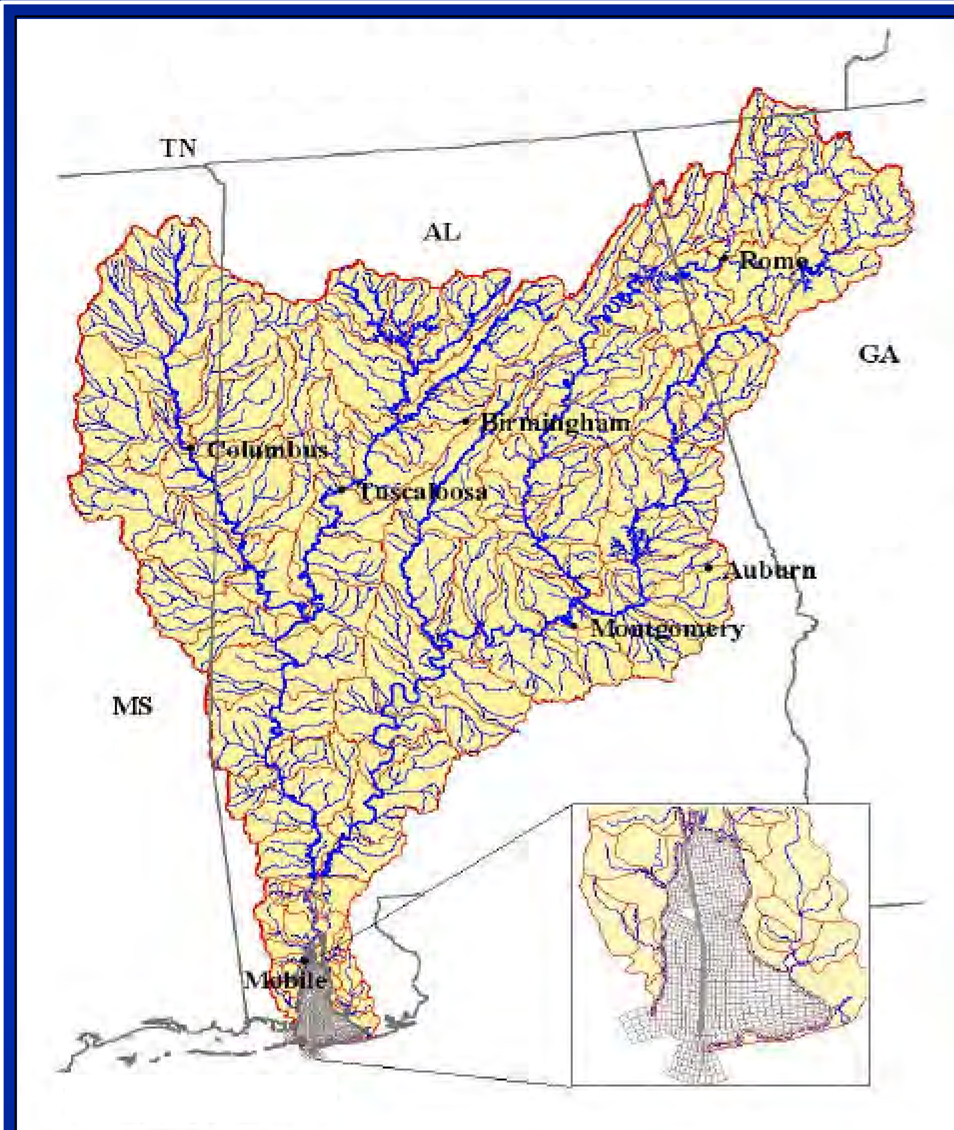
Loading Budget Analysis for Mobile Bay Modeling



Prepared for:

Mobile Bay National Estuary Program

U.S. Army Corps of Engineers, Mobile District

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December 7, 2001

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Executive Summary

The objective of this project was to assess pollutant loadings contributed to Mobile Bay by the Mobile River basin, which encompasses over two-thirds of Alabama and portions of Georgia, Tennessee, and Mississippi. Urban development and land practices in the bay area and throughout the far reaches of the basin impact the bay's water quality characteristics. The major water quality issues currently facing water resource managers in the region include nutrient enrichment, sedimentation, pesticides and toxics, habitat degradation, metals, bacterial contamination, and the health of the estuarine environment and its fisheries.

