *J. Geophys. Res.*, 114, D08301, doi:10.1029/2008JD011224.
- Che-Jen Lin, Pruek Pongprueksaa, O. Russell Bullock Jr., Steve E. Lindberg, Simo O. Pehkonen, Carey Jangg, Thomas Braverman, Thomas C. Hoh, Scientific uncertainties in atmospheric mercury models II: Sensitivity analysis in the CONUS domain, *Atmospheric Environment* 41 (2007) 6544–6560.
- Holmes, C. D., Jacob, D. J., Corbitt, E. S., Mao, J., Yang, X., Talbot, R., and Slemr, F.: Global atmospheric model for mercury including oxidation by bromine atoms, *Atmos. Chem. Phys.*, 10, 12037-12057, doi:10.5194/acp-10-12037-2010, 2010.
- Jung-Hun Woo, John Graham, Emily Savelli, Shan He, and Gary Kleiman (NESCAUM), Development of REMSAD emissions tagging scheme in support of MANE-VU contribution assessment, <http://www.epa.gov/ttnchie1/conference/ei15/session4/woo.pdf>.
- Lohman, K.; Seigneur, C.; Edgerton, E.; Jansen, J. *Environ. Sci. Technol.*; (Article); 2006; 40(12); 3848-3854. DOI: [10.1021/es051556v](https://doi.org/10.1021/es051556v).
- Seigneur, C., K. Vijayaraghavan, and K. Lohman (2006), Atmospheric mercury chemistry: sensitivity of global model simulations to chemical reactions, *J. Geophys. Res.*, 111, D22306, doi:10.1029/2005JD006780.
- Selin, N.E., Jacob, D.J., Park, R.J., Yantosca, R.M., Strode, S., Jaegle, L., Jaffe, D.A., 2007. Chemical cycling and deposition of atmospheric mercury: global constraints from observations. *Journal of Geophysical Research* 112, D02308.
- Selin, N.E. and Jacob, D.J., Seasonal and spatial patterns of mercury wet deposition in the United States: Constraints on the contribution from North American anthropogenic sources, *Atmospheric Environment* 42 (2008) 5193–5204.
- Selin, N. E., Global Biogeochemical Cycling of Mercury: A Review, *Ann. Rev. Environ. Resrcs.*, 2009.
- Sillman, S., F. J. Marsik, K. I. Al-Wali, G J. Keeler, and M. S. Landis (2007), Reactive mercury in the troposphere: Model formation and results for Florida, the northeastern United States, and the Atlantic Ocean, *J. Geophys. Res.*, 112, D23305, doi:10.1029/2006JD008227.
- US Environmental Protection Agency (USEPA), [Model-based Analysis and Tracking of Airborne Mercury Emissions to Assist in Watershed Planning Report \(PDF\)](http://www.epa.gov/owow/tmdl/techsupp.html), August 2008, available at <http://www.epa.gov/owow/tmdl/techsupp.html> (http://water.epa.gov/lawsregs/lawsguidance/cwa/tmdl/upload/final300report_10072008.pdf).

State of Florida Mercury Total Maximum Daily Load (TMDL) Project

PMF Analysis of Wet Deposition Data – Draft Report



The University of Michigan Air Quality Laboratory, Ann Arbor, Michigan

July 2, 2012

PMF Analysis of Wet Deposition Data

The following report describes results of the application of the Positive Matrix Factorization (PMF) model analysis of Florida TMDL project wet deposition data collected at field monitoring sites. The wet deposition data collected was described and submitted as part of previous project subtasks. While the Community Multiscale Air Quality (CMAQ) model was utilized as a deterministic tool to estimate source contributions on a 4km grid across the state of Florida using an emissions tagging approach (submitted and discussed as part of previous project subtasks), this report summarizes results from source apportionment analyses using PMF for each of the six TMDL project wet deposition monitoring sites.

1. Precipitation Monitoring at Supersites/Satellite Sites

Four Supersite locations, combined with two Satellite site locations, formed a spatially diverse wet deposition monitoring network of operating sites for the Florida TMDL project. The four Supersites were located in Pensacola, Jacksonville, Tampa, and Davie, while the two Satellite sites were located in Orlando and Everglades National Park (Figure 1). The scope of this precipitation monitoring component of the project was to include the continuous characterization of key constituents of precipitation necessary for the mercury (Hg) TMDL assessment. The monitoring at the six wet deposition sites included sample collection for subsequent analysis for total Hg, major ions, and trace elements.



Figure 1. Location of the six TMDL project routine wet deposition monitoring sites.

The six wet deposition monitoring sites included the counties of Escambia, Duval, Orange, Hillsborough, Broward, and Miami-Dade:

- The Escambia County Supersite was located on U.S. Navy property approximately 19 km NW of downtown Pensacola (lat. 30.5500, long. -87.3751), and was a collaborative site with Southern Company Services. Precipitation

monitoring at this site (identified as OLF in Figure 1) began in October 2008 and continued through the end of August 2010.

- The Duval County Supersite was located on a farm managed by the City of Jacksonville-Parks and Recreation approximately 29 km WSW of downtown Jacksonville (lat. 30.2475, long. -81.9516). Precipitation monitoring at this site (identified as JKS in Figure 1) began in March 2009 and continued through the end of August 2010.
- The Hillsborough County site was located in private property approximately 8 km SE of the City of Tampa (lat. 27.9137, long. -82.3749), and was a coordinated site with staff at Hillsborough County. Precipitation monitoring at this site (identified as TPA in Figure 1) began in January 2009 and continued through the end of August 2010.
- The Broward County site was located at a county-operated air monitoring site (Site #8) located approximately 12 km SW of the City of Fort Lauderdale (lat. 26.0854, long. -80.2407), and was a coordinated site with staff at Broward County. Precipitation monitoring at this site (identified as DVE in Figure 1) began in February 2009 and continued through the end of August 2010.
- The Orange County site was a wet deposition-only site located on the property of the University of Central Florida (lat. 28.5921, long. -81.1903), and was a coordinated site with staff at Orange County. Precipitation monitoring at this site (identified as UCF in Figure 1) began in March 2009 and continued through the end of August 2010.
- The Miami-Dade County site was located within Everglades National Park at the Beard Research Center (lat. 25.3898, long. -80.6803), and was a coordinated site with staff of ENP. Precipitation monitoring at this site (identified as ENP in Figure 1) began in November 2008 and continued through the end of August 2010.

Automated Sequential Precipitation Samplers (ASPS)

The importance of collecting wet deposition on an event basis for receptor modeling and meteorological analysis is now well known (Ross 1990; Dvonch et al 1999; Landis et al 2002; Dvonch et al 2005). Wet deposition was collected on a daily-event basis using the University of

Michigan Automated Sequential Precipitation Sampler (ASPS). This sampler is a computer-controlled precipitation sampling system designed and built by the UMAQL that allows unattended wet-only event-precipitation collection (Figure 2). The Florida mercury TMDL atmospheric monitoring plan included deployment of one ASPS unit at each of the six monitoring locations. The ASPS allows for the concurrent automated collection of up to four different samples using independent sampling trains. The Hg sampling train was composed of



Figure 2. Photo of ASPS – Automated Sequential Precipitation Sampler – as deployed for TMDL project at Everglades National Park monitoring site.

glass and Teflon and samples were collected into acid-cleaned sampling bottles. A separate sampling train was used for trace elements and major ions. The sampler utilizes sampling racks that hold eight individual bottles connected to discrete sampling trains, and automatically sequences to a new sampling bottle each day to allow for discrete precipitation events to be characterized on a daily basis. Each bottle is sealed before and after the precipitation sample is collected using the computer controlled rack module and valves. The sample racks are housed in the base of the sampler in a temperature-controlled chamber that is kept between 5-8°C.

Sample Shipment and Processing, and Laboratory Analysis for Mercury, Trace Elements, Major Ions, and Mercury Isotopes

All sample preparation, handling, and processing employed ultra-clean techniques as described by Landis and Keeler (1997) and Hoyer et al. (1995). All supplies for wet deposition collection were acid-cleaned at the UMAQL, and were subsequently shipped to the six individual monitoring sites on a routine basis during the period October 2008 through August 2012. After field sample collection, samples were shipped from the monitoring sites to FDEP Central

Laboratory for total mercury analysis, and to UMAQL for analysis of trace elements and major ions.

Mercury. Laboratory determinations for total Hg in precipitation were conducted at the FDEP Central Laboratory. After oxidation with BrCl, total Hg in precipitation was purged from solution in a Hg-free argon stream after reduction with NH₂OH and reduction of divalent Hg by SnCl₂ to Hg⁰, and concentrated onto a gold trap. Total Hg was then quantified using a dual amalgamation technique followed by cold-vapor atomic fluorescence spectrometry (CVAFS).

Trace Elements. Laboratory analyses of trace elements in precipitation were carried out at the UMAQL. Samples were acidified with concentrated HNO₃ to a 0.2% solution (v/v) in the sample bottle and stored in a dark cold room for a minimum of 14 days before analysis to provide adequate time for optimal leaching (Graney et al 2004). Precipitation samples were analyzed for a suite of trace elements using a Finnigan MAT Element magnetic sector field high resolution ICP-MS using a method similar to that previously described (Keeler et al 2006).

Major Ions. Laboratory analyses for major ions were completed at the UMAQL. Precipitation samples were analyzed for major anions using a Dionex (Sunnyvale, CA) ion chromatography system.

2. Positive Matrix Factorization

While one of the primary goals of the Florida Mercury TMDL was to estimate the loading of Hg to the State freshwater bodies, of equal importance was an improved understanding of the relative impact of source types and source regions (within-state, out-of-state) contributing to the total deposition. Previously, the Community Multiscale Air Quality (CMAQ) model was utilized as a deterministic tool to estimate these source contributions on a 4km grid across the state of Florida using an emissions tagging approach (submitted and discussed as part of previous project subtasks).

An additional source apportionment approach described here is carried out utilizing the observed wet deposition data collected at project measurement sites, and a multivariate receptor modeling technique, the major advantage of which being the ability to identify and apportion the impact of major source types on a receptor site with lack of source information. Among the multivariate receptor modeling methods, Positive Matrix Factorization (PMF) is a recently developed factor analysis technique where the factor score matrix and factor-loading matrix are constrained to non-negative values (Paatero 1997). The PMF model is a weighted least-squares fit, with weights based on the known standard deviations of the elements of the data matrix. The PMF model is described in detail by Paatero (1997). Since PMF uses realistic error estimates, the PMF approach offers improvements over the Principal Components Analysis (PCA) approach. One of the critical steps in PMF modeling is the identification of source types with the chemical composition profile of each factor, and the determination of the appropriate number of factors. The identification of specific source types contributing to a factor is accomplished using known indicator species or elemental ratios. PMF allows the calculation of factor contributions for the major sources impacting the site. In many instances the co-mingling of source contributions on one factor occurs and further analysis is required to determine the source types contributing. Identification of the major source contributors (and the relative proportion of their contribution) is possible in many cases as the major sources or combinations of sources have distinct major and trace elemental signatures that distinguish themselves from each other (Gordon, 1988). PMF compares well with other source receptor modeling approaches in use, giving quite similar results (Hopke et al, 2006; Keeler et al., 2006). Utilizing this receptor modeling technique, observed data provided for analysis and determination of source contributions to the measured wet deposition during the study period at each of the project wet deposition monitoring sites (Figure 1).

3. Results

Davie monitoring site (DVE in Figure 1):

PMF analysis of data from the Davie site identified five significant factors, or source types. The first factor was identified as a marine contributor, with significant loadings of Sr and Mg. The second factor, including a strong loading of Ca, was identified as associated with cement production. The waste incineration factor was identified by loadings of Pb and Sb. An oil combustion factor was identified by significant loadings of V and Ni. The last factor was identified as a crustal contributor, with loadings of Rb and Mn. Of these five identified source types, three of these factors contributed significantly to Hg wet deposition, based on the 5th percentile of the bootstrap uncertainty. As illustrated in Figure 3, the waste incineration factor accounted for 50% of the measured Hg wet deposition at the Davie site, while the oil combustion factor contributed 25%, and the crustal factor accounted for 13%, with 11% of the measured Hg left unexplained by this analysis.

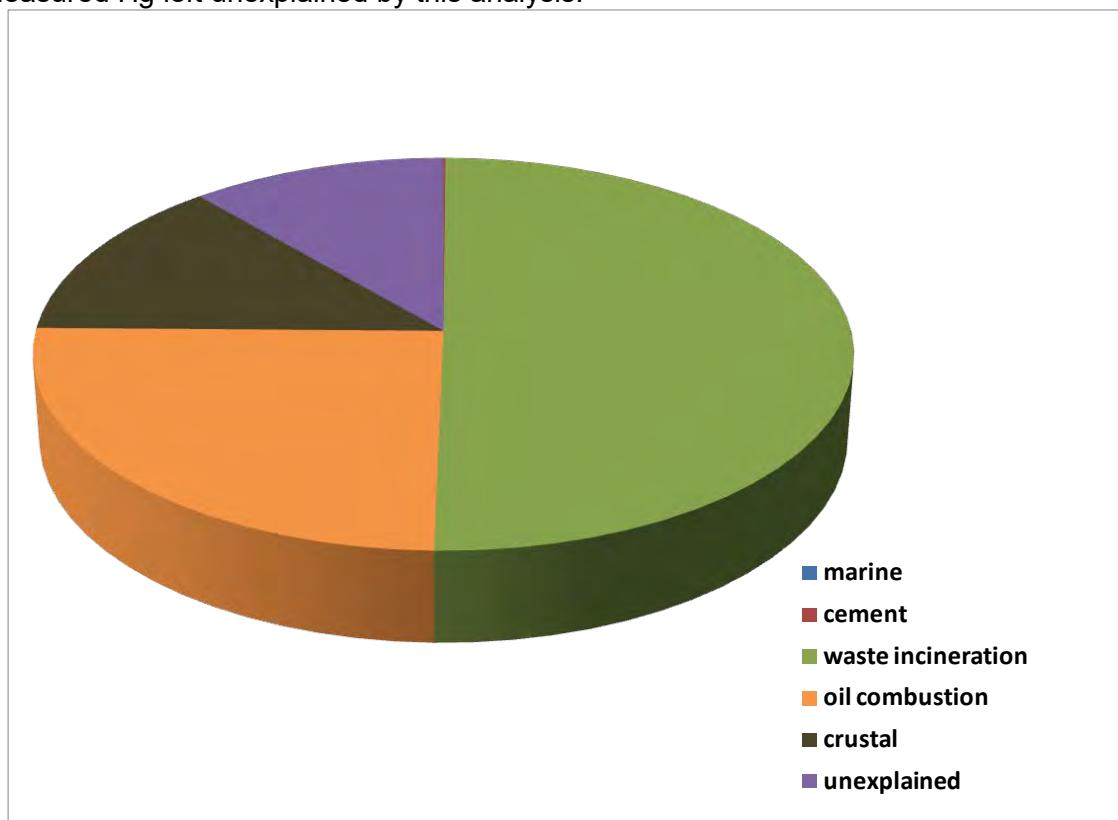


Figure 3. Percent contributions by PMF identified source types to measured Hg wet deposition at the Davie TMDL project monitoring site ($r^2 = 0.70$).

Everglades National Park monitoring site (ENP in Figure 1):

PMF analysis of data from the Everglades National Park site identified four significant factors. The first factor was identified as a combined oil combustion/industrial source contributor. The second factor represented a crustal source, the third factor a marine source, and the last factor was identified as waste incineration. Of these four identified source types, only the oil combustion/industrial source factor contributed significantly to Hg wet deposition, based on the 5th percentile of the bootstrap uncertainty, accounting for 69% of the Hg wet

deposited at the ENP site. 31% of the measured Hg was left unexplained by this analysis, as illustrated in Figure 4.

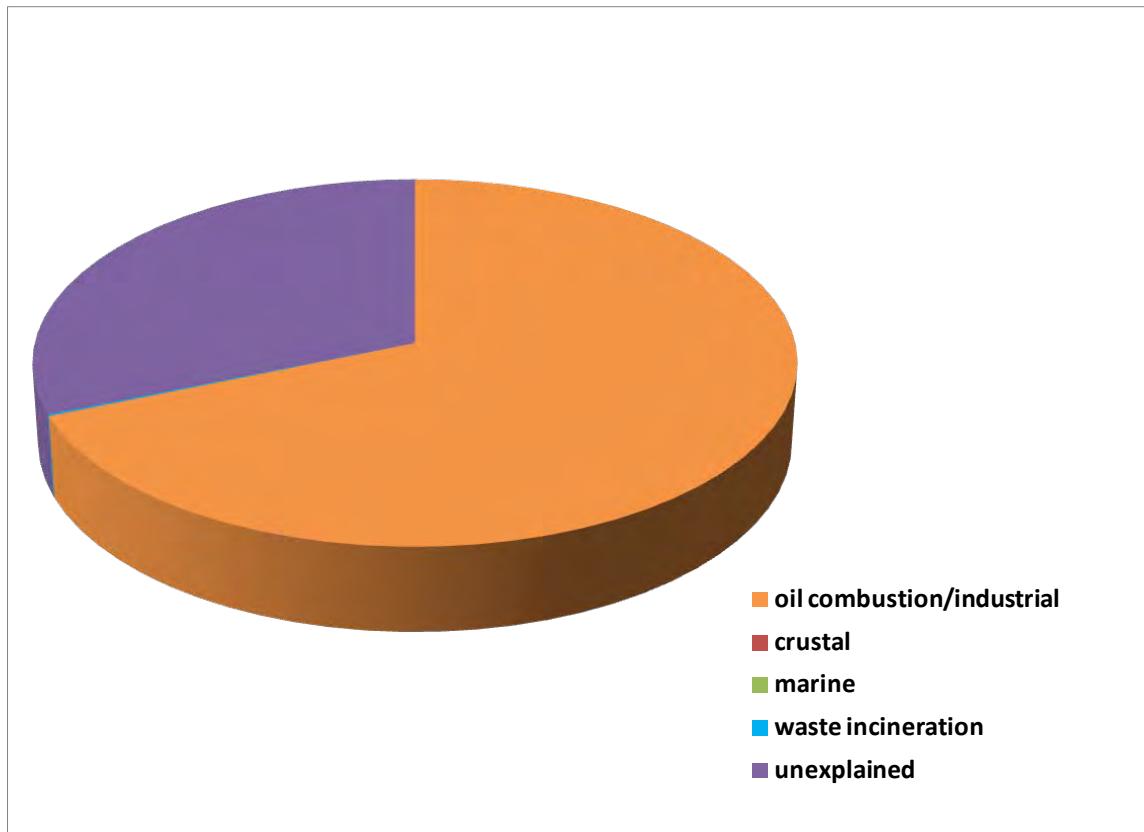


Figure 4. Percent contributions by PMF identified source types to measured Hg wet deposition at the Everglades National Park TMDL project monitoring site ($r^2 = 0.60$).

Tampa monitoring site (TPA in Figure 1):

PMF analysis of data from the Tampa site identified six significant factors, or source types. The first factor was identified as a fertilizer source, with a strong loading of P. The second factor was identified as a waste incineration factor, the third factor as oil combustion, the fourth factor as a marine source, and the fifth factor as a crustal contributor. The last factor was identified as a coal combustion source, with significant loadings of S and Se. Of these six identified source types only the coal combustion factor was found to contribute significantly to measured Hg wet deposition at the TPA site, based on the 5th percentile of the bootstrap uncertainty, contributing 81%. 19% of the measured Hg was left unexplained by this analysis, as illustrated in Figure 5.

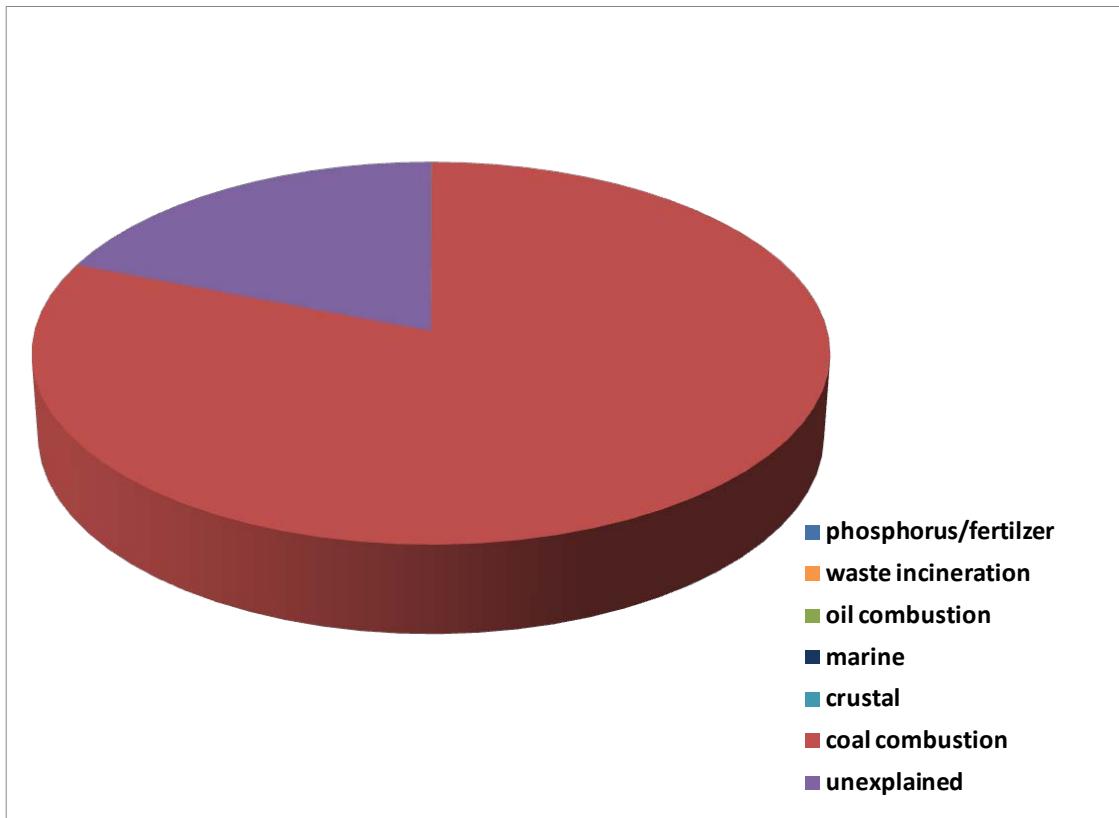


Figure 5. Percent contributions by PMF identified source types to measured Hg wet deposition at the Tampa TMDL project monitoring site ($r^2 = 0.77$).

Orlando monitoring site (UCF in Figure 1):

PMF analysis of data from the Orlando site identified four significant factors, or source types. The first factor was identified as a crustal contributor, the second factor a coal combustion source, the third factor a marine contributor, and the last factor from waste incineration. Of these four identified source types only the coal combustion factor was found to contribute significantly to measured Hg wet deposition at the UCF site, based on the 5th percentile of the bootstrap uncertainty, contributing 37%. While the waste incineration factor did contribute a large amount to Hg deposition, the analysis did not identify this as statistically significant, resulting in 63% of the measured Hg as left unexplained by this analysis, as illustrated in Figure 6.

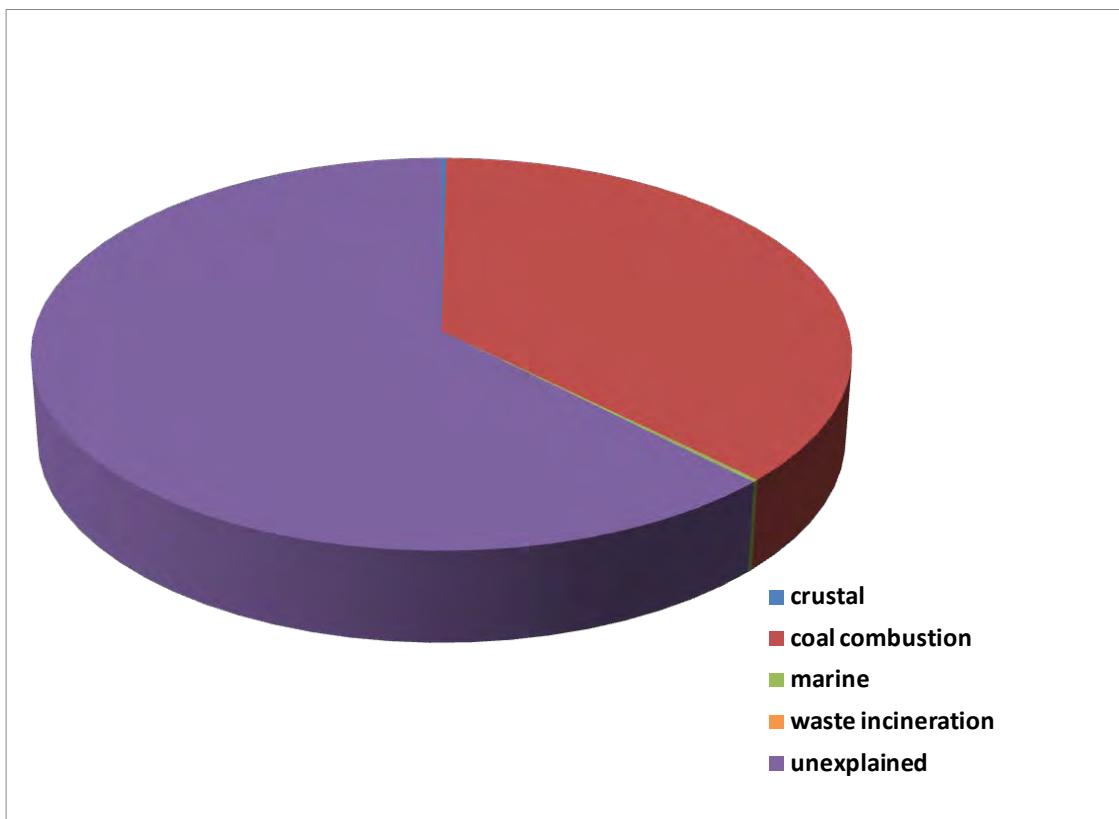


Figure 6. Percent contributions by PMF identified source types to measured Hg wet deposition at the Orlando TMDL project monitoring site ($r^2 = 0.69$).

Jacksonville monitoring site (JKS in Figure 1):

PMF analysis of data from the Jacksonville site identified five significant factors, or source types. The first factor was identified as a combined waste incineration/oil combustion source. The second factor was identified as a crustal contributor, with the third factor as a combined cement production/industrial source contributor. The fourth factor was identified as a marine source, and the fifth factor as coal combustion. Of these five identified factors, only the coal combustion factor was found to contribute significantly to measured Hg wet deposition at the JKS site, based on the 5th percentile of the bootstrap uncertainty, contributing 74% and leaving 26% of the measured Hg left unexplained by this analysis, as illustrated in Figure 7.

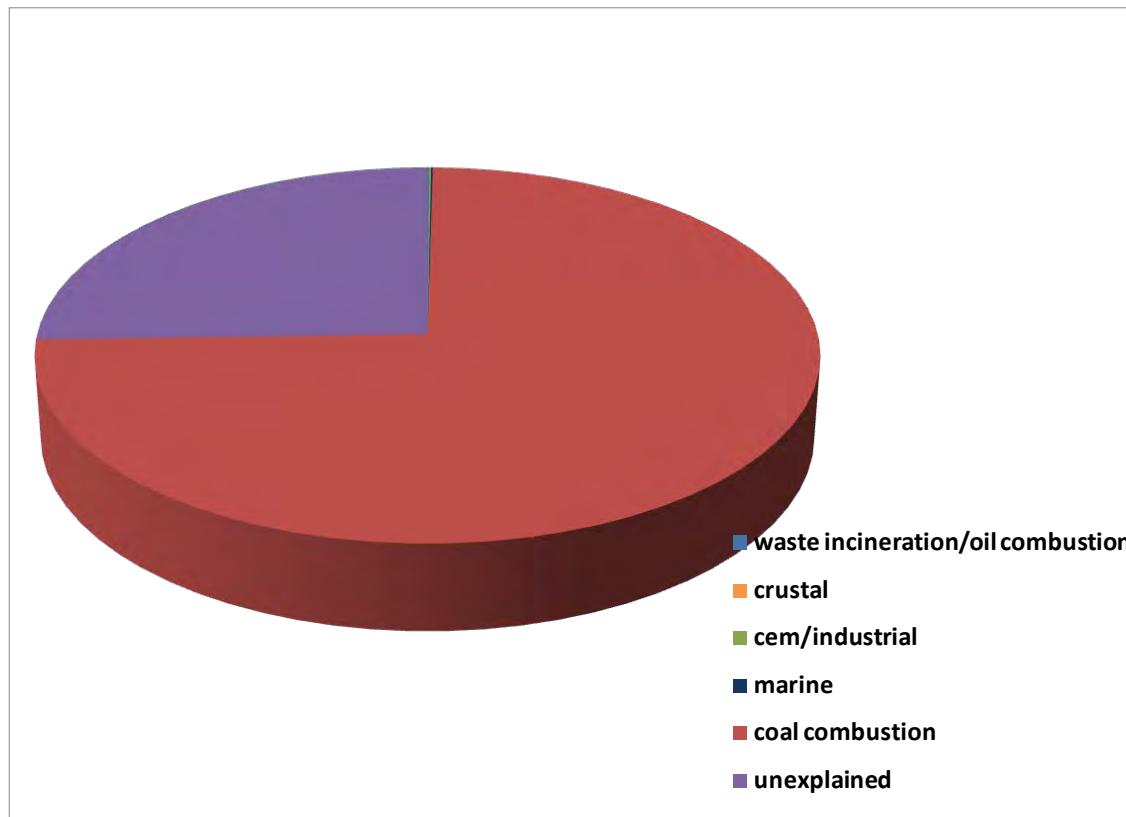


Figure 7. Percent contributions by PMF identified source types to measured Hg wet deposition at the Jacksonville TMDL project monitoring site ($r^2 = 0.60$).

Pensacola monitoring site (OLF in Figure 1):

PMF analysis of data from the Pensacola site identified five significant factors, or source types. The first factor was identified as a marine contributor, and the second factor as coal combustion. The third factor was identified as a combined crustal/refinery contributor, with the forth factor as a combined cement production/industrial source contributor. The fifth factor was identified as waste incineration. Of these five identified factors, only the coal combustion factor was found to contribute significantly to measured Hg wet deposition at the OLF site, based on the 5th percentile of the bootstrap uncertainty, contributing 60% and leaving 40% of the measured Hg left unexplained by this analysis, as illustrated in Figure 8.

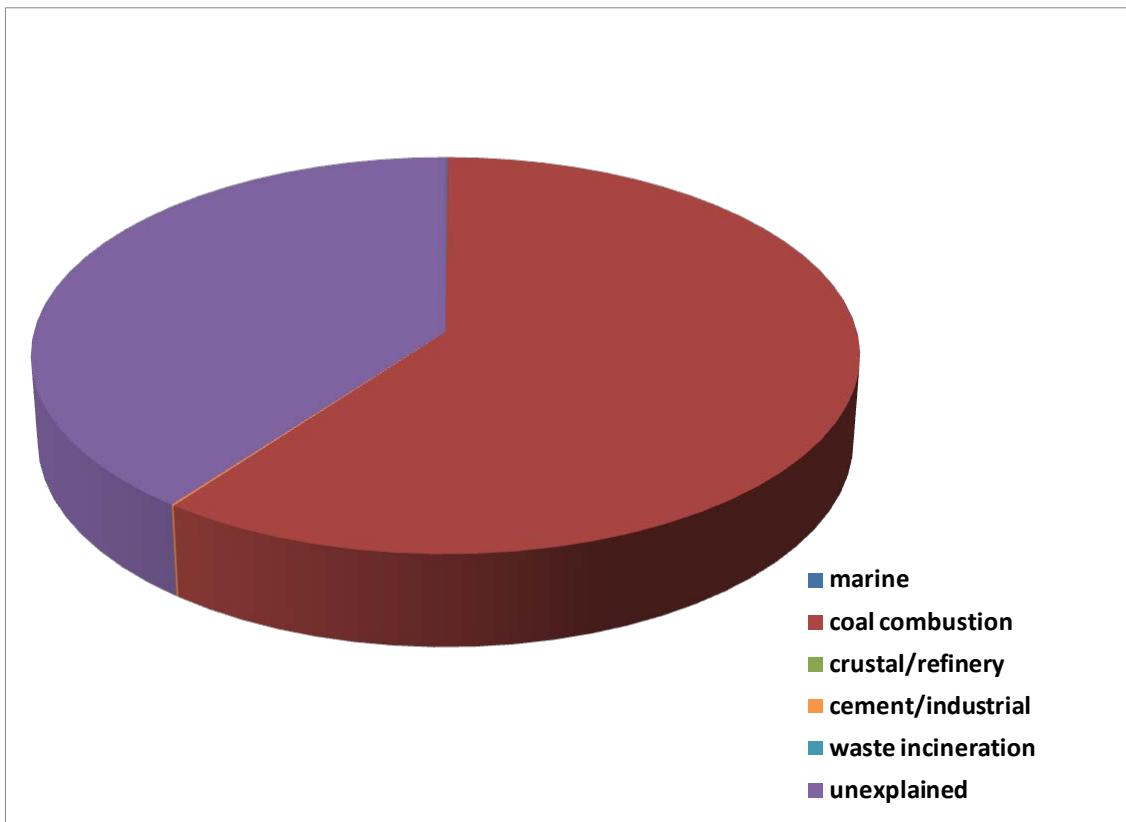


Figure 8. Percent contributions by PMF identified source types to measured Hg wet deposition at the Pensacola TMDL project monitoring site ($r^2 = 0.70$).

4. Summary

While one of the primary goals of the Florida Mercury TMDL was to estimate the loading of Hg to the State freshwater bodies, of equal importance was an improved understanding of the relative impact of source types and source regions (within-state, out-of-state) contributing to mercury deposition. The Community Multiscale Air Quality (CMAQ) model was utilized as a primary deterministic tool to estimate these source contributions on a 4km grid across the state of Florida using an emissions tagging approach (submitted and discussed as part of previous project reports). While CMAQ was the primary model utilized for source attribution analysis on a statewide basis, field measurement data also collected as part of the project allowed for an independent source apportionment analysis utilizing a multivariate receptor modeling approach.

This current report described results of the application of the U.S. Environmental Protection Agency (EPA) Positive Matrix Factorization (PMF) model (version 3.0), a receptor model and multivariate statistical analysis software developed specifically for air quality management applications, for analysis of Florida TMDL project field measurement-based wet deposition data collected at project field monitoring sites. Receptor models provide scientific support for air quality management by identifying and quantifying contributions for source apportionment. To ensure that receptor modeling tools are available for use in the development and implementation of air quality standards, the U.S. EPA's Office of Research and Development (ORD) has and continues to develop a suite of receptor modeling tools that are freely distributed to the air quality management community. EPA-PMF is one of the receptor models that ORD has developed, and has been utilized as part of this TMDL project. The algorithms used in the EPA-PMF model to compute profiles and contributions have been peer reviewed by leading scientists in the air quality management community and have been certified to be scientifically robust.

Application of EPA-PMF to the TMDL measurement data-sets revealed a range of source apportionment observations. Identified source types across the measurement sites primarily included coal combustion, waste incineration, oil combustion, cement production, crustal, and marine contributors. In terms of quantified contributions to Hg wet deposition, measurement sites located closest to large local emission point sources, or dense urban areas, were found to have the largest local contributions to measured mercury wet deposition. These included local source contributions of greater than 70% of the total measured mercury wet deposition at several of the monitoring sites located nearest to the local emission sources and dense urban areas. This finding is similar to previous mercury source apportionment studies in areas near local emission point sources, including one conducted in Steubenville, Ohio (Keeler et al., 2006). These observations are also consistent with those found within the CMAQ-derived source attribution analyses previously completed for the project using an emissions tagging approach, which found local emission sources to have the largest impact on mercury deposition at locations nearest to the sources, within 50-100 km, with much smaller local source impacts at locations beyond these distances.

8. References

- Bergquist, B.A. and Blum, J.D. (2007): Mass-dependent and -independent fractionation of Hg isotopes by photo-reduction in aquatic systems. *Science*, **318**, 417-420
- Blum, J.D. and Bergquist, B.A. (2007): Reporting of variations in the natural isotopic composition of mercury. *Analytical and Bioanalytical Chemistry*, **233**, 353-359.
- Dvonch, J.T., Graney, J.R., Keeler, G.J. and Stevens, R.K. (1999): Use of elemental tracers to source apportion mercury in south Florida precipitation. *Environ. Sci. Technol.*, **33**, 4522-4527.
- Dvonch, J.T., Keeler, G.J., and Marsik, F.J. (2005): The influence of meteorological conditions on the wet deposition of mercury in southern Florida. *J. Appl. Meteor.*, **44**, 1421-1435.
- Gordon GE (1988): Receptor models. *Environ. Sci. Technol.*, **22**, 1132-1142.
- Graney, J. R.; Landis, M. S.; Norris, G. A. (2004): Concentrations and solubilities of metals from indoor and personal exposure PM2.5 samples. *Atmos. Environ.*, **38**, 237-247.
- Hopke PK, Ito K, Mar T, Christensen WF, Eatough DJ, Henry RC, Kim E, Laden F, Lall R, Larson TV, Liu H, Neas L, Pinto J, Stolzel M, Suh H, Paatero P, Thurston GD. (2006) PM source apportionment and health effects: 1. Intercomparison of source apportionment results. *Journal of Exposure Science and Environmental Epidemiology*, **16**, 275-86.
- Hoyer, M. E.; Burke, J. B.; Keeler, G. J. (1995) Atmospheric sources, transport and deposition of mercury in Michigan: two years of event precipitation. *Water, Air, Soil Pollut.*, **80**, 199-208.
- Keeler GJ, Landis MS, Norris GA, Christianson EM, Dvonch JT. (2006): Sources of mercury wet deposition in eastern Ohio, USA. *Environ. Sci. Technol.*, **40**, 5874-5881.
- Landis, M. S.; Keeler, G. J. (1997): Critical evaluation of a modified automatic wet-only precipitation collector for mercury and trace element determinations. *Environ. Sci. Technol.*, **31**, 2610-2615.
- Landis, M. S.; Vette, A. F.; Keeler, G. J. (2002): Atmospheric Mercury in the Lake Michigan Basin: Influence of the Chicago/Gary Urban Area. *Environ. Sci. Technol.*, **36**, 4508-4517.
- Norris, G.; Henry, R.; Vedantham, R. EPA Unmix 5.0 User Guide; U.S. Environmental Protection Agency: Washington, DC, 2006.
- Paatero P. Least square formulation of robust non-negative factor analysis.(1997) *Chemometrics Intelligent Laboratory Systems* , **37**, 23-35.
- Ross, H. B. (1990): Trace metal wet deposition in Sweden: insight gained from daily wet only collection. *Atmos. Environ.*, **24A**, 1929.