To address the project's objectives, two general assessment techniques were taken. The primary assessment method involved development and application of a comprehensive modeling platform to analyze loadings to the bay and the distribution of loadings throughout the contributing drainage area. This method addressed nutrient (total nitrogen and phosphorus), BOD_5, sediment, and metals issues. The second technique involved assessment of watershed indicators, which are factors likely to influence water quality. This analysis looked into urban runoff potential, fertilizer and pesticide (toxic organic contaminant) application, silviculture practices, livestock distributions, and mercury.

The comprehensive modeling platform was designed to support loading analysis for this project and to provide a basis for future analysis of water quality in Mobile Bay. It was composed of two models developed in parallel: a watershed model and a bay model. The emphasis of modeling for this effort was to develop the watershed model representative of the entire Mobile River basin. The EPA's Better Assessment Science Integrating Point and Nonpiont Sources (BASINS, Version 2.0) – Nonpoint Source Model (NPSM) was selected as the watershed modeling platform for the watershed model. The model simulated both point and nonpoint source pollutant contributions in the watershed and routed flow and water quality through stream networks to Mobile Bay. A preliminary version of the bay model was also developed, in order to simulate Mobile Bay's response to contributions from the watershed model. This model was configured to represent hydrodynamics with capabilities for representation of water quality parameters. The Environmental Fluid Dynamics Code (EFDC) was selected as the basis for the bay model.

The watershed model was run to estimate flow and pollutant loading to Mobile Bay for both existing and future conditions. The watershed model was run for the period 1970 through 1995 to estimate contributions to the bay for an array of hydrologic conditions and to characterize the distribution of pollutant loading throughout the Mobile River basin. To support watershed and bay management, the model was configured to represent the impacts of potential future changes in the contributing watershed. Future urban development and industry growth both have considerable impacts on the bay's water quality and must be understood to take appropriate protective action.

1.0 Introduction

This report summarizes the procedures and results of a study undertaken to analyze pollutant contributions to Mobile Bay. The study was funded by the Mobile Bay National Estuary Program (MBNEP) and the Department of the Army – Mobile District Corps of Engineers (Corps). The purpose of this study was to analyze and model point and nonpoint sources of pollution in the Mobile River basin contributing to Mobile Bay. The model is expected to support management of Mobile Bay and its watershed for future use.

The main objectives of this study were identified as follows:

- Develop a pollutant mass balance for the Mobile River basin, accounting for both point and nonpoint sources

- Assess the total load of pollutants, specifically nutrients (nitrogen and phosphorus), BOD_5, sediments, heavy metals, and toxic organic contaminants contributed by the Mobile River basin to Mobile Bay

- Characterize the distribution of sources and loads within the basin

To meet these objectives and develop a framework to support the decision-making process for MBNEP and the Corps in the future, a phased approach was undertaken. Three separate phases were conducted. Phase I focused on developing predictive models of the entire Mobile River basin and Mobile Bay itself to support pollutant load estimation. Phase II focused on making refinements to the predictive models, in order to permit a more detailed analysis of pollutant loading to the bay. Phase III considered management alternatives and their impacts on pollutant loading to the bay.

1.1 Phase I – Configuration of the Mobile River Basin and Bay Models

In order to estimate pollutant loads to Mobile Bay under historical, current, and hypothetical conditions, a predictive modeling framework was developed. The primary goal in developing this framework was to simulate major watershed processes, including hydrology and pollutant accumulation and transport. Simulating these major watershed processes supported estimation of pollutant loading from the entire contributing drainage area to Mobile Bay.

Although the goal of this study was to estimate pollutant contributions to Mobile Bay, the long-term goal of predictive analysis of water quality in the bay itself was considered when configuring the modeling framework. The predictive watershed model was designed to support linkage to a predictive bay model. This design consideration was tested through development of a predictive model of Mobile Bay.

Phase I of this study specifically included the following steps:

- Analysis of historical hydrologic conditions and selection of a modeling period
- Configuration of the watershed model for existing conditions
- Development and evaluation of the existing conditions loading for nutrients
- Linkage of the watershed model to the bay model
- Preliminary configuration and execution of hydrodynamics for the bay model

1.2 Phase II - Model Refinements and Development of Loading Estimates

The second phase of the project involved refining the watershed and bay models. Refinements were made to improve the accuracy of pollutant loading estimations and to make estimates for additional parameters. The steps for this phase include:

- Refinement of the watershed model through further calibration and representation of additional pollutants
- Development and evaluation of the existing conditions loading for the refined model

1.3 Phase III - Alternative Simulations

After developing and refining the model to represent existing conditions, the model was configured to represent and evaluate future loadings. The third phase involved the following:

- Prediction of the future land use distribution in selected areas of the contributing watershed
- Simulation of the effects of land use changes on loadings to Mobile Bay
- Simulation of point source facilities discharging at permitted conditions
- Development and calculation of loadings for the simulated future conditions

2.0 Watershed Background Information

The Mobile River basin is the sixth largest river system in the United States, in terms of drainage area, and the fourth largest in terms of discharge. The drainage area is 350 miles long with a maximum width of 250 miles and encompasses 32 USGS 8-digit cataloging units (Hydrologic Unit Codes or HUCs). The river system drains a watershed of more than 43,000 square miles, which includes more than two-thirds of Alabama, and portions of Mississippi, Georgia, and Tennessee. The largest towns and cities in the basin include Columbus in Mississippi; Rome in Georgia; and Anniston, Gadsden, Auburn, Birmingham, Mobile, Montgomery, and Tuscaloosa in Alabama.

Mobile Bay is located in the southernmost segment of Alabama and drains the Mobile River basin, which is a dominant influence on many factors affecting water quantity and quality in the bay. The bay is approximately 31 miles long and 10 miles wide with an average depth of 10 feet (Baya et al., 1998). There are seven major subbasins in the Mobile River basin that contribute flow to Mobile Bay (Figure 2-1):

- Mobile River
- Tombigbee
- Black Warrior
- Alabama
- Cahaba
- Coosa
- Tallapoosa

Mobile Bay has abundant natural resources that provide many recreational and commercial uses. Major uses of the bay and the bay area include the Tennessee-Tombigbee Waterway, Port of Mobile, fisheries, tourism and recreation, and coastal development. Local ecosystems are being subjected to increasing pressures from activities including commercial and recreational fishing, silviculture, oil and gas extraction, shipping and channel excavation, industrial construction and wastes, residential development, municipal waste treatment discharges, and nonpoint source runoff. The Mobile Bay area's population growth has also been of increasing concern as it contributes to increasing pressures on the surrounding environment.

The water quality conditions of the estuary are significantly influenced by upstream river inputs from the Mobile River basin above the bay. Land practices and alterations in natural flow regimes in the basin's tributaries can have significant effects on the receiving waterbodies. Inflow to the bay from the upstream waterbodies can change salinity levels, as well as provide nutrients and sediments (trace metals and minerals) that can affect the overall productivity of the estuarine cycle. An assessment of the entire Mobile River basin is vital to meeting long-term water quality goals in Mobile Bay.