Florida Department of Environmental Protection
Division of Water Resource Management
Bureau of Watershed Management
2600 Blair Stone Road, Mail Station 3565
Tallahassee, Florida 32399-2400
(850) 245-8561
www2.dep.state.fl.us/water/

FLORIDA DEPARTMENT OF ENVIRONMENTAL PROTECTION

Division of Environmental Assessment and Restoration
Bureau of Watershed Restoration

Mercury TMDL for the State of Florida

Appendix G

Quality Assurance Project Plan (QAPP)

Watershed Evaluation and TMDL Section



May 22, 2012

Appendix G: Quality Assurance Project Plan (QAPP)

QUALITY ASSURANCE PROJECT PLAN

Florida Mercury Total Maximum Daily Load Project

Atmospheric Sampling and Analysis

Prepared by:
The University of Michigan Air Quality Laboratory

Dr. Gerald J. Keeler, Director
109 South Observatory, Room 6646
Ann Arbor, MI 48109
(734) 936-1836
jkeeler@umich.edu

March 31, 2009

QAPP IDENTIFICATION AND APPROVALS

Title: *Quality Assurance Project Plan for the Florida Mercury TMDL Project, Atmospheric Sampling and Analysis, March 31, 2009*

The following individuals or organization representatives commit to the implementation of the latest version of the QAPP referenced above:

G. Keeler

UMAQL, Principal Investigator Date

J. T. Dvonch

UMAQL, Co-Investigator Date

F. Marsik

UMAQL, Co-Investigator Date

J. Blum

UMAQL, Co-Investigator Date

J. Barres

UMAQL, Laboratory Manager Date

E. Edgerton

ARA, Principal Investigator Date

R. Frydenborg

FDEP, Environmental Administrator Date

D. Miller

FDEP, Contract Manager Date

A. Tintle

FDEP, Laboratory Quality Assurance Officer Date

M. Blizzard

FDEP, Quality Assurance Date

M. Landis

USEPA ORD-NERL Date

G. Noah

USEPA SESD Date

TABLE OF CONTENTS

PREFACE	1
DISTRIBUTION LIST	2
LIST OF TABLES	3
LIST OF FIGURES	3
PROCEDURES AND PROTOCOLS BY ORGANIZATION	4
Atmospheric Research and Analysis	4
Florida Department of Environmental Protection	4
University of Michigan	4
U. S. Environmental Protection Agency	4
ACRONYMS AND ABBREVIATIONS	5
1.0 PROJECT DESCRIPTION AND ORGANIZATION	8
1.1 Introduction	8
1.1.1 Subtask 1: Long-Term Atmospheric Monitoring at Supersites	9
1.1.1.1 Roles and Responsibilities: Supersite Data Management and Reporting Timelines	11
1.1.2 Subtask 2: Long-Term Precipitation Monitoring at Supersites/Satellite Sites	12
1.1.2.1 Roles and Responsibilities: Precipitation Monitoring Data Management and Reporting Timelines	12
1.1.3 Subtask 3: Short-Term Intensive Deposition Monitoring	13
1.1.3.1 Roles and Responsibilities: Intensive Deposition Monitoring Data Management and Reporting Timelines	13
1.2 Site Locations	14
1.3 Atmospheric Sampling Objectives	16
1.4 Project Personnel	16
1.5 Personnel Training	19
1.6 Quality Objectives and Criteria	19
1.6.1 Continuous Chemical Measurements	20
1.6.1.1 Mercury in Air	20
1.6.1.2 Trace Gases in Air	20
1.6.1.3 Fine Particulate Anions, Acidic Gases, EC/OC and Fine Particulate Mass in Air	21
1.6.2 Continuous Meteorological Measurements	22
1.6.3 Discrete Measurements	23
1.6.3.1 Total Mercury in Precipitation	23
1.6.3.2 Trace Metals in Air and Precipitation	24
1.6.3.3 Stable Mercury Isotopes in Precipitation	26
1.6.3.4 Discrete Filter Measurements of PM _{2.5} and PM ₁₀ Mass	28
2.0 SAMPLING AND MEASUREMENTS	30
2.1 Sampling Procedures	30

2.1.1 Preparation	30
2.1.2 Sample Identification	30
2.1.3 Sample Collection.....	31
2.1.3.1 Continuous Measurements.....	31
2.1.3.1.1 Speciated Mercury.....	31
2.1.3.1.2 Ambient Ions.....	32
2.1.3.1.3 Meteorological Measurements	32
2.1.3.2 Discrete Measurements.....	32
2.1.3.2.1 Wet Deposition Measurements	32
2.1.3.2.2 Sequential Particulate Measurements.....	33
2.1.4 Sample Handling	33
2.1.5 Sample Preservation in the Field.....	34
2.1.6 Sample Transportation	34
2.1.7 Sample Receipt and Storage at Laboratory.....	35
2.1.8 Sample Processing.....	35
2.2 Analytical Procedures	36
2.2.1 Mercury.....	36
2.2.1.1 Ambient Atmospheric Mercury (ARA).....	36
2.2.1.2 Total Mercury in Precipitation (FDEP)	36
2.2.1.3 Mercury Stable Isotopes in Precipitation (UMGS).....	37
2.2.2 Ions.....	37
2.2.2.1. Ambient Ions (ARA)	37
2.2.2.2. Ions in Precipitation (UMAQL).....	37
2.2.3 Trace Metals.....	37
2.2.3.1 Ambient Particulate Trace Metals (EPA ORD-NERL)	38
2.2.3.2 Trace Elements in Precipitation (UMAQL).....	38
2.3 Calibration Procedures and Frequency	38
2.4 Preventative Maintenance	40
2.5 Quality Control Checks	40
3.0 DATA MANAGEMENT	42
3.1 Data Reduction, Validation, and Reporting	43
3.1.1 Data Reduction.....	43
3.1.2 Data Integrity and QC Validation	44
3.1.3 Data Storage	44
3.2 Data Assessment	44
3.3 Data Distribution	45
3.4 Data Audits	45
4.0 PROJECT ASSESSMENT AND OVERSIGHT.....	46
4.1 QA Responsibilities	46
4.2 Performance and System Audits.....	46
4.3 Corrective Action	46

4.4 Quality Assurance Reports	46
REFERENCES.....	48
APPENDICES.....	49

PREFACE

This document is a project-specific Quality Assurance Project Plan (QAPP) for the Atmospheric Monitoring Task of the Florida Mercury TMDL Project. It was developed using the U.S. Environmental Protection Agency (EPA) Quality Assurance document guidelines set forth in *EPA QA/R-5, EPA Requirements for Quality Assurance Project Plans, EPA QA/G-5, Guidance for Quality Assurance Project Plans* and *IDQTF UFP-QAPP Manual v1, March 2005*. It is consistent with the EPA *Quality Assurance Handbook for Air Pollution Measurement Systems, Vol I-IV*.

Inquiries concerning the contents of this document may be directed to:

James Barres, UM Air Quality Laboratory, Ann Arbor, MI, jbarres@umich.edu

DISTRIBUTION LIST

<u>Name</u>	<u>Organization</u>	<u>E-mail Address</u>
Gerald Keeler	Univ. of Mich.	jkeeler@umich.edu
Joel Blum	Univ. of Mich.	jblum@umich.edu
Curt Pollman	ALL, Inc	cpollman@aqualuxlucis.org
Eric Edgerton	ARA, Inc	ericedge@gte.net
Russel Frydenborg	FDEP	russel.frydenborg@dep.state.fl.us
Thomas Atkeson	FDEP	thomas.atkeson@dep.state.fl.us
Denise Miller	FDEP	denise.miller@dep.state.fl.us
Matthew Landis	USEPA ORD-NERL	landis.matthew@epa.gov
Greg Noah	USEPA Region 4 SESD	noah.greg@epa.gov

LIST OF TABLES

Table 1.1	Instrumentation/Measurements for Atmospheric Monitoring.	9
Table 1.2	Data Capture and Analytes Quantified for Atmospheric Monitoring.	11
Table 1.3	Instrumentation, Accuracy and Detection Limits for Hg in Air	20
Table 1.4	Instrumentation, Accuracy and Detection Limits for Trace Gases in Air	21
Table 1.5	Instrumentation and Accuracy Specifications for AIM and SHARP Measurements	22
Table 1.6	Instrumentation and Accuracy Specifications for Meteorological Measurements.	23
Table 1.7	Data Quality Objectives for Total Mercury in Precipitation.	23
Table 1.8	Trace Element Method Detection Limits (MDLs).	25
Table 1.9	Data Quality Objectives For Trace Elements in Air and Precipitation.	26
Table 1.10a	Laboratory Data Quality Objectives –PM _{2.5} /PM ₁₀ (Dichotomous Sampler)	28
Table 1.10b	Field Data Quality Objectives –PM _{2.5} /PM ₁₀ (Dichotomous Sampler).....	29
Table 2.1	Automated and Manual Calibration Schedules for Hg and Trace Gas Analyzers	39

LIST OF FIGURES

Figure 1.1.	Atmospheric Monitoring Approximate Site Locations.	14
Figure 1.2.	Project Management Structure.	16
Figure 3.1	Data Flow Chart for TMDL Project	42

PROCEDURES AND PROTOCOLS BY ORGANIZATION

Atmospheric Research and Analysis

SpecHg-SOP	Semi-continuous measurement of ambient speciated mercury
ADS-SOP	Determination of ambient acidic and basic gases
AIM-MAN	Semi-continuous measurement of ambient ions
SHARP-MAN	Continuous measurement of ambient particulate mass
ASPS2-SOP	Automated collection of daily event precipitation
PMdichot-MAN	Automated collection of ambient fine and coarse PM
Met4A-MAN	Collection of BP, RH and T data
OCEC-SOP	Automated collection of EC and OC in ambient fine PM
AMBGAS-SOP	Automated collection of trace gas and flow data
SRsensor-MAN	Collection of SR data
LWS-MAN	Collection of leaf wetness data
Sonic-MAN	Collection of WD and WS data via sonic anemometer
Rainfall-MAN	Collection of incident precipitation data
FL-DOC	FirstLight data management software documentation

Florida Department of Environmental Protection

HGpcp-SOP	Analysis of mercury in precipitation by CVAFD
PMmass-SOP	Measurement of mass on sample filters
Data-SOP	Standard Operating Procedure for Records Maintenance and Storage
Report-SOP	Standard Operating Procedure for Reporting Qualified Data

University of Michigan

ACtable-SOP	Acid cleaning steps for all sampling supplies
TEpcp-SOP	Analysis of trace elements by ICP-MS
IONSpccp-SOP	Analysis of ions by IC
HGisotopes-SOP	Determination of Mercury Isotopic Composition in Precipitation

U. S. Environmental Protection Agency

TEpcp-SOP	Extraction and analysis of trace elements on Teflon® filters
-----------	--

ACRONYMS AND ABBREVIATIONS

ADS	Acid Denuder System (URG Model 3000C)
AIM	Ambient Ion Monitor (URG Model 9000C)
AQL	University of Michigan Air Quality Laboratory
ARA	Atmospheric Research & Analysis, Inc
ASPS	Automated Sequential Precipitation Sampler II
CNR	Consiglio Nazionale della Ricerche, Inst. for Atmos. Pollution, Rende, Italy
CVAFS	Cold Vapor Atomic Fluorescence Spectroscopy
EOQ	End of the calendar quarter
ED-XRF	Energy Dispersive X-Ray Fluorescence
EPA	U.S. Environmental Protection Agency
EPA ORD-NERL	EPA Office of Research and Development National Exposure Research Laboratory
EPA Region 4 SESD	EPA Region 4 Science and Ecosystem Support Division
FDEP	Florida Department of Environmental Protection
Hg ⁰	Elemental Mercury
Hg(p)	Particulate Mercury
HR-ICPMS	High Resolution Magnetic Sector Field Inductively Coupled Plasma Mass Spectrometry
IDQTF	Intergovernmental Data Quality Task Force
L/min	liters per minute
MC-ICPMS	Multi Collector Inductively Coupled Plasma Mass Spectrometry
MDL	Method Detection Limit
MMAD	Mass Median Aerodynamic Diameter
mL	milliliters
MQ	Milli-Q deionized water, 18 MΩ·cm
MΩ·cm	mega ohm centimeter
m ³	cubic meter
ng/L	nanograms per liter
NDIR	Nondispersive Infrared sensor
NIST	National Institute of Standards and Technology
PI	Principal Investigator
PM _{2.5}	Particulate matter < 2.5 micrometer mass median aerodynamic diameter
QA	Quality Assurance
QAO	Quality Assurance Objectives
QAPP	Quality Assurance Project Plan
QC	Quality Control
RH	Relative Humidity
RGM	Divalent Reactive Gaseous Mercury
SAS	Statistical Analysis Software Package, (SAS Institute, Cary, NC)
SHARP	Synchronized Hybrid Ambient Real-time Particulate monitor (Thermo-Environmental Model 5030)
SRM	Standard Reference Material
SOP	Standard Operating Procedure
TMDL	Total Maximum Daily Load
UFP	Uniform Federal Policy
UM	University of Michigan

UMAQL
UMGS
 $\mu\text{g}/\text{m}^3$

University of Michigan Air Quality Laboratory
University of Michigan Geological Sciences
micrograms per cubic meter

PROJECT PERSONNEL SIGN-OFF SHEET

The following individuals have read the sections of this document that pertain to their role in the project and commit to the implementation of the QA/QC guidelines presented:

1.0 PROJECT DESCRIPTION AND ORGANIZATION

1.1 Introduction

Atmospheric emissions and deposition processes are now recognized as a major route of contamination to many soils, sediments and aquatic systems. Excessive levels of mercury in many species of fish constitute the second-most prevalent indicator, following only eutrophication, of water quality impairment in the US. Both watershed loads plus wet and dry deposition processes must be quantified in order to determine the total loading of any contaminant to an ecosystem.

Earlier studies in South Florida by the UMAQL and others working with the FDEP, EPA ORD-NERL and EPA Region 4 focused on rainfall as the primary pathway (>95%) for delivery of mercury to the Everglades marsh (Dvonch *et al.*, 1995; 1998; 1999). These early measurements included only the wet part of the load, as available technologies could only approximate dry deposition fluxes.

Dry deposition of particulate and gaseous contaminants, including mercury, trace elements, nitrogen species, and other nutrients are also likely very important. The dry deposition flux for some contaminants could be of equal or even greater magnitude than the wet deposition of that contaminant in certain regions. The difference between wet and dry deposition is that the underlying surface or land use type significantly impacts the dry deposition of Hg and other pollutants. Thus, to accurately assess the loadings of Hg and other pollutants to the State of Florida it is necessary to address the spatial differences in land use and the differences in the aquatic ecosystems that are found across the large and diverse state.

To quantify the loadings of mercury across the state, a combined monitoring and modeling approach will be employed. For air quality monitoring and modeling, a combination of long-term comprehensive monitoring sites (Supersites) together with a small number of additional event precipitation sites (Satellite Sites) will be employed for sample collection for a two-year period. In addition, a number of atmospheric deposition monitoring sites (Supplemental Sites) will be deployed surrounding the Supersites to evaluate the spatial patterns and variability in each region during selected months.

The UMAQL has extensive experience in conducting large field efforts such as the Mercury TMDL study. In coordination with the UMAQL and FDEP, ARA will provide for the setup and operation of four Supersite comprehensive monitoring sites across the state. ARA is uniquely qualified to handle this task with their years of experience in running atmospheric monitoring sites similar to those we are proposing in this study. The four proposed Supersite monitoring locations are Tampa, Ft. Lauderdale, Pensacola, and Jacksonville. Two additional wet deposition-only sites will be located in Orlando and in the Everglades National Park. FDEP will coordinate with UMAQL to provide for site operation and maintenance for the two additional wet deposition sites. UMAQL will provide the initial site setup and training of personnel for the two additional wet deposition only sites. ARA will provide instrument upgrades, site installation, site operation and maintenance, and data management support for two complete years of site operation at the four Supersites. In support of the overall project objectives, the Atmospheric Monitoring consists of three major elements: long-term atmospheric monitoring at Supersites, precipitation monitoring at Supersite and Satellite sites, and month-long intensive deposition monitoring at near-field locations (Supplemental sites) surrounding Supersites. These roles and responsibilities of each project team member within these three elements are detailed in the following subtasks.

1.1.1 Subtask 1: Long-Term Atmospheric Monitoring at Supersites

Four Supersites will serve as the basis for the long-term atmospheric monitoring component of the Florida mercury TMDL project. The four proposed site locations include the vicinities of Pensacola, Tampa, Jacksonville, and Fort Lauderdale. The scope of this subtask will include the long-term characterization of key atmospheric constituents necessary for the Florida mercury TMDL assessment. The long-term monitoring at Supersites will include measurements of speciated atmospheric mercury, trace gases , elemental and organic carbon, chemical characterization of fine and coarse particulate matter, as well as surface meteorology. The instruments to be used to carry out the primary and continuous data measures at each Supersite are listed in Table 1.1. Table 1.2 provides a complete listing of the individual constituents to be analyzed, both routinely and during month-long intensive campaigns.

Table 1.1 Instrumentation/Measurements for Atmospheric Monitoring.

Class	Variable(s)	Detection	Manufacturer	Model	Time
Hg	Hg ⁰	CVAFS	Tekran	2737A or B	5-minute, 1-hour
	RGM	CVAFS	Tekran	2737A or B	1-hour
	Hg _{PM2.5}	CVAFS	Tekran	2737A or B	1-hour
Cont. Gas	O ₃	UV absorption	Thermo-Env.	49c or i	5-minute, 1-hour
	CO	NDIR	Thermo-Env.	48c or i	5-minute, 1-hour
	SO ₂	UV fluorescence	Thermo-Env.	43c or i	5-minute, 1-hour
	NO	NO-Q ₈ CL	Thermo-Env.	42c or i	5-minute, 1-hour
	NO _y	NO-Q ₈ CL	Thermo-Env.	42c or i	5-minute, 1-hour
Discrete Gas Sampler	HNO ₃ /HNO ₂ /NH ₃ /SO ₂ /HCl	IC	URG	3000C-ADS	weekly, day/night
Discrete Particle	PM _{2.5} Major Ions	IC	URG	ADS	weekly, day/night
Cont. Particle	PM _{2.5} Major Ions	IC	URG	AIM	1-hour
	PM _{2.5} OC/EC	NDIR	Sunset Labs.	RT-ECOC	1-hour
	PM _{2.5} Mass	Light Scattering	Thermo-Env.	Sharp	5-minute, 1-hour
Dichotomous Sampler	PM _{2.5} and PM _{2.5-10} Mass	Gravimetric	R&P	2025	daily
	PM _{2.5} and PM _{2.5-10} Trace Elements	EDXRF or ICPMS	R&P	2025	daily
Wet	Total-Hg	CVAFS	UM	ASPS	event
	Trace Elements	ICP-MS	UM	ASPS	event
	Hg Isotopes	ICP-MS	UM	ASPS	event
	Major Ions	IC	UM	ASPS	event
Meteorology	Wind Speed	sonic anemometer	RMYoung	81000	5-minute, 1-hour
	Wind Direction	sonic anemometer	RMYoung	81000	5-minute, 1-hour
	Temperature	thermistor	Paroscientific	Met4A	5-minute, 1-hour
	Relative Humidity	thermistor	Paroscientific	Met4A	5-minute, 1-hour
	Barometric Pressure	manometer	Paroscientific	Met4A	5-minute, 1-hour
	Solar Radiation	pyranometer	Campbell Sci.	LI200 X-L	5-minute, 1-hour
	Precipitation	rain gauge	ETI	NOAH-IV	5-minute, 1-hour
	Surface	conductivity	Campbell Sci.	237	5-minute, 1-hour

Table 1.2 Data Capture and Analytes Quantified for Atmospheric Monitoring.

Class	Variable(s)	Detection	Minimum # of Samples	Laboratory	Analytes
Hg	Hg ⁰	CVAFS	Daily (85% data)	ARA (in field)	Hg ⁰
	RGM	CVAFS	Daily (85% data)	ARA (in field)	RGM
	Hg _{PM2.5}	CVAFS	Daily (85% data)	ARA (in field)	Hg _{PM2.5}
Cont. Gas	O ₃	UV absorption	Daily (85% data)	ARA (in field)	O ₃
	CO	NDIR	Daily (85% data)	ARA (in field)	CO
	SO ₂	UV fluorescence	Daily (85% data)	ARA (in field)	SO ₂
	NO	NO-O ₃ CL	Daily (85% data)	ARA (in field)	NO
	NO _y	NO-O ₃ CL	Daily (85% data)	ARA (in field)	NO _y
Discrete Gas Sampler	HNO ₃ /HNO ₂ /NH ₃ /SO ₂ /HCl	IC	Weekly (85% data)	UMAQL	HNO ₃ , HNO ₂ , NH ₃ , SO ₂ , HCl
Discrete Particle	PM _{2.5} Major Ions	IC	Weekly (85% data)	UMAQL	sulfate, nitrate, nitrite, phosphate, ammonium, and sodium
Cont. Particle	PM _{2.5} Major Ions	IC	Daily (85% data)	ARA (in field)	sulfate, nitrate, nitrite, phosphate, ammonium, sodium, calcium, potassium and
	PM _{2.5} OC/EC	NDIR	Daily (85% data)	ARA (in field)	OC, EC
	PM _{2.5} Mass	Light Scattering	Daily (85% data)	ARA (in field)	PM _{2.5} mass
Dichotomous Sampler	PM _{2.5} and PM _{2.5-10} Mass	Gravimetric	Daily (85% data)	FDEP	PM _{2.5} mass, PM _{2.5-10} mass
	Trace	EDXRF or ICPMS	Daily (85% data)	USEPA-NERL	Mg, Al, P, S, Ti, V, Cr, Mn, Fe, Co, Ni, Cu, Zn, As, Se, Rb, Sr, Mo, Cd, La, Ce, Sm, Pb
Routine Wet	Total-Hg	CVAFS	75*	FDEP	Hg
	Trace	HR-ICP-MS	75*	UMAQL	Mg, Al, P, S, Ti, V, Cr, Mn, Fe, Co, Ni, Cu, Zn, As, Se, Rb, Sr, Mo, Cd, La, Ce, Sm, Pb
	Hg Isotopes	MC-ICP-MS	22*	UMAQL	$\delta^{202}\text{Hg}$, $\delta^{201}\text{Hg}$, $\delta^{200}\text{Hg}$, $\delta^{199}\text{Hg}$, $\gamma^{201}\text{Hg}$, $\gamma^{199}\text{Hg}$
Intensive Wet	Major Ions	IC	75*	UMAQL	sulfate, nitrate, nitrite, chloride, ammonium, and sodium
	Total-Hg	CVAFS	50**	FDEP	Hg
	Trace	HR-ICP-MS	50**	UMAQL	Mg, Al, P, S, Ti, V, Cr, Mn, Fe, Co, Ni, Cu, Zn, As, Se, Rb, Sr, Mo, Cd, La, Ce, Sm, Pb
Intensive Dry Deposition	Hg Isotopes	MC-ICP-MS	15**	UMAQL	$\delta^{202}\text{Hg}$, $\delta^{201}\text{Hg}$, $\delta^{200}\text{Hg}$, $\delta^{199}\text{Hg}$, $\gamma^{201}\text{Hg}$, $\gamma^{199}\text{Hg}$
	Major Ions	IC	50**	UMAQL	sulfate, nitrate, nitrite, chloride, ammonium, and sodium
	Total-Hg	CVAFS	50**	UMAQL	Hg
Meteorology	Trace	HR-ICP-MS	50**	UMAQL	Mg, Al, P, S, Ti, V, Cr, Mn, Fe, Co, Ni, Cu, Zn, As, Se, Rb, Sr, Mo, Cd, La, Ce, Sm, Pb
	Major Ions	IC	50**	UMAQL	sulfate, nitrate, nitrite, chloride, ammonium, and sodium
	Wind	sonic anemometer	Daily (85% data)	ARA (in field)	wind speed
	Wind Direction	sonic anemometer	Daily (85% data)	ARA (in field)	wind direction
	Temperature	thermistor	Daily (85% data)	ARA (in field)	temperature
	Relative Humidity	thermistor	Daily (85% data)	ARA (in field)	relative humidity
	Barometric Pressure	manometer	Daily (85% data)	ARA (in field)	barometric pressure
	Solar Radiation	pyranometer	Daily (85% data)	ARA (in field)	solar radiation
	Precipitation	rain gauge	Daily (85% data)	ARA (in field)	precipitation
	Surface	conductivity	Daily (85% data)	ARA (in field)	surface wetness

* Per site for each full year, based upon climatological norms.

** Per intensive, based upon climatological

1.1.1.1 Roles and Responsibilities: Supersite Data Management and Reporting Timelines

For Subtask 1, ARA will provide field operation of the four Supersites, including field operation of all Supersite instruments described in Table 1.1, as well as QA of all associated data generated in the field. For subsequent laboratory analyses related to samples collected as part of Subtask 1, FDEP Central Laboratory will provide for the pre- and post-weighing of filters for the dichotomous samplers. EPA ORD-NERL will provide for the trace element analysis of dichotomous sample filters. ARA will provide sample media and UMAQL will conduct the ion chromatography analysis for the weekly-integrated discrete gas/particle samplers. Data for all continuous analyzers (Hg speciation, gas analyzers, particle analyzers, meteorological parameters) will be reported by ARA to the UMAQL and FDEP one calendar quarter *after* the end of a quarter's worth of data collection. FDEP will report data for PM mass determinations to the UMAQL within 20 weeks after the end of a quarter's worth of data collection. UMAQL will report data for ion chromatography analysis to FDEP within two calendar quarters after the end of a quarter's worth of data collection. EPA ORD-NERL will report data for trace element analysis to UMAQL and FDEP within 22 weeks after the end of a quarter's worth of data collection. The initial quarter of data collection for all Subtask 1 activities is defined to conclude on December 31, 2008; subsequent project quarters will be coincident with calendar quarters (e.g., ending March 31, June 30, September 30).

1.1.2 Subtask 2: Long-Term Precipitation Monitoring at Supersites/Satellite Sites

In addition to the four Supersite locations in the vicinities of Pensacola, Tampa, Jacksonville, and Fort Lauderdale, two additional Satellite sites have been identified for daily collection of wet deposition only. Combined, these six sites will form a spatially diverse long-term wet deposition monitoring network. ARA will provide for field operations of precipitation monitoring at the four Supersites, and FDEP will provide for field operation of the two Satellite sites, one in Orange County and one in Everglades National Park. The scope of Subtask 2 includes the long-term characterization of key constituents of precipitation necessary for the Florida mercury TMDL assessment. The long-term monitoring at the six wet deposition sites will include sample collection and analysis for total mercury, major ions (sulfate, nitrate, nitrite, chloride, ammonium, and sodium), trace elements (Mg, Al, P, S, Ti, V, Cr, Mn, Fe, Co, Ni, Cu, Zn, As, Se, Rb, Sr, Mo, Cd, La, Ce, Sm, Pb), and stable mercury isotopic composition ($\delta^{202}\text{Hg}$, $\delta^{201}\text{Hg}$, $\delta^{200}\text{Hg}$, $\delta^{199}\text{Hg}$, $\Delta^{201}\text{Hg}$, $\Delta^{199}\text{Hg}$). The methodologies to be used to carry out the collection and analysis of the constituents in precipitation measures at each site are listed in Table 1.1. Table 1.2 provides a listing of the individual constituents to be analyzed for the wet deposition samples.

1.1.2.1 Roles and Responsibilities: Precipitation Monitoring Data Management and Reporting Timelines

For Subtask 2, ARA, as described above for Subtask 1 will be providing field operation of the four Supersites that will include the ASPS precipitation collector. FDEP will provide for field operation of the two Satellite sites, one in Orange County and one at Everglades National Park. For subsequent laboratory analyses related to Subtask 2, FDEP Central Laboratory will provide for analysis of total mercury in precipitation samples,

and UMAQL will conduct the trace element analysis as well as the ion chromatography analysis and mercury isotope analysis for the precipitation samples. FDEP Central Laboratory will report data for total mercury in precipitation to UMAQL within 23 weeks after the end of that quarter's worth of data collection. UMAQL analyses of trace elements, major ions, and mercury isotopes in precipitation samples will be completed within 2 calendar quarters after the end of a quarter's worth of data collection. UMAQL will integrate these data with data from FDEP analyses of total mercury in precipitation for subsequent project reporting to FDEP. The initial quarter of data collection for all Subtask 2 activities is defined to conclude on December 31, 2008, with subsequent quarters being the calendar quarters (e.g., March 31, June 30, September 30).

1.1.3 Subtask 3: Short-Term Intensive Deposition Monitoring

In order to support and supplement the long-term air quality monitoring and modeling, a number of atmospheric deposition “Supplemental” monitoring sites will be deployed surrounding the Supersites to evaluate the spatial patterns and variability in each region during selected months. These deposition measurement intensives will take place at near-field locations surrounding each of the four proposed Supersites: in the vicinities of Pensacola, Tampa, Jacksonville, and Fort Lauderdale. There will be one deposition intensive at each Supersite during the two-year duration of the mercury TMDL field project. Each of these deposition intensives will last one month in duration, for a total of four atmospheric deposition measurement intensives. The field intensives will be conducted by UMAQL staff in coordination with the on-going long-term atmospheric monitoring at the Supersites, as well as the long-term wet deposition monitoring at the Supersites and Satellite sites.

Two of the measurement intensives will take place during summer 2009 and two will take place during summer 2010. The primary purpose of the measurement intensives is to evaluate and characterize the spatial patterns and variability surrounding each Supersite, which will be information critical to the successful execution of the overall mercury TMDL atmospheric modeling component. The short-term intensive monitoring at a minimum of four Supplemental sites surrounding each of the Supersites will include collection and analysis for total mercury, major ions (sulfate, nitrate, nitrite, and chloride), and trace elements (Mg, Al, P, S, Ti, V, Cr, Mn, Fe, Co, Ni, Cu, Zn, As, Se, Rb, Sr, Mo, Cd, La, Ce, Sm, Pb) in both wet and dry deposition. In addition, a subset of the wet deposition samples with appropriate levels of total Hg will be analyzed for Hg stable isotope ratios ($\delta^{202}\text{Hg}$, $\delta^{201}\text{Hg}$, $\delta^{200}\text{Hg}$, $\delta^{199}\text{Hg}$, $\Delta^{201}\text{Hg}$, $\Delta^{199}\text{Hg}$). The specific analytes, methodologies and laboratories to be used to carry-out the laboratory analysis of the constituents in deposition measures from the intensive periods at each site will match those used for the long-term measurements at the Supersites, as described for Subtasks 1 and 2 and listed in Table 1.1 and Table 1.2.

1.1.3.1 Roles and Responsibilities: Intensive Deposition Monitoring Data Management and Reporting Timelines

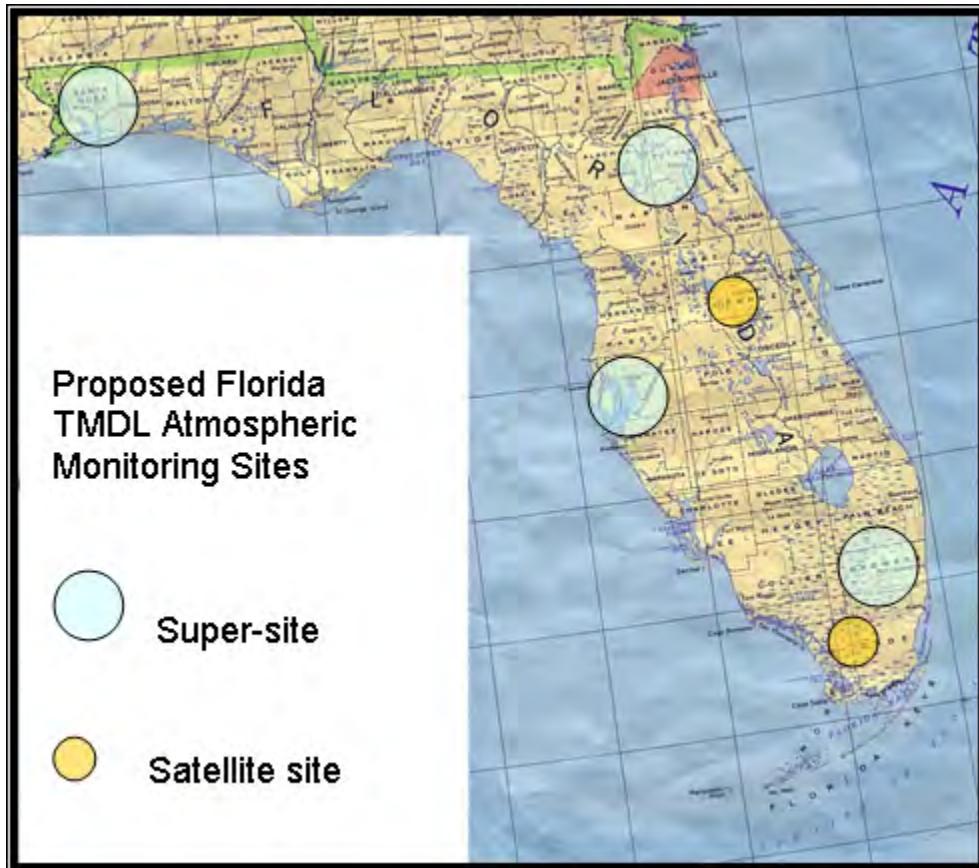
For Subtask 3, ARA will provide on-going field operation of the four Supersites, including the ASPS precipitation collection. UMAQL will provide for set-up and collection of all other samples described for Subtask 3, including daily wet deposition and dry deposition sample collection at each of the four Supplemental field sites and surrounding Supersites during each deposition measurement intensive period. For subsequent laboratory analyses related to Subtask 3, FDEP Central Laboratory will provide for analysis of total mercury in precipitation samples, and UMAQL will conduct the total Hg in dry deposition analysis, the trace element and major ion analysis for both wet deposition and dry deposition samples, as well as Hg isotope analysis of a subset of the precipitation samples with sufficient volume. Data from intensive monitoring for trace elements and major ions

in wet deposition and dry deposition, total Hg in dry deposition, and Hg isotopes in wet deposition will be reported by UMAQL to FDEP by March 31st, 2010 for samples collected during measurement intensives #1 and #2 (conducted in-field during summer 2009), and by March 31st, 2011 for samples collected during measurement intensives #3 and #4 (conducted in-field during summer 2010). The FDEP Central Laboratory will report data for total mercury determinations in precipitation from the intensive samples to the UMAQL by December 31st, 2009 for samples collected during measurement intensives #1 and #2 (conducted in-field during summer 2009), and by December 31st, 2010 for samples collected during measurement intensives #3 and #4 (conducted in-field during summer 2010).

1.2 Site Locations

Six general regions for the sampling sites have been identified and include the counties of Escambia, Duval, Orange, Hillsborough, Broward, and Miami-Dade. These site locations provide state-wide coverage for the atmospheric monitoring and are representative of major land use areas and Hg emission sources across the state. Figure 1.1 shows the locations of Supersites and Satellite (i.e., precipitation only) sites. The Escambia County Supersite is located on U.S. Navy property approximately 19 km NW of downtown Pensacola (lat. 30.5500, long. -87.3751). The Duval County Supersite is located on a farm managed by the City of Jacksonville-Parks and Recreation approximately 29 km WSW of downtown Jacksonville (lat. 30.2475, long. -81.9516). The Hillsborough County site is located on private property approximately 8 km SE of the City of Tampa (lat. 27.9137, long. -82.3749). The Broward County site is located at a county-operated air monitoring site (Site #8) located approximately 12 km SW of the City of Fort Lauderdale (lat. 26.0854, long. -80.2407).

Figure 1.1. Atmospheric Monitoring - Approximate Site Locations.



1.3 Atmospheric Sampling Objectives

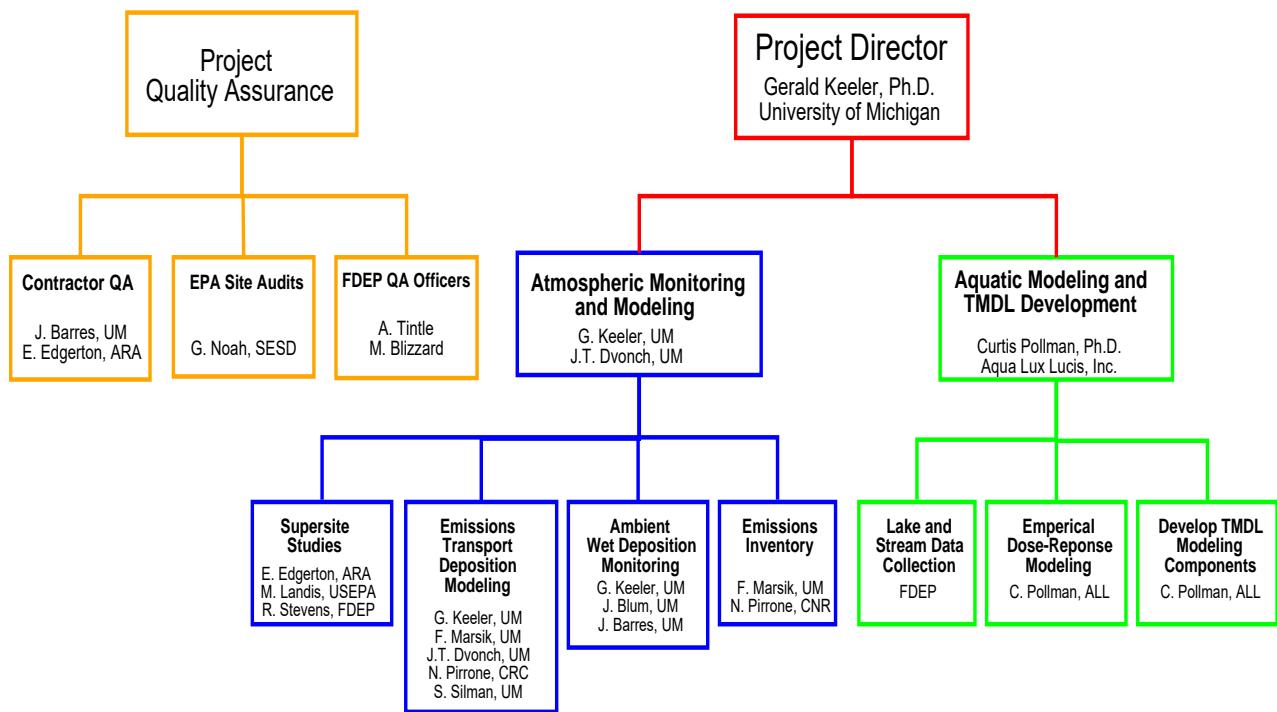
- This project task has the following goals:
- Establish enhanced monitoring and research field sites located in strategic areas throughout the state of Florida that are representative of the diverse land use patterns in Florida.
- Provide high quality long-term characterization of the atmospheric constituents required to perform state-wide Mercury TMDL calculations.
- Provide short term high resolution characterization of atmospheric processes also in support of the Mercury TMDL calculations.

The atmospheric sampling task will establish a network of monitoring sites in Florida. The network will include sites that are close to major emission sources across the state, sites downwind from these sources, and sites that are more distant from major anthropogenic sources.

1.4 Project Personnel

The management structure associated with this project is summarized in the Figure 1.2. A biographical sketch of the primary participants in the measurement aspects of this study are also provided below.

Figure 1.2. Project Management Structure.



Gerald J. Keeler, Ph.D. (Principal Investigator, UM) is an expert on atmospheric mercury and trace elements. He founded the UMAQL in 1990 and has since become an international leader in atmospheric sampling and characterization of toxic metals. He has participated on several state and federal review and advisory committees and is frequently requested to lead panel discussions and present plenary lectures at international conferences and workshops. Dr. Keeler has extensive experience on the sampling, analysis and modeling of atmospheric mercury in all its forms. Dr. Keeler will serve as PI for the project and will be responsible for all coordination with subcontractors and the Florida Department of Environmental Protection. He will be responsible for all atmospheric data preparation and reporting.

J. Timothy Dvonch, Ph.D. (Co-Investigator, UM) is an environmental health expert with extensive experience in measurements of atmospheric pollutants for human health and environmental exposure projects. Dr. Dvonch also has considerable experience in the development and evaluation of atmospheric Hg speciation methodologies. He has experience and publications dealing with receptor modeling methodologies and the source apportionment of airborne pollutants including Hg. Dr. Dvonch was a key participant in the South Florida Atmospheric Mercury Monitoring and Modeling Study and published one of the first research papers on characterization of the sources of mercury in wet deposition. He will take part in project management, data analysis and reporting.

Frank J. Marsik, Ph.D. (Co-Investigator, UM) is a meteorologist at the University of Michigan with extensive experience in atmospheric measurement campaigns. Dr. Marsik has considerable experience in the use of synoptic and micro-meteorological parameters for the characterization of the atmospheric transport and deposition of Hg (both wet and dry). These include modeling of these parameters to calculate meteorological air mass back-trajectories as well as the measurement and modeling of Hg dry deposition. Dr. Marsik also has experience in the first known use of NEXRAD radar data for evaluation of impacts of cloud chemistry and local source emissions on the wet deposition of Hg. He will be responsible for the atmospheric modeling tasks of the project and will also participate in the data analysis and report writing.

Joel D. Blum, Ph.D. (Co-Investigator, UM) is an expert in trace element and isotope geochemistry and biogeochemistry, with emphasis on heavy-metal pollutants in the environment. He has conducted extensive research on mercury in freshwater ecosystems, terrestrial ecosystems, wildfires, the arctic atmosphere, and in foodwebs. He has also directed investigations using trace elements and high precision measurements of Pb, Sr, Nd and Os isotopes to study heavy element mobility in soils, groundwater and atmospheric particles. In the past 8 years Dr. Blum pioneered development of very high precision mercury isotope ratio measurement and the application of mercury isotopes as tracers of atmospheric sources of mercury and as tracers of mercury redox transformations in the environment. He will be involved in trace element and mercury isotope measurement and interpretation, as well as data analysis and report writing.

James A. Barres, M.S. (AQL Lab Manager, UM) is responsible for the day-to-day management of all activities associated with the Laboratory. As such, he is responsible for insuring that laboratory personnel are properly trained for their assigned tasks and that there is strict adherence to UMAQL standard operating procedures (SOPs), which have been established to insure that QA goals are met. Mr. Barres has extensive experience in field measurement and laboratory management through his work with both the University of Michigan Air Quality Laboratory and the University of Michigan Center for Great Lakes and Aquatic Studies. His research has focused on the measurement of trace element concentrations in near surface waters in the Great Lakes region, with emphasis on the development of procedures and methods of collection, storage and analysis of trace elements. For this project, Mr. Barres will be responsible for directing the fabrication of the ASPS units and for installation, training and support of the units. He will be responsible for QA related activities associated with precipitation supply preparation, sample collection, transport, preservation, analysis and data processing.

Eric Edgerton, M.S. (President/Scientist, ARA) is an expert in the design, setup and operation of long-term atmospheric monitoring networks. His areas of expertise include atmospheric chemistry, measurement of trace atmospheric species (including Hg), development of continuous methods for atmospheric constituents, and geochemical cycles of sulfur, nitrogen and carbon. Mr. Edgerton received his B.A. in Atmospheric Chemistry from Cornell University (1974) and his M.S. in Environmental Engineering from the University of Florida (1981). Mr. Edgerton will be responsible for the direction, oversight and QA/QC of the continuous measurements at the 4 Supersites. This includes coordinating the site selection, set-up and oversight of the continuous measurements database.