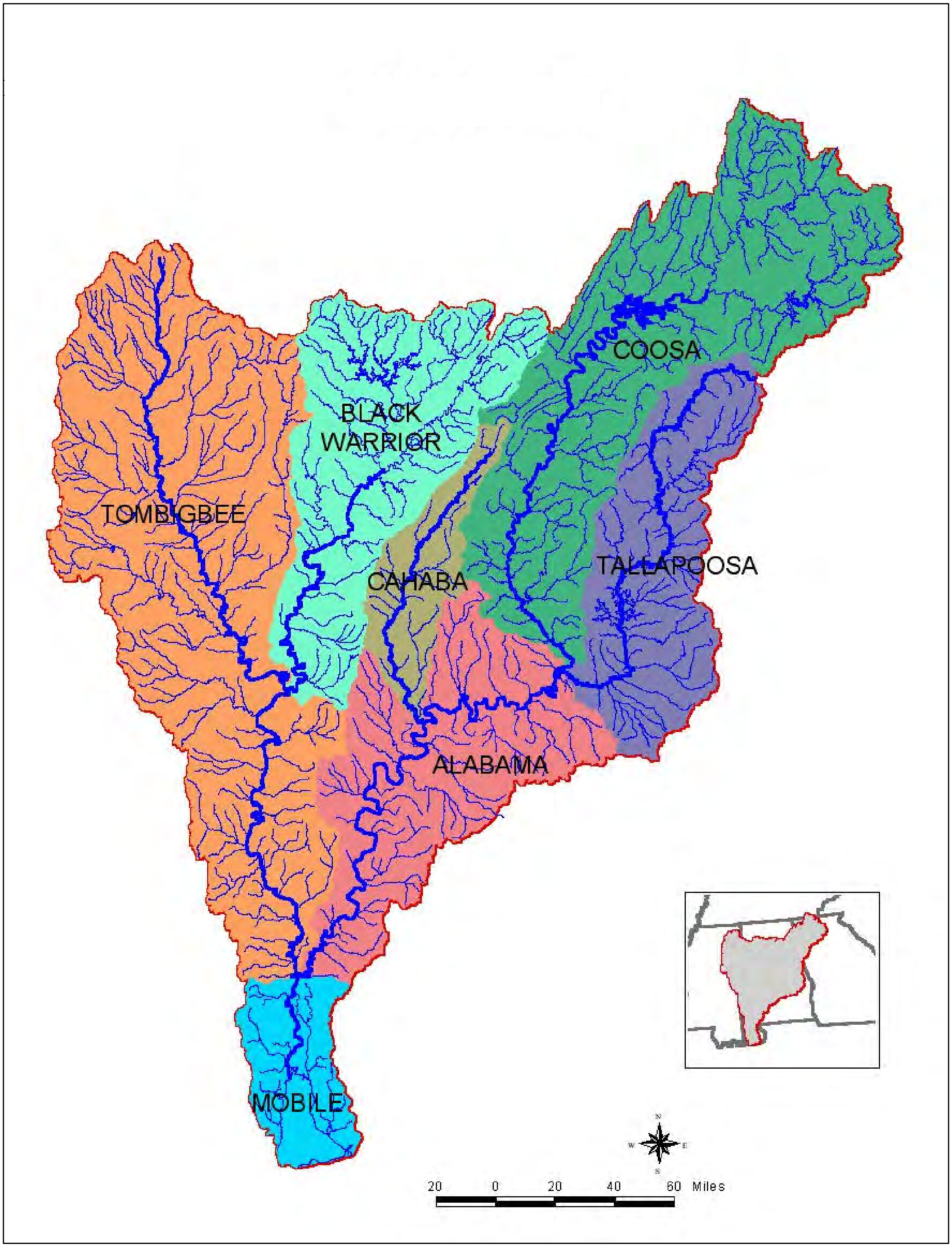

Figure 2-1. Mobile River subbasins

2.1 Topography

The topography in the Mobile River basin ranges from rugged mountains to coastal lowlands, including sloughs, bayous, marshes, and bays. The Mobile River basin is divided into five major physiographic regions as defined in the USGS National Water-Quality Assessment (NAWQA) Program - Mobile River Basin Study (USGS, 1998). The elevation in the Mobile River basin varies from sea level near Mobile Bay to over 4,000 feet above mean sea level in the Blue Ridge Mountains region of Georgia. Figure 2-2 presents the variability of elevation in the Mobile River basin, as well as the basin's physiographic regions. The five major regions in the basin are the Coastal Plains, Appalachian Plateaus, Valley and Ridge, Piedmont, and Blue Ridge.

Fifty six percent (26,179 square miles) of the basin is in the Coastal Plain region. The Coastal Plain, made up mostly of unconsolidated or poorly consolidated sand, gravel, clay, and limestone, is underlain by sand and gravel aquifer systems. The Appalachian Plateaus region encompasses 12 percent (4,926 square miles) of the basin and is dominated by relatively flat plateaus of sandstone, limestone, and shale. The region is underlain by fractured-rock systems and interconnected fractured-rock systems. The Valley and Ridge region consists of a series of parallel ridges and valleys, which have a northeast trend. The region includes 16 percent of the basin (6,232 square miles) and is underlain by sandstone, shale, limestone, and dolomite rocks. Caves and sinkholes in the limestone rocks of the Appalachian Plateaus and the Valley and Ridge regions increase the susceptibility of groundwater to contamination from surface water. The Blue Ridge and Piedmont regions are located in the northeast corner of the basin and encompass approximately 16 percent of the watershed and cover 477 and 6,268 square miles, respectively. These two regions are characterized by igneous and metamorphic rocks and are underlain by a fractured crystalline rock aquifer.