Matthew S. Landis, PhD: (Research Sci., EPA ORD-NERL) As the EPA-NERL atmospheric mercury research principal investigator, Dr. Landis has the responsibility to identify the gaps in EPA's understanding of atmospheric mercury transport, transformation and deposition. His expertise and current research activities include a dynamometer study to quantify mercury emissions from mobile vehicles, a study to investigate the oxidation of elemental mercury (Hg^0) to divalent reactive gaseous mercury in the free troposphere, a study to evaluate the impact of coal combustion on mercury deposition in the Ohio River Basin, a study to investigate the benefit of continuous ambient mercury speciation data to successful application of source apportionment models, development of an automated surrogate surface mercury dry deposition sampler, and an effort to develop HR-ICPMS analysis methods for the quantification of trace elements in highly time resolved (~30 minutes) and low mass PM2.5 samples. For this study, Dr. Landis will be responsible for deployment and technical support for his automated particulate collector, speciated mercury technical support, and oversight of the trace element analysis on the sequential particulate filters.

Curriculum vitae are found in the Appendix.

1.5 Personnel Training

Training of laboratory analysts and field operators will be provided as appropriate. The UMAQL, ARA, FDEP and EPA have extensive combined experience in the laboratory and field procedures required for this project. Operators for the monitoring sites will receive specific instruction on the operation and maintenance of all instrumentation and in the proper handling of samples using clean techniques. Laboratory analyses will be performed by experienced personnel. Training will be provided as required to ensure high quality results.

1.6 Quality Objectives and Criteria

The measurements to be made during this research program can be divided into three major categories: continuous chemical measurements, continuous meteorological measurements and discrete precipitation, particulate and gas measurements. The Quality Assurance Objectives for each category will be discussed separately.

1.6.1 Continuous Chemical Measurements

1.6.1.1 Mercury in Air

The integrated Tekran Instruments Corporation (Knoxville, TN) ambient mercury speciation system (Models 2537A/1130/1135) will be used to measure ambient Hg⁰, RGM, and Hg(p) continuously throughout the course of the project (Landis et al. 2002). Target accuracy and detection limits are provided in Table 1.3. Internal, automated zeros and calibrations (i.e., span checks) will be performed every 3 days using an internal Hg⁰ permeation source (i.e., located within the Model 2537A analyzer). Manual standard addition injections will be performed each month and manual calibrations of the model 2537A internal permeation tube will be performed every six (6) months. Manual standard addition and calibrations will be performed by making multiple injections of Hg⁰ through the injection port on the front of the 2537A, using a Tekran Model 2505 primary calibration system and a Hamilton Company (Reno, NV) NIST traceable digital micro-syringe. The permeation rate for the internal permeation source is set in the following manner. First, multiple calibrations of the instrument are performed using the internal permeation source. Second, multiple injections are performed using the Tekran 2505 primary standard. The results of this procedure are used to calculate and enter a new permeation rate into the Tekran setup parameters. Refer to the Appendix (SpecHG-SOP) for the details regarding the calibration procedures and maintenance of the Model 2537A.

Table 1.3 Instrumentation, Accuracy and Detection Limits for Hg in Air

Variable	Instrument	Accuracy	Detection Limit (pg/m ³)
Hg ⁰	Tekran 2537A	±5%	50
RGM	Tekran 2537A/1130	±15%	2
Hg(p)	Tekran 2537A/1135	±15%	2

1.6.1.2 Trace Gases in Air

Trace gases will be measured continuously at each Supersite at a reference height of 8-10 m above ground level by placing inlets, and the NOy converter, in a weatherproof housing atop a 10-m tilt-down tower. Data will be acquired as 1-minute averages, then aggregated and reported as 5-minute and 60-minute averages. Table 1.4 provides information on accuracy and detection limit targets for the trace gas measurements. See AMBGAS-SOP in the Appendices for more details.

Ozone analyzers will be subjected to automated zero, span and precision checks each night using a Thermo-Environmental Model 49PS primary standard. Manual calibrations with the Model 49PS will be performed once a month. The remaining trace gases will be calibrated automatically every third day using tank standards (Scott-Marrin, Riverside, CA) diluted with zero air. Automated zeros will be performed every day for NO and NOy and every 120 minutes for CO and SO₂ in order to track baseline stability. Manual calibrations of each trace gas analyzer will be performed monthly.

Table 1.4 Instrumentation, Accuracy and Detection Limits for Trace Gases in Air

Variable	Instrument	Accuracy	Detection Limit (ppb)
Ozone (O_3)	TE 49c	$\pm 5\%$	1
Carbon Monoxide (CO)	TE 48C	$\pm 10\%$	20
Sulfur Dioxide (SO_2)	TE 43C	$\pm 10\%$	0.1
Nitric Oxide (NO)	TE 42c	$\pm 10\%$	0.05
Reactive Odd Nitrogen (NOy)	TE 42c	$\pm 15\%$	0.1

1.6.1.3 Fine Particulate Anions, Acidic Gases, EC/OC and Fine Particulate Mass in Air

The URG-9000C Ambient Ion Monitor (AIM) will be used to obtain semi-continuous (i.e. hourly) measurements of fine particulate sulfate, nitrate, nitrite, phosphate and chloride, and gaseous nitric acid, nitrous acid, sulfur dioxide and hydrochloric acid. Other anions and gases can be measured with the AIM (e.g., fluoride and bromide), but are virtually always below the analytical detection limit. The AIM samples air at a flow rate of 3.0 L/min through a size segregating $PM_{2.5}$ impactor inlet and then into a parrell plate membrane diffusion denuder which scrubs the acidic gases in a dilute solution of hydrogen peroxide. Particulate anions are then nucleated (grown) at high RH and collected in deionized water via cyclonic separation. Gases and particles are collected in this manner for 60 minutes. After the collection period, the solutions containing particulate anions and acidic gases are injected into an ion chromatograph and analyzed for target ions. Procedures for determination of precision, accuracy and blank values are still under development and will be appended to this document on or before June 30, 2009.

Quarterly calibrations are done on the AIM system and on the associated Dionex Model ICS-2000 ion chromatograph (IC). System calibrations set the parameters of ambient temperature, orifice temperature, orifice delta pressure, ambient orifice delta pressure, ambient pressure and inlet flow. For the IC calibration, aqueous multi-anion standards, plus an independent, mid-range calibration verification solution (CVS), are prepared by the ARA laboratory and distributed to the sites each quarter. The calibration standards are injected into the instrument in sequence to generate a calibration curve. The CVS is then analyzed and the new calibration curve is accepted if ion recoveries from the CVS are within ± 10 percent. Immediately prior to the next calibration, the CVS is again analyzed to determine detector drift. In addition, monthly standard addition injections will be performed. The full operation manual may be found in the Appendices (AIM-MAN).

Fine particulate mass will be measured continuously with a Thermo-Environmental (Franklin, MA) Model 5030 synchronized hybrid ambient real-time particulate (SHARP) monitor. The model 5030 uses nephelometry and beta attenuation to provide continuous (5-minute and 60-minute) $PM_{2.5}$ mass data. Ambient air is drawn through a size segregating cyclone inlet at 16.67 L/min, then heated, if necessary, to reduce sample RH to $\leq 40\%$. Sample then travels through a nephelometer section which measures light scattering at 880 nanometers. Sample air then passes through a section of filter tape and $PM_{2.5}$ mass deposited on the tape is measured via beta attenuation. Beta attenuation data are used to continuously mass calibrate the output of the

nephelometer. Table 1.5 provides accuracy and detection limit information for continuous PM_{2.5} and acid gas measurements. The full operation manual may be found in the Appendices (SHARP-MAN).

Fine particulate organic and elemental carbon will be determined with a Sunset Laboratory Inc. (Tigard, OR) Semi-Continuous Carbon Aerosol Analyzer. Ambient air is drawn through a size segregating cyclone inlet into the system and collected on a quartz filter mounted in the quartz furnace. After collection, carbon on the filter is thermally desorbed as CO₂ and quantified by non-dispersive infrared (NDIR). The NDIR is calibrated with external sucrose and methane standards (Appendix OCEC-SOP).

Table 1.5 Instrumentation and Accuracy Specifications for AIM and SHARP Measurements

Variable	Instrument	Accuracy	Detection Limit ($\mu\text{g}/\text{m}^3$)
SO ₄ ²⁻	AIM	$\pm 10\%$	0.1
NO ₃ ⁻	AIM	$\pm 10\%$	0.1
NO ₂ ⁻	AIM	$\pm 10\%$	0.1
Cl ⁻	AIM	$\pm 10\%$	0.05
PO ₄ ³⁻	AIM	$\pm 10\%$	0.2
SO ₂	AIM	$\pm 20\%$	0.2
HNO ₃	AIM	$\pm 20\%$	0.2
HNO ₂	AIM	$\pm 20\%$	0.2
HCl	AIM	$\pm 20\%$	0.1
PM _{2.5} Mass	SHARP	$\pm 5\%^a$	0.5

Note: accuracy based on comparison with 24-hour FRM samples.

1.6.2 Continuous Meteorological Measurements

For this study, meteorological measurements are made to characterize the mean meteorological conditions at the site during each measurement period. The measurements obtained at the site will not require stringent precision and accuracy criteria, given that these measurements will only be used to generate time-averaged (5-minute and 60-minute) values of the quantities measured. The measurements to be made for this purpose are presented in Table 1.6, along with the manufacturer's accuracy specifications. Individual documents in the Appendices provide more detail. See Met4A-MAN, LWS-MAN, Rainfall-MAN, Sonic-MAN, and SRsensor-MAN.

Table 1.6 Instrumentation and Accuracy Specifications for Meteorological Measurements.

Variable	Instrument	Accuracy
Temperature (8 m)	ParoScientific Met4A	± 0.25 deg C
Relative Humidity (8 m)	ParoScientific Met4A	± 2.0 %
Barometric Pressure (8 m)	ParoScientific Met4A	± 0.1 mbar
Wind Direction (10 m)	R.M. Young Model 81000 Sonic Anemometer	± 3 deg
Wind Speed (10 m)	R.M. Young Model 81000 Sonic Anemometer	± 0.1 m/sec
Global Radiation (2 m)	Licor LI200X Pyranometer	$+/- 5\%$ of reading
Incident Precipitation (1 m)	ETI Model NOAH-IV rain gauge	± 0.02 "
Surface Wetness (0.2 m)	CSI Sensor 237	---

Note: Reference height, above ground level, in parentheses

1.6.3 Discrete Measurements

1.6.3.1 Total Mercury in Precipitation

During the course of this project, precipitation samples will be collected to determine total mercury concentrations and to calculate wet deposition. The determination of the mercury content in collected samples will be performed using CVAFS at FDEP. Project QAO goals associated with the wet mercury analysis are summarized in Table 1.7. The standard reference material that will be used for verifying the accuracy of mercury analysis in water samples by CVAFS is NIST 1641d. A summary of the analytical methods to be used is presented in Section 2.2 of this document.

Table 1.7 Data Quality Objectives for Total Mercury in Precipitation.

QA Criteria	QA Operation/Type	Frequency	Acceptance Criteria	Control Action	Reporting Units
Precision	Analytical Replication*	5%	rsd < 20%	Re-analyze/ flag	Percentage
Accuracy	SRM Analysis NIST 1641d	Daily	$\pm 15\%$ of Certif. Concentration	Re-analyze/ Flag	Percentage
Blanks	Procedural	Daily	<MDL	Re-analyze/ flag	Mass/vol
Calibration	Standard Curve	Daily	$r^2 > 0.995$	Repeat until criteria met	---

rsd = relative standard deviation (standard deviation/mean x 100)

MDL = method detection limit

*: Matrix spike duplicates are analyzed from the same sample. If a replicate value is below the practical quantitation limit, precision is reported from the relative percent difference of the matrix spikes.

Method Detection Limits (MDL) will be determined for mercury in precipitation using EPA Method 200.1. This entails measuring seven replicate analyses from a sample with a low concentration of mercury from each medium and calculating the MDL as follows:

$$MDL = (t) \times (S)$$

where t = Student's t value for a 99 percent confidence level and a standard deviation estimate with n-1 degrees of freedom (t = 3.14 for seven replicate analyses), and S = standard deviation of the replicate analyses.

1.6.3.2 Trace Metals in Air and Precipitation

During the course of this project, samples will be collected to determine the levels of a suite of trace metals in ambient aerosols and precipitation. Daily precipitation samples will be collected with the ASPS and daily or weekly particulate samples will be collected with the sequential Dichotomous sampler and day/night denuder/filter pack sampler (ADS). The determination of the elemental content in precipitation and ADS filter samples will be performed using HR-ICPMS at UMAQL. Dichotomous sampler filters will be analyzed by ED-XRF or HR-ICPMS at EPA ORD-NERL. Details of the HR-ICPMS analysis for both precipitation and filters are given in Appendix TEpcp-SOP. If ED-XRF becomes the method of choice for the dichotomous sampler filters, the appropriate SOP will be appended to this QAPP.

Method Detection Limits obtained with the UM Thermo Finnigan Element2 HR-ICPMS running precipitation from Steubenville, Ohio and filter extractions from Detroit, Michigan are shown in Table 1.8. MDLs specific to the current project (for both precipitation by UM and filter extraction analysis by EPA) will be determined when the trace element analysis begins and will be appended to this QAPP on or before June 30, 2009. The method of calculating the MDLs is given later in this section. MDLs reflect instrument limitations from the sample matrix, preparation and analysis.

Table 1.8 Trace Element Method Detection Limits (MDLs).

Element	MDL (ppb)	
	Precip	Filt Extr
Rb85	0.0029	0.0012
Sr88	0.0113	0.0112
Mo95	0.0304	0.0069
Cd111	0.0251	0.0067
In115	0.0015	
Sn118	0.0070	
Sb123	0.0639	0.0062
La139	0.0009	0.0042
Ce140	0.0014	0.0056
Sm147	0.0002	0.0034
Pb208	0.0320	0.0379
Mg24	0.4900	0.1946
Al27	3.4900	0.1876
P31	0.1380	0.5646
S32	6.8000	6.5289
Ti47	0.0834	0.0337
V51	0.0045	0.0094
Cr52	0.0089	0.0101
Mn55	0.0700	0.1766
Fe57	0.9690	1.0474
Co59	0.0013	0.0049
Ni60	0.0810	0.0356
Cu63	1.4800	0.0825
Zn66	1.0600	0.2173
K39	0.9000	0.5494
As75	0.0180	0.0139
Se77	0.0350	

Project QA/QC goals associated with the elemental analysis are summarized in Table 1.9. Precision and accuracy goals were set to be suitable for the modeling while allowing for single pass

analysis even while analyzing a large suite of elements. A summary of the analytical methods to be used is presented in Section 2.2 of this document.

Table 1.9 Data Quality Objectives For Trace Elements in Air and Precipitation.

QA Criteria	QA Operation/Type	Frequency	Acceptance Criteria	Control Action	Reporting Units
Precision	Analytical Replication	15%	rsd < 20%	Re-analyze/Flag	Percentage
Accuracy	Standard Reference Materials	Daily	+/- 25%	Recalibrate/Flag	Percentage
Blanks	Procedural	10%	<MDL	Re-analyze/Flag	Mass/vol
	Field	10%	<10% of sample values	Flag	Mass/vol
Calibration	Standard Curve	Daily	r ² >0.995	Flag	---

rsd = relative standard deviation (standard deviation/mean x 100)

MDL = method detection limit

The Method Detection Limits (MDL) will be determined separately for metals in ambient aerosol and precipitation samples using EPA method 200.1. This entails measuring seven replicate analyses from a sample with low analyte concentrations and calculating the MDL as follows:

$$\text{MDL} = (t) \times (S)$$

where t = Student's t value for a 99 percent confidence level and a standard deviation estimate with n-1 degrees of freedom (t = 3.14 for seven replicate analyses), and S = standard deviation of the replicate analyses.

1.6.3.3 Stable Mercury Isotopes in Precipitation

During the course of this project, samples will be collected to determine the stable isotopic composition of mercury in precipitation. The determination of the stable isotopic composition of mercury in collected samples will be performed using MC-ICPMS following mercury concentration measurement by CVAFS. High precision mercury isotope ratios are measured relative to the NIST Hg standard reference material (SRM-3133), which is concentration-matched to the samples and analyzed before and after each sample (Blum and Bergquist, 2007). Samples are pre-concentrated, run at a concentration of 2 ng/g Hg, and run in duplicate or triplicate when sufficient sample is available. External standards are analyzed at least every eight samples for QA/QC and isotopic compositions are reported as the per mil (‰, or parts per thousand) deviation in the isotope ratios (²⁰²Hg/¹⁹⁸Hg, ²⁰¹Hg/¹⁹⁸Hg, ²⁰⁰Hg/¹⁹⁸Hg, ¹⁹⁹Hg/¹⁹⁸Hg) from the SRM-3133. Project QA/QC goals associated with the mercury isotope analyses are $\delta^{202}\text{Hg}/^{198}\text{Hg} \pm 0.10\text{\textperthousand}$ for replication of the external standard and for replication of repeat analyses of samples. A summary of the analytical methods to be used is presented in Section 2.0 of this document.

1.6.3.4 Discrete Filter Measurements of PM_{2.5} and PM₁₀ Mass

Twenty-four hour ambient particulate sample will be collected on Teflon filters using an R&P Model 2025D Sequential Dichotomous air sampler. All filters will be weighed in order to determine PM2.5 (fine) and PM2.5-10 (coarse) mass. See Appendix PMmass-SOP. As described above, selected filters will also be analyzed for trace elements via ED-XRF or HR-ICPMS. Data quality objectives for filter-based measurements of PM2.5 and PM2.5-10 are shown in Table 1.10. Acceptable weighing room temperature and relative humidity ranges ensure consistency for pre- and post weights which may be weeks apart. Collection completeness is the percentage of filters that yield mass results after losses due to filter damage or loss, balance problems, etc.

Flow checks, leak checks and time checks in the field will be performed every other week (see Table 1.10b). Flow checks will employ an inlet adapter provided by R&P and a NIST traceable BIOS Defender primary flow standard. Flow controllers will be recalibrated if they fall outside tolerances. Time checks will compare the time displayed by the Model 2025D with an atomic clock. Time will be adjusted on the Model 2025D if the display differs from the atomic clock by more than 2 minutes. Data from the Model 2025D will be downloaded, via connection to the RS232 port, and ingested into the project database each day. See Appendix PMdichot-MAN.

Table 1.10a Laboratory Data Quality Objectives –PM_{2.5}/PM₁₀ (Dichotomous Sampler)

Requirement	Frequency	Acceptance Criteria	Action / Information
Reporting Units	All data	µg	
Filters Visual defects Collection efficiency Conditioning Equilibration time Temperature range Humidity range	All filters Purchase spec All filters “ “	Defect free >99 % ≥24 hours 20-23±2° C on a 24-hr avg 30-40 ±5 % RH on a 24-hr avg	Discard defective filters Reject shipment Repeat equilibration Record T° & RH continuously Do not work outside range
Equipment Analytical balance Mass reference stds	Purchase spec “	0.1 µg sensitivity NIST traceable	
Balance calibration Instrument Reference weights	Annually Annually	Manufacturer Specs Manufacturer Specs	Manufac Recommendation Manufac Recommendation
QC checks Balance zero Laboratory Blank Tare Weight Laboratory Duplication Balance calib check - (100 mg & 200 mg)	Every filter 1/Batch* 1/Batch* Every Batch**	0.0000 ± 15µg ± 15µg ± 3µg	Rezero Reweigh or Flag samples Reweigh or Flag samples Reweigh or Flag samples

* Batch-maximum of 15 samples

** Frequency of verification is before and after every batch

Table 1.10b Field Data Quality Objectives –PM_{2.5}/PM₁₀ (Dichotomous Sampler)

Requirement	Frequency	Acceptance Criteria	Action / Information
Equipment Sampler Flow rate transfer std	Purchase spec “	USEPA method ± 2% accuracy	
Collection Completeness	Quarterly	75%	Report < 75%
Sampler calibration Flow control device Flow rate transfer std	Monthly or on Flow check failure Annually	± 5% ± 2%	Manufacturer recertification
QC checks Field Blanks Field flow check Field Leak Check Time Check	Monthly Fortnightly Fortnightly Fortnightly	± 5% <30 mm Hg +/- 2 minutes	Report Data Recalibrate Sampler Troubleshoot/repair leak Reset Time

2.0 SAMPLING AND MEASUREMENTS

Continuous measurements (e.g. meteorology) generally do not involve exchange of sample media between the field and a remote laboratory or preparation center. However, a discussion of sample preparation is appropriate for the Tekran Models 1130 and 1135, due to their use of annular denuders and particulate traps, respectively, to quantify RGM and Hg(p). Sampling procedures for filter-based measurements and precipitation measurements are discussed, as well.

2.1 Sampling Procedures

2.1.1 Preparation

Quartz annular denuders used for sampling RGM will be cleaned and prepared according to the procedures outlined in Appendix RGMprep-PRO. Quartz particulate traps are prepared by the manufacturer. Prior to sampling they will be checked and conditioned. This involves checking the amount of quartz wool that is packed in the trap (should not be too firm) and baking the trap at 800°C for approximately 30 minutes. Traps are then sealed to prevent contamination and shipped directly to field sites.

All filters used for sampling will be prepared and handled according to the procedures outlined in Appendix PMmass-SOP. Site operators will inform the FDEP PM_{2.5} Lab of their specific filter requirements at least two weeks in advance to ensure adequate time for filter preparation and shipping by the lab.

Preparation of precipitation sampling media will follow the procedures outlined in Appendix HGpcp-SOP, section 2. All fluorinated polyethylene, Teflon®, polypropylene and glass collection bottles and apparatus, reagent bottles and analytical supplies that come into contact with the samples will be cleaned according to the procedures outlined in Appendix ACtable-SOP. Prior to use, sample bottles are labeled, sealed and weighed, then triple-bagged for transport into the field. All other items are dried in a HEPA filtered air-drying box and triple-bagged in polyethylene zip-lock bags for storage and transport.

2.1.2 Sample Identification

Each sample deployed and collected will be identified by a unique sample ID. Sample IDs will indicate the type of sample (e.g., Day or Night denuder), the year of collection, site of collection and sequence number. Sequence number will be related to collection date in electronic or paper field logs. Sample IDs for the day/night denuder filter pack will be prefixed with the letters DSC, DCA and DFP for daytime sodium carbonate denuder, citric acid denuder and filter pack, respectively. Corresponding nighttime samples will be prefixed with NSC, NCA and NFP. For example, DCA08-7*0001 refers to the first daytime citric acid denuder collected at OLF (site 7) in 2008.

Fine and coarse sequential Dichot filters will use similar nomenclature for sample IDs and will be prefixed with the letters DFRMF and DFRMC, respectively.

Sample IDs for bottles used to collect precipitation samples in the ASPS are slightly different. The base tape on the bottle is labeled with the site code, the date on, the rack position, and the funnel ID number during setup. When a bottle contains a sample, the operator applies a 2nd label preprinted with the site code, a sequential sample number, a 'PCP' for precipitation, and either a 'HG' or 'MET' tag. The ASPS records the date and time of

the first tip of the rain gauge. The date is used as the sample date and will be hand written on the preprinted label when the site operator collects the sample, as well as recorded in permanent records.

An example of the labeling for the 22nd Pensacola sample collected since the beginning of the project is given below:

Base tape: **OLF 12/23/08 G47** (hand-written site code, on date, position in the rack, and funnel ID code with a Sharpie® when the bottle rack is loaded on 12/23/08)

Preprinted label: **OLF-22-PCP-HG Precip Date: 12/27/08** (preprinted label applied to the base tape when the sample is removed from the collector 1 or 2 weeks later, date of rain hand-written with a Sharpie® on the preprinted label)

As noted, all samples deployed will be given a unique sample ID. IDs are written on sample tracking forms and transferred to spread sheets for future data processing. In the event that a sample filter/container/bottle is contaminated during the deployment (e.g., filter/container/bottle is dropped on the ground), that sample will be marked as voided on the field and tracking logs.

2.1.3 Sample Collection

2.1.3.1 Continuous Measurements

2.1.3.1.1 SPECIATED MERCURY

In order to effectively monitor ambient levels of Hg⁰, RGM, and Hg(p) in the atmosphere, a Mercury Speciation System manufactured by Tekran Instruments Corporation (Knoxville, TN) is used. The system includes a Mercury Vapor Analyzer Model 2537A, a Mercury Speciation Unit (Denuder Unit) and Pump Module Model 1130, and a Mercury Particulate Unit Model 1135 (The Tekran 1130/1135 speciation units are programmed to collect one-hour composite RGM and Hg(p) samples at 10 L/min volumetric. The Tekran 2537A will continuously sample at 1 L/min and the 1130 pump module will pump 9 L/min during the denuder/quartz filter sampling period. During the denuder/quartz filter sampling period, RGM is collected onto a KCl-coated quartz annular denuder and Hg(p) is collected onto the quartz filter. During this period Hg⁰ is passed through the system and quantified by the 2537A every 5 minutes (12 five-minute elemental Hg⁰ determinations for each one-hour denuder/quartz filter sampling period). Following the one-hour denuder/quartz filter sampling period, the 1130 pump module will flush the system with zero air (15 minutes). The Pyrolyzer will be preheated to 800°C (5 minutes), the quartz filter will then be heated to 800°C (15 minutes), and the denuder will be heated to 500°C (15 minutes). During the heating cycle, the Hg(p) collected on the quartz filter and the RGM collected on the denuder are thermally decomposed to Hg⁰ and purged into the 2537A. After the heating cycle, the system will be cooled and purged with zero air for another 10 minutes before resuming another one-hour collection period).

2.1.3.1.2 AMBIENT IONS

Ambient air is drawn into the AIM at 3 L/min through a PM_{2.5} size segregating cyclone inlet to remove the coarse particulate matter. Sample air is then drawn through a parallel plate membrane liquid diffusion denuder to remove acidic and basic gases that would otherwise create a positive particulate phase artifact. Steam is injected to nucleate aerosols which are collected in an inertial separator cyclone. Denuder and cyclone aqueous samples are collected into 5 mL syringes and subsequently injected into the IC. After the particulate analysis is complete the gas phase ions are also analyzed.

2.1.3.1.3 METEOROLOGICAL MEASUREMENTS

The measurement procedures associated with each meteorological instrument will follow those contained in the USEPA Quality Assurance Handbook for Air Pollution Measurement Systems, Volume IV: Meteorological Measurements (EPA-454/B-08-002, March 2008). See Appendices Met4A-MAN, LWS-MAN, Rainfall-MAN, Sonic-MAN, and SRsensor-MAN.

2.1.3.2 Discrete Measurements

2.1.3.2.1 WET DEPOSITION MEASUREMENTS

The sampling method for mercury, trace elements and major ions in precipitation will employ an ASPS to obtain precipitation for analysis. Collection of all precipitation samples will follow the procedures outlined in Appendices ASPS-SOP and HGpcp-SOP. The ASPS uses the MIC-B funnel cover system to facilitate wet-only collection of precipitation and excludes dry deposited material from the samples during non-precipitation periods. It has two specially designed precipitation sensors that allow for complete collection of precipitation events even during light rain. When precipitation falls on the sensor grid, a relay is energized and the motor switches on to move the lid from the collection funnels to the lid support. The electrically heated sensor grid dries when the precipitation stops and a printed circuit controller de-energizes the relay, which switches the motor on again to move the lid back over the collection funnel.

The original MIC-B precipitation collection funnel has been replaced with the University of Michigan custom-made insert that supports four discrete precipitation collection trains. This design allows for separate collection of precipitation for mercury and trace element/ion analysis (Landis and Keeler, 1997). For this study 2 sample trains will be employed, one for mercury and one for trace elements. The major ions sample will be poured off of the trace element samples that have sufficient volume to be split. Separation of sample types makes it possible to provide the best storage and handling for each type. Glass funnels and fluorinated polyethylene sample bottles are the accepted standard for mercury samples. Polypropylene funnels and bottles conform to the current scientific standards for trace element and major ion samples. All acid cleaned parts of the trace element sample train will be subjected to a hot deionized water (MQ) soak to remove hydrochloric and nitric acid residuals. This process has been shown to be effective at removing potential chloride and nitrate artifacts from the major ions subsample.

The ASPS is capable of obtaining eight precipitation samples without operator intervention. The cabinet of the collector is refrigerated so that the samples can be kept from overheating between bottle changes. A microprocessor-controlled system advances collection to a new bottle after each sample and records pertinent meteorological data (Appendix ASPS-SOP).

One of every 10 sample bottles deployed to the sites will be designated as a Field Blank. Preprinted sample labels will be organized with 9 precipitation event ID codes (e.g., OLF-9-PCP-HG) and a Field Blank (e.g., OLF-10-FB-HG). After the site operator labels 9 precipitation samples, he/she will take one of the empty bottles from the rack and apply the 10th label, designating that bottle as a field blank. Throughout the project collection period, all precipitation ID numbers evenly divisible by 10 (i.e., 10, 20, 30, 40, ...) will be a field blanks.

In the laboratory, deionized water (MQ) will be added to the bottles. They will be processed and analyzed as samples and the analyte mass(es) in the bottle determined.

2.1.3.2.2 SEQUENTIAL PARTICULATE MEASUREMENTS

Both coarse and fine particulate samples will be collected on Teflon® filters using a Dichotomous Partisol®-Plus Model 2025 Sequential Air Sampler (Appendix PMdichot-MAN). The Model 2025 splits a PM-10 sample stream into its fine (PM2.5) and coarse (particles between 2.5 and 10 micron MMAD) fractions using an U.S. EPA-designed virtual impactor for the additional 2.5 micron cutpoint. The unit uses an R&P PM10 inlet operating at 16.7 L/min to make the initial particle size cutoff at a 10 micron MMAD. The virtual impactor or “dichotomous splitter,” follows the inlet and two separate flow controllers maintain the fine particle stream at 15.0 L/min and the coarse particle stream at 1.67 L/min. The system contains two supply and two storage magazines, each having a capacity of up to 16 filter cassettes, as well as a filter exchange mechanism that replaces two filter cassettes at the same time. For this study, samplers will collect samples using Teflon® filters (for mass determination and trace metals analysis).

2.1.4 Sample Handling

There is no sample handling in the case of the collection devices (annular quartz denuders and quartz particulate traps) used to sample RGM and Hg(p). Therefore, a discussion of sample handling is not relevant. However, clean practices are maintained during all maintenance operations that require opening the sample path.

All particulate filters and samples will be handled by FDEP Laboratories and ARA personnel according to Appendix PMmass-SOP. Normally, site operators will receive two magazines from the FDEP PM_{2.5} Lab every week, each containing the requested number of unexposed pre-weighed filters, accompanied by a filter custody log. The filter custody log will be signed and dated with the time of receipt and returned with the next shipment of exposed filters to the lab. A copy of the signed filter custody log will be retained with site records. Site operators will use information from the filter custody log sheet to generate an individual sample ID for each filter in the sample record database that will include the specific sample run date for each filter. All filters in one magazine will be assigned as DFRMF (Fine) samples and all filters in the second magazine will be assigned as DFRMC (Coarse) samples. Magazines will be stored in a secure, dry, controlled environment and will remain capped at all times inside the soft cooler pack until they are deployed. Filters will be deployed for sampling in the order received from the FDEP PM_{2.5} Lab and in accordance with the sample run dates shown in the sample record database. Unexposed filters that do not sample before the filter expiration date shown

on the filter custody log sheet from the lab will be marked as void in the sample record database and in the field filter log.

Site operators will wear clean particle-free gloves at all times when handling filter magazines and will take every precaution to prevent contamination. Under no circumstances will there be any contact with the active surface of the filter (i.e., inside the cassette retaining ring). Should that occur or in the event a filter is otherwise contaminated during deployment (e.g., filter dropped), that sample will be marked as void in the sample record database and in the field filter log.

Precipitation samples contain low levels of trace metals and therefore must be processed with care to avoid contamination. When handling precipitation samples (following procedures outlined in Appendix HGpcp-SOP), operators wear particle-free gloves and position themselves downwind of samples at all times. After collection, samples are triple-bagged in polyethylene bags and transported to the lab as soon as possible for analysis at the designated facility, FDEP for total mercury samples and UMAQL for trace element/ion samples. Upon arrival at the laboratory, all samples processing and handling will take place inside the Class 1000 clean laboratory. A subset of the precipitation samples analyzed for total mercury will be selected, by UMGS and UMAQL, for subsequent mercury isotope analysis. Upon receipt at FDEP and after they have been analyzed for total mercury, these samples will be maintained by FDEP in the Class 1000 clean laboratory at ambient temperature until they are shipped from the FDEP laboratory to UMGS. The mercury isotope samples subsequently will be kept refrigerated by UMGS except during shipping.

2.1.5 Sample Preservation in the Field

All particulate samples on Teflon® filters will be preserved according to the procedures in Appendix PMmass-SOP. On each prescribed filter change out day, site operators will remove the DFRMF and DFRMC magazines and store them in a refrigerator or freezer at a controlled temperature below $\leq 4^{\circ}\text{C}$, along with a resettable min/max thermometer. The time and date the filters are placed in the refrigerator or freezer will be recorded in the field filter log.

All mercury and trace metal/ion precipitation samples collected will be placed in individual, uniquely labeled acid-cleaned containers (fluorinated polyethylene or polypropylene bottles, respectively). The cabinet of the ASPS collector is refrigerated so that the samples can be kept stable between bottle changes. Mercury sample bottles will be pre-charged with 20mL of dilute ultra-pure hydrochloric acid to stabilize the sample preventing loss of the mercury. When eight precipitation events have taken place or 14 days have passed (whichever happens first) the samples will be transported to the analytical laboratory. The sample containers will be triple-bagged using new, polyethylene zip-seal bags. Once at the laboratory facilities, both mercury and trace element/ion samples will be immediately refrigerated. The major ion aliquot will be poured off of the trace element sample and will be refrigerated until analysis.

2.1.6 Sample Transportation

Filters containing particulate matter will be transported to FDEP according to the procedures outlined in Appendix PMmass-SOP. Site operators will ship exposed filters back to the lab in the same coolers in which they were received, packed with “blue ice” to maintain filters below ambient temperature. Where available, site operators will ship via FDEP courier service. Where this service is not available, site operators will ship exposed filters via a commercial carrier providing 2-day delivery service. When a commercial carrier is used, filters will be shipped to the lab on either a Monday or Tuesday to ensure filters are not held over a weekend in the event of a

delivery exception. Shipping via overnight delivery may sometimes be required during holidays. When preparing filters for shipping, field operators will complete the field filter log with the applicable run/storage data and update the sample record database. The field filter log will be signed and dated with the time the filters are relinquished. The completed and signed field filter log will accompany the filter shipment, and a copy will be retained with site records.

Precipitation samples will be prepared for shipment according to Appendices HGpcp-SOP and TEpcp-SOP, and are transported using commercial, “next-day or second-day” transportation services. At this juncture, the major ions samples are still part of the trace element sample. Experience has shown that the transport period without refrigeration does not compromise sample integrity. Mercury samples will be shipped to FDEP and trace element/ion samples to UMAQL.

All samples will be shipped with their respective sample tracking forms, which will be used upon receipt at the designated analytical laboratory for sample validation and tracking during the analytical process.

2.1.7 Sample Receipt and Storage at Laboratory

Samples shipped from the field sites to the UMAQL, ARA, FDEP or EPA will be received by the laboratory's manager. Upon receipt of the shipped samples, all sample tracking logs will be checked against the samples received. Following this initial sample verification, all samples will be refrigerated until they can be processed.

2.1.8 Sample Processing

Upon being conditioned, filters containing particulate matter will be post-weighed at the FDEP facility according to Appendix PMmass-SOP. Once a stable post-weight has been attained, the filters will then be shipped to EPA ORD-NERL for trace element analysis.

Precipitation samples contain low levels of trace metals and therefore must be processed with care to avoid contamination. For proper sample stabilization and preservation, precipitation samples collected for mercury analysis will be oxidized with concentrated BrCl by adding a solution of KBr and KBrO₃ to the preserved sample (acidified with HCl). Samples collected for quantification of additional trace elements will be acidified with HNO₃ (to 0.2% v/v solutions) prior to analysis by HR-ICP-MS (Landis and Keeler, 1997). See Appendix TEpcp-SOP for details.

Upon receipt of the precipitation samples at the University of Michigan Air Quality Laboratory's analytical laboratory, trace element/ion samples will be logged in and checked to be certain the tracking form matches the bottle label. Samples will be stored under refrigeration until they can be processed. Total sample volume will be determined by weight and recorded. Before the samples are acidified, a small amount is poured off for ion analysis. Then the samples will be acidified with concentrated ultra-pure nitric acid to 0.2% v/v HNO₃. After acidification, trace element samples will be put back in their polyethylene zip-seal bags and stored for 30 days at room temperature to ensure that all particulate material in the samples has been extracted. Ion samples will be stored under refrigeration until they are analyzed.

Precipitation samples to be analyzed for mercury will be sent to the FDEP Mercury Laboratory. Upon receipt by the FDEP Mercury Laboratory, the samples will be taken to the Class 1000 clean laboratory in the container that was used for shipping. In the clean laboratory, the bottles will be removed from the shipping container and plastic bags and arranged on a laboratory bench, where FDEP sample labels will be applied to the bottles. After labels are applied, 350mL of laboratory de-ionized water will be added to the field blank samples. Then, the mass of each bottle with cap will be obtained using a balance in the clean laboratory and recorded in a logbook. The samples will then be

preserved with trace metal grade hydrochloric acid to a pH below 2 and a solution of KBr/KBrO₃ will be added. The samples then will be stored in the clean laboratory at ambient temperature until analysis by Cold Vapor Atomic Fluorescence.

Precipitation Field Blanks will be processed by adding 350 mL of MQ de-ionized water to the sample bottle. After addition of the water, the blank is processed and analyzed as a sample.

The precipitation samples to be analyzed for mercury isotope analysis will already have been processed as total mercury samples by the FDEP laboratory.

2.2 Analytical Procedures

2.2.1 Mercury

2.2.1.1 Ambient Atmospheric Mercury (ARA)

For details of the analysis performed by the 2537A to determine the levels of mercury in each 5-minute sample, refer to Appendix SpecHG-SOP. The system is programmed so that the Hg⁰ determinations are reported in units of ng m⁻³, and zero-air purge, filter heating cycle, and denuder heating cycles are reported in units of pg m⁻³. The Hg(p) and RGM concentrations are automatically corrected for the flow of both the 2537A and the 1130 pump module.

2.2.1.2 Total Mercury in Precipitation (FDEP)

The determination of the mercury content in collected precipitation samples, to be conducted by FDEP, is briefly discussed below. For more details refer to Appendix HGpcp-SOP and the project QAO goals associated with this mercury analysis as summarized in Table 1.7

All analytical procedures for determination of mercury content in precipitation are carried out in a Class 1000 clean room. Nitrogen utilized for purging is 99.998% purity and is stripped of any mercury using a gold-coated bead trap before use in the purge system. Clean room gloves are worn at all times and all glassware with which the samples and reagents come into contact is cleaned weekly using the acid cleaning procedure described earlier.

Dissolved gaseous Hg⁰ is purged from solution in a mercury-free nitrogen stream after appropriate sample pre-treatment and reduction. Hg⁰ liberated from solution is concentrated on a gold trap, which is then analyzed by cold-vapor atomic fluorescence. A mercury-free pre-treated soda lime trap is utilized in the purge system to capture acid gases that may damage the gold trap.

At the start of each day of analysis, the analyzer is calibrated using a five-point calibration curve using various amounts of a 1 ng/ml aqueous standard. Control standards are analyzed every 6 samples to ensure that the CVAFS instrument has not changed in sensitivity. System and reagent blanks are generated on each day of analysis and subtracted from the day's standard curve.

Bottles designated as field blanks will have had 350mL of deionized water (MQ) added to them. They will be processed and analyzed as samples, the mass of mercury in the bottle determined and the results tabulated as part of the QA reports.

2.2.1.3 Mercury Stable Isotopes in Precipitation (UMGS)

A sub-set of precipitation samples will also be analyzed for stable mercury isotope ratios by MC-ICPMS (Blum and Bergquist, 2007). Mercury stable isotope analyses will be conducted by UMGS (HGisotopes-SOP). Mercury stable isotope ratios will be analyzed using a Nu-Instruments Nu-Plasma Multi-Collector ICP-, housed at the UMGS. Clean room gloves are worn at all times and all glassware with which the samples and reagents come into contact is cleaned weekly using the acid cleaning procedure described in previous sections.

2.2.2 Ions

2.2.2.1. Ambient Ions (ARA)

Sample analysis within the URG-AIM system is analyzed as follows: Full details can be found in the Appendix (AIM-MAN).

2.2.2.2. Ions in Precipitation (UMAQL)

Precipitation samples will be analyzed by UMAQL for dissolved anions and cations by ion chromatography (Appendix IONSpcp-SOP). A small aliquot of precipitation will be removed from each trace element sample having a total volume greater than 50 mL before it is acidified. Chloride, nitrate, nitrite, sulfate, sodium, ammonium, and calcium will be quantified. Each sample will be passed through a 0.22 µm cellulose filter prior to analysis to remove particulates. Two 0.5 mL vials will be prepared at the same time, one for the anion run and one for cation run. Standards, reference materials and samples will be introduced from an auto-sampler into the packed column where the analytes are separated and concentrated. Detection is by suppressed conductivity and the sample response quantified by a standard curve.