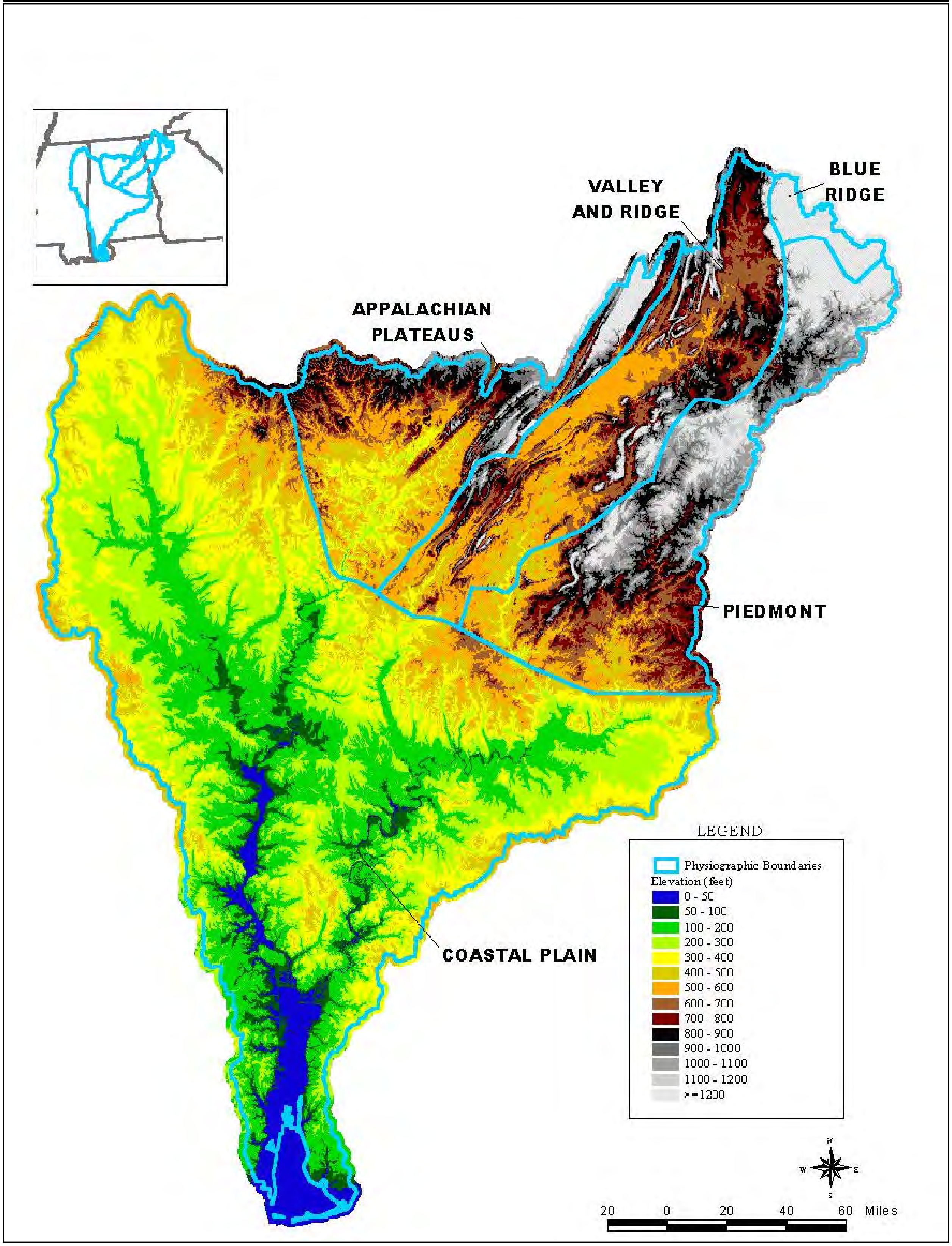

Figure 2-2. Elevations in the Mobile River basin

2.2 Soils

Soil composition varies widely throughout the basin and plays an important role in hydrology. Hydrologic soil groups, which categorize soils based on infiltration characteristics and are used for watershed runoff estimation, provide a good basis for presenting the soil distribution throughout the basin. Soils in the Mobile River basin fall into each of the four major hydrologic soil groups as defined by the Soil Conservation Service (1974); A, B, C, and D. Figure 2-3 presents the soil distributions for the Mobile River basin.

The predominant soil is type B, with types C and D also present in large areas of the basin. Characteristics of the 4 soil groups in the basin are presented in Table 2-1.