2.2.3 Trace Metals

The HR-ICPMS Standard Operating Procedure (TEpcp-SOP) found in the Appendices includes details of both the analysis of precipitation and the extraction and analysis of ambient filters. Analytical results from the EPA and UM instruments have been compared in the past and are considered to give equivalent data.

If ED-XRF becomes the analytical method for the filter samples, the QAPP will be updated to include a Standard Operating Procedure and summary text for that instrument.

2.2.3.1 Ambient Particulate Trace Metals (EPA ORD-NERL)

Sample analysis using the Thermo Finnigan Element2 HR-ICPMS requires that the analytes be in an aqueous medium. For this reason, the material on each filter must be extracted from the Teflon® filters. Sample filters with particulate material are put into 50 mL acid cleaned polypropylene centrifuge tubes and wetted with 100 µl of ethanol prior to being submerged in 40 mL of solution of ultra-pure 0.2% HNO₃ and 0.1% HCl (v/v). The samples are sonicated, then allowed to stand for 30 days before being analyzed by HR-ICPMS.

Just prior to analysis (TEpcp-SOP), a portion of the extract will be transferred to a 15 mL acid cleaned polypropylene centrifuge tube. Sample is introduced into the plasma by pneumatic nebulization into radio frequency plasma where energy transfer processes cause desolvation, atomization and ionization. The ions are extracted from the plasma through a differentially pumped vacuum interface and separated on the basis of their mass-to-charge ratio and kinetic energy. Resolution selection and peak characteristics for each target trace element is considered in the method to eliminate interferences from polyatomic ions derived from the plasma gas, reagents, or sample matrix. Instrument drift and suppression, or enhancement of instrument response caused by the sample matrix, will be corrected by internal standardization.

2.2.3.2 Trace Elements in Precipitation (UMAQL)

Trace metals will be analyzed using a Finnigan Element2 HR-ICPMS (details in Appendix TEpcp-SOP), housed at the University of Michigan analytical laboratory. Clean room gloves are worn at all times and all labware with which the samples and reagents come into contact is cleaned weekly using the acid cleaning procedure described in previous sections. Just prior to analysis, a portion of the sample will be transferred to a small polypropylene auto sampler vial. Sample is introduced into the plasma by pneumatic nebulization into radio frequency plasma where energy transfer processes cause desolvation, atomization and ionization. The ions are extracted from the plasma through a differentially pumped vacuum interface and separated on the basis of their mass-to-charge ratio and kinetic energy. Resolution selection and peak characteristics for each target trace element is considered in the method to eliminate interferences from polyatomic ions derived from the plasma gas, reagents, or sample matrix. Instrument drift and suppression, or enhancement of instrument response caused by the sample matrix, will be corrected by internal standardization.

Bottles designated as field blanks will have had 350mL of deionized water (MQ) added to them. They will be processed and analyzed as samples and the masses of the suite of trace elements in the bottle determined.

2.3 Calibration Procedures and Frequency

Automated and manual calibration schedules for Hg and trace gas analyzers are shown in Table 2.1. Tekran analyzers will be subjected to automated zero and span checks every third day, using an internal, temperature-controlled permeation tube filled with Hg⁰. Manual standard addition injections will be performed each month and manual calibrations of the model 2537A internal permeation tube will be performed every six (6) months. Manual standard addition and calibrations will be performed by making multiple injections of Hg⁰ through the injection port on the front of the 2537A, using a Tekran Model 2505 primary calibration system and a Hamilton Company (Reno, NV) NIST traceable digital micro-syringe. The digital syringe will be recertified annually by the manufacturer. Complete descriptions of calibration procedures and frequency for analysis of Hg⁰, RGM, and Hg(p) by the Tekran speciation system can be found in Appendix SpecHG-SOP.

Quarterly calibrations are done on the AIM system and on the associated Dionex Model ICS-2000 ion chromatograph (IC). System calibrations set the parameters of ambient temperature, orifice temperature, orifice delta pressure, ambient orifice delta pressure, ambient pressure and inlet flow. For the IC calibration, aqueous multi-anion standards, plus an independent, mid-range calibration verification solution (CVS), are prepared by the ARA laboratory and distributed to the sites each quarter. The calibration standards are injected into the instrument in sequence to generate a calibration curve. The CVS is then analyzed and the new calibration curve is accepted if ion recoveries from the CVS are within +/- 10 percent. Immediately prior to the next calibration, the CVS is again analyzed to determine detector drift. In addition, monthly standard addition injections will be done. The full operation manual may be found in the Appendices (AIM-MAN).

Ozone analyzers will be subjected to automated zero, span and precision checks each night using a Thermo-Environmental Model 49PS primary standard. Manual calibrations with the Model 49PS will be performed once a month. The remaining trace gases will be calibrated automatically every third day using tank standards (Scott-Marrin, Riverside, CA) diluted with zero air. Automated zeros will be performed every day for NO and NOy and every 120 minutes for CO and SO₂ in order to track baseline stability. Manual calibrations of each trace gas analyzer will be performed monthly.

Table 2.1 Automated and Manual Calibration Schedules for Hg and Trace Gas Analyzers

Instrument	Automated Calibration	Manual Calibration
Tekran 2537A	Every 3 days (zero/span)	Bi -annually
TE 49c (O ₃)	Daily (zero/span/precision)	Monthly
TE 48c (CO)	Zero – every 120 minutes Span- every 3 days	Monthly
TE 43c (SO ₂)	Zero – every 120 minutes Span- every 3 days	Monthly
TE 42c (NO/NOy)	Zero-daily Span-every 3 days	Monthly

Ambient particulate samplers (AIM, sequential dichots, day/night samplers), will be subjected to bi-weekly flow calibrations using a BIOS Defender series primary flow device. The BIOS will be recertified by the manufacturer on an annual basis.

For precipitation samples, at the start of each day of laboratory analysis for mercury, the CVAFS instrument is calibrated using a five-point calibration curve using various amounts of a 1 ng/ml aqueous standard (see Appendix HGpcp-SOP for details). Control standards are analyzed every 6 samples to ensure that the CVAFS instrument has not changed in sensitivity. System and reagent blanks are generated on each day of analysis (Keeler and Landis, 1999).

The SRM for mercury in water (NIST 1641d) will be used as an external SRM in each analytical run. Each laboratory conducting mercury analyses for the project will participate in inter-laboratory comparisons, including FDEP's Hg round-robin inter-laboratory comparisons.

At the start of each day of laboratory analysis for trace elements in precipitation samples, the HR-ICPMS instrument is calibrated using a three-point calibration curve (see Appendix TEpcp-SOP for details). Control standards for specific elements are analyzed to ensure the stability of the HR-ICPMS instrument sensitivity (Landis and Keeler, 1997). If the deviation from expected is greater than 25%, on any single element, the result is flagged. If many of the elements have larger deviations, the samples affected are re-analyzed after re-calibration. In addition to the control standards, a SRM is analyzed each day of sample analysis to evaluate instrument performance. NIST 1640 diluted to 2, 5 and 10% is used for this purpose.

If ED-XRF becomes the analytical method for the filter samples, the QAPP will be updated to include information on calibration procedures and frequency for that instrument.

Meteorological sensors will be calibrated as follows. Sonic anemometers (wind speed and wind direction) and ParoScientific Met4As (T, RH and BP) will be re-certified at the manufacturer on an annual schedule. The ETI electronic rain gauge will be calibrated in the field once a quarter using certified weights to mimic accumulated precipitation. The solar radiation sensor will be calibrated quarterly against a transfer standard. The surface wetness sensor cannot be calibrated, per se, but a response check will be performed weekly by spraying deionized water on the sensor.

2.4 Preventative Maintenance

Maintenance procedures for field and laboratory activities, including spare parts lists and sources of repair and replacement, are included in relevant Standard Operating Procedures in the Appendices of this document. All maintenance or repair to equipment will be documented in a laboratory notebook or electronic site log. Documentation will include instrument identification, a description of the problem(s), work performed, vendor service records, date and analyst's initials.

2.5 Quality Control Checks

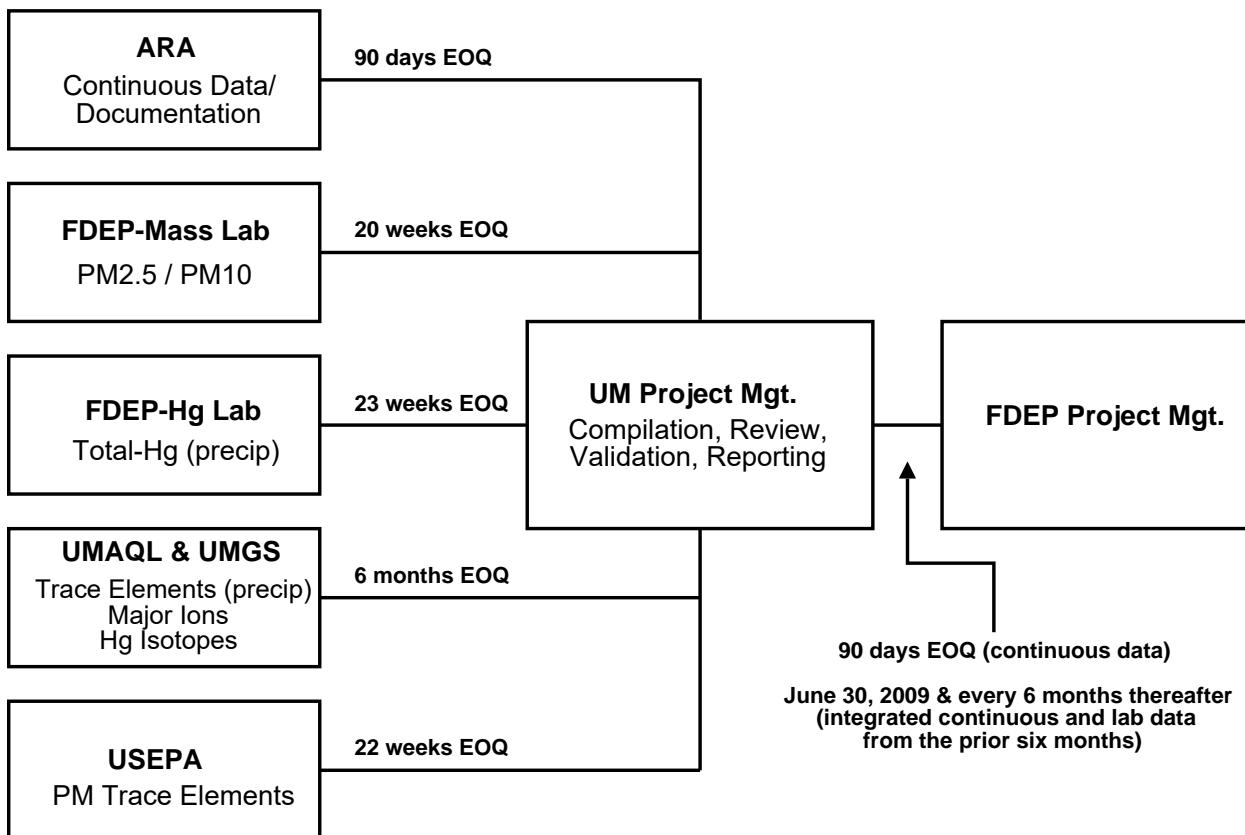
Procedures for field and laboratory internal quality control checks, including protocols for acceptance criteria, frequency of checks, and corrective action are described in the relevant Standard Operating Procedures and Protocols in the Appendices. Summary information has been provided in the following tables in this QAPP:

- Table 1.1. Instrumentation/Measurements for Atmospheric Monitoring
- Table 1.2 Data Capture and Analytes Quantified for Atmospheric Monitoring
- Table 1.3. Instrumentation, Accuracy and Detection Limits for Hg in Air
- Table 1.4. Instrumentation, Accuracy and Detection Limits for Trace Gases in Air
- Table 1.5. Instrumentation and Accuracy Specifications for AIM and SHARP Measurements
- Table 1.6. Instrumentation and Accuracy Specifications for Meteorological Measurements
- Table 1.7. Data Quality Objectives for Total Mercury in Precipitation
- Table 1.8 Trace Element Method Detection Limits (MDLs)
- Table 1.9. Data Quality Objectives for Trace Elements in Air and Precipitation
- Table 1.10. Laboratory and Field Data Quality Objectives - PM_{2.5} / PM₁₀
- Table 2.1. Automated and Manual Calibration Schedules for Hg and Trace Gas Analyzers

3.0 DATA MANAGEMENT

An overview of data flow through the Hg TMDL project is shown in Figure 3.1. Data, samples and associated documentation are collected more or less continuously at field sites (not shown) and transferred to ARA and laboratories on set schedules. Continuous data from analyzers (e.g., Tekran and AIM) and flow data from discrete samplers are validated at ARA and submitted to UM-Project Management within 90 days following the end of a calendar quarter (EOQ). The FDEP Mass laboratory receives shipments of sequential Dichot samples on a fixed schedule, weighs and performs internal QA on each sample and submits data to UM within 20 weeks EOQ. The FDEP Hg laboratory reports total-Hg in precipitation samples within 23 weeks EOQ. The UMAQL analyzes a range of sample media, performs internal QA and submits data when finalized to UM. Finally, ED-XRF data may also flow into UM from the EPA XRF laboratory (as well as intensive campaign collaborators) on a schedule that is yet to be determined.

Figure 3.1 Data Flow Chart for TMDL Project



All data will be subjected to a final review and data sets will be prepared for submittal to FDEP. Continuous data (atmospheric Hg, trace gases, meteorology, continuous PM) will be submitted to FDEP within 90 days EOQ, and interim data reports integrating continuous data and all laboratory data will be submitted to FDEP every 6 months, starting June 30, 2009. The initial interim data report will include all data collected through December 31, 2008. Subsequent interim data reports will include the next 6 months of data collection (i.e., December 31, 2009 report to include data collected through June 30, 2009). A fully QA/QC'd database for the 1st year and complete 2 years of project monitoring will be provided to FDEP by June 30, 2010 and March 31, 2011, respectively.

3.1 Data Reduction, Validation, and Reporting

3.1.1 Data Reduction

Data management for continuous variables begins on-site with acquisition of 1-minute data and associated diagnostic variables by the data acquisition system via digital or analog connection to each piece of equipment. Note that Tekran data are generated in 5-minute intervals while AIM and Sunset Carbon Analyzer data are generated in 60-minute intervals. The 1-minute data are then pushed each morning to the ARA data management center in Plano, TX and loaded into a SQL server master database. From this point onward, all data are managed using FirstLight, a series of custom software programs for reviewing, screening, adjusting, validating and reporting air quality data (for additional information on FirstLight, see FL-DOC). As the 1-minute data flow into FirstLight, they are subjected to a series of range checks designed to screen out data points that are clearly invalid. After screening, data flags are read and embedded calibration data are extracted and analyzed. Response factors derived from calibration data are then applied to 1-minute values, and the adjusted 1-minute data are then used to calculate 5-minute averages and summary statistics (max., min., standard deviation, median and count).

Data handling and reporting for samples processed and analyzed at FDEP Laboratories are detailed in 2 Appendices, Data-SOP and Report-SOP.

Field data for discrete samples are recorded on electronic or pre-printed forms that provide space for operator comments and suggestions and pertinent observations. In addition, the acceptability of each sample is recorded and judged by the field operator. Pertinent sampling information is entered into a computer database. Analytical results from laboratory procedures are recorded in bound laboratory notebooks and later entered into a computer database. Analyzer outputs are collected on various electronic media including fixed drives and diskettes. All databases are backed up to network drives and removable high volume disk media (e.g. DVD). These raw data are stored and will be archived for a minimum of 5 years after the completion of the project.

Continuous data are collected at each Supersite by various electronic data acquisition systems, downloaded to the ARA data management center in Plano, TX, written to a computer hard drive and a networked database daily. All databases are backed up to removable high volume disk media (e.g., DVD). These raw data are stored on-site and offsite and will be archived for a minimum of 5 years after the completion of the project.

During the course of this project, a clear record will be kept by each group allowing any final data point to be traced back to their original raw data.

3.1.2 Data Integrity and QC Validation

The 5-minute and 60-minute averages are then subjected to another round of automated screening. At this stage, data screening includes not only the adjusted 5-minute averages, but summary statistics and diagnostic variables, as well. For example, 5-minute standard deviations are used to determine if an analyzer is off-line (s.d.=0) or if data are unreasonably noisy (s.d. > predefined threshold). Similarly, diagnostic data, such as flows and temperatures, are used to determine whether or not an analyzer is operating under the proper conditions and to flag associated data accordingly. FirstLight then recalculates 60-minute averages and summary statistics (based on valid 5-minute averages) and 24-hour averages and summary statistics (based on valid 60-minute averages).

Following the automated screening process, all data are subjected to manual review using the FirstLight graphical interface. This step includes review of 5-minute averages and associated statistics, calibration data, diagnostic data and associated documentation. It also includes inter-parameter consistency checks, another round of range checks and nearest neighbor comparisons. 60-minute and 24-hour averages are automatically recalculated if any 5-minute average is flagged invalid. After these steps, continuous data are at Level 1 validation and ready for submittal to UM. Data submissions will include 5-minute and 60-minute averages. Each reporting interval will also include standard deviation, minimum, maximum and count. Raw unprocessed data will also be made available to UM to facilitate validation and provide a fully tracable record.

For laboratory measurements, each analyst and/or technician is responsible for determining that the results of each analytical determination have all associated QC measurements and that the acceptance criteria are met and documented according to protocol. All records are generated in accordance with previously established protocols developed for UMAQL projects. This records management system employs validation by the field manager, laboratory manager, or PI, as appropriate. Hand written records are entered into computer databases and all data are stored on hard disk in a central computer. The electronic filing directory system to be used is described in the following section.

FDEP Mercury and Gravimetric Laboratory data validation procedures are documented in Data-SOP in the Appendices.

3.1.3 Data Storage

All database files are identified by the filename and subdirectory structure. Final data records are retained on the computer drive until reports and publications are written and accepted, or for a minimum of 5 years after completion of the project (per requirements of Contract SP673 with FDEP), whichever is longer. After completion of the project and a final review by the Project Manager, all electronic data will be duplicated on DVD and stored in replicate for a minimum of five years after conclusion of the project contract at FDEP, UM and ARA. Written data shall be stored for a period of five years after conclusion of the project contract at UM.

Data handling and reporting for samples processed and analyzed at FDEP Laboratories are detailed in 2 Appendices, Data-SOP and Report-SOP.

3.2 Data Assessment

All data will be evaluated to determine if they meet the criteria outlined previously for precision, accuracy, completeness, and blank values. Samples not meeting criteria will be re-analyzed, where possible, or flagged as previously described. Flagged data will alert the user that they did not meet QA criteria, and why, and will be clearly documented in the final report and data sheets.

Data from samples processed and analyzed at FDEP Laboratories will be assessed in accordance with guidelines detailed in Appendices Data-SOP and Report-SOP.

3.3 Data Distribution

Data from each entity participating in the project (e.g., FDEP labs, ARA, EPA, UMAQL, UMGS) will be sent to the UM Project Management in keeping with the schedules described previously for merging, validation and reporting to FDEP. Interim data deliverables submitted to FDEP Project Management for the purposes of demonstrating progress, facilitating scientific discussion or presentation will be considered DRAFT data. A final database from Year 1 of monitoring will be provided to FDEP by June 30, 2010. A Project final database for all monitoring for the project will be provided to FDEP by March 31, 2011. Data in the Year 1 and Project final databases will have been fully merged and validated by the UM Project Management team and suitable for public distribution.

3.4 Data Audits

All data are subject to project auditing by or on behalf of FDEP at any time during the project and clear records will be kept by each entity participating in the project allowing any processed data points to be traced back to the original raw data.

4.0 PROJECT ASSESSMENT AND OVERSIGHT

4.1 QA Responsibilities

The personnel structure of the UMAQL and ARA make it impossible to provide complete separation of quality assurance oversight and assessment from the efforts to collect and process project data. The scope of this project and most of the work require the combined specializations of all key group members, leaving no separate individual to serve exclusively in a QA capacity. However, each individual on this project is professionally vested in maintaining high standards in order to maximize the value of the research products. Within these contractor groups, E. Edgerton will be responsible for the direction, oversight and QA/QC of the continuous measurements at the 4 Supersites. J. Barres will be responsible for QA related activities associated with precipitation supply preparation, sample collection, transport, preservation, analysis and data processing. FDEP Laboratory QA Officer, A. Tintle, will be responsible for QA related activities associated with the FDEP Mercury and Gravimetric Laboratories. M. Landis will be responsible for deployment, technical support and QA activities for the automated particulate collector, speciated mercury technical support, and for QA activities for the trace element analyses of the sequential particulate filters by USEPA ORD-NERL.

4.2 Performance and System Audits

Regular checks and calibrations of the field instruments will be performed by the site operator. Internal audits will be performed by ARA on at least an annual schedule, with initial audits within the first month of sampling at each site. The Tekran and AIM analyzers require a higher level of oversight and will be audited twice a year by ARA. EPA Region 4 SESD personnel (G.. Noah) will also conduct external audits of TMDL equipment and operation, at project startup and periodically thereafter. The UMAQL may request an external audit by other auditors, as well. The results of audits will be provided in the quality assurance reports described under Section 4.4 .

4.3 Corrective Action

As mentioned earlier in the Quality Assurance section of this document, there are procedures that are followed to identify any major source of error should it occur. The data are flagged and the appropriate procedures are followed (as outlined in the relevant standard operating procedures and protocols in the appendices).

4.4 Quality Assurance Reports

For the duration of the project, Quarterly Reports will be submitted to FDEP Project Management. A Project Final Report will be submitted to FDEP at the completion of the project. The required contents of the final report will be determined by FDEP Project Management and the participating contract groups.

In addition, beginning on or before June 30, 2009, UMAQL will provide an interim data report to FDEP which will include data files from both the field data and the data from laboratory analyses. The interim data reports and files will provide documentation/integration of the data measurements with respect to common site/date identification, and will provide an initial QA/QC assessment by ARA Inc. and UMAQL. The interim data reports will serve as the basis for discussion between UMAQL and FDEP regarding an understanding of data formatting and content, and any known QA/QC issues regarding the data. The initial interim data report will include all data collected through the end of the 1st calendar quarter of Task 04 (established as through December 31, 2008). Subsequent interim data reporting from UMAQL to FDEP will occur every 6 months, to include the next 6 months of data collection (i.e., December 31, 2009 report to include data collected through June 30, 2009).

REFERENCES

- Blum, J.D. and Bergquist, B.A. (2007): Reporting of variations in the natural isotopic composition of mercury. *Analytical and Bioanalytical Chemistry*, 233, 353-359.
- Dvonch, J.T., Vette, A.F., Keeler, G.J., Evans, G. and Stevens, R. An intensive multi-site pilot study investigating atmospheric mercury in Broward County, Florida. *Water Air Soil Pollut.*, 80: 169-78 (1995).
- Dvonch, J.T., Graney, J.R., Marsik, F.J., Keeler, G.J. and Stevens, R.K. An investigation of source-receptor relationships for mercury in south Florida using event precipitation data. *Sci. Total Environ.*, 213: 95-108 (1998).
- Dvonch, J.T., Graney, J.R., Keeler, G.J. and Stevens, R.K. Use of elemental tracers to source apportion mercury in south Florida precipitation. *Environ. Sci. Technol.*, 33: 4522-4527 (1999).
- EPA Method 200.1 Determination of Acid-Soluble Metals, in *Methods for the Determination of Metals in Environmental Samples* by Environmental Monitoring Systems Laboratory, EPA, 1992, pp 3-14.
- Keeler, G.J. and Landis, M.S. (1999) Sampling and Analysis for Vapor and Particulate Phase Mercury in Ambient Air Utilizing Cold Vapor Atomic Fluorescence Spectrometry, In: Compendium of Methods for the Determination of Inorganic Compounds in Ambient Air, U.S. Environmental Protection Agency, National Risk Management Research Laboratory, Cincinnati, OH, EPA-625/R-96-010a, January 1999.
- Landis, M.S., Keeler G.J., 1997. Critical evaluation of a modified automatic precipitation collector for mercury and trace element determinations. *Environ. Sci. Technol.* 31, 2610-2615 (1997).
- Landis, M.S.; Stevens, R.K.; Schaedlich, F.; Prestbo E. (2002). Development and characterization of an annular denuder methodology for the measurement of divalent inorganic reactive gaseous mercury in ambient air. *Environ. Sci. Technol.* 36, 3000-3009.
-

APPENDICES

Filename	Title [originator]
SpecHG-SOP	<i>Field Standard Operating Procedures for Measurement of Ambient Gaseous and Particulate Mercury [ARA]</i>
AIM-MAN	<i>Ambient Ion Monitor (AIM) Pre-Installation Requirements Checklist and Confirmation [URG]</i>
SHARP-MAN	<i>Synchronized Hybrid Ambient Real-time Particulate Monitor Model 5030: Instruction Manual [THERMO]</i>
ACtable-SOP	<i>Acid Cleaning Groups – Standard Operating Procedure [UMAQL]</i>
ASPS2-SOP	<i>Mercury and Trace Elements in Precipitation Samples using the Automated Sequential Precipitation Sampler II: Standard Operating Procedures for Field Operators [UMAQL]</i>
TEpcp-SOP	<i>Determination of Trace Elements in Precipitation, Dry Deposition, Ambient Aerosols, and Other Samples using Inductively Coupled Plasma – Mass Spectrometry: Standard Operating Procedure [UMAQL]</i>
HGpcp-SOP	<i>Trace-level Total Mercury in Water by Purge and Trap (Dual Gold Traps) and Cold Vapor Atomic Fluorescence Detection (CVAFD) [FDEP]</i>
HGisotopes-SOP	<i>Determination of Mercury Isotopic Composition in Precipitation [UMGS]</i>
IONSpccp-SOP	<i>Analysis of Precipitation, Acid Aerosols, and Other Samples by Ion Chromatography – Standard Operating Procedure [UMAQL]</i>
ADS-SOP	<i>Compendium Method IO-4.2 Determination of Reactive Acidic and Basic Gases and Strong Acidity of Atmospheric Fine Particles [EPA]</i>
PMdichot-MAN	<i>R & P 2025 Dichotomous Partisol®-Plus Model 2025 Sequential Air Sampler: Operating Manual [R&P]</i>
PMmass-SOP	<i>Determination of PM_{2.5} in Ambient Air by Gravimetric Analysis [FDEP]</i>
FL-DOC	<i>Description of FirstLight Data Management Software [ARA]</i>
Met4A-MAN	<i>User's Manual for MET4 and MET4A Meteorological Measurement Systems [Paroscientific]</i>
OCEC-SOP	<i>Standard Operating Procedure (SOP) for the Analysis of Organic and Elemental Carbon (OC/ED) Using the Sunset Laboratory Semi-Continuous Carbon Aerosol Analyzer [Sunset Laboratory]</i>
AMBGAS-SOP	<i>Automated collection of trace gas and flow data [ARA]</i>

APPENDICES, cont'

Filename	<i>Title [originator]</i>
SRsensor-MAN	<i>LI-COR Terrestrial Radiation Sensors - Instruction Manual [LI-COR]</i>
LWS-MAN	<i>Model 237 Leaf Wetness Sensor - Instruction Manual [CSI]</i>
Sonic-MAN	<i>Model 81000 Ultrasonic Anemometer - Operating Instructions [R.M.Young]</i>
Rainfall-MAN	<i>NOAH IV Total Precipitation Gauge - Technical Manual [ETI]</i>
Data-SOP	<i>Standard Operating Procedure for Records Maintenance and Storage [FDEP]</i>
Report-SOP	<i>Standard Operating Procedure for Reporting Qualified Data [FDEP]</i>

Curriculum Vitae



Florida Department of Environmental Protection
Division of Water Resource Management
Bureau of Watershed Management
2600 Blair Stone Road, Mail Station 3565
Tallahassee, Florida 32399-2400
(850) 245-8561
www2.dep.state.fl.us/water/

FLORIDA DEPARTMENT OF ENVIRONMENTAL PROTECTION

Division of Environmental Assessment and Restoration
Bureau of Watershed Restoration

Mercury TMDL for the State of Florida

Appendix H

Fish Tissue, Water Chemistry and Sediment Chemistry Sampling Results

Watershed Evaluation and TMDL Section



May 22, 2012

**Appendix H: Fish Tissue, Water Chemistry and Sediment Chemistry
Sampling Results**

Table G-1. Lake and Stream Statewide Mercury TMDL Sampling Station Location

Lakes				
Waterbody	Waterbody #	Latitude	Longitude	County
Pate Lake	L002	30.69223	-85.74645	Washington
Lake Claire	L018	28.60951	-81.20278	Orange
Lake Gordon	L024	27.85550	-81.62766	Polk
Lake Alcyone	L025	30.626607	-83.252117	Hamilton
Lake Henry	L029	28.09272	-81.66759	Polk
Bonable Lake	L031	29.13827	-82.52339	Marion
T-Pit	L034	30.25021	-82.31202	Baker
Unknown Lake	L035	28.333773	-82.539625	Pasco
Holly Lake	L047	30.77563	-86.18025	Walton
Lake Hamilton	L049	28.05026	-81.64025	Polk
Eden Lake	L050	27.26151	-80.24379	Martin
Cresent Lake	L051	29.42923	-81.50153	Putnam
Lake Victor	L057	30.95069	-85.89529	Holmes
Unknown L060	L060	28.11773	-80.93928	Osceola
Lester	L061	28.12362	-81.99832	Polk
Lake Winnemissett	L064	29.02326	-81.24863	Volusia
Lake Dexter	L067	29.10882	-81.48661	Volusia
Webb Lake	L069	26.83869	-81.95465	Charlotte
Lake Weir	L070	29.01728	-81.96059	Marion
Green Pit #2	L071	27.14754	-82.3967	Sarasota
Lake Davis	L072	28.82122	-82.28939	Citrus
Unkown Lake	L075	27.21826	-80.24818	Martin
Lake Washington	L076	28.1434	-80.74729	Brevard
Lake Myakka	L079	27.26883	-82.28832	Sarasota
Unnamed Lake	L085	30.659965	-84.554574	Gadsden
Unknown Lake L086	L086	28.44197	-81.41355	Orange
Royal Country Estate	L087	25.960679	-80.293383	Dade
Arrowhead Village	L091	26.70894	-81.89515	Lee
Berkshire Lake HOA	L092	26.16182	-81.7223	Collier
Swan Lake	L094	28.598077	-80.846759	Brevard
Green Pit #1	L095	27.14287	-82.39634	Sarasota
Lake Yale	L096	28.92738	-81.75851	Lake
Sorrento Lake	L097	27.15924	-82.46644	Sarasota
Dead Lakes	L1009	30.13502	-85.1988	Gulf
Unknown (Roberts Lk)	L101	28.16646	-81.58641	Polk
Black Lake	L103	30.746761	-85.892894	Holmes
Blue Cypress	L104	27.72668	-80.77127	Indian River
Lake Hampton	L105A	29.86122	-82.16841	Bradford
Lake Jeffery	L105B	30.2101935	-82.69176821	Columbia
Lake Jackson	L107	30.532930	-84.346580	Leon
Lake Miccosukee	L109	30.60506	-84.0033	Jefferson
Lake Alfred	L1097	28.0968	-81.73955	Polk
Lake Ellen	L1099	30.1127	-84.39915	Wakulla

Lakes				
Waterbody	Waterbody #	Latitude	Longitude	County
Mirror	L110	28.03835	-81.74422	Polk
Swift Creek Pond	L1107	30.11934	-82.29497	Union
Lake Rochelle	L111	28.07701	-81.72839	Polk
Campbell Lake	L1115	30.36691	-86.29384	Walton
Lake Poinsett	L112	28.35033	-80.86457	Brevard
Lake George	L1142	29.21389	-81.58574	Volusia
Peach	L117	28.58371	-81.53189	Orange
Peach-2	L117	28.58379	-81.53176	Orange
Lake Louisa	L1183	28.49305	-81.74515	Lake
Lake Octahatchee	L1186	30.606952	-83.197585	Hamilton
Lake Park Lake	L119	26.52597	-81.8812	Lee
Rock Lake	L1194	28.11361	-82.55693	Hillsborough
Lake Placid	L1242	27.264714	-81.357709	Highlands
Hurricane Lake	L1252	30.94122	-86.75793	Okaloosa
Lake Crosby	L1274	29.94388	-82.15674	Bradford
Suwannee Lake	L1297	30.300224	-82.928846	Suwannee
Lake Buffum	L1304	27.78745	-81.67564	Polk
Lake Otter	L1310	30.02371	-84.41893	Wakulla
Lake Osborne	L1313	26.60203	-80.07639	Palm Beach
Lake Louise	L1363	30.31799	-82.87869	Suwannee
Lake Myrtle	L1384	27.94642	-81.65257	Polk
Loughman Lake	L1410	28.64134	-80.93303	Brevard
Gator Lake	L1412	26.57269	-81.82491	Lee
Lake Eloise	L1413	27.98383321	-81.70304444	Polk
Lake Winterset	L1421	27.97460321	-81.68167444	Polk
Bear Lake	L1424	30.86358	-86.83296	Santa Rosa
Lake Pasadena	L1438	28.3215	-82.21907	Pasco
Lake Miona	L1494	28.900361	-82.00622	Sumter
Ward Lake	L1501	27.4299	-82.48452	Manatee
Lake Pierce	L1527	27.95829	-81.51558	Polk
Clearwater Lake	L1533	29.668348	-81.880015	Putnam
Lake Rousseau	L1557	29.04147	-82.50994	Citrus
Lake Rousseau 2	L1557	29.00954	-82.61405	Citrus
Lake Deaton	L1558	28.83414	-81.98257	Sumter
Lake Tarpon	L1566	28.13508	-82.7352	Pinellas
Lake Parker	L1642	28.06128	-81.91964	Polk
Lake Panasoffkee	L1644	28.8065	-82.12954	Sumter
Riggins Lake	L1655	30.396023	-83.365735	Madison
Ocean Pond (L123ALT)	L166	30.21701	-82.43081	Baker
Lochloosa Lake	L1668	29.51001	-82.11276	Alachua
Hay Pond	L1674	30.61183329	-83.82187124	Jefferson
Burrell Lake	L1678	28.093368	-82.448618	Hillsborough
Lake Juliana	L1688	28.12854	-81.80883	Polk
Unnamed lake	L1695	27.66344	-82.04238	Polk
Legs Lake	L1730	28.10201	-81.93614	Polk
Lake Lizzie	L1736	28.879248	-81.63503	Lake

Lakes				
Waterbody	Waterbody #	Latitude	Longitude	County
East Lake	L1741	28.70597386	-81.34596205	Seminole
Lake Okahumpka	L1753	28.8287	-82.00749	Sumter
Lake Hooker	L1755	27.980611	-82.263498	Hillsborough
Lake Jessup	L1772	28.70904	-81.2467	Seminole
Lake Thonotosassa	L1790	28.05846	-82.27894	Hillsborough
Grassy Pond	L1818	30.590982	-83.322168	Madison
John's Pond	L1822	30.24147	-82.754238	Columbia
Lake Macy	L1827	28.97241	-81.23256	Volusia
Lake Bradley	L1829	28.73208	-82.29045	Citrus
Bethea Lake	L1830	30.2185535	-82.79967821	Suwannee
Juniper Lake	L188	30.770502	-86.128771	Walton
Cherry Lake	L219	30.61681	-83.41449	Madison
Compass Lake	L231	30.60591	-85.38488	Jackson
Lake Sampson	L295	29.9271	-82.18504	Bradford
Steinhatchee Quarry Pit	L332	29.83984	-83.2953	Lafayette
Georges Lake	L353	29.791473	-81.855445	Putnam
Palestine Lake	L354	30.11736	-82.40505	Union
Lake Catherine	L372	29.0648	-81.83386	Marion
Lake Kerr	L374	29.35686	-81.80095	Marion
Cherry Lake	L376	28.600792	-81.81059	Lake
Eagle Lake	L419	27.9834	-81.76253	Polk
Mill Dam Lake	L440	29.17978	-81.83547	Marion
Lake Avalon	L462	26.11254	-81.76063	Collier
Unknown Lake	L487	29.37958	-81.77498	Marion
Lake Emma	L512	28.61372	-81.85083	Lake
Santa Fe Lake	L513	29.7393	-82.08013	Alachua
Deer Point Lake	L547	30.28161582	-85.59427518	Bay
Lake Butler	L573	30.03252	-82.33723	Union
Hunters Creek Pond	L616	28.37317	-81.41834	Orange
Lake Magdalene	L634	28.08155329	-82.48238124	Hillsborough
Sand Pond	L672	29.93116	-84.34653	Franklin
Basin Bayou	L694	30.4938	-86.24264	Walton
Little Henderson (TAC)	L732	28.84844	-82.32801	Citrus
Platt Lake	L768	28.09424329	-82.47760124	Hillsborough
Carraway Lake	L780	29.17576698	-81.31951047	Volusia
Lake Disston	L810	29.295403	-81.376854	Flagler
Unnamed (Lake Mattie)	L869	28.14982	-81.787892	Polk
Lake Alberta	L873	30.608401	-84.065595	Leon
Lake Monroe	L879	28.83222698	-81.26264047	Seminole
Cowpen Lake	L891	29.6012	-82.00401	Putnam
Parrish Lake	L923	27.61008	-82.31187	Manatee
Lake McCloud	L940	27.97229	-81.75201	Polk
Lake Hartridge	L965	28.05141	-81.74681	Polk
Lake Tracy	L975	28.11119	-81.63409	Polk
Ocheesee Pond	L981	30.65983	-84.97198	Jackson
Smith Lake	L999	29.06373	-81.9909	Marion

Streams				
Waterbody	Waterbody #	Latitude	Longitude	County
Burnt Grocery Creek	S02	30.64185	-86.85401	Santa Rosa
Perdido River	S023	30.69005	-87.44042	Escambia
Simms Creek	S024	29.70359	-81.69512	Putnam
Alligator Creek	S03	30.77802	-86.87488	Santa Rosa
Econfina Creek	S032	30.55518	-85.43492	Bay
Little River	S041	30.55335	-84.51442	Gadsden
New River	S042	29.95979	-84.71954	Franklin
Black Creek S Fork	S043	30.07237	-81.84542	Clay
Reedy Creek	S044	28.28705	-81.54128	Osceola
North Mosquito Creek	S045	30.68957	-84.65557	Gadsden
Blackwater Creek	S046	28.857452	-81.43689	Lake
Alapaha River	S048	30.44839	-83.09628	Hamilton
Etoniah Creek	S049	29.7347	-81.84693	Putnam
Mule Creek	S05	30.51129	-84.82797	Liberty
Jack's Branch	S050	26.74728	-81.51297	Hendry
Ocklawaha River 1	S053	29.21732	-81.98610	Marion
Ocklawaha River 2	S057	29.50553	-81.91194	Putnam
Freeman Creek	S06	30.40118	-84.59334	Leon
Lettmer Creek	S060	26.34589	-81.77046	Lee
Ocklawaha River 3	S061	29.20456	-81.99337	Marion
Choctaw River	S062	30.91900	-85.85316	Holmes
Lower Peace River	S063	27.15697	-81.90428	Desoto
Julington Creek	S066	30.13335	-81.58678	Duval
L-8 Canal	S067	26.804664	-80.42291	Palm Beach
Econfina River	S069	30.14375	-83.86399	Taylor
Suwannee River 1	S071	30.42127	-83.13467	Hamilton
Fenholloway River	S072	30.009454	-83.77958	Taylor
Faka Union Canal	S074	26.0912	-81.52207	Collier
Rock Springs Run	S077	28.7726	-81.50273	Orange
Ten Mile Canal	S078	26.55187	-81.85517	Lee
Ocklawaha River 4	S079	29.47725	-81.74389	Putnam
Blackwater River (upper)	S08	30.93292	-86.73521	Okaloosa
Holmes Creek	S081	30.79994	-85.60247	Holmes
Hillsborough River	S082	28.08378	-82.28517	Hillsborough
St. Johns River #3	S084	30.00956	-81.68917	St. John's
L6 Canal	S087	26.36798	-80.51587	Palm Beach
Ocean Canal	S092	26.678664	-80.40757	Palm Beach
Flint Creek	S093	26.07618	-82.26319	Hillsborough
Ocklawaha River 5	S099	29.37619	-81.90233	Marion
Black Creek Mouth	S100	30.04386	-81.7124	Clay
I-75 Canal	S101	26.15403	-81.44288	Collier
Wakulla River	S1022	30.20993	-84.26032	Wakulla
Suwannee River 2	S104	30.39293	-82.93296	Suwannee
Black Creek Canal	S1041	25.545194	-80.34192	Dade
SJR#6	S107	29.67753	-81.64661	Putnam

Streams				
Waterbody	Waterbody #	Latitude	Longitude	County
Suwannee River	S1081	29.39867	-83.03296	Dixie
Alafia River	S1082	27.86711	-82.1445	Hillsborough
Santa Fe River	S1113	29.86904	-82.74437	Gilchrist
Suwannee River	S1137	29.795354	-82.91994	Gilchrist
Hogtown Creek	S1153	29.65296	-82.37177	Alachua
Yon Creek	S119	30.53375	-84.77108	Gadsden
Tallahassee Creek	S1194	30.55669	-84.75429	Gadsden
Miami Canal	S121	25.84709	-80.3136	Dade
Bullfrog Creek	S1215	27.79659	-82.34962	Hillsborough
L-28 Interceptor Canal	S1220	26.163554	-80.89406	Collier
Juniper Creek	S123	30.35866	-85.21219	Calhoun
Juniper Run	S1244	29.20251	-81.63443	Lake
Orange Creek	S126	29.51447	-81.93573	Putnam
Sixteen Mile Cr	S127	29.65809	-81.46163	St. Johns
St. John's River	S1297	29.980154	-81.62167	St. John's
Rocky Creek	S1306	30.12828	-83.64545	Taylor
Upper Steinhatchee River	S1326	29.88702	-83.26404	Lafayette
Mill Creek	S1331	30.25434	-83.28327	Lafayette
Wacissa River	S1337	30.32438	-83.98695	Jefferson
Whiskey George Creek	S135	29.84393	-84.87545	Franklin
Upper Peace River	S1368	27.81418	-81.79549	Polk
Shoal River	S1377	30.77113	-86.5027	Okaloosa
Wekiva River	S1398	29.22192	-82.74782	Levy
Weeki Wachee	S1399	28.52219	-82.58866	Hernando
Caloosahatchee Riv	S1421	26.76898	-81.44036	Hendry
Frog Creek	S1441	27.58933	-82.54113	Manatee
Itchepachasassa	S1450	28.13998	-82.14944	Hillsborough
Black Creek	S146	30.02548	-84.98167	Liberty
Chipola River	S1471	30.71839	-85.19996	Jackson
Upper St Marry's River	S148	30.52448	-82.23027	Baker
Sopchoppy River	S157	30.17043	-84.49837	Wakulla
Deep Creek	S164	30.3658	-82.61981	Columbia
New River	S173	30.12806	-84.89585	Liberty
Depot Creek	S179	29.7476	-85.19492	Gulf
Suwannee River - Upper	S196	30.44491	-82.67113	Hamilton
Lostman's Creek	S2010	25.56475	-80.99853	Monroe
North Prong	S2011	25.46073	-80.86598	Dade
Ichetucknee River	S2012	29.9484	-82.78939	Suwannee
Turnpike Canal	S216	26.75968	-80.13333	Palm Beach
Black Creek	S226	30.47369	-85.98888	Walton
Bootheel Creek	S245	27.11543	-81.41017	Highlands
Sandy Creek	S260	30.141024	-85.40717	Bay
Alaqua Creek	S261	30.69251	-86.24147	Walton
Little Charlie Bowleg Creek	S275	27.47631	-81.5566	Highlands
Mill Creek	S277	29.40144	-81.92861	Marion
Blackwater River	S289	30.710357	-86.866304	Santa Rosa

Streams				
Waterbody	Waterbody #	Latitude	Longitude	County
Big Coldwater Creek	S290	30.7522	-86.98868	Santa Rosa
Taylor Creek	S292	27.31631	-80.83852	Okeechobee
Bear Creek	S293	30.43549	-85.40951	Bay
Big Creek	S302	30.3887	-84.78957	Liberty
Myakka River	S307	27.3459	-82.15532	Manatee
Swift Creek	S313	30.03183	-82.53047	Union
Fisheating Creek	S362	26.93293	-81.31592	Glades
Sampson Creek	S367	30.06493	-81.50128	St. Johns
Haw Creek	S385	29.404874	-81.3541	Flagler
L31N Canal	S389	25.48338	-80.5627	Dade
St. Mary's River	S404	30.79096	-81.84416	Nassau
Crooked River	S405	29.925	-84.62653	Franklin
Eaton Creek	S415	29.26614	-81.87337	Marion
Ochlockonee River	S428	30.58578	-84.35893	Gadsden
Yellow River	S431	30.62876	-86.81074	Santa Rosa
Telogia Creek	S454	30.3596	-84.79225	Liberty
Manatee River	S459	27.46839	-82.25839	Manatee
C111 Canal	S486	25.42983	-80.55954	Dade
Daughtrey's Creek	S497	26.74239	-81.85417	Lee
Glades Road Canal	S528	26.33468	-80.17074	Palm Beach
Peachland Canal	S555	27.01013	-82.06753	Charlotte
St. Lucie River	S564	27.317594	-80.33698	St. Lucie
Six Mile Creek	S604	27.996777	-82.350673	Hillsborough
California Creek	S610	29.45777	-83.15246	Dixie
Lost Creek	S633	30.20366	-84.43594	Wakulla
Interceptor Canal	S643	27.23971	-80.78581	Okeechobee
Tamiami Canal	S686	25.90163	-81.31086	Collier
Oak Creek	S690	26.32848	-81.76354	Lee
Withlacoochee River	S735	28.822488	-82.182787	Sumter
Golden Gate Canal	S747	26.17214	-81.7003	Collier
Dunn's Creek	S784	29.575844	-81.62353	Putnam
Myakka River	S791	27.12306	-82.351	Sarasota
Big Juniper Creek	S824	30.73074	-86.89821	Santa Rosa
C44 Canal	S856	27.007774	-80.46976	Martin
Loxahatchee River	S900	26.974104	-80.16394	Martin
St Marks River	S923	30.20244	-84.17719	Wakulla
Hillsborough River	S942	28.05642	-82.36544	Hillsborough
Little Withlacoochee River	S964	28.5752	-82.19742	Sumter
Otter Creek	S988	29.21379	-82.77741	Levy

Table G-2. Sampling Site Conditions, Alkalinity and Field Measurements for Stations Sampled for the Statewide Mercury TMDL

- = Measurement was not recorded/No data

Waterbody Number	Waterbody	Sample Date	Alkalinity (mg/L)	Field Measurements							
				Sample Depth	Secchi Depth	Site Depth	DO (mg/L)	pH	Specific Conductance ($\mu\text{mhos}/\text{cm}$)	Temperature (°C)	Redox (mvolt)
L002	Pate Lake	9/25/2008	0.65	1.0	1.4	4	7.43	4.4	34	25.9	541
L018	Lake Claire	10/22/2008	32	1.0	1.7	3.4	5.20	6.84	109	25.3	539
L024	Lake Gordon	11/13/2008	3.3	1.0	0.4	2.5	7.56	5.65	157	22.2	402
L025	Lake Alcyone	9/21/2009	0.8	1	1.6	3.5	9.3	5.98	23	29.24	-
L029	Lake Henry	10/30/2008	5.8	1.0	0.6	2	7.87	6.64	217	18.5	585
L031	Bonable Lake	5/13/2009	1.2	1.0	0.4	1.4	5.56	5.64	78	26.56	372
L034	T-Pit	2/17/2009	0.65	0.5	0.4	1	7.48	4.13	61	13.6	530
L035	Unknown Lake	1/28/2010	1.5	1	2.06	4.42	8.66	4.56	54	15.7	-
L047	Holly Lake	5/19/2009	2.1	1	2.0	3.0	7.52	6.21	19.0	23.46	126
L049	Lake Hamilton	11/24/2008	10	1.0	0.8	2.25	9.60	7.11	232	15.6	331
L050	Eden Lake	2/9/2009	6.1	1	1.4	2.5	8.1	5.89	120	14.7	-
L051	Cresent Lake	11/20/2008	38	1.0	0.35	3.6	8.82	6.94	469	15.2	310
L057	Lake Victor	5/19/2009	6.8	1	1.7	6.0	5.67	6.47	30.0	24.2	115
L060	Unknown L060	12/15/2008	32	1	0.8	1.7	0.96	6.27	95	15.3	282
L061	Lester Lake	6/17/2009	29	0.1	0.5	1.7	8.46	7.98	183	31.8	210
L064	Lake Winnemissett	11/25/2008	6.2	1.0	3.4	6.2	8.63	7.23	146	17.4	345
L067	Lake Dexter	11/20/2008	57	1.0	0.8	2.2	6.34	7.02	511	14.9	305
L069	Webb Lake	2/24/2009	39	1	2.3	2.3	8.1	8.54	112	19.9	261
L070	Lake Weir	5/6/2009	14	1.0	1.2	6.5	7.85	8.63	222	26	90
L071	Green Pit #2	6/9/2009	156	0.1	0.7	1.5	8.04	8.65	692	29.01	-5
L072	Lake Davis	6/10/2009	134	0.1	0.4	0.4	2.51	7.47	333	33.07	258
L075	Unkown Lake	2/9/2009	60	1	1.8	1.8	8.78	7.42	207	17.72	-
L076	Lake Washington	12/18/2008	59	1	0.5	2.2	7.83	7.49	363	19.8	298
L079	Lake Myakka	12/10/2008	40	0.5	0.8	0.9	9.24	7.78	465	21.7	-
L085	Unnamed Lake	3/10/2010	56	1	3.3	3.5	11.04	8.66	140	15.7	286
L086	Unknown Lake L086	5/7/2009	41	1.0	1.6	3.5	8.5	8.98	145	27.2	63
L087	Royal Country Estate	5/19/2009	93	0.75	1.3	1.3	8.11	8.4	231.0	27.63	375

Waterbody Number	Waterbody	Sample Date	Alkalinity (mg/L)	Field Measurements							
				Sample Depth	Secchi Depth	Site Depth	DO (mg/L)	pH	Specific Conductance ($\mu\text{mhos}/\text{cm}$)	Temperature ($^{\circ}\text{C}$)	Redox (mvolt)
L091	Arrowhead Village	2/24/2009	97	1	0.75	1.4	9.15	9.12	262	19.4	356
L092	Berkshire Lake HOA	2/23/2009	131	1	0.8	2.5	8.98	8.7	356	21.3	334
L094	Swan Lake	1/14/2010	148	1	2	5.95	10.29	7.53	360	12.77	-
L095	Green Pit #1	6/9/2009	123	0.1	1.25	3	8.11	8.57	504	29.42	53
L096	Lake Yale	5/14/2009	132	1.0	0.6	4.5	4.87	8.14	406	27.7	79
L097	Sorrento Lake	2/25/2009	54	1	0.35	2.7	10.39	9.23	474	18.2	319
L1009	Dead Lakes	8/19/2009	15	1	1.3	3.5	5.68	6.49	57	28.04	290
L101	Unknown (Roberts Lk)	11/24/2008	57	1.0	2.8	2.8	9.06	7.31	165	17	304
L103	Black Lake	3/2/2010	0.65	1	1	6.3	8.57	4.85	22	11.32	449
L104	Blue Cypress	12/15/2008	29	1	0.5	2	8.55	6.96	153	18.8	296
L105A	Lake Hampton	11/18/2008	0.65	1.0	1.02	4.6	7.97	6.29	92	18.2	407
L105B	Lake Jeffery	12/9/2009	2.6	1	1.7	3.1	10.5	6.25	90	16.17	115
L107	Lake Jackson	4/1/2009	7.6	1	2	2.1	5.56	6.3	29	18.24	172
L109	Lake Miccosukee	8/19/2009	6.7	1	1.4	3	1.68	5.68	26	27.83	330
L1097	Lake Alfred	8/13/2009	63	1	0.5	3	7.03	8.74	428	31	206
L1099	Lake Ellen	4/2/2009	0.65	1	1.4	2.9	7.6	5.41	44	19.76	263
L110	Mirror Lake	8/13/2009	48	1	0.9	3.4	7.01	8.28	229	31.5	269
L1107	Swift Creek Pond	3/10/2009	0.65	1	0.15	1.3	7.62	4.76	94	17.96	348
L111	Lake Rochelle	6/10/2009	70	0.1	0.9	4	9.33	9.55	291	32.03	191
L1115	Campbell Lake	9/23/2009	0.65	1	2.7	2.7	6.94	4.63	141	30.16	407
L112	Lake Poinsett	12/18/2008	53	1	0.4	1.2	7.54	7.36	468	19.4	286
L1142	Lake George	8/17/2009	44	1	1	3	6.19	7.27	746	28.9	-
L117	Peack Lake	6/4/2009	30	1	-	17	3.72	7.29	129	29.2	307
L1183	Lake Louisa	6/25/2009	2.8	1	1.4	2.7	6.65	6.02	107	31.15	342
L1186	Lake Octahatchee	9/21/2009	9.3	1	0.8	2.3	4.24	5.32	61	26.59	-
L119	Lake Park Lake	2/24/2009	198	1	0.29	2.3	10.6	8.58	2230	17.6	274
L1194	Rock Lake	12/21/2009	26	1	0.74	2.7	7.15	6.83	224	17.2	91
L1242	Lake Placid	10/14/2009	3.5	1	2.9	8.3	7.53	6.54	109	29.5	428
L1252	Hurricane Lake	8/5/2009	11	1	1.61	4.7	7.52	8.54	30	31.3	346
L1274	Lake Crosby	5/13/2009	3.2	1.0	0.9	3.3	6.26	6.28	181	26.97	147
L1297	Suwannee Lake	6/24/2009	7.1	0.5	1	1	3.41	6.04	54	32.4	109

Waterbody Number	Waterbody	Sample Date	Alkalinity (mg/L)	Field Measurements							
				Sample Depth	Secchi Depth	Site Depth	DO (mg/L)	pH	Specific Conductance (µmhos/cm)	Temperature (°C)	Redox (mvolt)
L1304	Lake Buffum	4/14/2009	1.5	1	0.5	3	6.3	5.77	195	23.45	195
L1310	Lake Otter	4/2/2009	47	1	1.5	1.9	9.68	6.53	124	20.48	-58.2
L1313	Lake Osborne	5/18/2009	140	1	1.5	3.4	7.41	8.43	571.0	28.42	280
L1363	Lake Louise	6/24/2009	2.2	1	1.3	3.1	6.95	5.93	67	31.6	159
L1384	Lake Myrtle	9/15/2009	6	1	1.1	3.5	6.95	6.68	190	29.32	282
L1410	Loughman Lake	7/14/2009	48	0.5	0.2	0.9	8	8.41	2210	29.64	271
L1412	Gator Lake	2/2/2010	161	1	2	2	5.7	7.64	632	18.5	278
L1413	Lake Eloise	9/15/2009	64	1	0.8	6.7	8.02	8.39	288	29.6	213
L1421	Lake Winterset	9/15/2009	39	1	1.55	8.6	7.75	7.92	261	29.6	244
L1424	Bear Lake	8/5/2009	20	1	1.12	4.5	7.89	8.66	46	32.2	238
L1438	Lake Pasadena	6/17/2009	15	0.1	0.8	0.8	6.19	6.75	138	33.5	169
L1494	Lake Miona	4/30/2009	62	1	1	2	5.61	7.49	264	24.5	344
L1501	Ward Lake	5/6/2009	138	1.0	1.0	2.3	9.3	8.87	743	28.77	314
L1527	Lake Pierce	4/14/2009	50	0.5	0.3	0.75	8.11	8.6	201	22.56	88
L1533	Clearwater Lake	2/24/2010	0.65	1	1	2.1	8.84	4.72	61	15.77	482
L1557	Lake Rousseau	3/11/2009	116	1	5.8	5.8	7.54	7.79	292	22.23	119
L1557	Lake Rousseau 2	5/13/2009	109	1.0	1.8	10.4	6.18	8.57	246	28.33	332
L1558	Lake Deaton	4/30/2009	31	1	1.37	2	5.59	7.19	228	25	305
L1566	Lake Tarpon	5/12/2009	96	1.0	0.8	3.5	9.15	9.04	996	28.9	77
L1642	Lake Parker	5/12/2009	67	0.5	0.4	1.0	10.91	9.5	283	29.11	52
L1644	Lake Panasoffkee	6/9/2009	136	0.1	1.8	1.8	7.68	9.42	214	30.25	235
L1655	Riggins Lake	3/30/2010	0.65	0.5	0.8	2.05	4.58	4.15	52	17.7	369
L166	Ocean Pond (L123ALT)	2/17/2009	0.65	1	0.65	2	10.84	4.8	68	16	527
	Lochloosa Lake										
L1668	Hay Pond	10/13/2009	31	1	0.7	2.8	7.24	7.57	102	29.01	405
L1674	Burrell Lake	2/10/2010	1.9	0.5	1.6	1.6	9.75	6.4	14	11.4	470
L1678	Lake Juliana	3/18/2010	51	1	3.5	3.5	10.8	8.74	118	18.05	214
L1688	Unnamed lake	6/17/2009	27	0.1	0.6	4.3	7.62	8.51	268	30.2	219
L1695	Legs Lake	4/22/2010	125	1	1.8	4.6	8.52	7.55	623	24.65	-
L1730	Lake Lizzie	5/4/2010	60	1	0.5	8.4	9.34	9.44	200	28.55	325
L1736		12/15/2009	35	1	0.8	3.2	4.5	7.1	251	18	131

Waterbody Number	Waterbody	Sample Date	Alkalinity (mg/L)	Field Measurements							
				Sample Depth	Secchi Depth	Site Depth	DO (mg/L)	pH	Specific Conductance (µmhos/cm)	Temperature (°C)	Redox (mvolt)
L1741	East Lake	1/21/2010	45	1	0.8	5.35	12.68	5.8	178	14.85	-19.2
L1753	Lake Okahumpka	6/10/2009	94	1	1.25	1.5	7.81	8.69	305	30.48	25
L1755	Lake Hooker	3/22/2010	28	0.5	0.4	1.1	8.13	6.94	199	18.71	-
L1772	Lake Jessup	7/14/2009	65	1	0.55	1.8	10.05	9.38	501	32.4	261
L1790	Lake Thonotosassa	5/5/2009	78	1.0	0.2	3.7	9.00	9.6	271	26.3	65
L1818	Grassy Pond	2/10/2010	0.82	1	1.2	1.4	6.61	5.95	27	11.06	390
L1822	John's Pond	12/8/2009	4.7	1	0.4	2.1	9.38	6.41	67	15.12	130
L1827	Lake Macy	8/6/2009	30	1	1	2	2.55	7.34	118	28.42	83
L1829	Lake Bradley	4/8/2010	21	1	0.78	3.7	0.6	6.27	80	21.1	341
L1830	Bethea Lake	12/8/2009	27	1	0.75	5.6	4.8	6.93	113	15.88	176
L188	Juniper Lake	3/9/2010	1.2	1	1.8	2.9	10.35	6.25	23	14.32	356
L219	Cherry Lake	6/23/2009	4.3	1	2.4	4.2	6.4	6.69	53	31.5	105
L231	Compass Lake	5/20/2009	2.6	1	2.1	2.1	7.75	6.54	27.0	21.68	149
L295	Lake Sampson	5/13/2009	24	1.0	1.3	3.6	7.02	7.69	215	26.84	103
L332	Steinhatchee Quarry Pit										
		8/3/2009	73	1	2.5	2.5	6.68	9.06	156	31.84	55
L353	Georges Lake	2/24/2010	0.65	1	1	6.5	9.73	5.35	55	14.98	440
L354	Palestine Lake	6/22/2009	0.65	0.1	0.97	2.6	6.73	4.67	105	32.5	319
L372	Lake Catherine	4/9/2009	0.65	1	1.2	3.7	7.56	4.81	63	20.72	223
L374	Lake Kerr	4/9/2009	0.65	1	1.1	3.8	7.84	5.68	160	19.19	179
L376	Cherry Lake	3/17/2010	1.5	1	1.2	3.2	9.07	5.98	124	17.19	424
L419	Eagle Lake	5/4/2009	2.3	1	3.8	7.1	7.17	6.56	276	25.5	130
L440	Mill Dam Lake	4/9/2009	2.8	1	1.6	7.1	7.66	6.6	63	21.03	129
L462	Lake Avalon	2/3/2010	132	1	3.4	5	8.56	8.26	398	19.46	306
L487	Unknown Lake	7/14/2009	0.65	1	1.5	2.5	0.17	4.82	27	28.35	105
L512	Lake Emma	6/25/2009	2.1	1	3.3	5.3	6.72	6.03	109	31.03	318
L513	Santa Fe Lake	6/22/2009	1.7	1	1.1	6.7	7.62	6.01	87	30	127
L547	Deer Point Lake	3/9/2010	21	1	1.3	3.7	9.29	6.92	65	14.67	390
L573	Lake Butler	5/28/2009	1.3	1	1.2	1.4	7.37	6.36	97.0	27.05	346
L616	Hunters Creek Pond	5/11/2009	28	1.0	3.5	7.5	6.72	8.03	196	29.26	88
L634	Lake Magdalene	2/17/2010	38	1	3.8	4.2	10.3	6.3	221	13.68	-

		Field Measurements									
Waterbody Number	Waterbody	Sample Date	Alkalinity (mg/L)	Sample Depth	Secchi Depth	Site Depth	DO (mg/L)	pH	Specific Conductance (µmhos/cm)	Temperature (°C)	Redox (mvolt)
L672	Sand Pond	4/2/2009	0.97	1	0.75	2.7	7.74	5.42	7840	20.42	142
L694	Basin Bayou	8/6/2009	7.4	0.5	1	1.6	6.14	6.48	1630	28.4	291
L732	Little Henderson	6/10/2009	78	0.1	2.75	5.3	7.1	8.53	249	29.61	66
L768	Platt Lake	2/17/2010	5.9	1	2	3.9	10.06	6.19	139	14.06	-
L780	Carraway Lake	11/17/2009	0.65	1	0.5	5.5	7.6	4.8	104	20.53	186
L810	Lake Disston	2/18/2010	1.6	1	0.8	4.6	10.38	5.35	83	11.6	-
L869	Unnamed (Lake Mattie)		5.5	1	0.7	2.6	8.92	6.37	281	14.56	369
		2/25/2010									
L873	Lake Alberta	3/31/2010	7.2	1	0.8	2.4	8.28	6.74	30	17.84	289
L879	Lake Monroe	11/19/2009	61	1	0.6	2.7	7.37	7.53	693	20.3	-25
L891	Cowpen Lake	10/21/2009	1	1	2.3	2.3	8.7	6.29	67	20.95	173
L923	Parrish Lake	8/11/2009	7.2	1	2.5	5.75	6.53	6.88	834	36.87	316
L940	Lake McCloud	5/4/2009	2.8	1	2.7	3.8	7.3	6.71	212	25.7	153
L965	Lake Hartridge	6/10/2009	52	0.1	1.1	4.1	8.9	9.43	254	31.4	231
L975	Lake Tracy	7/15/2009	75	1	2	2.3	6.48	8.25	223	31.45	232
L981	Ocheesee Pond	5/20/2009	2.1	1	1.6	5.3	4.85	5.62	23.0	21.36	244
L999	Smith Lake	5/14/2009	2.3	1.0	1.8	4.1	6.72	6.44	147	27.4	158
S02	Burnt Grocery Creek	4/28/2010	0.85	0.5	0.7	0.7	8.74	5.6	16	20.14	118
S023	Perdido River	7/21/2009	1.9	0.5	1	1	7.29	5.82	27	23.77	189
S024	Simms Creek	12/16/2008	24	1	1.8	3.9	6.8	6.92	104	16.2	320
S03	Alligator Creek	9/6/2010	0.65	1	1.5	1.5	6.35	4.97	16	23.73	452
S032	Econfina Creek	9/25/2008	0.65	0.2	NA	0.4	7.01	5.22	20	18.38	484
S041	Little River	7/13/2010	18	0.5	0.5	0.8	6.05	6.86	89	28.05	302
S042	New River	5/18/2009	12	1	0.6	-	3.63	6.2	64.0	25.46	153
S043	Black Creek S Fork	6/17/2009	7.7	1	0.6	3.25	5.63	5.38	55	25.61	177
S044	Reedy Creek	10/22/2008	35	1.0	0.65	4.5	0.06	6.2	188	23.22	428
S045	North Mosquito Creek	7/13/2010	20	0.5	0.9	0.9	3.27	6.42	89	27.6	305
S046	Blackwater Creek	11/19/2009	81	1	1.2	2.3	5.8	7.41	405	20.83	227
S048	Alapaha River	7/8/2009	163	0.5	0.5	0.5	5.73	7.28	344	26.28	118
S049	Etoniah Creek	4/14/2010	34	0.5	1	1	4.45	6.47	171	21.77	177
S05	Mule Creek	4/27/2010	0.65	0.5	0.7	0.7	8.01	4.64	24	17.86	180

Waterbody Number	Waterbody	Sample Date	Alkalinity (mg/L)	Field Measurements							
				Sample Depth	Secchi Depth	Site Depth	DO (mg/L)	pH	Specific Conductance (µmhos/cm)	Temperature (°C)	Redox (mvolt)
S050	Jack's Branch	2/2/2010	222	0.5	2	2	4.18	7.36	1112	19.29	288
S053	Ocklawaha River 1	5/6/2009	173	1.0	2.6	2.6	4.44	7.52	447	23.46	91
S057	Ocklawaha River 2	11/17/2008	163	1.0	1.8	1.8	4.25	7.36	529	18.7	256
S06	Freeman Creek	9/6/2010	17.00	0.5	1	1	4.7	6.6	65	31.68	303
S060	Lettmer Creek	2/24/2009	257	0.25	0.5	0.5	4.55	7.75	567	18.3	333
S061	Ocklawaha River 3	10/27/2008	102	1.0	0.8	2	3.05	6.83	325	20.4	293
S062	Choctaw River	4/27/2010	24	1	0.45	2.1	7.52	7.1	77	21.97	158
S063	Lower Peace River	8/26/2009	71	1	0.6	2.4	5.93	7.43	438	29.5	19
S066	Julington Creek	6/18/2009	64	1	0.6	5.8	1.55	6.57	272	26.8	223
S067	L-8 Canal	10/22/2009	89	1	0.3	1.2	5.81	7.58	361	23.82	366
S069	Econfina River	8/18/2009	228	1	1.5	1.5	3.91	7.35	439	23.9	166
S071	Suwannee River 1	12/10/2008	42	1	0.46	2.9	6.07	6.64	151	14.7	305
S072	Fenholloway River	4/1/2010	123	0.7	0.5	1	4.67	7.28	552	18.46	355
S074	Faka Union Canal	2/23/2009	173	1	2.1	2.1	14.5	7.79	520	20.1	297
S077	Rock Springs Run	6/4/2009	98	0.25	-	1	4.07	7.88	267	23.3	322
S078	Ten Mile Canal	2/24/2009	187	0.5	1.3	1.3	13.32	8.1	768	20.7	275
S079	Ocklawaha River 4	11/18/2008	149	1.0	1.5	2.8	7.45	7.8	528	17.3	311
S08	Blackwater River (upper)	4/28/2010	0.65	1	1.3	1.3	8.16	4.94	23	18.48	166
S081	Holmes Creek	9/25/2008	97	0.5	NA	-	6.50	7.76	217	18.92	482
S082	Hillsborough River	5/6/2009	159	1.0	2.0	2.0	6.3	8.04	361	24.16	354
S084	St. Johns River #3	1/20/2009	70	1	0.7	2.1	9.91	7.78	657	12.5	299
S087	L6 Canal	12/7/2009	272	1	2	4	4.92	7.97	983	22.63	111
S092	Ocean Canal	10/22/2009	286	1	0.6	4	3.77	7.88	1083	24.68	334
S093	Flint Creek	10/1/2008	61	0.1	-	0.3	2.85	7.84	245	26.63	476
S099	Ocklawaha River 5	11/17/2008	171	1.0	2	2	6.06	7.6	442	17.9	300
S100	Black Creek Mouth	1/20/2009	34	1	1	3	7.97	7.32	286	13.3	310
S101	I-75 Canal	2/23/2009	289	1	2.3	-	4.3	7.69	615	19.4	362
S1022	Wakulla River	4/1/2009	119	1	1.85	1.85	8.53	6.72	273	20.14	-
S104	Suwannee River 2	6/24/2010	22	0.5	0.4	0.8	4.97	6.44	154	29.92	80
S1041	Black Creek Canal	10/21/2009	199	1	4.7	4.7	8.06	7.93	509	26.5	285

Waterbody Number	Waterbody	Sample Date	Alkalinity (mg/L)	Field Measurements							
				Sample Depth	Secchi Depth	Site Depth	DO (mg/L)	pH	Specific Conductance (µmhos/cm)	Temperature (°C)	Redox (mvolt)
S107	SJR#6	12/16/2008	83	1	0.8	1.7	8.47	7.5	651	16.1	299
S1081	Suwannee River	3/17/2010	57	1	1	4.4	8.5	5.03	163	16.38	-
S1082	Alafia River	2/8/2010	92	0.5	1	1	9.59	7.84	409	13.88	342
S1113	Santa Fe River	12/28/2009	157	1	2	2	5.8	7.67	390	20.21	78
S1137	Suwannee River	11/23/2009	148	1	2.3	9.5	7.06	7.25	364	20.91	134
S1153	Hogtown Creek	4/12/2010	96	0.5	1	1	8.83	7.83	295	17.81	226
S119	Yon Creek	7/13/2010	1.7	0.5	0.6	0.6	6.43	5.72	27	25.28	375
S1194	Tallahassee Creek	7/13/2010	12	0.5	0.8	0.8	6.4	6.69	69	25.38	305
S121	Miami Canal	5/19/2009	218	1	2.8	2.9	7.9	8.04	626.0	26.83	323
S1215	Bullfrog Creek	7/1/2010	38	1	1.5	1.5	6.76	7.18	362	27.2	339
S1220	L-28 Interceptor Canal	10/21/2009	187	1	1.8	3.7	5.09	7.66	417	24.06	297
S123	Juniper Creek	7/14/2010	0.65	0.75	1	1	7.15	4.73	20	25.43	345
S1244	Juniper Run	7/22/2009	59	1	-	-	8.16	7.18	1406	24.2	-
S126	Orange Creek	12/22/2008	49	0.25	1	1.0	4.82	7.26	132	16.4	333
S127	Sixteen Mile Cr	2/18/2009	170	0.5	0.9	0.9	12.01	7.69	725	18.8	275
S1297	St. John's River	11/17/2009	60	1	0.6	5	7.81	7.83	800	20.27	98
S1306	Rocky Creek	8/3/2009	200	0.5	0.8	0.8	4.96	8.08	396	22.36	-146
S1326	Upper Steinhatchee River	8/3/2009	173	0.5	0.75	1	4.55	8.06	344	23.45	58
S1331	Mill Creek	6/24/2010	75	0.5	0.6	0.6	5.9	7.32	155	25.11	373
S1337	Wacissa River	8/20/2009	145	0.5	1	1	6.02	7.89	287	21.59	286
S135	Whiskey George Creek	2/23/2010	0.65	1	0.5	2.5	6.69	4.51	39	13.25	434
S1368	Upper Peace River	8/27/2009	53	1	0.5	1	4.27	7.06	306	27.83	17
S1377	Shoal River	7/22/2009	4.4	0.5	1.5	1.5	7.79	6.53	31	25.72	132
S1398	Wekiva River	7/8/2009	106	1	2	2	6.37	5.91	237	24.42	-
S1399	Weeki Wachee	8/11/2009	146	1	2.5	2.5	5.86	7.9	324	24.58	-40
S1421	Caloosahatchee Riv	2/24/2009	123	1	1.12	5.3	10.51	7.85	509	20.8	284
S1441	Frog Creek	2/8/2010	170	0.5	1	1	7.89	7.67	712	12.65	327
S1450	Itchepachasassa	1/20/2010	107	0.5	0.75	0.75	8.62	6.78	347	14.41	-
S146	Black Creek	4/28/2010	12	0.5	0.6	1	5.62	6.13	47	18.73	129

Waterbody Number	Waterbody	Sample Date	Alkalinity (mg/L)	Field Measurements							
				Sample Depth	Secchi Depth	Site Depth	DO (mg/L)	pH	Specific Conductance (µmhos/cm)	Temperature (°C)	Redox (mvolt)
S1471	Chipola River	7/22/2009	108	1	2.3	3	7.56	7.84	232	24.28	141
S148	Upper St Marry's River	9/15/2010	0.65	0.5	0.45	0.8	1.89	3.9	83	23.96	566
S157	Sopchoppy River	6/24/2010	5.4	0.5	0.5	0.7	4.98	5.79	41	29.23	135
S164	Deep Creek	3/24/2010	0.65	0.5	0.8	0.8	8.1	4.4	72	13.92	401
S173	New River	9/7/2010	0.65	0.5	0.4	0.8	4.29	4.15	45	25.48	584
S179	Depot Creek	2/23/2010	0.65	1	0.8	3.35	4.82	4.7	56	11.8	419
S196	Suwannee River - Upper										
		3/24/2010	0.65	1	0.8	2.7	7.95	4.07	76	14.49	446
S2010	Lostman's Creek	3/3/2010	179	0.5	1.2	1.2	6	7.57	8750	18.07	248
S2011	North Prong	5/26/2010	180	0.5	1	1	2.2	7.48	646	26	72
S2012	Ichetucknee River	8/25/2010	148.00	1	1.75	1.75	7.72	8.09	325	23.39	358
S216	Turnpike Canal	12/8/2009	119	1	2.9	2.9	4.32	7.39	307	21.76	91
S226	Black Creek	9/22/2009	0.65	0.5	0.8	0.8	7.39	4.38	33	23.95	366
S245	Bootheel Creek	9/1/2010	0.65	0.8	0.4	1.6	5.21	4.47	88	26.05	192
S260	Sandy Creek	4/1/2010	1.9	0.5	0.75	0.75	8.42	5.45	26	14.35	446
S261	Alaqua Creek	7/14/2010	0.65	0.5	0.9	0.9	7.64	5.54	14	24.18	313
S275	Little Charlie Bowleg Creek										
		5/5/2010	7.7	0.5	0.3	0.7	1.77	5.77	135	25.2	-
S277	Mill Creek	5/18/2010	24	0.5	0.4	0.8	2.7	6.05	102	22.54	348
S289	Blackwater River	8/5/2009	0.65	0.5	-	2	6.91	5.26	21	26.6	465
S290	Big Coldwater Creek	7/21/2009	2.3	1	2	2	7.8	5.98	33	23.93	158
S292	Taylor Creek	9/1/2010	59.00	1	0.6	1.8	2.4	6.82	321	27.96	88
S293	Bear Creek	4/28/2010	1.8	0.3	0.5	0.5	7.9	5.67	25	16.28	99
S302	Big Creek	9/22/2009	0.65	0.25	0.4	0.4	7.03	3.99	34	24.2	374
S307	Myakka River	8/25/2009	33	1	1.1	2.1	5.45	6.79	361	27.23	32
S313	Swift Creek	9/15/2010	0.65	0.5	0.6	0.8	2.7	4.93	66	22.63	437
S362	Fisheating Creek	8/26/2009	12	1	0.4	1.2	3.07	6.21	185	28.06	71
S367	Sampson Creek	6/8/2010	125	0.5	-	-	2.49	6.95	311	24.31	-
S385	Haw Creek	12/2/2009	56	0.5	0.3	1	1.55	6.73	1213	15.91	66
S389	L31N Canal	12/29/2009	207	1	2.8	2.8	2.03	7.46	561	24.13	105
S404	St. Mary's River	3/24/2010	1.8	1	0.6	6.7	7.04	5.44	66	15.91	392

Waterbody Number	Waterbody	Sample Date	Alkalinity (mg/L)	Field Measurements							
				Sample Depth	Secchi Depth	Site Depth	DO (mg/L)	pH	Specific Conductance (µmhos/cm)	Temperature (°C)	Redox (mvolt)
S405	Crooked River	2/24/2010	4.1	1	0.64	2.5	5.69	5.71	74	13.2	399
S415	Eaton Creek	1/14/2010	41	0.3	0.3	0.4	9.11	4.27	162	8.71	43.7
S428	Ochlockonee River	9/7/2010	27.00	1	0.8	1.3	5.52	6.83	102	27.43	247
S431	Yellow River	7/22/2009	9.1	1	1.1	3.5	6.45	6.81	35	25.34	324
S454	Telogia Creek	5/18/2009	4	1	1.0	2.0	7.05	6.04	30.0	20.74	142
S459	Manatee River	5/5/2009	92	1.0	1.0	2.0	5.4	7.4	817	26	316
S486	C111 Canal	12/29/2009	201	1	2.6	2.6	3.06	7.48	554	24.5	43
S497	Daughtrey's Creek	2/2/2010	241	0.5	1	1	4.24	7.46	1016	18.16	289
S528	Glades Road Canal	12/8/2009	157	1	2.8	3.5	3.93	7.52	561	22.13	108
S555	Peachland Canal	2/25/2009	90	0.25	0.5	0.5	5.55	7.6	488	18.1	271
S564	St. Lucie River	10/20/2009	191	1	0.9	2.4	5.83	7.7	2060	23.62	295
S604	Six Mile Creek	2/3/2010	135	1	1.7	5.4	8.8	7.7	502	17.67	-22
S610	California Creek	8/3/2009	177	1	2.1	2.2	2.26	7.88	403	25.76	-
S633	Lost Creek	9/21/2009	0.8	0.5	0.7	0.8	5.56	3.78	66	25.09	461
S643	Interceptor Canal	5/27/2010	73	1	0.7	1.3	1.75	7.09	467	29.1	225
S686	Tamiami Canal	2/3/2010	140	1	2	2	3.41	7.42	338	19.93	281
S690	Oak Creek	7/8/2010	226	0.5	0.6	0.6	4.64	7.15	525	28.64	87
S735	Withlacoochee River	11/12/2009	153	1	0.6	1.4	5.63	7.67	381	21.13	137
S747	Golden Gate Canal	2/23/2009	263	0.25	1.4	2	13.4	8.09	1009	21.7	267
S784	Dunn's Creek	11/19/2009	73	1	0.9	5.5	3.94	7.15	830	19.76	76
S791	Myakka River	2/25/2009	94	0.5	0.9	1	7.8	7.47	655	19.5	312
S824	Big Juniper Creek	7/21/2009	1.1	0.5	1.5	1.5	7.86	5.82	18	25.01	160
S856	C44 Canal	10/20/2009	169	1	0.5	3.9	3.65	7.57	644	24.54	333
S900	Loxahatchee River	10/22/2009	214	1	2	2	4.12	7.52	723	24.3	333
S923	St Marks River	5/18/2009	122	1	2.6	2.6	4.27	7.62	265.0	20.08	98
S942	Hillsborough River	5/12/2010	103	1	1.3	3.6	2.46	7.09	267	25.36	-
	Little Withlacoochee River	11/17/2009	172	0.5	1	1	4.2	7.47	339	18.49	229
S988	Otter Creek	7/8/2009	161	1	1	1.6	2.16	7.03	10325	27.14	-

Table G-3. Fish Tissue, Water Column and Sediment Mercury Concentrations in Waters Sampled for the Statewide Mercury TMDL

† = Sediment data were only collected for lake sampling locations

* = Average includes Spotted Bass data

** = Average includes Spotted Sunfish data

- = No data

Waterbody Number	Waterbody	Average Fish Tissue Total Mercury Concentration ($\mu\text{g/g}$ Wet Weight)	Water Column				Sediment [†]	
			Filtered Total Mercury (ng/L)	Total Mercury (ng/L)	Filtered Methyl Mercury (ng/L)	Methyl Mercury (ng/L)	Total Mercury (ng/L)	Methyl Mercury (ng/L)
L002	Pate Lake	0.874	0.57	1.5	0.038	0.093	0.37	0.0150
L018	Lake Claire	0.674	1.3	1.8	0.38	0.5	0.027	0.00010
L024	Lake Gordon	0.316	0.3	0.22	0.21	0.23	0.25	0.00042
L025	Lake Alcyone	0.397	0.2	0.38	0.022	0.022	0.04	0.00023
L029	Lake Henry	0.215	2.5	3.8	0.09	0.12	0.29	0.00200
L031	Bonable Lake	0.448	0.96	5.2	0.023	0.13	0.035	0.00038
L034	T-Pit	0.700	6.7	7.7	0.84	1.1	0.02	0.00013
L035	Unknown Lake	0.668	1.1	1.8	0.24	0.31	0.24	0.00043
L047	Holly Lake	0.641	0.45	0.89	0.054	0.08	0.14	0.035
L049	Lake Hamilton	0.220	1.5	2.6	0.025	0.064	0.061	0.000
L050	Eden Lake	0.646	1.6	1.8	0.23	0.31	0.21	0.00360
L051	Cresent Lake	0.149	3.6	5.2	0.35	0.41	0.016	0.00008
L057	Lake Victor	0.167	0.5	1.1	0.046	0.15	0.14	0.00078
L060	Unknown L060	0.152	1.6	1.6	0.22	0.32	0.0063	0.0001
L061	Lester Lake	0.139	0.86	1.4	0.17	0.53	0.24	0.0043
L064	Lake Winnemissett	No Fish	0.68	1.2	0.026	0.048	-	-
L067	Lake Dexter	0.205	2.3	2.7	0.21	0.23	0.24	0.00140