Table 2-1. Characteristics of the four soil groups in the Mobile River basin

Soil Type	Runoff Potential	Infiltration Rates (when thoroughly wetted)	Soil Texture and Drainage
A	Low	High	Typically deep, well-drained sands or gravels
B	Moderately Low	Moderate	Typically deep, moderately well to well-drained moderately fine to coarse-textured soils
C	Moderately High	Slow	Typically poorly-drained, moderately fine to fine-textured soils containing a soil layer that impedes water movement or exhibiting a moderately high water table
D	High	Extremely Slow	Typically clay soils with a higher water table and high swelling potential that may be underlain by impervious material

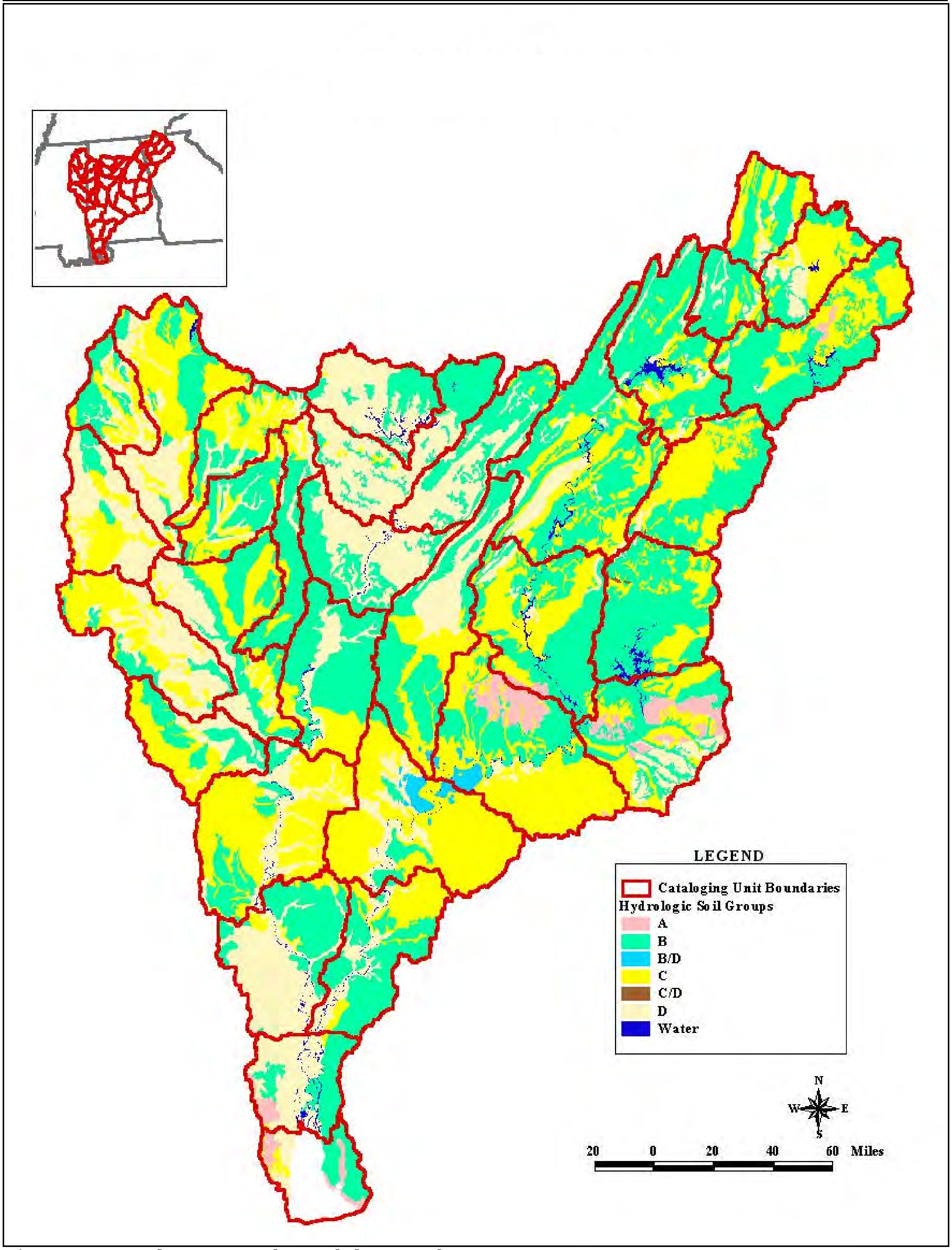

Figure 2-3. Soil groups in the Mobile River basin

2.3 Land Use

Land use data for the Mobile River basin were obtained from the USGS Multi-Resolution Landuse Characterization. This GIS coverage represents conditions in the basin during the 1990's. The coverage categorizes urban areas, rural areas, and water into more than 25 categories. These can be grouped into 7 major categories for summary purposes: urban, forest, cropland, pasture/hay, barren, water, and wetlands.

The major land use in the Mobile River basin is forested land. The remaining land uses are mainly agriculture with a small percentage of other land uses, including wetlands, streams, lakes, and reservoirs (NAWQA, 1998). Agricultural activities in the basin include row crops such as cotton, corn, hay, and soybeans, as well as aquaculture, and poultry and cattle production. Major industries include silviculture, chemical, pulp and paper, iron and steel, coal, textile manufacturing, and hydro-electric power. The 7 major land use groups and their associated percentages of coverage within the basin are presented in Table 2-2. Figure 2-4 shows the major land uses and their distribution in the Mobile River basin.

Table 2-2. Land use distribution in the Mobile River basin

Land Use	Percentage
Urban	2%
Forest	69%
Cropland	8%
Pasture and Hay	11%
Barren	2%
Water	2%
Wetlands	6%

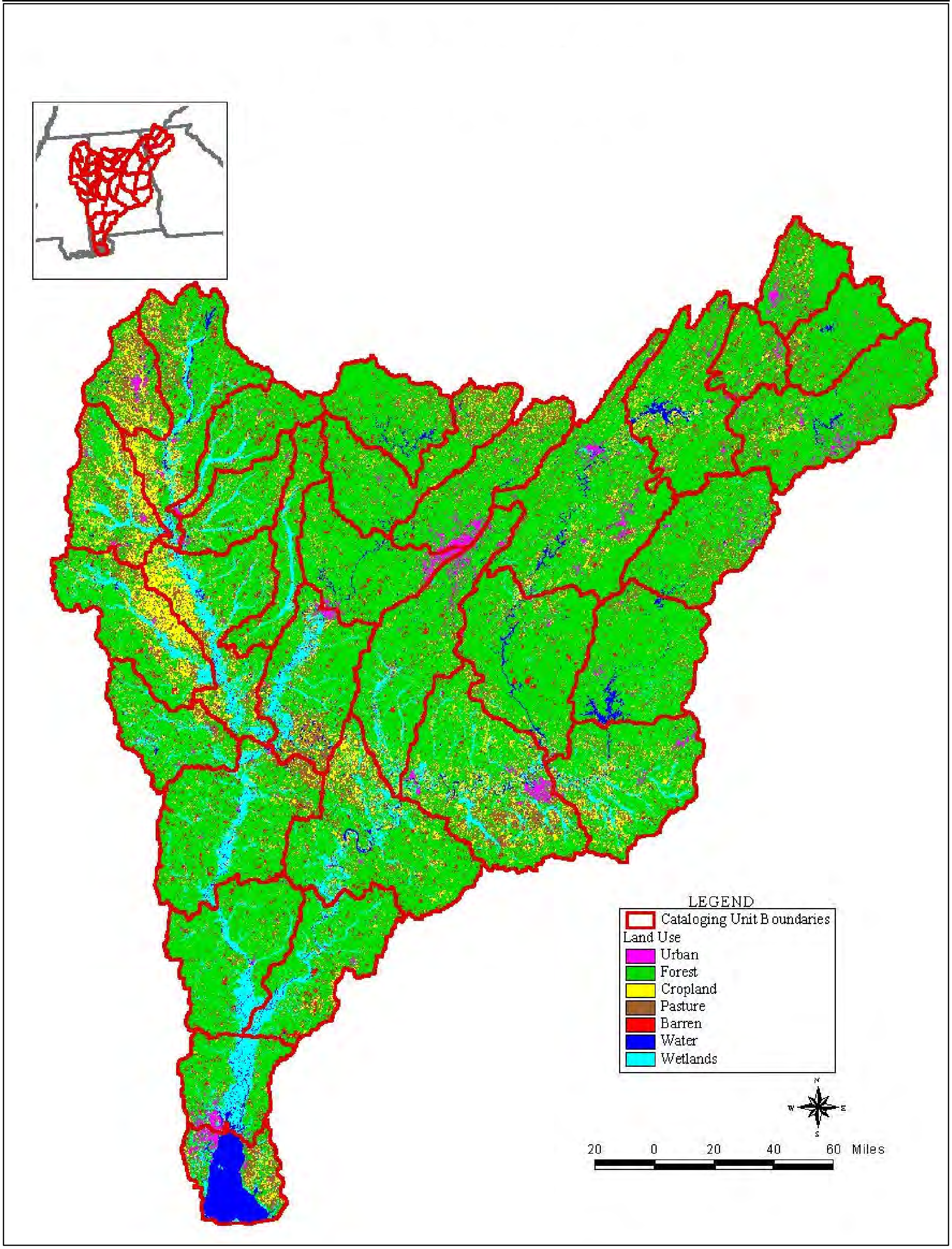

Figure 2-4. Land uses in the Mobile River basin

3.0 Technical Approach

In order to meet the objectives defined for Phases I through III of the project, development of a comprehensive watershed model was necessary to represent the Mobile River basin and an estuarine model to represent Mobile Bay. A watershed model is essentially a series of algorithms applied to watershed characteristics data. The algorithms represent naturally occurring land-based processes over an extended period of time, including hydrology and pollutant transport. Many watershed models are also capable of simulating in-stream processes using the land-based calculations as input.

Estuarine models are similar to watershed models in that they are composed of a series of algorithms applied to characteristics data. The characteristics data, however, represents physical and chemical aspects of an estuary or bay. These models vary from simple 1-dimensional box models to complex 3-dimensional models capable of simulating water movement, salinity, temperature, sediment transport, and water quality in an estuarine environment.

3.1 Model Requirements

Required capabilities of the watershed and estuarine models for the Mobile River basin and Mobile Bay were identified prior to model selection. Requirements for the watershed model included:

- simulating nonpoint source runoff and pollutant transport for multiple land use categories
- simulating flow and pollutant transport in streams and reservoirs
- representing multiple water quality constituents, including nutrients, metals, and sediment
- representing point source contributions
- estimating both local contributions to Mobile Bay and contributions from the upstream regions of the drainage area
- producing time-variable output for evaluation and application to an estuarine model

Requirements for the estuarine or bay model included:

- receiving time-variable output from the watershed model
- representing the key physical characteristics of the tidally-influenced bay in three dimensions
- modeling multiple water quality constituents, including nutrients, metals, and sediment (not for this project, but for long-term resource management)