Waterbody Number	Waterbody	Average Fish Tissue Total Mercury Concentration ($\mu\text{g/g}$ Wet Weight)	Water Column				Sediment [†]	
			Filtered Total Mercury (ng/L)	Total Mercury (ng/L)	Filtered Methyl Mercury (ng/L)	Methyl Mercury (ng/L)	Total Mercury (ng/L)	Methyl Mercury (ng/L)
L069	Webb Lake	0.628	0.72	1.4	0.05	0.074	0.015	0.00010
L070	Lake Weir	0.377	0.23	0.86	0.022	0.06	0.0051	0.00009
L071	Green Pit #2	0.311	0.3	1.8	0.058	0.14	0.072	0.00050
L072	Lake Davis	0.359	0.64	4.2	0.031	0.054	0.032	0.00160
L075	Unkown Lake	0.273	0.46	0.99	0.061	0.085	0.095	0.015
L076	Lake Washington	0.321	2.3	2.5	0.11	0.11	0.014	0.00020
L079	Lake Myakka	0.236	2.6	5.8	0.049	0.08	0.12	0.00045
L085	Unnamed Lake	0.203	0.2	0.37	0.022	0.042	0.84	0.0002
L086	Unknown Lake L086	0.075	0.18	0.34	0.022	0.022	0.27	0.00025
L087	Royal Country Estate	0.088	0.24	0.35	0.022	0.022	0.051	0.00010
L091	Arrowhead Village	0.206	0.18	0.6	0.022	0.074	0.041	0.00014
L092	Berkshire Lake HOA	0.078	0.15	0.37	0.022	0.022	0.077	0.00067
L094	Swan Lake	0.261	0.11	0.33	0.022	0.025	0.077	0.00018
L095	Green Pit #1	0.303	0.24	0.86	0.65	1.2	0.067	0.00038
L096	Lake Yale	0.179	0.53	1.6	0.062	0.51	0.26	0.003
L097	Sorrento Lake	0.035	0.14	0.45	0.022	0.024	0.026	0.00027
L1009	Dead Lakes	0.574	1.1	1.8	0.17	0.23	0.19	0.00052
L101	Unknown (Roberts Lk)	0.555	0.8	1	0.054	0.081	0.38	0.00210
L103	Black Lake	0.730	1.3	2.1	0.15	0.21	0.25	0.00054
L104	Blue Cypress	0.339	4.7	5.6	0.83	0.86	0.0048	0.0001
L105	Lake Hampton	0.565	0.68	1.9	0.022	0.039	0.34	0.0027
L105B	Lake Jeffery	0.521	0.29	0.67	0.022	0.035	0.015	0.00010
L107	Lake Jackson	0.312	0.33	0.73	0.067	0.098	0.033	0.00046

Waterbody Number	Waterbody	Average Fish Tissue Total Mercury Concentration ($\mu\text{g/g}$ Wet Weight)	Water Column				Sediment [†]	
			Filtered Total Mercury (ng/L)	Total Mercury (ng/L)	Filtered Methyl Mercury (ng/L)	Methyl Mercury (ng/L)	Total Mercury (ng/L)	Methyl Mercury (ng/L)
L109	Lake Miccosukee	0.328	0.44	0.91	0.03	0.047	0.059	0.00074
L1097	Lake Alfred	0.168	0.7	1.6	0.022	0.064	0.21	0.00034
L1099	Lake Ellen	0.864	1.2	2.4	0.042	0.077	0.027	0.00039
L110	Mirror Lake	0.085	0.31	1	0.022	0.031	0.014	0.00010
L1107	Swift Creek Pond	0.530	4.2	6.9	0.057	0.082	0.22	0.00066
L111	Lake Rochelle	0.110	0.26	0.86	0.032	0.063	0.14	0.00047
L1115	Campbell Lake	0.965	0.39	1.3	0.032	0.05	0.016	0.00420
L112	Lake Poinsett	0.290	3.2	3.7	0.14	0.15	0.014	0.0001
L1142	Lake George	0.261	3.1	4.6	0.17	0.17	0.17	0.0025
L117	Peack Lake	0.282	0.75	1.5	0.2	0.29	0.01	0.00011
L1183	Lake Louisa	0.989	1.2	3.1	0.092	0.17	0.011	0.00016
L1186	Lake Octahatchee	0.322	1.5	2.1	0.17	0.26	0.041	0.00062
L119	Lake Park Lake	0.101	0.7	1.3	0.032	0.058	0.073	0.00060
L1194	Rock Lake	0.973	3	3.4	0.83	0.92	0.42	0.00070
L1242	Lake Placid	0.888	0.22	0.6	0.028	0.076	0.0051	0.00010
L1252	Hurricane Lake	0.332	0.32	0.65	0.036	0.058	0.067	0.00190
L1274	Lake Crosby	0.442	0.58	1.5	0.036	0.088	0.30	0.0017
L1297	Suwannee Lake	0.230	0.64	1.3	0.1	0.18	0.024	0.00011
L1304	Lake Buffum	0.449	0.51	2.1	0.022	0.068	0.20	0.00040
L1310	Lake Otter	0.793	1.9	2.4	0.53	0.43	0.012	0.00034
L1313	Lake Osborne	0.105	0.14	0.7	0.022	0.022	0.16	0.00028
L1363	Lake Louise	0.344	0.49	1.5		0.078	0.20	0.0031
L1384	Lake Myrtle	0.641	0.72	1.5	0.033	0.056	0.19	0.00079

Waterbody Number	Waterbody	Average Fish Tissue Total Mercury Concentration ($\mu\text{g/g}$ Wet Weight)	Water Column				Sediment [†]	
			Filtered Total Mercury (ng/L)	Total Mercury (ng/L)	Filtered Methyl Mercury (ng/L)	Methyl Mercury (ng/L)	Total Mercury (ng/L)	Methyl Mercury (ng/L)
L1410	Loughman Lake	0.358	5.2	5.9	0.22	0.5	0.12	0.00100
L1412	Gator Lake	1.221	1.1	1.3	0.31	0.39	0.0055	0.00010
L1413	Lake Eloise	0.143	0.18	0.56	0.022	0.07	0.31	0.00049
L1421	Lake Winterset	0.322	0.16	0.7	0.028	0.12	0.19	0.00061
L1424	Bear Lake	0.265	0.27	0.68	0.025	0.052	0.18	0.00300
L1438	Lake Pasadena	0.448	0.69	1.4	0.14	0.21	0.0058	0.00011
L1494	Lake Miona	0.208	1.4	2	0.05	0.073	0.0077	0.0001
L1501	Ward Lake	0.042	0.13	0.28	0.022	0.022	0.25	0.00028
L1527	Lake Pierce	0.544	0.46	6.2	0.06	0.38	0.0067	0.00020
L1533	Clearwater Lake	0.218	0.55	0.89	0.04	0.071	0.19	0.00037
L1557	Lake Rousseau 2	0.159	0.3	0.43	0.036	0.063	0.23	0.0011
L1558	Lake Deaton	0.322	0.4	1.1	0.057	0.086	0.19	0.0027
L1566	Lake Tarpon	0.275	0.18	0.39	0.022	0.044	0.29	0.0010
L1642	Lake Parker	0.089	0.39	0.4	0.053	0.19	0.035	0.0004
L1644	Lake Panasoffkee	0.386	0.5	0.54	0.059	0.069	0.058	0.00028
L1655	Riggins Lake	0.190	4.6	4.9	0.13	0.18	0.011	0.00015
L166	Ocean Pond (L123ALT)	0.658	1.5	3.1	0.032	0.049	0.23	0.0014
L1668	Lochloosa Lake	0.222	0.52	1.4	0.026	0.039	0.21	0.00042
L1674	Hay Pond	0.188	0.54	0.82	0.048	0.09	0.19	0.00240
L1678	Burrell Lake	0.339	0.24	0.33	0.051	0.053	0.036	0.00010
L1688	Lake Juliana	0.173	0.28	0.92	0.048	0.1	0.019	0.00019
L1695	Unnamed lake	0.095	0.25	0.7	0.15	0.17	0.09	0.00028
L1730	Legs Lake	0.129	0.22	0.74	0.043	0.15	0.0039	0.00010

Waterbody Number	Waterbody	Average Fish Tissue Total Mercury Concentration ($\mu\text{g/g}$ Wet Weight)	Water Column				Sediment [†]	
			Filtered Total Mercury (ng/L)	Total Mercury (ng/L)	Filtered Methyl Mercury (ng/L)	Methyl Mercury (ng/L)	Total Mercury (ng/L)	Methyl Mercury (ng/L)
L1736	Lake Lizzie	No Fish	0.67	0.95	0.062	0.096	-	-
L1741	East Lake	0.323	0.42	0.65	0.13	0.19	0.17	0.00068
L1753	Lake Okahumpka	0.207	0.5	1.4	0.052	0.077	0.17	0.0095
L1755	Lake Hooker	0.073	0.71	2.7	0.051	0.11	0.20	0.0005
L1772	Lake Jessup	0.273	0.5	0.99	0.024	0.07	0.25	0.00051
L1790	Lake Thonotosassa	0.108	0.27	1.3	0.035	0.12	0.17	0.00055
L1818	Grassy Pond	No Fish	1.2	2	0.074	0.13	-	-
L1822	John's Pond	0.343	2.1	3.9	0.058	0.095	0.18	0.00083
L1827	Lake Macy	0.336	1.2	2	0.14	0.14	0.21	0.00073
L1829	Lake Bradley	0.338	1.7	2.2	0.7	0.9	0.22	0.00160
L1830	Bethea Lake	0.226	0.44	1.2	0.11	0.28	0.13	0.00088
L188	Juniper Lake	0.986	0.89	1.4	0.069	0.088	0.21	0.00170
L219	Cherry Lake	0.673	0.46	0.68	0.036	0.045	0.05	0.00023
L231	Compass Lake	0.580	0.69	1.3	0.08	0.13	0.19	0.0039
L295	Lake Sampson	0.520	0.52	1	0.039	0.062	0.32	0.0012
L332	Steinhatchee Quarry Pit	0.175	0.28	0.41	0.022	0.035	0.027	0.00023
L353	Georges Lake	0.669	0.29	1.3	0.022	0.04	0.32	0.00057
L354	Palestine Lake	0.622	1.2	1.8	0.071	0.13	0.18	0.0035
L372	Lake Catherine	1.024	0.4	1.5	0.027	0.069	0.14	0.0025
L374	Lake Kerr	0.508	0.26	1.2	0.022	0.028	0.16	0.00089
L376	Cherry Lake	0.329	0.62	1.2	0.072	0.054	0.032	0.00027
L419	Eagle Lake	0.368	0.21	0.6	0.022	0.032	0.074	0.00019
L440	Mill Dam Lake	0.359	0.25	0.68	0.022	0.03	0.2	0.0011

Waterbody Number	Waterbody	Average Fish Tissue Total Mercury Concentration ($\mu\text{g/g}$ Wet Weight)	Water Column				Sediment [†]	
			Filtered Total Mercury (ng/L)	Total Mercury (ng/L)	Filtered Methyl Mercury (ng/L)	Methyl Mercury (ng/L)	Total Mercury (ng/L)	Methyl Mercury (ng/L)
L462	Lake Avalon	0.110	0.16	0.23	0.027	0.03	0.031	0.0002
L487	Unknown Lake	0.589	0.9	1.5	0.61	0.64	0.038	0.00024
L512	Lake Emma	0.520	0.63	1.1	0.05	0.071	0.016	0.00011
L513	Santa Fe Lake	0.485	0.88	1.6	0.092	0.2	0.067	0.00022
L547	Deer Point Lake	0.545	0.91	1.4	0.077	0.097	0.21	0.0012
L573	Lake Butler	0.663	0.72	1.8	0.022	0.06	0.3	0.0012
L616	Hunters Creek Pond	0.453	0.21	0.37	0.022	0.023	0.25	0.00027
L616R	UNNAMED LAKE	-	-	-	-	-	0.2	0.00033
L634	Lake Magdalene	0.403	0.5	0.58	0.041	0.063	0.023	0.00001
L672	Sand Pond	0.687	5.3	6.6	0.26	0.41	0.11	0.00066
L694	Basin Bayou	0.423	2.5	4.2	0.13	0.21	0.18	0.00670
L732	Little Henderson	0.496	0.34	0.59	0.045	0.041	0.24	0.0012
L768	Platt Lake	0.653	0.65	1.3	0.051	0.1	0.011	0.00010
L780	Carraway Lake	0.828	5.3	5.8	0.4	0.51	-	-
L810	Lake Disston	0.852	4.9	5.3	0.42	0.43	0.24	0.00055
L869	Unnamed (Lake Mattie)	0.201	1	2.5	0.027	0.058	0.22	0.00110
L873	ALBERTA LAKE	0.503	0.68	1.9	0.05	0.13	0.23	0.00075
L879	Lake Alberta	1.025	0.34	0.62	0.038	0.046	0.28	0.00048
L86R	UNNAMED LAKE (SW POND)	-	-	-	-	-	0.44	0.00099
L891	Cowpen Lake	0.108	0.5	0.58	0.022	0.022	0.0034	0.00010
L923	Parrish Lake	0.256	2.4	3.1	0.073	0.071	0.043	0.00015
L940	Lake McCloud	0.288	0.34	0.85	0.022	0.031	0.03	0.00031
L965	Lake Hartridge	0.236	0.3	0.58	0.036	0.072	0.12	0.00028

Waterbody Number	Waterbody	Average Fish Tissue Total Mercury Concentration ($\mu\text{g/g}$ Wet Weight)	Water Column				Sediment [†]	
			Filtered Total Mercury (ng/L)	Total Mercury (ng/L)	Filtered Methyl Mercury (ng/L)	Methyl Mercury (ng/L)	Total Mercury (ng/L)	Methyl Mercury (ng/L)
L975	Lake Tracy	0.242	0.27	0.51	0.025	0.044	0.084	0.00015
L981	Ocheesee Pond	0.552	1.2	2.6	0.53	0.98	0.082	0.0019
L999	Smith Lake	0.636	0.41	0.78	0.022	0.026	0.19	0.00240
S02	Burnt Grocery Creek*	0.245	0.37	0.63	0.052	0.071	-	-
S023	Perdido River*	0.609	0.82	2.3	0.18	0.18	-	-
S024	Simms Creek*	0.205	1.4	1.8	0.2	0.28	-	-
S03	Alligator Creek*	0.709	0.46	1.50	0.11	0.17	-	-
S032	Econfina Creek*	0.436	0.98	1.5	0.21	0.26	-	-
S041	Little River*	0.305	1.5	3.5	0.12	0.19	-	-
S042	New River*	0.579	5.5	6.8	0.79	0.88	-	-
S043	Black Creek S Fork	0.931	4.9	5.6	0.79	0.9	-	-
S044	Reedy Creek	0.386	1.6	2.2	0.43	0.52	-	-
S045	North Mosquito Creek*	0.103	0.6	1.2	0.034	0.053	-	-
S046	Blackwater Creek*	0.408	1	2	0.24	0.18	-	-
S048	Alapaha River*	0.628	0.99	1.6	0.41	0.75	-	-
S049	Etoniah Creek*	0.604	1.8	2.2	0.88	0.98	-	-
S05	Mule Creek*	0.269	2.1	3.3	0.2	0.26	-	-
S050	Jack's Branch*	0.847	0.34	0.59	0.069	0.16	-	-
S053	Ocklawaha River 1	0.411	0.17	0.48	0.025	0.047	-	-
S057	Ocklawaha River 2	0.323	0.66	0.92	0.2	0.18	-	-
S06	Freeman Creek	0.724	0.85	1.60	0.28	0.44	-	-
S060	Lettmer Creek	0.419	0.38	0.93	0.076	0.081	-	-
S061	Ocklawaha River 3	0.500	1.4	1.9	0.31	0.34	-	-

Waterbody Number	Waterbody	Average Fish Tissue Total Mercury Concentration ($\mu\text{g/g}$ Wet Weight)	Water Column				Sediment [†]	
			Filtered Total Mercury (ng/L)	Total Mercury (ng/L)	Filtered Methyl Mercury (ng/L)	Methyl Mercury (ng/L)	Total Mercury (ng/L)	Methyl Mercury (ng/L)
S062	Choctaw River**	0.598	0.73	3.4	0.12	0.23	-	-
S063	Lower Peace River*	0.322	2.3	4.6	0.26	0.38	-	-
S066	Julington Creek*	0.339	3.2	4.4	0.77	0.84	-	-
S067	L-8 Canal	0.251	0.56	4.4	0.11	0.2	-	-
S069	Econfina River*	0.597	0.48	0.73	0.15	0.2	-	-
S071	Suwannee River 1*	0.352	3.7	4.5	0.25	0.27	-	-
S072	Fenholloway River*	0.100	3.6	4.2	0.46	0.55	-	-
S074	Faka Union Canal*	0.207	0.1	0.12	0.022	0.022	-	-
S077	Rock Springs Run*	0.164	1.2	1.8	0.61	0.76	-	-
S078	Ten Mile Canal	0.268	0.16	0.28	0.023	0.034	-	-
S079	Ocklawaha River 4*	0.353	0.68	1.4	0.11	0.14	-	-
S08	Blackwater River (upper)*	0.245	1.9	2.7	0.28	0.25	-	-
S081	Holmes Creek**	0.354	0.44	0.94	0.081	0.14	-	-
S082	Hillsborough River	0.733	0.14	0.55	0.022	0.038	-	-
S084	St. Johns River #3	0.289	2.2	4	0.063	0.07	-	-
S087	L6 Canal	0.497	0.46	0.64	0.055	0.065	-	-
S092	Ocean Canal	0.190	0.51	1.1	0.17	0.22	-	-
S093	Flint Creek*	0.150	0.47	1.9	0.047	0.16	-	-
S099	Ocklawaha River 5	0.332	0.91	1.3	0.15	0.21	-	-
S100	Black Creek Mouth*	0.286	2	3.4	0.23	0.29	-	-
S101	I-75 Canal	1.100	0.61	0.7	0.21	0.37	-	-
S1022	Wakulla River*	0.098	0.55	0.73	0.029	0.033	-	-
S104	Suwannee River 2*	0.246	4	5.6	0.57	0.53	-	-

Waterbody Number	Waterbody	Average Fish Tissue Total Mercury Concentration ($\mu\text{g/g}$ Wet Weight)	Water Column				Sediment [†]	
			Filtered Total Mercury (ng/L)	Total Mercury (ng/L)	Filtered Methyl Mercury (ng/L)	Methyl Mercury (ng/L)	Total Mercury (ng/L)	Methyl Mercury (ng/L)
S1041	Black Creek Canal*	0.133	0.2	0.27	0.044	0.066	-	-
S107	SJR#6	0.288	2	3.1	0.082	0.093	-	-
S1081	Suwannee River*	0.416	2.3	3.3	0.25	0.41	-	-
S1082	Alafia River*	0.151	1.5	2.3	0.32	0.4	-	-
S1113	Santa Fe River*	0.410	0.35	0.51	0.037	0.056	-	-
S1137	Suwannee River	0.598	0.53	0.77	0.045	0.072	-	-
S1153	Hogtown Creek*	0.187	0.55	1.1	0.21	0.28	-	-
S119	Yon Creek*	0.285	1.5	3	0.35	0.45	-	-
S1194	Tallahassee Creek	0.664	0.95	1.6	0.12	0.14	-	-
S121	Miami Canal*	0.069	0.52	0.65	0.036	0.05	-	-
S1215	Bullfrog Creek*	0.208	0.9	2.4	0.22	0.23	-	-
S1220	L-28 Interceptor Canal	0.432	0.51	0.73	0.13	0.12	-	-
S123	Juniper Creek*	0.185	0.85	2.10	0.21	0.25	-	-
S1244	Juniper Run*	0.326	0.25	0.42	0.061	0.1	-	-
S126	Orange Creek*	0.392	1.5	2.2	0.4	0.38	-	-
S127	Sixteen Mile Cr	0.250	0.48	1.2	0.034	0.042	-	-
S1297	St. John's River	0.407	2.4	3.6	0.043	0.046	-	-
S1306	Rocky Creek*	0.296	0.32	0.46	0.075	0.076	-	-
S1326	Upper Steinhatchee River*	0.452	2.4	3	0.39	0.59	-	-
S1331	Mill Creek*	0.257	2.8	3.3	0.55	0.54	-	-
S1337	Wacissa River*	0.126	0.1	0.25	0.025	0.022	-	-
S135	Whiskey George Creek*	0.267	3.6	5.5	0.11	0.12	-	-
S1368	Upper Peace River*	0.213	2.4	4.2	0.19	0.25	-	-

Waterbody Number	Waterbody	Average Fish Tissue Total Mercury Concentration ($\mu\text{g/g}$ Wet Weight)	Water Column				Sediment [†]	
			Filtered Total Mercury (ng/L)	Total Mercury (ng/L)	Filtered Methyl Mercury (ng/L)	Methyl Mercury (ng/L)	Total Mercury (ng/L)	Methyl Mercury (ng/L)
S1377	Shoal River**	0.699	0.88	2.2	0.15	0.26	-	-
S1398	Wekiva River*	0.384	0.36	0.67	0.055	0.055	-	-
S1399	Weeki Wachee*	0.151	0.1	0.27	0.025	0.025	-	-
S1421	Caloosahatchee Riv	0.337	0.73	0.88	0.063	0.077	-	-
S1441	Frog Creek*	0.135	1	1.6	0.38	0.46	-	-
S1450	Itchepachasassa*	0.276	0.86	1.7	0.15	0.21	-	-
S146	Black Creek*	0.491	4.3	5.2	0.32	0.42	-	-
S1471	Chipola River	0.411	0.32	1.1	0.058	0.1	-	-
S148	Upper St Marry's River	0.950	2.90	3.20	0.24	0.27	-	-
S157	Sopchoppy River*	0.543	4.7	5.7	0.71	0.78	-	-
S164	Deep Creek*	0.376	4.1	4.8	0.25	0.26	-	-
S173	New River*	0.374	3.80	4.60	0.24	0.30	-	-
S179	Depot Creek	0.507	3.2	4.4	0.13	0.16	-	-
S196	Suwannee River - Upper*	0.327	3.9	4.5	0.17	0.17	-	-
S2010	Lostman's Creek	0.862	0.47	1.1	0.12	0.22	-	-
S2011	North Prong	1.818	1.8	2.5	0.32	0.56	-	-
S2012	Ichetucknee River*	0.258	0.10	0.21	0.02	0.02	-	-
S216	Turnpike Canal	0.233	0.3	0.58	0.026	0.027	-	-
S226	Black Creek	0.911	2.1	3.3	0.27	0.24	-	-
S245	Bootheel Creek*	0.322	4.30	4.40	1.60	1.60	-	-
S260	Sandy Creek*	0.549	1.2	2.1	0.17	0.18	-	-
S261	Alqua Creek*	0.814	0.48	0.99	0.14	0.17	-	-
S275	Little Charlie Bowleg Creek*	0.423	7.4	7.9	4	4.3	-	-

Waterbody Number	Waterbody	Average Fish Tissue Total Mercury Concentration ($\mu\text{g/g}$ Wet Weight)	Water Column				Sediment [†]	
			Filtered Total Mercury (ng/L)	Total Mercury (ng/L)	Filtered Methyl Mercury (ng/L)	Methyl Mercury (ng/L)	Total Mercury (ng/L)	Methyl Mercury (ng/L)
S277	Mill Creek*	0.219	3.2	4.5	0.71	0.84	-	-
S289	Blackwater River*	0.519	1.4	2.6	0.24	0.35	-	-
S290	Big Coldwater Creek**	1.080	0.91	2.1	0.12	0.16	-	-
S292	Taylor Creek*	0.368	3.00	3.80	1.10	1.20	-	-
S293	Bear Creek*	0.413	0.9	1.5	0.27	0.25	-	-
S302	Big Creek*	0.346	2.6	3.7	0.2	0.34	-	-
S307	Myakka River*	0.304	2.6	3.7	0.58	0.56	-	-
S313	Swift Creek*	0.436	4.30	5.10	0.45	0.46	-	-
S362	Fisheating Creek	1.478	5.8	7.1	3.1	3.5	-	-
S367	Sampson Creek*	0.701	0.72	1.5	0.28	0.47	-	-
S385	Haw Creek*	0.455	2.7	3.1	1	1.2	-	-
S389	L31N Canal	0.326	0.1	0.1	0.022	0.022	-	-
S404	St. Mary's River*	0.448	3.2	4.4	0.57	0.6	-	-
S405	Crooked River*	0.419	3.7	5.7	0.2	0.24	-	-
S415	Eaton Creek*	0.509	1.7	3.6	0.15	0.18	-	-
S428	Ochlockonee River*	0.769	1.20	3.00	0.20	0.32	-	-
S431	Yellow River**	0.358	1.1	2.6	0.16	0.27	-	-
S454	Telogia Creek*	0.471	2.1	3.9	0.26	0.36	-	-
S459	Manatee River*	0.453	0.17	0.86	0.083	0.17	-	-
S486	C111 Canal*	0.015	0.1	0.17	0.022	0.025	-	-
S497	Daughtrey's Creek	0.591	0.25	0.69	0.072	0.098	-	-
S528	Glades Road Canal*	0.109	0.28	0.46	0.035	0.047	-	-
S555	Peachland Canal*	0.096	0.18	0.42	0.022	0.033	-	-

Waterbody Number	Waterbody	Average Fish Tissue Total Mercury Concentration ($\mu\text{g/g}$ Wet Weight)	Water Column				Sediment [†]	
			Filtered Total Mercury (ng/L)	Total Mercury (ng/L)	Filtered Methyl Mercury (ng/L)	Methyl Mercury (ng/L)	Total Mercury (ng/L)	Methyl Mercury (ng/L)
S564	St. Lucie River*	0.000	0.28	0.67	0.032	0.048	-	-
S604	Six Mile Creek	0.276	0.62	0.99	0.11	0.14	-	-
S610	California Creek*	1.093	3.5	4.3	0.96	1.1	-	-
S633	Lost Creek*	0.697	5.5	6.2	0.21	0.24	-	-
S643	Interceptor Canal	0.288	3.2	3.7	0.71	0.82	-	-
S686	Tamiami Canal*	0.416	0.7	1.2	0.088	0.13	-	-
S690	Oak Creek	0.649	0.3	0.67	0.12	0.18	-	-
S735	Withlacoochee River	0.315	1.1	1.8	0.12	0.18	-	-
S747	Golden Gate Canal	0.106	0.28	0.58	0.042	0.084	-	-
S784	Dunn's Creek*	0.288	1.4	2.4	0.21	0.26	-	-
S791	Myakka River	0.364	1.6	2.1	0.17	0.26	-	-
S824	Big Juniper Creek**	0.985	0.62	1.2	0.14	0.19	-	-
S856	C44 Canal	0.179	0.48	1.5	0.1	0.14	-	-
S900	Loxahatchee River*	0.454	0.45	0.79	0.12	0.14	-	-
S923	St Marks River*	0.306	0.74	1.1	0.094	0.12	-	-
S942	Hillsborough River*	0.648	2.6	3.2	1.8	1.8	-	-
S964	Little Withlacoochee River	0.569	0.41	1	0.12	0.17	-	-
S988	Otter Creek	0.476	2.3	3.1	0.41	0.5	-	-

Table G-4. Major Ion Concentrations at Lake and Stream Stations Sampled for the Statewide Mercury TMDL

Waterbody Number	Waterbody	Calcium (mg/L)	Chloride (mg/L)	Magnesium (mg/L)	Potassium (mg/L)	Sodium (mg/L)	Sulfate (mg/L)
L002	Pate Lake	0.65	3.9	0.55	0.3	2.6	4.7
L018	Lake Claire	15.1	9.1	1.4	1.76	5.8	5.1
L024	Lake Gordon	7.7	20	6.3	8.24	8.7	23
L025	Lake Alcyone	0.65	6	0.47	0.37	3.4	1.3
L029	Lake Henry	7.9	35	6.3	8.19	19.7	27
L031	Bonable Lake	3.8	7.7	1.2	0.33	4.2	8.5
L034	T-Pit	1.2	7.1	1.42	0.66	5	2.1
L035	Unknown Lake	2.6	11	1.55	0.93	5.5	3.1
L047	Holly Lake	0.72	2.8	0.5	0.3	1.7	0.46
L049	Lake Hamilton	7.3	34	7.8	9.07	18.9	36
L050	Eden Lake	3.8	27	1.9	1.31	15.7	2
L051	Cresent Lake	29.8	100	10.1	3.81	50.8	27
L057	Lake Victor	1.75	3	1.28	0.46	1.6	0.71
L060	Unknown L060	12.9	8.6	1.6	1.58	5.1	0.57
L061	Lester	11	26	5.3	4.74	11.6	8
L064	Lake Winnemissett	9.4	20	2.3	2.82	12.2	24
L067	Lake Dexter	32.5	110	10.8	4.5	62.8	18
L069	Webb Lake	15.1	9.9	1.6	0.3	6.6	0.65
L070	Lake Weir	4.57	47	5.72	3.6	25.8	13
L071	Green Pit #2	114	37	19.5	2.94	24.6	180
L072	Lake Davis	58.4	29	4.78	2	14	15
L075	Unkown Lake	22.7	25	2.6	1.7	14.3	3.2
L076	Lake Washington	31.9	66	6.2	2.97	28.7	8.2
L079	Lake Myakka	41.5	23	21	8.36	16.3	130
L085	Unnamed Lake	16.6	7	4.78	1	5.1	3.5
L086	Unknown Lake L086	17	14	1.8	1.5	10.2	7.5

Waterbody Number	Waterbody	Calcium (mg/L)	Chloride (mg/L)	Magnesium (mg/L)	Potassium (mg/L)	Sodium (mg/L)	Sulfate (mg/L)
L087	Royal Country Estate	33.8	16	2.82	2.6	10.2	1.7
L091	Arrowhead Village	33.8	20	7	2.1	11.7	10
L092	Berkshire Lake HOA	57	27	3.1	2.1	16.2	13
L094	Swan Lake	67.2	24	1.96	1.5	13	18
L095	Green Pit #1	70.6	23	13.8	2.21	17.3	96
L096	Lake Yale	31.4	44	13.8	8.7	28.2	4.2
L097	Sorrento Lake	61.3	45	30.7	10.4	30.2	210
L1009	Dead Lakes	7.85	5.1	0.86	0.39	3.1	1.5
L101	Unknown (Roberts Lk)	7.1	9.1	2.4	8.85	19.5	11
L103	Black Lake	0.84	2.6	0.43	0.61	1.4	0.4
L104	Blue Cypress	13.7	25	3.4	2.85	13.6	2.8
L105	Lake Hampton	3.8	14	2	0.82	8	13
L105B	Lake Jeffery	3.15	21	1.16	0.45	11.8	2.4
L107	Lake Jackson	2.27	2.3	1.02	0.3	1.4	0.2
L109	Lake Miccosukee	2.16	2.3	0.79	0.89	1.2	0.2
L1097	Lake Alfred	15.7	58	17	22.9	34.2	47
L1099	Lake Ellen	2.44	6.1	0.68	0.3	3.6	4.4
L110	Mirror	23.4	22	5.07	5	13	27
L1107	Swift Creek Pond	5.09	13	2.88	1	7.3	11
L111	Lake Rochelle	19.4	32	7.7	11.2	17.3	12
L1115	Campbell Lake	2.1	35	3.15	0.65	21.6	11
L112	Lake Poinsett	33.1	99	7.5	3.32	41.9	26
L1142	Lake George	33	180	13.6	3.8	96.6	47
L117	Peach	14.4	18	1.9	2.44	11	12
L1183	Lake Louisa	5.04	20	2.72	2.2	9.7	10
L1186	Lake Octahatchee	6.75	6.9	2.26	1.7	3.5	4.8
L119	Lake Park Lake	81.6	570	44.6	13.8	317	56
L1194	Rock Lake	14.4	42	2.55	6.3	24	8.6
L1242	Lake Placid	4.09	17	3.93	5.8	6.8	18

Waterbody Number	Waterbody	Calcium (mg/L)	Chloride (mg/L)	Magnesium (mg/L)	Potassium (mg/L)	Sodium (mg/L)	Sulfate (mg/L)
L1252	Hurricane Lake	2.38	2.5	1.45	0.3	1.5	0.59
L1274	Lake Crosby	11.3	34	3.03	1	15.5	20
L1297	Suwannee Lake	4.24	8.9	1.4	0.69	3.4	0.96
L1304	Lake Buffum	5.47	32	7.5	9.7	13.4	30
L1310	Lake Otter	29.2	310	20.3	5.6	170	43
L1313	Lake Osborne	57.5	75	10.4	5.7	46.5	36
L1363	Lake Louise	3.55	12	1.26	1	6.4	3.8
L1384	Lake Myrtle	5.35	30	7.23	9.6	14.2	29
L1410	Loughman Lake	57.1	640	41.2	12.1	369	110
L1412	Gator Lake	69.4	92	9.91	3.3	45.5	4.4
L1413	Lake Eloise	26.9	30	6.34	6.4	18	31
L1421	Lake Winterset	17.8	31	7.29	7.4	18.9	34
L1424	Bear Lake	3.96	2.3	2.46	0.3	1.3	0.82
L1438	Lake Pasadena	7.87	27	5.51	2.4	9.2	5.7
L1494	Lake Miona	23.6	35	5.1	3.7	20.7	9.8
L1501	Ward Lake	87.4	55	23	8.6	31.2	170
L1527	Lake Pierce	19.3	16	7.51	4.8	7.5	23
L1533	Clearwater Lake	2.34	8.2	1.86	0.56	5.5	9.3
L1557	Lake Rousseau	47.1	6.7	5.49	0.32	3.6	22
L1557	Lake Rousseau 2	45	7	5.75	0.3	3.9	22
L1558	Lake Deaton	8.94	46	4.74	2.5	26.1	3.9
L1566	Lake Tarpon	62.3	210	10.8	5.7	97.7	35
L1642	Lake Parker	28	28	5.23	3.5	14.6	14
L1644	Lake Panasoffkee	59.2	12	5.52	0.3	6.4	30
L1655	Riggins Lake	1.78	3.5	0.75	0.3	2.2	0.25
L166	Ocean Pond (L123ALT)	2.43	12	1.33	0.53	7.5	7.8
L1668	Lochloosa Lake	12.3	10	3.31	0.96	6.3	3
L1674	Hay Pond	0.96	2	0.42	0.3	1	0.21
L1678	Burrell Lake	20.7	4.4	1.06	0.3	3.3	3

Waterbody Number	Waterbody	Calcium (mg/L)	Chloride (mg/L)	Magnesium (mg/L)	Potassium (mg/L)	Sodium (mg/L)	Sulfate (mg/L)
L1688	Lake Juliana	9.3	34	12.6	9.3	15.9	38
L1695	Unnamed lake	40.1	13	15.9	1.9	73.6	150
L1730	Legs Lake	19.8	20	6.34	1.9	11.7	8.1
L1736	Lake Lizzie	17.3	27	8.37	18.7	5.5	33
L1741	East Lake	18.1	22	3.09	2.9	12.2	7.2
L1753	Lake Okahumpka	32.9	39	6.09	8	19.6	1.4
L1755	Lake Hooker	13.1	30	4.55	10.2	13.6	14
L1772	Lake Jessup	34.4	110	10.4	4.1	62.9	29
L1790	Lake Thonotosassa	32.4	30	6.33	5.4	17.5	14
L1818	Grassy Pond	1.4	5.1	0.7	0.38	2.7	0.2
L1822	John's Pond	5.17	8.5	1.3	2.8	4.3	3.7
L1827	Lake Macy	12.9	14	1.89	0.81	7.6	4.1
L1829	Lake Bradley	10.1	7.5	1.19	1.4	4.4	0.61
L1830	Bethea Lake	9.58	13	2.23	4.1	5.8	4.5
L188	Juniper Lake	0.81	3.3	0.36	0.3	2.7	1.1
L219	Cherry Lake	3.28	6.5	1.13	0.46	4.1	6.7
L231	Compass Lake	1.8	3	0.76	0.3	1.7	2.4
L295	Lake Sampson	21.5	32	2.76	1.5	13.9	22
L332	Steinhatchee Quarry Pit	28.6	4.3	2.04	0.3	2.2	2.1
L353	Georges Lake	2.27	9.6	1.07	0.48	5.8	7.8
L354	Palestine Lake	2.66	16	2.61	0.91	10.2	16
L372	Lake Catherine	3.01	9.9	1.18	0.57	5.6	9.4
L374	Lake Kerr	9.55	26	3.23	0.81	14.3	28
L376	Cherry Lake	6.35	21	2.73	3.4	10.2	15
L419	Eagle Lake	9.98	32	12.1	12.3	17.1	65
L440	Mill Dam Lake	3.3	10	1.48	0.6	5.7	7.4
L462	Lake Avalon	54.3	45	5.69	1.8	25.7	3.2
L487	Unknown Lake	1.46	3.9	0.52	0.3	1.7	1.4
L512	Lake Emma	3.99	20	2.86	4	9.6	11

Waterbody Number	Waterbody	Calcium (mg/L)	Chloride (mg/L)	Magnesium (mg/L)	Potassium (mg/L)	Sodium (mg/L)	Sulfate (mg/L)
L513	Santa Fe Lake	3.21	16	1.83	1.7	9.4	8.1
L547	Deer Point Lake	7.87	4.9	1.31	0.3	3	2.3
L573	Lake Butler	4.48	17	1.98	1.9	9.3	12
L616	Hunters Creek Pond	12.4	35	3.41	4.3	19.1	7.2
L634	Lake Magdalene	20.5	36	2.22	3.6	21.4	14
L672	Sand Pond	53.3	2300	165	48	1310	310
L694	Basin Bayou	7.28	510	19.4	5.9	150	68
L732	Little Henderson (TAC)	40.3	20	3.46	0.86	11.2	24
L768	Platt Lake	6.99	28	1.92	3.3	17.1	10
L780	Carraway Lake	4.29	13	3.12	3.8	7.3	14
L810	Lake Disston	5.74	15	1.84	1.1	8.2	3.1
L869	Unnamed (Lake Mattie)	5.64	50	10	13	24.8	40
L873	Lake Alberta	2.21	3	1.13	0.3	1.9	0.41
L879	Lake Monroe	32.8	160	11.2	3.8	82.3	25
L891	Cowpen Lake	2.54	12	1.4	0.68	8.3	9.2
L923	Parrish Lake	34	73	30.6	22.1	81.9	260
L940	Lake McCloud	8.23	24	8.98	10.6	10.1	48
L965	Lake Hartridge	19.8	29	6.25	6.1	16.2	25
L975	Lake Tracy	26.1	19	3.4	3.4	11.3	15
L981	Ocheesee Pond	1.09	2.6	0.55	0.33	1.4	0.52
L999	Smith Lake	5.67	26	3.26	2.3	14.6	18
S02	Burnt Grocery Creek	0.38	2.7	0.44	0.3	1.8	0.62
S023	Perdido River	1.18	3.9	0.81	0.47	2.2	1.6
S024	Simms Creek	9.6	12	3.2	0.71	5.7	6.9
S03	Alligator Creek	0.23	2.8	0.27	0.3	1.7	0.26
S032	Econfina Creek	1.1	2.7	0.43	0.3	1.6	1.4
S041	Little River	6.11	6.9	2.53	0.91	7.5	3.8
S042	New River	8.93	6.3	0.74	0.3	3.6	2.3
S043	Black Creek S Fork	6.1	12	2.2	0.3	6.8	5.1

Waterbody Number	Waterbody	Calcium (mg/L)	Chloride (mg/L)	Magnesium (mg/L)	Potassium (mg/L)	Sodium (mg/L)	Sulfate (mg/L)
S044	Reedy Creek	16.6	27	4.1	4.01	16.6	7.7
S045	North Mosquito Creek	6.11	7.5	4.64	1.3	3.4	0.58
S046	Blackwater Creek	50.2	25	13.2	1.3	14	86
S048	Alapaha River	69.8	6.8	2.98	1.7	4.3	6.9
S049	Etoniah Creek	17.7	12	7.04	1.9	6.3	21
S05	Mule Creek	0.93	2.3	0.54	0.3	1.3	1.3
S050	Jack's Branch	113	160	16.8	7.8	91.2	74
S053	Ocklawaha River 1	70.1	13	10.2	1.2	7.3	44
S057	Ocklawaha River 2	73.7	41	12	1.39	23.4	49
S06	Freeman Creek	3.92	6.5	1.63	0.88	3.4	2.1
S060	Lettmer Creek	104	29	4.21	2.1	18.6	4.2
S061	Ocklawaha River 3	50.3	17	9	2.94	9.4	35
S062	Choctaw River	8.37	4.6	1.91	1.2	3.4	2.5
S063	Lower Peace River	36.1	28	15.3	7.7	36.1	91
S066	Julington Creek	32.3	37	6.6	2.14	21.4	29
S067	L-8 Canal	34.8	44	8.56	4.8	24.9	26
S069	Econfina River	73.7	5.1	17	0.3	2.9	8.7
S071	Suwannee River 1	18.7	9.1	4.5	1.99	6.5	14
S072	Fenholloway River	37.1	44	15.2	1.3	60.7	81
S074	Faka Union Canal	79.1	47	5.57	0.34	26.7	33
S077	Rock Springs Run	31.8	9.8	9.67	1.4	5.4	20
S078	Ten Mile Canal	77.9	120	13.9	4.3	62.7	30
S079	Ocklawaha River 4	65.7	52	11.7	1.49	29.5	43
S08	Blackwater River (upper)	0.76	3.1	0.54	0.32	1.67	1
S081	Holmes Creek	39.8	5.9	1.5	1.04	4.2	1.7
S082	Hillsborough River	61.3	13	4.4	0.54	6.5	12
S084	St. Johns River #3	39.8	130	12.6	4.5	73.7	42
S087	L6 Canal	74.7	160	37.3	9.6	109	60
S092	Ocean Canal	97.8	150	30.6	8.1	97.6	99

Waterbody Number	Waterbody	Calcium (mg/L)	Chloride (mg/L)	Magnesium (mg/L)	Potassium (mg/L)	Sodium (mg/L)	Sulfate (mg/L)
S093	Flint Creek	26.8	27	5.3	4.3	15.4	13
S099	Ocklawaha River 5	76.2	13	11.1	1.02	7.9	44
S100	Black Creek Mouth	17.5	52	5.9	2.04	29.7	16
S101	I-75 Canal	110	33	6.22	2.4	19.7	1.1
S1022	Wakulla River	40.2	7.1	8.66	0.55	4.8	11
S104	Suwannee River 2	14.9	6.6	5.22	1.1	12.9	32
S1041	Black Creek Canal	81.7	45	6.21	3.3	29.7	15
S107	SJR#6	41.4	130	11.9	3.9	66.6	37
S1081	Suwannee River	23	7.5	3.73	1.3	5	9.5
S1082	Alafia River	38	31	17.7	4.8	31.4	77
S1113	Santa Fe River	64.8	11	7.88	0.78	6.6	26
S1137	Suwannee River	56.2	8.1	9.94	1.1	7.4	28
S1153	Hogtown Creek	33.4	24	7.8	0.84	9.7	14
S119	Yon Creek	1.57	3.5	0.91	0.56	1.8	0.82
S1194	Tallahassee Creek	4.18	8.3	2.9	2.1	3.9	0.4
S121	Miami Canal	71.6	72	12.2	2.7	46.1	2.5
S1215	Bullfrog Creek	33.8	25	14.4	9.2	13	90
S1220	L-28 Interceptor Canal	78.3	25	6.19	1.8	20.2	4.4
S123	Juniper Creek	0.7	2.4	0.36	0.3	1.5	1
S1244	Juniper Run	50.2	350	27	6.2	197	100
S126	Orange Creek	17.5	8.4	5	0.87	4.5	5.6
S127	Sixteen Mile Cr	84	92	15.8	3.1	42.5	65
S1297	St. John's River	40	180	15	4.2	96.1	50
S1306	Rocky Creek	54.9	5.7	19.6	0.31	3.4	7.9
S1326	Upper Steinhatchee River	66.4	7.6	7.74	0.3	4.5	0.83
S1331	Mill Creek	23.2	4.4	8.58	0.3	2.5	1.4
S1337	Wacissa River	47.6	5.3	8.75	0.52	3.5	5.9
S135	Whiskey George Creek	0.97	4.3	0.35	0.3	2.7	0.51
S1368	Upper Peace River	21.8	20	9.34	5.8	26.7	52

Waterbody Number	Waterbody	Calcium (mg/L)	Chloride (mg/L)	Magnesium (mg/L)	Potassium (mg/L)	Sodium (mg/L)	Sulfate (mg/L)
S1377	Shoal River	2.13	3.4	1.15	0.4	1.6	1.2
S1398	Wekiva River	38.7	4.7	6.62	0.3	3.4	7.8
S1399	Weeki Wachee	56.1	8.4	6.68	0.33	4.9	11
S1421	Caloosahatchee Riv	51.3	61	12.4	6.7	34.8	38
S1441	Frog Creek	92.9	75	29	9.2	33.5	120
S1450	Itchepachasassa	41.3	31	6.87	8.4	22.2	20
S146	Black Creek	7.16	3.9	0.51	0.34	2.4	0.64
S1471	Chipola River	43.9	5.6	2.45	0.52	2.6	1.6
S148	Upper St Marry's River	1.5	7.8	0.91	0.3	5.2	0.33
S157	Sopchoppy River	6.68	3.6	1.07	0.3	2	0.95
S164	Deep Creek	3.55	8.5	1.91	0.3	5.2	0.37
S173	New River	1.55	3.8	0.3	0.3	1.9	0.71
S179	Depot Creek	1.42	7.8	0.67	0.3	4.4	0.56
S196	Suwannee River - Upper	1.58	6	1.05	0.3	4.5	0.88
S2010	Lostman's Creek	142	2100	192	54	1530	280
S2011	North Prong	57.3	97	11.6	3.6	61.2	2.6
S2012	Ichetucknee River	55.5	7	7.91	0.45	4.4	18
S216	Turnpike Canal	49.2	19	2.55	0.96	11.8	4.8
S226	Black Creek	1.47	3.9	0.59	0.3	2.1	2.3
S245	Bootheel Creek	3.41	14	2.4	2.6	7	3.2
S260	Sandy Creek	1.55	4.2	0.41	0.3	2.3	1.2
S261	Alaqua Creek	0.52	2.1	0.28	0.3	1.3	0.8
S275	Little Charlie Bowleg Creek	8.72	24	4.7	4.9	9.7	4.8
S277	Mill Creek	12	12	3.33	0.43	7.6	0.95
S289	Blackwater River	0.69	3.1	0.59	0.3	1.7	1.2
S290	Big Coldwater Creek	1.58	4.3	1.36	0.46	1.9	0.75
S292	Taylor Creek	24.6	48	7.39	11.4	24.4	22
S293	Bear Creek	1.85	2.9	0.42	0.45	1.9	2.3
S302	Big Creek	2.54	4.1	0.45	0.3	1.8	1.1

Waterbody Number	Waterbody	Calcium (mg/L)	Chloride (mg/L)	Magnesium (mg/L)	Potassium (mg/L)	Sodium (mg/L)	Sulfate (mg/L)
S307	Myakka River	35.6	15	17.4	6.8	12.5	110
S313	Swift Creek	6.72	8.2	2.41	0.3	4.6	0.78
S362	Fisheating Creek	10.8	36	4.98	3.3	19.1	10
S367	Sampson Creek	47.7	17	3.88	1.5	12.6	11
S385	Haw Creek	57	310	21.5	3.9	148	31
S389	L31N Canal	72.6	54	8.15	2.7	35.8	2
S404	St. Mary's River	4.06	10	1.7	0.46	6.1	2.2
S405	Crooked River	3.99	15	1.46	0.56	8.5	2.2
S415	Eaton Creek	20.9	11	7.05	0.62	6.7	22
S428	Ochlockonee River	7.79	9.8	3.63	2.7	6	5.3
S431	Yellow River	3.63	3.4	1.08	0.45	1.9	1.2
S454	Telogia Creek	2.3	3.5	0.67	0.48	1.9	1.2
S459	Manatee River	87.7	20	38.8	9.1	13.6	270
S486	C111 Canal	75.1	53	7.39	3.3	34.9	3.1
S497	Daughtrey's Creek	109	160	14.3	2.7	78.8	31
S528	Glades Road Canal	64	60	7.4	7.8	37.8	30
S555	Peachland Canal	51.6	84	6.13	1.5	40.2	24
S564	St. Lucie River	112	470	42.9	11.1	302	92
S604	Six Mile Creek	84.6	21	8.73	2.2	11.5	91
S610	California Creek	76.3	11	6.13	0.3	6.4	21
S633	Lost Creek	1.94	4.7	0.4	0.3	2.4	0.34
S643	Interceptor Canal	34.9	81	9.26	11.7	42.6	34
S686	Tamiami Canal	56.3	22	3.29	1.1	14.3	2.6
S690	Oak Creek	92.6	25	2.93	2.3	16.3	15
S735	Withlacoochee River	74.1	13	5.66	1.7	7.9	26
S747	Golden Gate Canal	133	130	11.6	6.1	71.6	85
S784	Dunn's Creek	40.6	180	14.2	3.7	93.9	45
S791	Myakka River	52	52	12.7	4.2	27.4	73
S824	Big Juniper Creek	0.63	2.7	0.46	0.3	1.5	0.73

Waterbody Number	Waterbody	Calcium (mg/L)	Chloride (mg/L)	Magnesium (mg/L)	Potassium (mg/L)	Sodium (mg/L)	Sulfate (mg/L)
S856	C44 Canal	72.8	85	10.4	7.1	50.7	36
S900	Loxahatchee River	90	88	8.46	3.6	54.2	34
S923	St Marks River	39.8	5.2	7.03	0.58	3.4	7.9
S942	Hillsborough River	42.8	18	4.18	2.6	10.9	6.9
S964	Little Withlacoochee River	68.9	10	2.33	0.47	5.6	1.9
S988	Otter Creek	135	3200	241	68	1930	440

Table G-5. Trophic Status and Water Clarity Parameter Concentrations at Lake and Stream Stations Sampled for the Statewide Mercury TMDL

- = No data

Waterbody Number	Waterbody	Trophic Status Parameters								Water Clarity Parameters	
		Carbon-Organic (mg/L)	Ammonia (N) (mg/L)	Nitrogen-Total Kjeldahl (mg/L)	NNOx (mg/L)	Phosphorus-Total (mg/L)	Chlorophyll a (ug/L)	Chlorophyll a-uncorrected (ug/L)	Pheophytin (ug/L)	Color (PCU)	TSS (mg/L)
L002	Pate Lake	1.7	0.05	0.22	0.005	0.007	5.2	5.6	0.42	15	4
L018	Lake Claire	13	0.01	0.52	0.01	0.009	4.8	5.2	0.43	100	4
L024	Lake Gordon	33	0.091	2.4	0.6	0.16	1.5	2.2	1	40	4
L025	Lake Alcyone	2.7	0.01	0.42	0.007	0.024	14	18	-	15	6
L029	Lake Henry	22	0.035	1.5	0.16	0.13	3.6	4.2	0.76	200	7
L031	Bonable Lake	5.2	0.01	0.93	0.18	0.076	8.9	10	1.5	30	7
L034	T-Pit	55	1.4	3.3	0.01	0.029	9.1	10	1.4	500	4
L035	Unknown Lake	14	0.092	1	0.011	0.009	3.8	4.3	-	80	4
L047	Holly Lake	4	0.01	0.52	0.012	0.011	4.5	5.3	1	15	4
L049	Lake Hamilton	12	0.013	1.3	0.004	0.038	15	16	1.7	60	13
L050	Eden Lake	22	0.03	1.5	0.062	0.013	4.6	5.2	0.69	250	4
L051	Cresent Lake	36	0.026	1.9	0.31	0.099	11	14	4.1	500	8
L057	Lake Victor	3.8	0.01	0.52	0.01	0.036	14	17	4.4	40	6
L060	Unknown L060	21	0.012	2.3	0.004	0.12	220	220	1.1	150	15
L061	Lester	14	0.11	1.3	0.089	0.06	13	15	2.8	60	4
L064	Lake Winnemissett	4.1	0.011	0.43	0.01	0.008	2	2.1	0.24	15	4
L067	Lake Dexter	24	0.12	1.7	0.026	0.14	3.3	3.9	0.8	200	4
L069	Webb Lake	11	0.014	1.3	0.004	0.014	3.1	3.3	0.24	30	4
L070	Lake Weir	7.8	0.01	1.5	0.75	0.013	15	15	1.3	20	8
L071	Green Pit #2	15	0.01	1.5	0.004	0.035	30	31	0.96	30	12
L072	Lake Davis	28	0.32	2.7	0.026	0.06	10	11	1	60	6
L075	Unkown Lake	14	0.01	0.94	0.013	0.023	3.1	3.4	0.27	80	4
L076	Lake Washington	32	0.027	2.1	0.22	0.046	6	6.5	0.35	200	4
L079	Lake Myakka	21	0.019	1.6	0.004	0.27	11	13	3.3	100	14

		Trophic Status Parameters								Water Clarity Parameters	
Waterbody Number	Waterbody	Carbon-Organic (mg/L)	Ammonia (N) (mg/L)	Nitrogen-Total Kjeldahl (mg/L)	NNOx (mg/L)	Phosphorus-Total (mg/L)	Chlorophyll a (ug/L)	Chlorophyll a-uncorrected (ug/L)	Pheophytin (ug/L)	Color (PCU)	TSS (mg/L)
L085	Unnamed Lake	3.4	0.01	0.37	0.02	0.013	3	3.1	-	15	4
L086	Unknown Lake L086	6	0.01	0.75	0.006	0.021	7.4	7.9	0.51	15	6
L087	Royal Country Estate	3.6	0.01	0.43	0.017	0.01	1.7	1.8	0.4	10	4
L091	Arrowhead Village	4.4	0.066	0.98	0.004	0.039	8	8.2	1.2	20	18
L092	Berkshire Lake HOA	6.4	0.01	0.86	0.028	0.025	13	13	0.75	20	11
L094	Swan Lake	10	0.055	0.89	0.022	0.015	3.8	4.2	-	20	4
L095	Green Pit #1	9.1	0.01	1.1	0.004	0.03	15	16	0.53	15	7
L096	Lake Yale	22	0.24	3.1	0.004	0.027	35	36	0.5	80	14
L097	Sorrento Lake	21	0.027	1.4	0.069	0.26	16	21	7.5	80	11
L1009	Dead Lakes	10	0.018	0.38	0.06	0.008	2.7	4.4	-	80	4
L101	Unknown (Roberts Lk)	8.8	0.011	0.68	0.009	0.016	4.6	4.8	0.24	20	4
L103	Black Lake	11	0.01	0.51	0.007	0.015	15	16	-	120	4
L104	Blue Cypress	29	0.019	1.7	0.022	0.17	2.3	2.7	0.43	300	4
L105	Lake Hampton	7.9	0.039	0.77	0.04	0.016	2.7	3.5	1.1	40	4
L105B	Lake Jeffery	12	0.01	0.68	0.006	0.009	3.5	4.7	-	50	6
L107	Lake Jackson	6.8	0.044	0.74	0.009	0.019	3.3	3.8	0.76	40	4
L109	Lake Miccosukee	6.2	0.014	0.61	0.004	0.039	11	14	-	50	4
L1097	Lake Alfred	16	0.013	2.5	0.005	0.034	64	66	-	80	20
L1099	Lake Ellen	8.3	0.041	0.66	0.082	0.017	3.7	5.4	2.7	60	4
L110	Mirror Lake	7.3	0.01	1.1	0.005	0.018	21	22	-	20	6
L1107	Swift Creek Pond	35	0.01	1.6	0.055	0.044	9.9	12	2.3	400	6
L111	Lake Rochelle	9.5	0.01	1.5	0.006	0.045	37	40	2.1	40	14
L1115	Campbell Lake	1.8	0.01	0.23	0.006	0.004	1.4	1.4	-	5	4
L112	Lake Poinsett	30	0.054	2.3	0.26	0.056	15	16	0.62	200	4
L1142	Lake George	24	0.055	0.98	0.084	0.077	18	20	-	200	6
L117	Peach-2	4.8	0.036	0.64	0.31	0.03	11	12	1.8	20	4
L1183	Lake Louisa	12	0.01	0.92	0.004	0.018	9	10	1.3	80	4
L1186	Lake Octahatchee	22	0.01	1.3	0.004	0.2	36	39	-	200	6
L119	Lake Park Lake	13	0.011	2.7	0.046	0.09	40	41	0.8	60	24

		Trophic Status Parameters								Water Clarity Parameters	
Waterbody Number	Waterbody	Carbon-Organic (mg/L)	Ammonia (N) (mg/L)	Nitrogen-Total Kjeldahl (mg/L)	NNOx (mg/L)	Phosphorus-Total (mg/L)	Chlorophyll a (ug/L)	Chlorophyll a-uncorrected (ug/L)	Pheophytin (ug/L)	Color (PCU)	TSS (mg/L)
L1194	Rock Lake	24	0.02	1.4	0.092	0.038	5.7	7	-	200	4
L1242	Lake Placid	3.8	0.01	0.37	0.008	0.011	5.5	5.8	-	15	4
L1252	Hurricane Lake	4.1	0.01	0.68	0.005	0.018	14	15	0.67	15	4
L1274	Lake Crosby	12	0.01	1	0.004	0.028	8.7	10	2.1	50	7
L1297	Suwannee Lake	6.4	0.01	0.78	0.004	0.048	7.4	15	13	40	4
L1304	Lake Buffum	7.7	0.05	1.3	0.032	0.085	30	35	5.8	120	16
L1310	Lake Otter	14	0.092	1.2	0.11	0.076	3.6	5	2	100	4
L1313	Lake Osborne	14	0.01	1.7	0.004	0.072	18	21	3.7	50	8
L1363	Lake Louise	14	0.01	1.1	0.004	0.021	7.5	8.2	0.74	60	6
L1384	Lake Myrtle	12	0.01	0.86	0.004	0.029	9.2	10	-	60	6
L1410	Loughman Lake	33	0.026	2.7	0.04	0.16	250	280	30	500	13
L1412	Gator Lake	21	0.083	1.2	0.25	0.066	7.2	7.9	-	50	4
L1413	Lake Eloise	6	0.01	0.99	0.005	0.025	24	25	-	30	8
L1421	Lake Winterset	5.8	0.01	0.92	0.006	0.014	21	22	-	20	5
L1424	Bear Lake	4.2	0.01	0.58	0.006	0.031	14	15	1.4	30	6
L1438	Lake Pasadena	15	0.011	1.7	0.026	0.051	14	15	1.8	50	7
L1494	Lake Miona	39	0.97	5	0.034	0.044	7.2	7.9	0.72	40	12
L1501	Ward Lake	13	0.01	1.6	0.004	0.13	15	16	0.85	40	8
L1527	Lake Pierce	10	0.05	3.9	0.004	0.21	79	86	5.8	100	117
L1533	Clearwater Lake	11	0.011	0.74	0.032	0.024	16	18	-	120	4
L1557	Lake Rousseau	1.2	0.015	0.26	0.97	0.038	1.3	1.6	0.31	5	4
L1557	Lake Rousseau 2	2.5	0.01	0.33	0.079	0.018	1.2	1.1	0.24	10	4
L1558	Lake Deaton	19	1.6	3.8	0.11	0.019	13	14	1.1	30	12
L1566	Lake Tarpon	11	0.01	1.7	0.004	0.044	39	41	0.99	50	15
L1642	Lake Parker	29	0.019	5.5	0.005	0.084	150	160	4.4	60	28
L1644	Lake Panasoffkee	8.6	0.01	0.89	0.004	0.023	5.7	6.6	1.1	20	4
L1655	Riggins Lake	44	0.012	1.2	0.004	0.044	1.4	1.8	0.56	250	4
L166	Ocean Pond (L123ALT)	7	0.023	0.54	0.11	0.043	1.5	1.7	0.3	100	4
L1668	Lochloosa Lake	20	0.01	1.5	0.005	0.046	38	43	-	150	12

		Trophic Status Parameters								Water Clarity Parameters	
Waterbody Number	Waterbody	Carbon-Organic (mg/L)	Ammonia (N) (mg/L)	Nitrogen-Total Kjeldahl (mg/L)	NNOx (mg/L)	Phosphorus-Total (mg/L)	Chlorophyll a (ug/L)	Chlorophyll a-uncorrected (ug/L)	Pheophytin (ug/L)	Color (PCU)	TSS (mg/L)
L1674	Hay Pond	4.3	0.01	0.52	0.004	0.024	21	23	-	50	6
L1678	Burrell Lake	5.7	0.01	0.46	0.004	0.011	1.7	1.7	0.4	20	4
L1688	Lake Juliana	6.6	0.01	1.5	0.004	0.029	28	29	0.6	40	12
L1695	Unnamed lake	16	0.01	0.61	0.008	0.7	7	7.9	1.1	40	4
L1730	Legs Lake	13	0.01	1.9	0.004	0.1	60	63	1.4	50	10
L1736	Lake Lizzie	16	0.012	1.5	0.005	0.12	29	32	-	120	4
L1741	East Lake	9	0.011	0.84	0.004	0.12	50	53	-	80	9
L1753	Lake Okahumpka	23	0.058	1.8	0.004	0.015	1.3	1.6	0.4	40	4
L1755	Lake Hooker	21	0.01	2.8	0.005	0.58	100	120	18	160	28
L1772	Lake Jessup	15	0.014	1.9	0.008	0.087	38	44	6.8	100	15
L1790	Lake Thonotosassa	18	0.014	2.8	0.004	0.23	180	200	14	75	36
L1818	Grassy Pond	12	0.01	0.83	0.004	0.074	26	30	-	120	4
L1822	John's Pond	24	0.22	1.9	0.21	0.36	11	15	-	250	11
L1827	Lake Macy	15	0.016	0.93	0.03	0.039	9.9	12	2.7	150	4
L1829	Lake Bradley	30	0.012	2	0.004	0.039	16	19	4	160	4
L1830	Bethea Lake	12	0.73	2.5	0.06	0.098	59	64	-	160	16
L188	Juniper Lake	4.1	0.01	0.32	0.14	0.011	3.9	4.6	-	40	4
L219	Cherry Lake	3.1	0.01	0.47	0.005	0.022	2.6	2.9	0.4	10	4
L231	Compass Lake	4.6	0.01	0.62	0.004	0.008	3.5	4.1	0.78	30	4
L295	Lake Sampson	14	0.013	0.92	0.004	0.023	7.6	8.7	1.4	50	4
L332	Steinhatchee Quarry Pit	3.3	0.01	0.32	0.014	0.011	1.8	1.6	0.4	5	4
L353	Georges Lake	4	0.01	0.35	0.005	0.034	5.6	6	-	60	4
L354	Palestine Lake	5.6	0.01	0.61	0.004	0.016	2.6	2.8	0.24	30	4
L372	Lake Catherine	4	0.013	0.6	0.054	0.008	4	4.4	0.48	15	4
L374	Lake Kerr	2.2	0.01	0.4	0.006	0.015	2.7	3.1	0.59	15	6
L376	Cherry Lake	13	0.01	0.87	0.14	0.015	6	6.7	0.85	80	6
L419	Eagle Lake	3.1	0.011	0.46	0.004	0.014	3.3	3.8	0.61	10	4
L440	Mill Dam Lake	5.2	0.01	0.6	0.004	0.014	4	4.2	0.37	15	4
L462	Lake Avalon	8.3	0.017	0.59	0.024	0.006	3.6	4	-	15	4

		Trophic Status Parameters								Water Clarity Parameters	
Waterbody Number	Waterbody	Carbon-Organic (mg/L)	Ammonia (N) (mg/L)	Nitrogen-Total Kjeldahl (mg/L)	NNOx (mg/L)	Phosphorus-Total (mg/L)	Chlorophyll a (ug/L)	Chlorophyll a-uncorrected (ug/L)	Pheophytin (ug/L)	Color (PCU)	TSS (mg/L)
L487	Unknown Lake	7.8	0.01	0.63	0.008	0.009	1.9	2.3	0.62	50	4
L512	Lake Emma	12	0.01	0.96	0.004	0.01	2.9	3.5	0.73	30	4
L513	Santa Fe Lake	14	0.01	1	0.004	0.04	56	60	2.6	100	7
L547	Deer Point Lake	6	0.012	0.28	0.042	0.009	1.4	1.5	-	80	4
L573	Lake Butler	5.7	0.01	0.67	0.033	0.028	3.2	3.8	0.66	60	5
L616	Hunters Creek Pond	9.8	0.01	0.84	0.004	0.015	1.4	1.4	0.5	20	4
L634	Lake Magdalene	10	0.013	0.72	0.017	0.01	1.9	2.2	-	30	4
L672	Sand Pond	26	0.54	2.5	0.04	0.013	5.6	6.3	0.8	300	8
L694	Basin Bayou	9.5	0.05	0.49	0.03	0.021	10	11	1.5	80	5
L732	Little Henderson (TAC)	14	0.012	1	0.007	0.012	2	2	0.24	30	4
L768	Platt Lake	10	0.01	1	0.013	0.039	22	26	-	40	6
L780	Carraway Lake	32	0.029	0.98	0.039	0.14	1.2	1.4	-	600	4
L810	Lake Disston	42	0.016	1.3	0.12	0.032	0.63	0.64	-	500	4
L869	Unnamed (Lake Mattie)	21	0.061	1.6	0.088	0.15	9	12	-	160	10
L873	Lake Alberta	5.5	0.01	0.68	0.006	0.065	19	44	40	60	9
L879	Lake Monroe	25	0.018	1.4	0.27	0.075	3.8	4.2	-	300	6
L891	Cowpen Lake	2.7	0.01	0.31	0.005	0.006	1.5	1.5	-	5	4
L923	Parrish Lake	8.6	0.01	0.92	0.011	0.044	8.9	11	-	30	4
L940	Lake McCloud	3.2	0.01	0.5	0.004	0.017	10	11	0.62	15	5
L965	Lake Hartridge	7	0.05	1.1	0.011	0.031	9.9	11	0.88	20	4
L975	Lake Tracy	8.5	0.012	0.96	0.004	0.022	7	7.6	0.63	15	6
L981	Ocheesee Pond	8.1	0.028	0.88	0.004	0.016	7.1	11	9	100	4
L999	Smith Lake	6.2	0.01	0.72	0.007	0.011	2.4	2.7	0.4	15	4
S02	Burnt Grocery Creek	1	0.01	0.08	0.19	0.004	0.63	0.68	0.4	15	4
S023	Perdido River	2.9	0.01	0.23	0.19	0.015	1.6	2.5	1.3	20	5
S024	Simms Creek	9.8	0.013	0.53	0.048	0.047	0.55	0.62	0.24	80	4
S03	Alligator Creek	3.10	0.02	0.21	0.01	0.03	0.55	0.83	0.41	50.00	6.00
S032	Econfina Creek	6.3	0.05	0.2	0.06	0.004	0.96	0.45	0.24	60	4
S041	Little River	5.7	0.034	0.83	2.5	0.13	2.2	2.6	0.53	100	22

		Trophic Status Parameters								Water Clarity Parameters	
Waterbody Number	Waterbody	Carbon-Organic (mg/L)	Ammonia (N) (mg/L)	Nitrogen-Total Kjeldahl (mg/L)	NNOx (mg/L)	Phosphorus-Total (mg/L)	Chlorophyll a (ug/L)	Chlorophyll a-uncorrected (ug/L)	Pheophytin (ug/L)	Color (PCU)	TSS (mg/L)
S042	New River	28	0.06	1.1	0.013	0.02	0.66	1	0.53	400	7
S043	Black Creek S Fork	14	0.023	0.55	0.071	0.11	0.55	0.4	0.24	120	4
S044	Reedy Creek	28	0.012	1.4	0.004	0.068	13	14	0.46	300	5
S045	North Mosquito Creek	2.8	0.012	0.36	2.8	0.024	1.5	1.6	0.4	20	4
S046	Blackwater Creek	12	0.034	0.65	0.54	0.055	0.9	1	-	200	4
S048	Alapaha River	5.4	0.01	0.28	0.02	0.07	5.5	6.4	1.2	50	11
S049	Etoniah Creek	30	0.09	1.5	0.52	0.16	0.55	0.93	0.63	200	4
S05	Mule Creek	11	0.01	0.36	0.022	0.027	0.55	0.47	0.4	120	4
S050	Jack's Branch	7.2	0.03	0.63	0.36	0.037	2	2.3	-	30	4
S053	Ocklawaha River 1	1.9	0.012	0.096	1.1	0.038	2	3	1.5	5	4
S057	Ocklawaha River 2	5.3	0.03	0.6	0.2	0.025	1.1	1.3	0.24	40	4
S06	Freeman Creek	7.40	0.01	0.58	0.00	0.03	7.40	8.60	1.60	50.00	4.00
S060	Lettmer Creek	11	0.052	0.83	0.35	0.025	0.64	0.89	0.36	50	4
S061	Ocklawaha River 3	35	0.29	1.9	0.35	0.062	1.4	2.5	1.7	400	4
S062	Choctaw River	3.1	0.021	0.33	0.62	0.054	2.7	3.2	0.58	60	24
S063	Lower Peace River	20	0.034	1.1	0.5	0.87	2.5	3.1	-	200	9
S066	Julington Creek	13	0.043	0.77	0.11	0.062	2.1	2.4	0.3	100	4
S067	L-8 Canal	16	0.06	1.6	0.19	0.14	3.9	6.1	-	200	36
S069	Econfina River	9.9	0.034	0.45	0.031	0.086	0.61	0.72	-	80	4
S071	Suwannee River 1	27	0.025	1	0.2	0.18	0.55	0.61	0.24	200	4
S072	Fenholloway River	42	0.033	0.93	0.41	0.33	0.55	0.4	0.4	500	4
S074	Faka Union Canal	4.6	0.01	0.42	0.004	0.01	1.5	1.5	0.24	15	4
S077	Rock Springs Run	1	0.011	0.16	1.3	0.085	0.84	1.3	0.65	5	4
S078	Ten Mile Canal	11	0.017	0.92	0.012	0.023	0.99	1.1	0.24	30	4
S079	Ocklawaha River 4	9.5	0.033	0.68	0.084	0.033	1.3	2	1	60	4
S08	Blackwater River (upper)	6.6	0.01	0.28	0.13	0.008	0.6	0.74	0.4	80	4
S081	Holmes Creek	1.8	0.05	0.12	0.39	0.035	0.55	0.1	0.24	15	4
S082	Hillsborough River	1	0.01	0.18	1.4	0.053	1.7	2.2	0.71	5	4
S084	St. Johns River #3	18	0.019	1.3	0.41	0.12	2.8	3.7	1.3	150	6

		Trophic Status Parameters								Water Clarity Parameters	
Waterbody Number	Waterbody	Carbon-Organic (mg/L)	Ammonia (N) (mg/L)	Nitrogen-Total Kjeldahl (mg/L)	NNOx (mg/L)	Phosphorus-Total (mg/L)	Chlorophyll a (ug/L)	Chlorophyll a-uncorrected (ug/L)	Pheophytin (ug/L)	Color (PCU)	TSS (mg/L)
S087	L6 Canal	42	0.075	2.5	0.12	0.027	0.55	0.48	-	160	4
S092	Ocean Canal	36	0.18	2.4	0.2	0.07	2.2	4.5	-	200	9
S093	Flint Creek	16	0.045	2.4	0.093	0.28	84	110	31	150	26
S099	Ocklawaha River 5	4.1	0.01	0.44	0.76	0.044	0.55	0.38	0.24	40	4
S100	Black Creek Mouth	13	0.045	0.86	0.17	0.099	1.1	1.5	0.62	150	4
S101	I-75 Canal	13	0.028	0.85	0.009	0.025	12	14	2.9	50	4
S1022	Wakulla River	2.5	0.016	0.2	0.49	0.038	1.4	2.3	1.4	20	4
S104	Suwannee River 2	43	0.044	1.2	0.1	0.62	1.1	2	1.6	400	7
S1041	Black Creek Canal	7	0.045	0.61	0.34	0.008	3.1	3	-	20	4
S107	SJR#6	17	0.013	1.2	0.24	0.091	5.8	7.6	2.7	150	6
S1081	Suwannee River	19	0.032	0.77	0.35	0.11	1.1	1.5	0.67	200	9
S1082	Alafia River	16	0.035	0.88	0.55	1.1	0.89	1.3	-	120	4
S1113	Santa Fe River	3.7	0.01	0.21	0.78	0.067	0.55	0.44	-	30	4
S1137	Suwannee River	3.6	0.01	0.3	1.3	0.23	0.91	1.1	-	40	4
S1153	Hogtown Creek	5.9	0.048	0.39	0.49	0.66	0.67	0.78	0.4	40	4
S119	Yon Creek	7	0.021	0.38	0.44	0.092	0.96	1.1	0.7	80	7
S1194	Tallahassee Creek	3.3	0.013	0.52	1.5	0.047	0.55	0.4	0.4	30	4
S121	Miami Canal	15	0.01	1.3	0.051	0.007	3	3.5	0.66	40	4
S1215	Bullfrog Creek	15	0.044	0.8	0.12	0.35	1	1.4	0.6	80	19
S1220	L-28 Interceptor Canal	16	0.054	1.1	0.019	0.029	5.9	6.9	-	80	4
S123	Juniper Creek	5.40	0.01	0.25	0.14	0.00	0.55	0.55	0.40	60.00	8.00
S1244	Juniper Run	2.3	0.01	0.21	0.013	0.019	0.55	0.4	0.4	40	4
S126	Orange Creek	11	0.026	0.58	0.21	0.049	0.58	0.58	0.24	120	5
S127	Sixteen Mile Cr	10	0.042	0.97	0.005	0.036	1.6	2.2	0.82	40	6
S1297	St. John's River	24	0.01	1	0.34	0.088	2	2.6	-	200	4
S1306	Rocky Creek	6.1	0.026	0.24	0.023	0.17	0.55	0.4	0.4	60	4
S1326	Upper Steinhatchee River	37	0.03	1.2	0.036	0.24	0.55	0.4	0.4	300	4
S1331	Mill Creek	37	0.1	0.92	0.042	0.047	0.55	0.44	0.4	400	4

		Trophic Status Parameters								Water Clarity Parameters	
Waterbody Number	Waterbody	Carbon-Organic (mg/L)	Ammonia (N) (mg/L)	Nitrogen-Total Kjeldahl (mg/L)	NNOx (mg/L)	Phosphorus-Total (mg/L)	Chlorophyll a (ug/L)	Chlorophyll a-uncorrected (ug/L)	Pheophytin (ug/L)	Color (PCU)	TSS (mg/L)
S1337	Wacissa River	1	0.013	0.16	0.24	0.036	2.3	3.1	-	5	4
S135	Whiskey George Creek	23	0.016	0.73	0.007	0.012	0.75	1.2	-	200	5
S1368	Upper Peace River	24	0.066	1.5	0.24	0.97	17	21	-	300	11
S1377	Shoal River	4	0.01	0.26	0.32	0.012	0.73	0.77	0.5	80	8
S1398	Wekiva River	1.2	0.01	0.088	0.44	0.046	0.59	0.7	0.4	15	4
S1399	Weeki Wachee	1	0.01	0.08	0.79	0.006	0.55	0.75	-	5	4
S1421	Caloosahatchee Riv	18	0.028	1.5	0.073	0.067	11	12	1.2	80	6
S1441	Frog Creek	19	0.068	1.3	0.58	0.59	5.9	7.2	-	120	4
S1450	Itchepachasassa	12	0.035	0.95	0.52	0.44	6.8	8.1	-	120	4
S146	Black Creek	18	0.067	0.8	0.01	0.016	0.62	2	2.3	200	4
S1471	Chipola River	1.9	0.026	0.22	1.8	0.019	0.78	0.87	0.4	30	8
S148	Upper St Marry's River	63.00	0.04	1.30	0.04	0.03	0.60	0.71	0.40	500.00	4.00
S157	Sopchoppy River	34	0.01	0.72	0.004	0.042	0.55	0.4	0.4	400	5
S164	Deep Creek	60	0.017	1.2	0.004	0.068	0.55	0.4	0.4	600	4
S173	New River	38.00	0.25	1.30	0.00	0.02	0.55	0.81	0.57	400.00	6.00
S179	Depot Creek	28	0.018	0.72	0.006	0.007	0.55	0.4	-	300	4
S196	Suwannee River - Upper	53	0.01	1.2	0.004	0.059	0.55	0.79	0.4	500	4
S2010	Lostman's Creek	13	0.01	0.98	0.03	0.011	5.3	5.6	-	50	5
S2011	North Prong	26	0.12	1.8	0.081	0.029	1.5	2	0.74	60	5
S2012	Ichetucknee River	1.00	0.01	0.17	0.40	0.05	0.92	1.20	0.47	5.00	4.00
S216	Turnpike Canal	10	0.043	0.81	0.008	0.008	1.1	1.8	-	40	4
S226	Black Creek	14	0.01	0.45	0.061	0.005	0.55	0.4	-	120	5
S245	Bootheel Creek	50.00	0.03	1.50	0.01	0.25	0.55	0.71	0.40	500.00	6.00
S260	Sandy Creek	4.4	0.01	0.15	0.016	0.004	0.55	0.4	0.4	50	4
S261	Alaqua Creek	1.5	0.01	0.095	0.086	0.004	0.55	0.42	0.4	15	5
S275	Little Charlie Bowleg Creek	49	0.065	1.9	0.024	0.55	0.65	1.2	0.77	500	4
S277	Mill Creek	46	0.06	1.5	0.022	0.039	0.85	1.5	1.6	400	5
S289	Blackwater River	5.8	0.01	0.29	0.14	0.006	0.85	1.3	0.64	60	6

		Trophic Status Parameters								Water Clarity Parameters	
Waterbody Number	Waterbody	Carbon-Organic (mg/L)	Ammonia (N) (mg/L)	Nitrogen-Total Kjeldahl (mg/L)	NNOx (mg/L)	Phosphorus-Total (mg/L)	Chlorophyll a (ug/L)	Chlorophyll a-uncorrected (ug/L)	Pheophytin (ug/L)	Color (PCU)	TSS (mg/L)
S290	Big Coldwater Creek	1.8	0.01	0.15	1	0.004	0.55	0.45	0.4	20	4
S292	Taylor Creek	30.00	0.14	1.80	0.19	0.44	4.60	5.50	1.20	300.00	5.00
S293	Bear Creek	4.5	0.01	0.22	0.049	0.005	0.55	0.4	0.4	50	4
S302	Big Creek	25	0.014	0.79	0.004	0.012	1.1	1.3	-	200	4
S307	Myakka River	24	0.015	1.1	0.023	0.33	1.1	2	-	300	6
S313	Swift Creek	62.00	0.04	1.70	0.01	0.21	0.70	1.00	0.51	500.00	4.00
S362	Fisheating Creek	32	0.12	1.8	0.085	0.26	5.3	6.5	-	400	7
S367	Sampson Creek	6.7	0.15	0.44	0.081	0.07	1.5	1.6	0.4	40	4
S385	Haw Creek	36	0.12	1.5	0.057	0.067	1.6	1.7	-	500	4
S389	L31N Canal	13	0.21	1	0.012	0.004	0.55	0.53	-	40	4
S404	St. Mary's River	32	0.021	0.88	0.031	0.033	0.55	0.4	0.4	400	4
S405	Crooked River	21	0.01	0.61	0.018	0.026	0.88	0.99	-	300	4
S415	Eaton Creek	36	0.051	1.3	0.083	0.048	2.5	3.7	-	400	9
S428	Ochlockonee River	7.70	0.05	0.63	0.39	0.14	3.40	5.10	2.50	100.00	13.00
S431	Yellow River	4.3	0.012	0.32	0.12	0.017	4.9	5.5	0.69	100	10
S454	Telogia Creek	7	0.023	0.43	0.083	0.048	0.55	0.4	0.7	120	9
S459	Manatee River	6	0.01	0.93	0.004	0.43	30	34	5	40	5
S486	C111 Canal	11	0.069	0.63	0.026	0.004	1.5	1.5	-	30	4
S497	Daughtrey's Creek	9.1	0.11	0.77	0.14	0.025	4.5	6	-	30	5
S528	Glades Road Canal	15	0.018	0.93	0.005	0.11	3.5	4	-	60	4
S555	Peachland Canal	12	0.041	1.1	0.009	0.055	11	14	4.7	60	6
S564	St. Lucie River	13	0.094	0.89	0.048	0.16	24	28	-	40	9
S604	Six Mile Creek	6.2	0.09	0.64	0.18	0.073	4	5.6	-	40	4
S610	California Creek	26	0.014	1.1	0.018	0.016	1.3	1.5	0.4	100	6
S633	Lost Creek	52	0.015	1.1	0.004	0.013	0.55	0.6	-	500	4
S643	Interceptor Canal	35	0.066	1.9	0.26	0.78	6.2	8	2.7	300	8
S686	Tamiami Canal	8.5	0.021	0.56	0.006	0.016	1.6	1.9	-	50	4
S690	Oak Creek	7.1	0.12	0.65	0.034	0.022	5.5	6.4	1.1	20	4
S735	Withlacoochee River	26	0.12	2.3	0.054	0.08	40	44	-	250	10

		Trophic Status Parameters								Water Clarity Parameters	
Waterbody Number	Waterbody	Carbon-Organic (mg/L)	Ammonia (N) (mg/L)	Nitrogen-Total Kjeldahl (mg/L)	NNOx (mg/L)	Phosphorus-Total (mg/L)	Chlorophyll a (ug/L)	Chlorophyll a-uncorrected (ug/L)	Pheophytin (ug/L)	Color (PCU)	TSS (mg/L)
S747	Golden Gate Canal	13	0.016	1.7	0.011	0.32	35	38	3.8	50	7
S784	Dunn's Creek	20	0.023	0.97	0.059	0.064	5.9	6.8	-	200	7
S791	Myakka River	9.4	0.01	2.4	0.004	0.14	82	89	7	60	24
S824	Big Juniper Creek	1.8	0.01	0.15	0.11	0.005	0.71	0.8	0.45	20	4
S856	C44 Canal	19	0.073	1.2	0.32	0.26	2.6	4.5	-	160	12
S900	Loxahatchee River	13	0.019	0.81	0.1	0.054	1.3	1.4	-	60	4
S923	St Marks River	3	0.01	0.2	0.062	0.044	0.55	1.1	0.94	20	4
S942	Hillsborough River	21	0.055	1.1	0.12	0.36	0.83	1.2	0.63	120	4
S964	Little Withlacoochee River	4.9	0.026	0.31	0.044	0.032	0.75	0.82	-	50	4
S988	Otter Creek	16	0.05	1.5	0.043	0.067	2.5	2.9	0.47	150	11



Florida Department of Environmental Protection
Division of Water Resource Management
Bureau of Watershed Management
2600 Blair Stone Road, Mail Station 3565
Tallahassee, Florida 32399-2400
(850) 245-8561
www2.dep.state.fl.us/water/

FLORIDA DEPARTMENT OF ENVIRONMENTAL PROTECTION

Division of Environmental Assessment and Restoration
Bureau of Watershed Restoration

Mercury TMDL for the State of Florida

Appendix I

Spatial Distribution of Water Column Total and Methylmercury in 133 Lakes and 131 Streams Collected in the 2008 – 2010 Period

Watershed Evaluation and TMDL Section



May 22, 2012

**Appendix I: Spatial Distribution of Water Column Total and Methylmercury in 133 Lakes and
131 Streams Collected in the 2008 – 2010 Period**

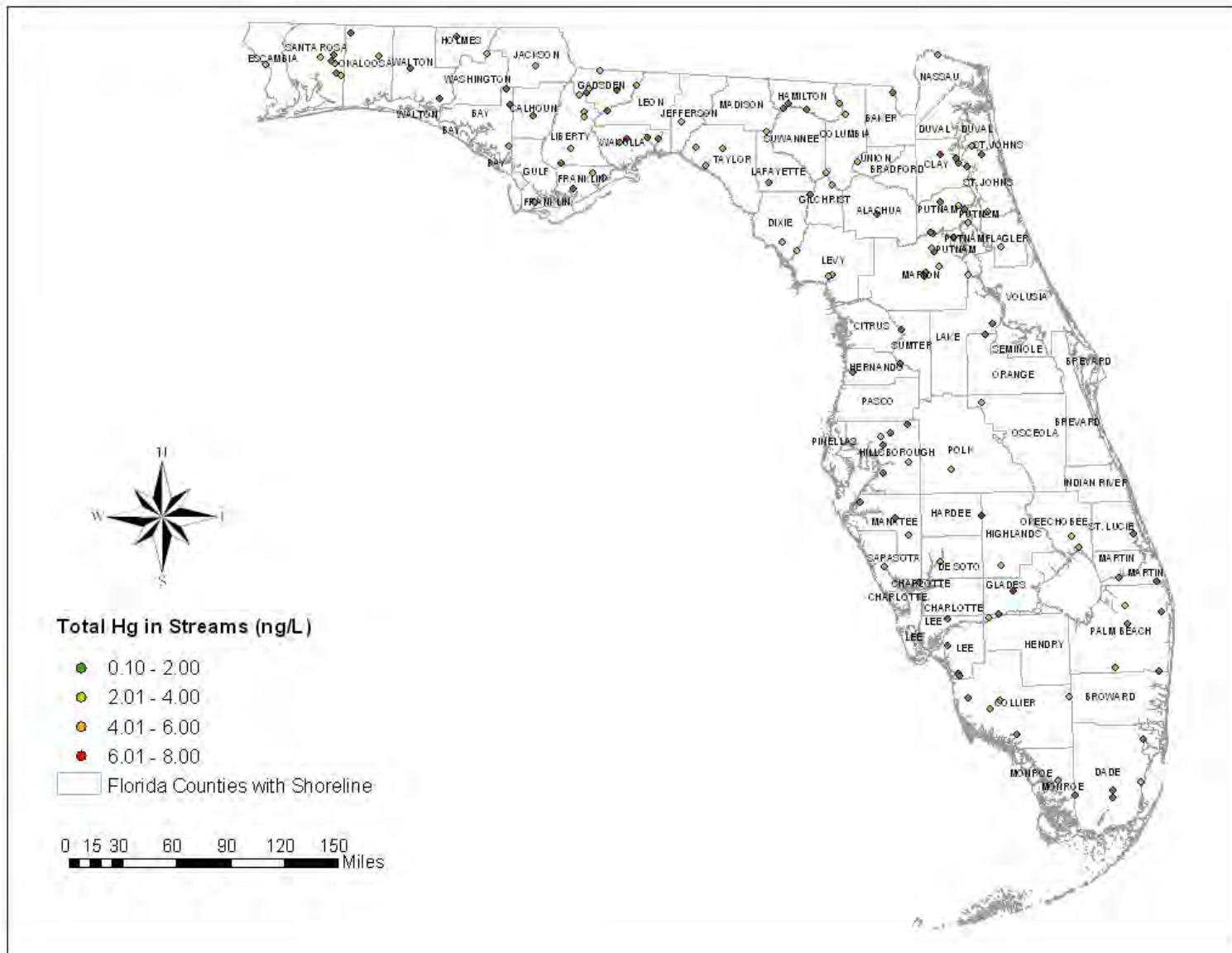


Figure I-1. Spatial Distribution of Water Column Total Mercury Concentration in Florida Streams

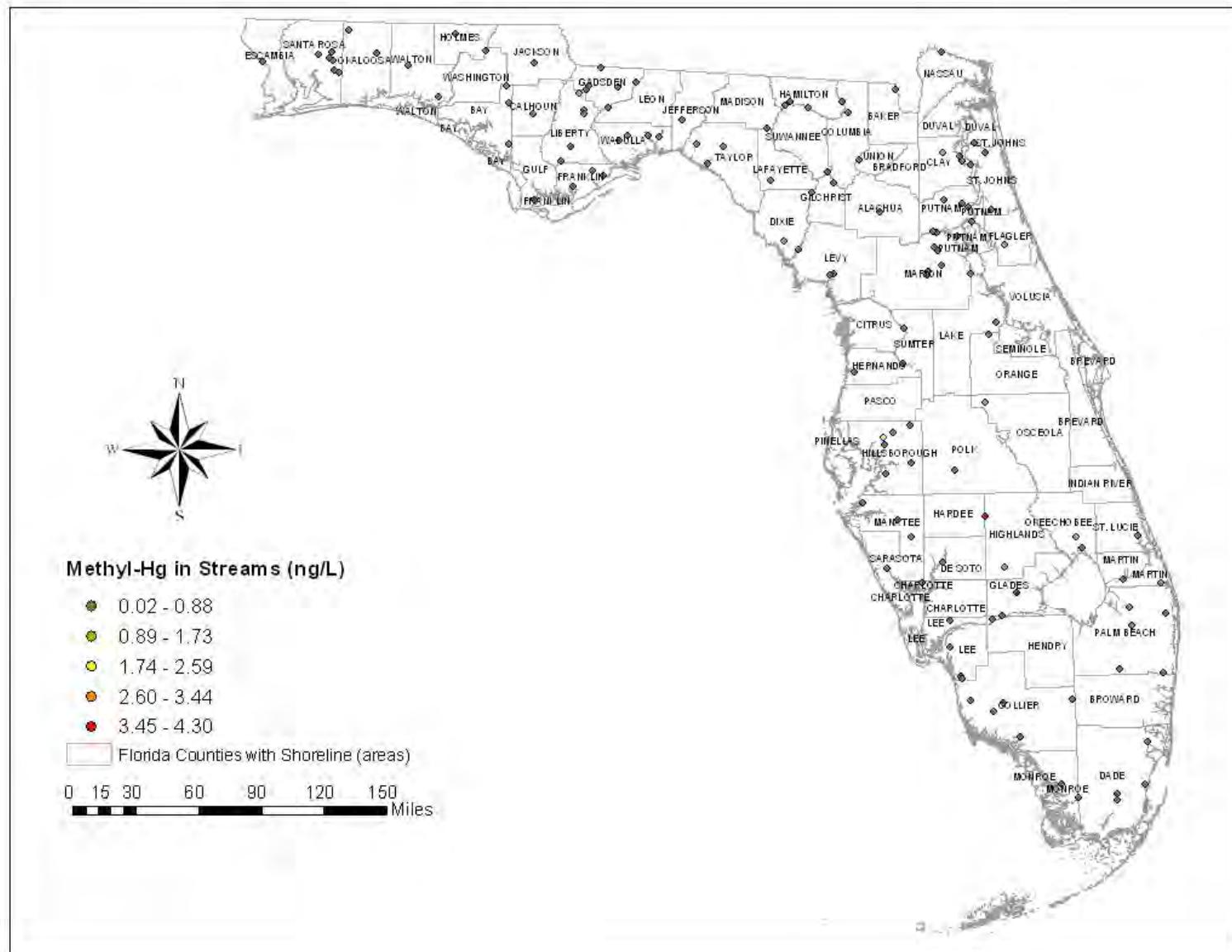


Figure I-2. Spatial Distribution of Water Column Methylmercury Concentration in Florida Streams

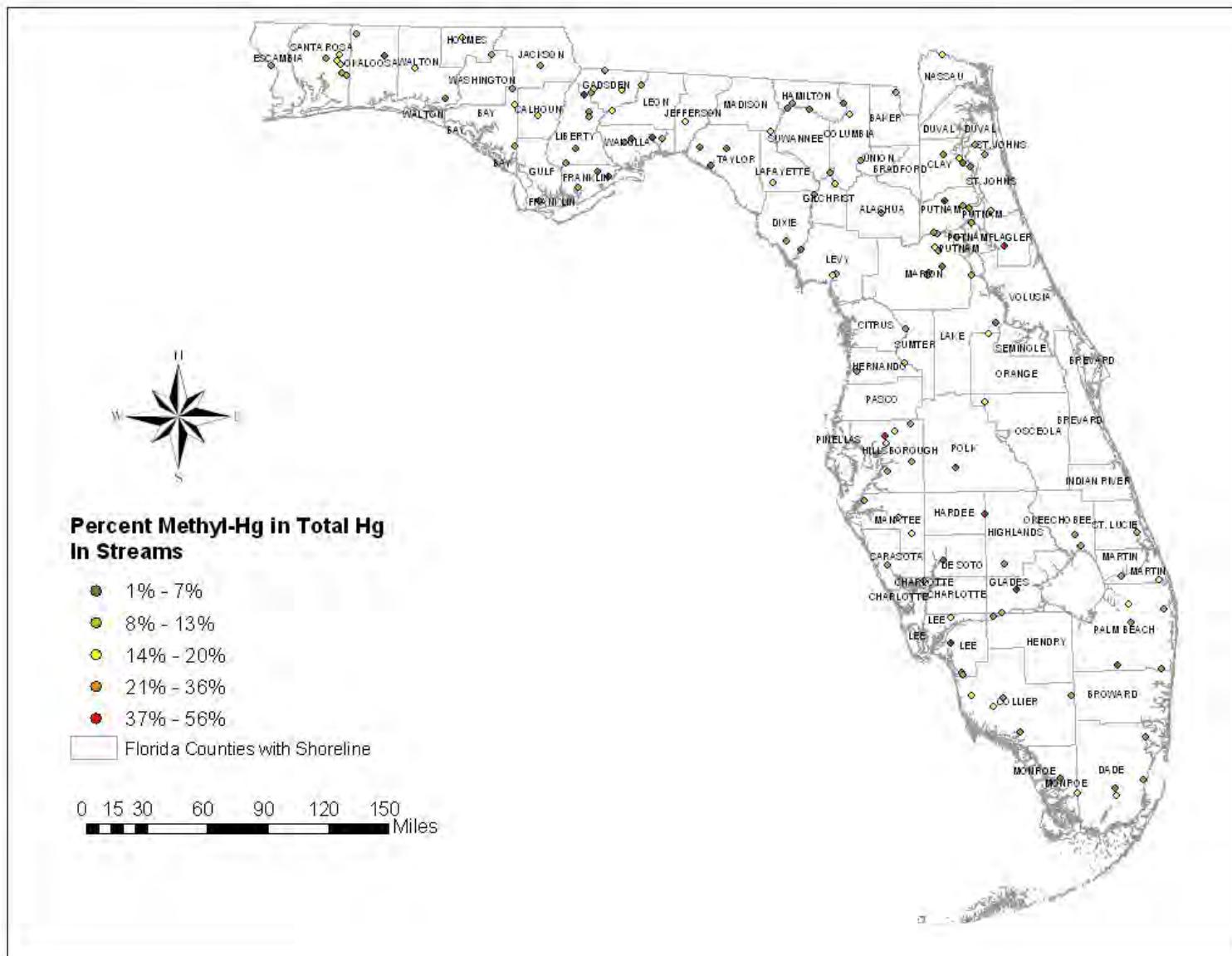


Figure I-3. Spatial Distribution of Water Column Methylmercury to Total Mercury Ratio in Florida Streams

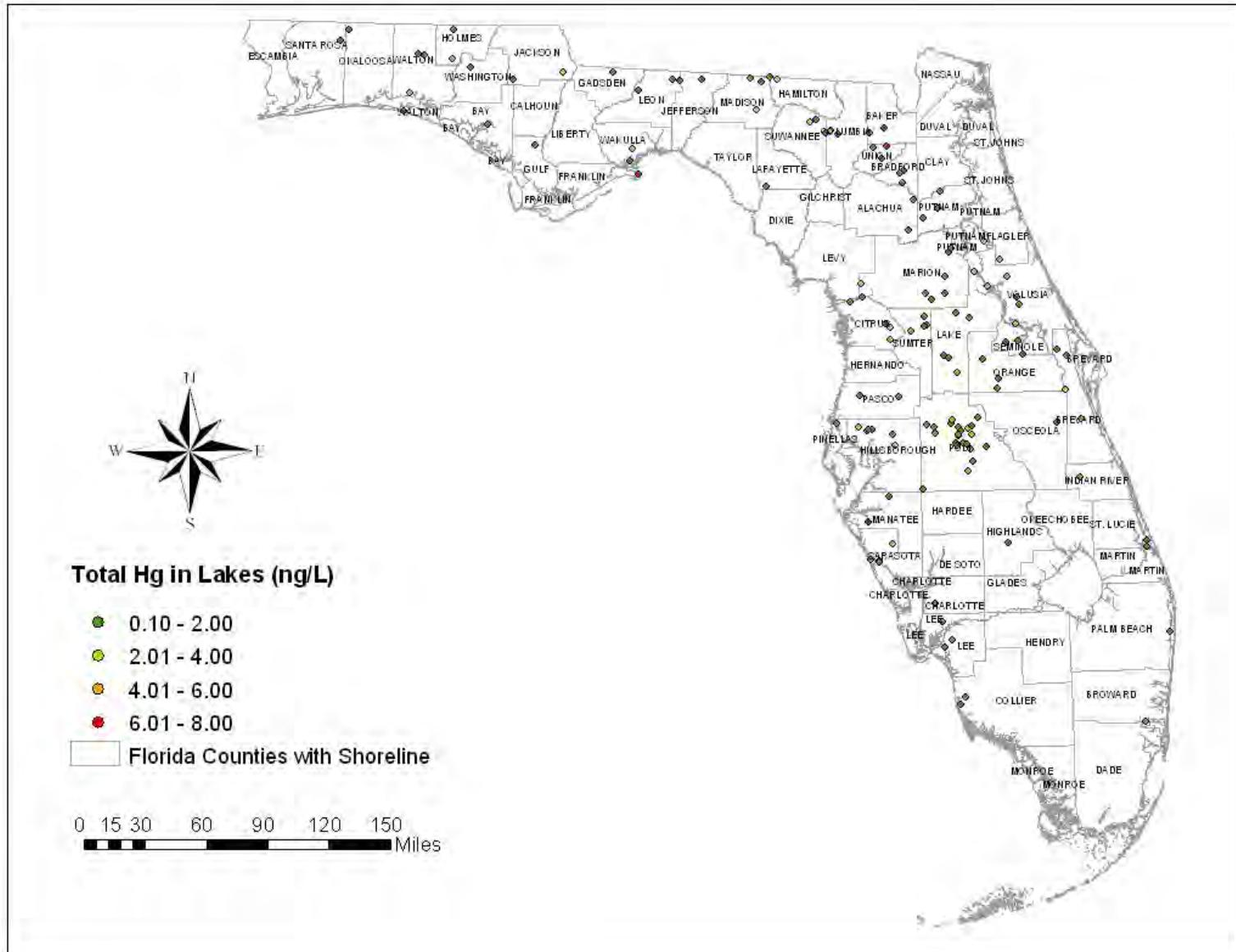


Figure I-4. Spatial Distribution of Water Column Total Mercury Concentration in Florida Lakes

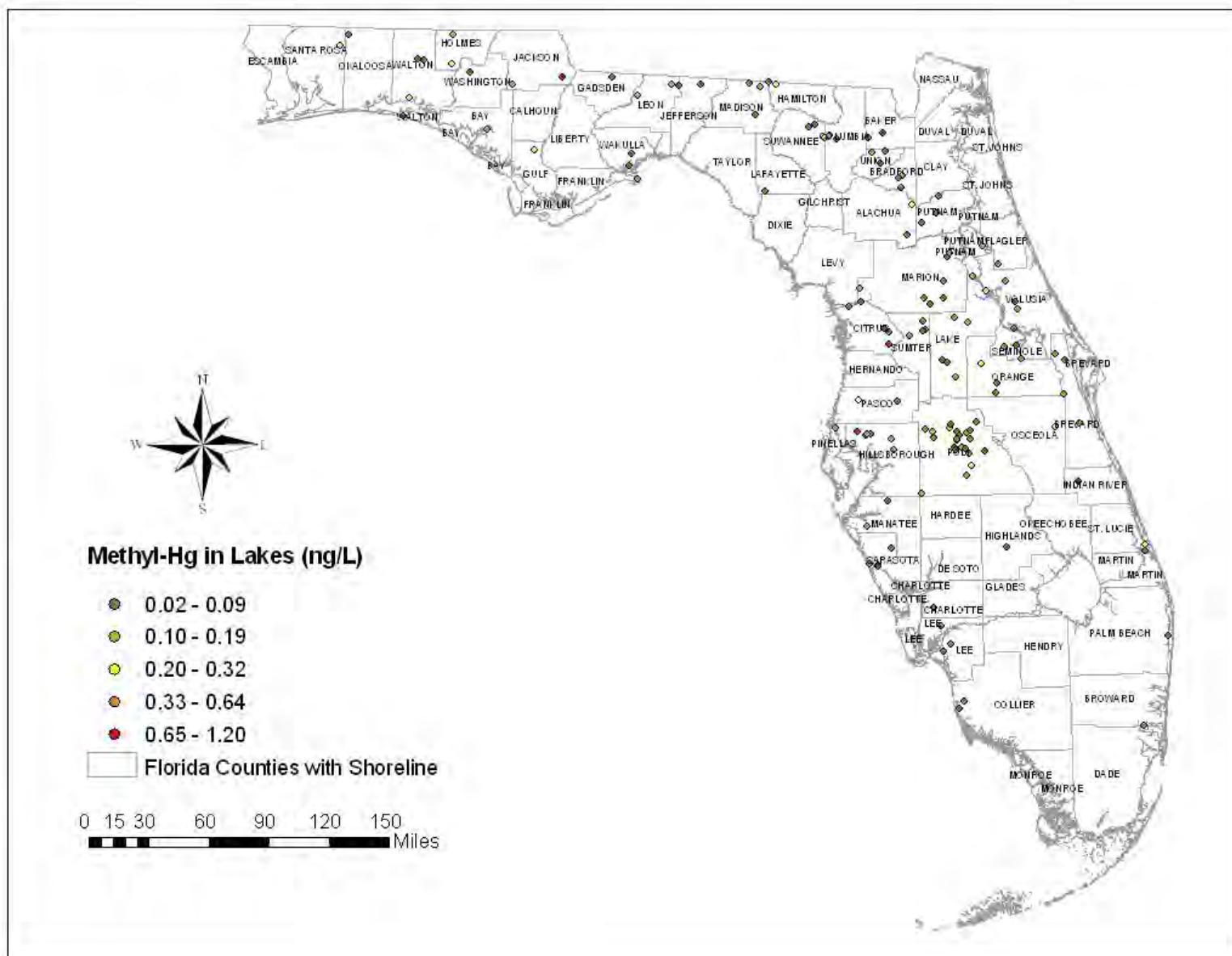


Figure I-5. Spatial Distribution of Water Column Methylmercury Concentration in Florida Lakes

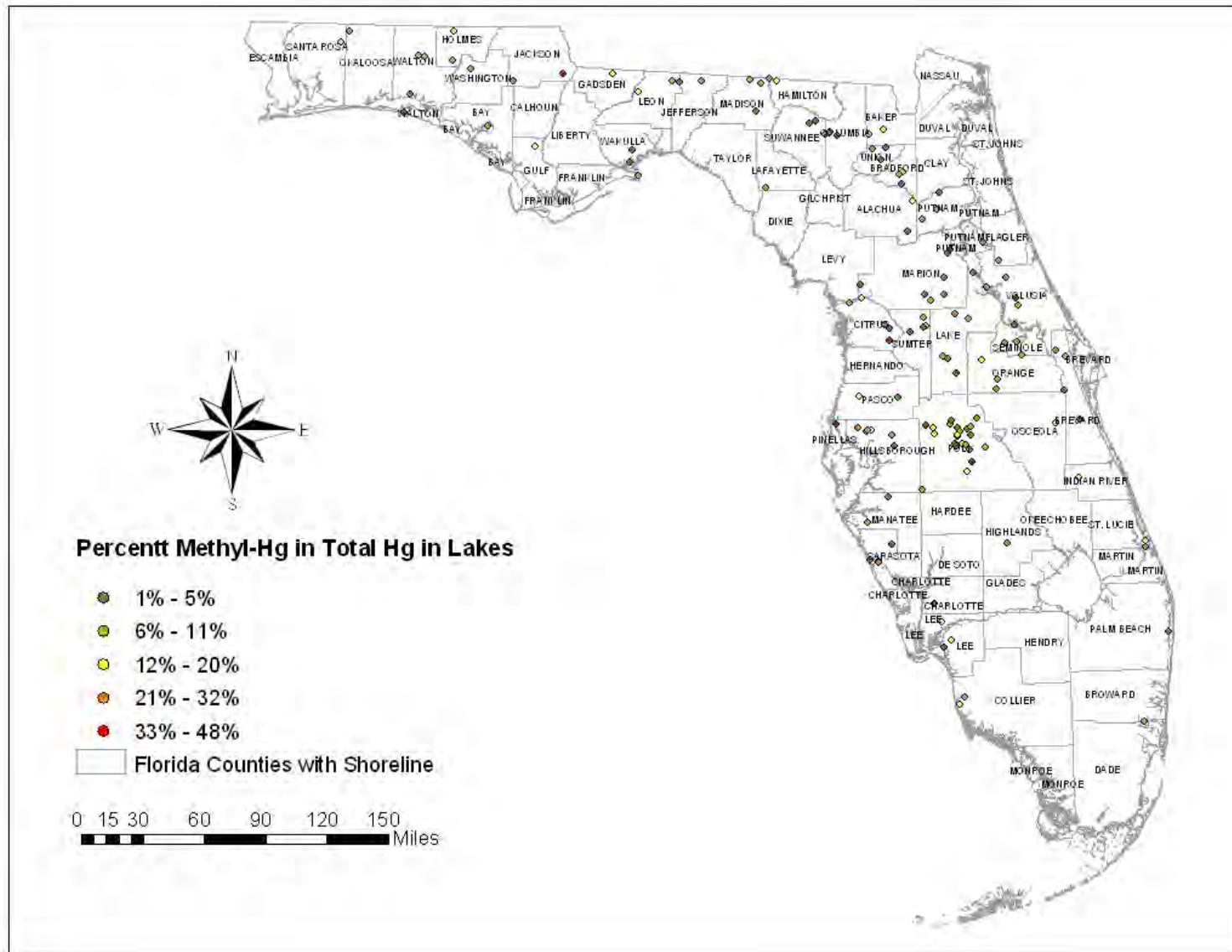


Figure I-6. Spatial Distribution of Water Column Methylmercury to Total Mercury Ratio in Florida Lakes



Florida Department of Environmental Protection
Division of Water Resource Management
Bureau of Watershed Management
2600 Blair Stone Road, Mail Station 3565
Tallahassee, Florida 32399-2400
(850) 245-8561
www2.dep.state.fl.us/water/

FLORIDA DEPARTMENT OF ENVIRONMENTAL PROTECTION

Division of Environmental Assessment and Restoration
Bureau of Watershed Restoration

Mercury TMDL for the State of Florida

Appendix J

Probability Distribution Functions

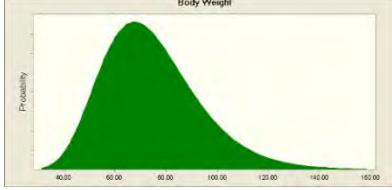
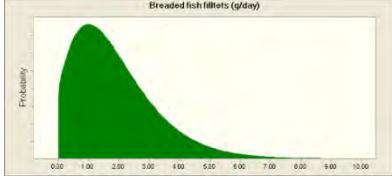
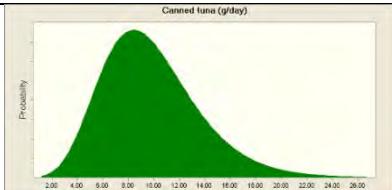
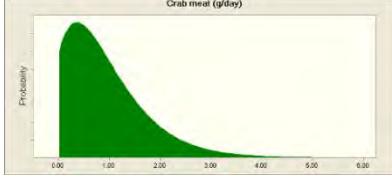
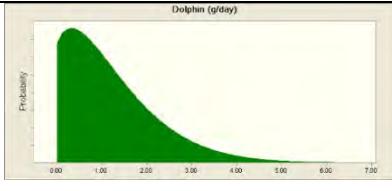
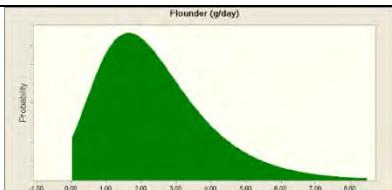
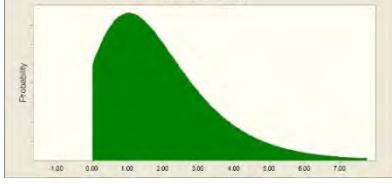
Watershed Evaluation and TMDL Section

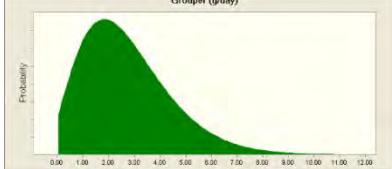
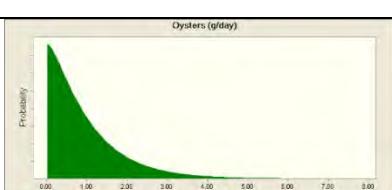
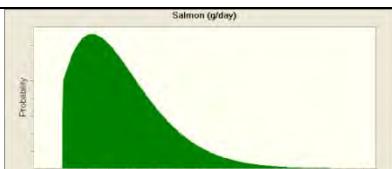
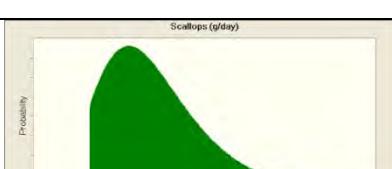
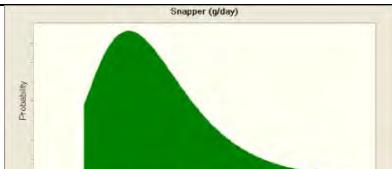
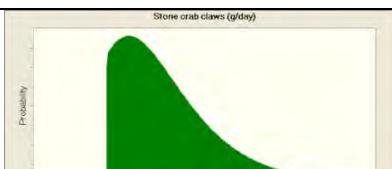


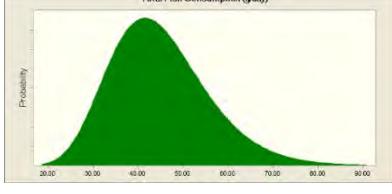
May 22, 2012

Appendix J: Probability Distribution Functions.

Table J-1. Probability Distribution Functions

Statistical Assumption	Distribution								
<p>Assumption: Body Weight Lognormal distribution with parameters:</p> <table> <tr> <td>Location</td> <td>0.00</td> </tr> <tr> <td>Mean</td> <td>74.55</td> </tr> <tr> <td>Std. Dev.</td> <td>19.32</td> </tr> </table>	Location	0.00	Mean	74.55	Std. Dev.	19.32			
Location	0.00								
Mean	74.55								
Std. Dev.	19.32								
<p>Assumption: Breaded fish fillets (g/day) Beta distribution with parameters:</p> <table> <tr> <td>Minimum:</td> <td>-0.60</td> </tr> <tr> <td>Maximum</td> <td>61.63</td> </tr> <tr> <td>Alpha</td> <td>2.84668</td> </tr> <tr> <td>Beta</td> <td>70.65138</td> </tr> </table> <p>Selected range is from 0.00 to infinity</p>	Minimum:	-0.60	Maximum	61.63	Alpha	2.84668	Beta	70.65138	
Minimum:	-0.60								
Maximum	61.63								
Alpha	2.84668								
Beta	70.65138								
<p>Assumption: Canned tuna (g/day) Lognormal distribution with parameters:</p> <table> <tr> <td>Location</td> <td>-4.90</td> </tr> <tr> <td>Mean</td> <td>9.81</td> </tr> <tr> <td>Std. Dev.</td> <td>3.86</td> </tr> </table> <p>Selected range is from 0.00 to infinity</p>	Location	-4.90	Mean	9.81	Std. Dev.	3.86			
Location	-4.90								
Mean	9.81								
Std. Dev.	3.86								
<p>Assumption: Crab meat (g/day) Beta distribution with parameters:</p> <table> <tr> <td>Minimum:</td> <td>-0.35</td> </tr> <tr> <td>Maximum</td> <td>54.97</td> </tr> <tr> <td>Alpha</td> <td>2.29038</td> </tr> <tr> <td>Beta</td> <td>100</td> </tr> </table> <p>Selected range is from 0.00 to infinity</p>	Minimum:	-0.35	Maximum	54.97	Alpha	2.29038	Beta	100	
Minimum:	-0.35								
Maximum	54.97								
Alpha	2.29038								
Beta	100								
<p>Assumption: Dolphin (g/day) Beta distribution with parameters:</p> <table> <tr> <td>Minimum:</td> <td>-0.34</td> </tr> <tr> <td>Maximum</td> <td>11.89</td> </tr> <tr> <td>Alpha</td> <td>1.63465</td> </tr> <tr> <td>Beta</td> <td>11.88145</td> </tr> </table> <p>Selected range is from 0.00 to infinity</p>	Minimum:	-0.34	Maximum	11.89	Alpha	1.63465	Beta	11.88145	
Minimum:	-0.34								
Maximum	11.89								
Alpha	1.63465								
Beta	11.88145								
<p>Assumption: Flounder (g/day) Maximum Extreme distribution with parameters:</p> <table> <tr> <td>Likeliest</td> <td>1.63</td> </tr> <tr> <td>Scale</td> <td>1.29</td> </tr> </table> <p>Selected range is from 0.00 to infinity</p>	Likeliest	1.63	Scale	1.29					
Likeliest	1.63								
Scale	1.29								
<p>Assumption: Freshwater (g/day) Maximum Extreme distribution with parameters:</p> <table> <tr> <td>Likeliest</td> <td>1.02</td> </tr> <tr> <td>Scale</td> <td>1.27</td> </tr> </table> <p>Selected range is from 0.00 to infinity</p>	Likeliest	1.02	Scale	1.27					
Likeliest	1.02								
Scale	1.27								

Statistical Assumption	Distribution
Assumption: Grouper (g/day) Beta distribution with parameters: Minimum: -0.77 Maximum 34.52 Alpha 3.4284 Beta 31.61398 Selected range is from 0.00 to infinity	
Assumption: Oysters (g/day) Beta distribution with parameters: Minimum: -0.13 Maximum 87.81 Alpha 1.15783 Beta 100 Selected range is from 0.00 to infinity	
Assumption: Salmon (g/day) Beta distribution with parameters: Minimum: -0.39 Maximum 14.33 Alpha 2.66386 Beta 26.55724 Selected range is from 0.00 to infinity	
Assumption: Scallops (g/day) Maximum Extreme distribution with parameters: Likeliest 0.28 Scale 0.32 Selected range is from 0.00 to infinity	
Assumption: Shrimp (g/day) Lognormal distribution with parameters: Location -3.30 Mean 4.60 Std. Dev. 1.51	
Assumption: Snapper (g/day) Maximum Extreme distribution with parameters: Likeliest 1.43 Scale 1.42 Selected range is from 0.00 to infinity	
Assumption: Stone crab claws (g/day) Maximum Extreme distribution with parameters: Likeliest 0.46 Scale 0.94 Selected range is from 0.00 to infinity	

Statistical Assumption	Distribution
Assumption: Total Fish Consumption (g/day) Lognormal distribution with parameters: Location -5.91 Mean 44.93 Std. Dev. 11.10	



Florida Department of Environmental Protection
Division of Water Resource Management
Bureau of Watershed Management
2600 Blair Stone Road, Mail Station 3565
Tallahassee, Florida 32399-2400
(850) 245-8561
www2.dep.state.fl.us/water/

FLORIDA DEPARTMENT OF ENVIRONMENTAL PROTECTION

Division of Environmental Assessment and Restoration
Bureau of Watershed Restoration

Mercury TMDL for the State of Florida

Appendix K

Background Information on Federal and State Stormwater Programs

Watershed Evaluation and TMDL Section



May 22, 2012

Appendix A: Background Information on Federal and State Stormwater Programs

In 1982, Florida became the first state in the country to implement statewide regulations to address the issue of nonpoint source pollution by requiring new development and redevelopment to treat stormwater before it is discharged. The Stormwater Rule, as authorized in Chapter 403, F.S., was established as a technology-based program that relies on the implementation of BMPs that are designed to achieve a specific level of treatment (i.e., performance standards) as set forth in Rule 62-40, F.A.C. In 1994, the Department's stormwater treatment requirements were integrated with the stormwater flood control requirements of the water management districts, along with wetland protection requirements, into the Environmental Resource Permit regulations.

Rule 62-40, F.A.C., also requires the state's water management districts to establish stormwater pollutant load reduction goals (PLRGs) and adopt them as part of a Surface Water Improvement and Management (SWIM) plan, other watershed plan, or rule. Stormwater PLRGs are a major component of the load allocation part of a TMDL. To date, they have been established for Tampa Bay, Lake Thonotosassa, the Winter Haven Chain of Lakes, the Everglades, Lake Okeechobee, and Lake Apopka.

In 1987, the U.S. Congress established Section 402(p) as part of the federal Clean Water Act Reauthorization. This section of the law amended the scope of the federal NPDES permitting program to designate certain stormwater discharges as "point sources" of pollution. The EPA promulgated regulations and began implementing the Phase I NPDES Stormwater Program in 1990. These stormwater discharges include certain discharges that are associated with industrial activities designated by specific standard industrial classification (SIC) codes, construction sites disturbing 5 or more acres of land, and the master drainage systems of local governments with a population above 100,000, which are better known as MS4s. However, because the master drainage systems of most local governments in Florida are interconnected, the EPA implemented Phase I of the MS4 permitting program on a countywide basis, which brought in all cities (incorporated areas), Chapter 298 urban water control districts, and the Florida Department of Transportation throughout the 15 counties meeting the population criteria. The Department received authorization to implement the NPDES Stormwater Program in 2000.

An important difference between the federal NPDES and the state's stormwater/environmental resource permitting programs is that the NPDES Program covers both new and existing discharges, while the state's program focus on new discharges only. Additionally, Phase II of the NPDES Program, implemented in 2003, expands the need for these permits to construction sites between 1 and 5 acres, and to local governments with as few as 1,000 people. While these urban stormwater discharges are now technically referred to as "point sources" for the purpose of regulation, they are still diffuse sources of pollution that cannot be easily collected and treated by a central treatment facility, as are other point sources of pollution such as domestic and industrial wastewater discharges. It should be noted that all MS4 permits issued in Florida include a reopen clause that allows permit revisions to implement TMDLs when the implementation plan is formally adopted.



Florida Department of Environmental Protection
Division of Water Resource Management
Bureau of Watershed Management
2600 Blair Stone Road, Mail Station 3565
Tallahassee, Florida 32399-2400
(850) 245-8561
www2.dep.state.fl.us/water/

FLORIDA DEPARTMENT OF ENVIRONMENTAL PROTECTION

Division of Environmental Assessment and Restoration
Bureau of Watershed Restoration

Mercury TMDL for the State of Florida

Appendix M

A Monte Carlo Analysis to Show that the Statewide Mercury TMDL will be Protective of the State Total Mercury Criteria for Ambient Waters

Watershed Evaluation and TMDL Section



August 15, 2012

The Department used the following steps to demonstrate that the statewide mercury TMDL will be protective of the total mercury criteria for Florida ambient waters:

The ratio (P) between the ambient methylmercury concentration (C_{Methyl}) and ambient total mercury concentration (C_{THg}) can be represented using Equation 1:

$$P = C_{\text{Methyl}} / C_{\text{THg}} \quad \text{Equation 1}$$

Re-arranging Equation 1, we have:

$$C_{\text{THg}} = C_{\text{Methyl}} / P \quad \text{Equation 2}$$

The ambient methylmercury concentration (C_{Methyl}) can be linked to the fish tissue mercury concentration (C_{FishHg}) using the bioaccumulation factor (BAF):

$$\text{BAF} = C_{\text{FishHg}} / C_{\text{Methyl}} \quad \text{Equation 3}$$

Re-arranging Equation 3, we have:

$$C_{\text{Methyl}} = C_{\text{FishHg}} / \text{BAF} \quad \text{Equation 4}$$

Substituting Equation 4 into Equation 2, we have:

$$C_{\text{THg}} = C_{\text{FishHg}} / \text{BAF} / P \quad \text{Equation 5}$$

Mercury fish tissue concentration data were collected from 264 Florida lakes and streams in the period from September of 2008 through October of 2010. At least 12 largemouth bass were collected from each waterbody by the Florida Fish and Wildlife. In waterbodies where no largemouth were collected or less than 12 largemouth bass were collected, spotted sun fish and/or spotted bass were collected in place of the largemouth bass. Fish tissue mercury concentration was analyzed from these fish samples by the Central Lab of the Department. For each waterbody, individual fish tissue concentrations were then averaged to create a waterbody mean fish tissue mercury concentration. Ambient methylmercury and total mercury concentration data were collected for each sampled waterbody at the same time when fish samples were collected. Using these ambient methylmercury and total mercury data and the waterbody mean fish tissue concentrations, the Department were able to establish distribution curves for both BAF and P (**Table M-1**)

Table M-1 Percentile Distribution of BAF and P Based on Samples Collected from 128 Lakes and 128 Streams in Florida

Percentile	BAF	P
5 percentile	3.77E+05	0.025
10 percentile	6.02E+05	0.037
15 percentile	7.76E+05	0.042
20 percentile	9.25E+05	0.052
25 percentile	1.16E+06	0.061
30 percentile	1.37E+06	0.068

Percentile	BAF	P
35 percentile	1.68E+06	0.076
40 percentile	1.97E+06	0.081
45 percentile	2.31E+06	0.087
50 percentile	2.67E+06	0.093
55 percentile	2.98E+06	0.102
60 percentile	3.27E+06	0.113
65 percentile	3.61E+06	0.127
70 percentile	4.27E+06	0.141
75 percentile	5.18E+06	0.159
80 percentile	6.10E+06	0.172
85 percentile	6.97E+06	0.198
90 percentile	9.41E+06	0.257
95 percentile	1.37E+07	0.364
100 percentile	2.44E+07	0.508

A Monte Carlo analysis was conducted using the Crystal Ball Fusion Edition (Release 11.1) software to examine the distribution of possible ambient total mercury concentrations (C_{THg}) once the fish tissue concentration target is achieved using Equation 5. Basically, the analysis identified the best distribution curves that fit BAF and P distribution. Random BAF and P values were then picked from these distribution curves by the Crystal Ball program and entered into Equation 5 to calculate C_{THg} . At the same time, C_{FishHg} value in Equation 5 was fixed at the 0.3 mg/Kg level to represent the fish tissue target. This process was iterated for 10,000 times. Each time, one possible case of C_{THg} was generated. After the analysis was finished, a cumulative frequency analysis was conducted using the simulated C_{THg} values. **Table M-2** shows the percent distribution of the C_{THg} results from the Monte Carlo analysis.

Percentile Ranking	C_{THg} Concentration (ng/L)
0.0005	0.02
0.01	0.06
0.02	0.09
0.03	0.11
0.04	0.13
0.05	0.15
0.06	0.17
0.07	0.19
0.08	0.21
0.09	0.22
0.1	0.24
0.15	0.33

Percentile Ranking	C_{THg} Concentration (ng/L)
0.2	0.43
0.25	0.53
0.3	0.65
0.35	0.77
0.4	0.91
0.45	1.07
0.5	1.26
0.55	1.50
0.6	1.77
0.65	2.09
0.7	2.49
0.75	3.02
0.8	3.76
0.85	4.87
0.9	6.66
0.91	7.08
0.92	7.72
0.93	8.51
0.94	9.33
0.95	10.55
0.96	12.22
0.97	14.72
0.98	17.88
0.99	25.78
0.991	26.93
0.992	27.94
0.995	34.26
0.9975	44.22
0.998	48.49
0.999	56.03
0.9995	65.85
0.9999	84.42

Based on **Table M-2**, it is obvious that, when the 0.3 mg/Kg fish tissue target was achieved, there is a more than 95% confidence that the ambient total mercury concentration will be lower than the 12 ng/L total mercury criteria for freshwater systems. In addition, there is a confidence level of 98% that the marine ambient total mercury concentration of 25 ng/L is protected.



Florida Department of Environmental Protection
Division of Water Resource Management
Bureau of Watershed Management
2600 Blair Stone Road, Mail Station 3565
Tallahassee, Florida 32399-2400
(850) 245-8561
www2.dep.state.fl.us/water/