- producing time and spatially-variable output for evaluation

3.2 Model Selection

The EPA's Better Assessment Science Integrating Point and Nonpoint Sources (BASINS, Version 2.0) – Nonpoint Source Model (NPSM) was selected as the watershed modeling platform for the Mobile River basin (USEPA, 1998). The BASINS-NPSM makes use of EPA's Hydrologic Simulation Program - FORTRAN (HSPF) to simulate hydrology (water budget for pervious and impervious land segments, accumulation and melting of snow and ice, and in-stream flow routing) and water quality (sediment, temperature, conventional pollutants, nutrients, pesticides, and user-defined constituents) (Bicknell et al., 1993).

The Environmental Fluid Dynamics Code (EFDC) was selected as the bay model (Hamrick, 1992). The EFDC is capable of modeling hydrodynamics (1-, 2-, or 3-dimensional representation, surface elevation, velocity, salinity, temperature, and suspended sediment) and water quality.

3.2.1 BASINS-NPSM Model

The EPA's BASINS Version, 2.0 and the NPSM were used to predict the significance of pollutant sources and levels in the Mobile River basin. BASINS is a multipurpose environmental analysis system for use in performing watershed and water quality-based studies. A geographic information system (GIS) provides the integrating framework for BASINS and allows for the display and analysis of a wide variety of landscape information (e.g., land uses, monitoring stations, point source dischargers).

The NPSM, which is launched from BASINS, acts as an interface to the HSPF, which in-turn, is used to simulate nonpoint source runoff from selected watersheds, as well as the transport and flow of the pollutants through stream reaches. The HSPF is a comprehensive package developed by EPA and USGS for simulating water quantity and quality for a wide range of organic and inorganic pollutants from complex watersheds. HSPF includes components to address urban and rural watershed hydrology, surface water quality analysis, and pollutant decay and transformation on the land surface and in the water column. It is a continuous simulation model that operates on an hourly time step using rainfall and other meteorological parameters as a driver. The model is intended to be used as a planning-level tool for watershed modeling that requires a dynamic simulation of both point source and nonpoint source pollutants. HSPF is a modular program that can be run in a hierarchical manner to simulate complex watershed and subwatershed systems.

3.2.2 EFDC Model

The EFDC is a comprehensive three-dimensional model capable of simulating hydrodynamics, salinity, temperature, suspended sediment, water quality, and the fate of toxic materials. The model uses stretched or sigma vertical coordinates and Cartesian or curvilinear, orthogonal horizontal coordinates to represent the physical characteristics of a waterbody. The hydrodynamic portion of the model solves three-dimensional, vertically hydrostatic, free surface, turbulent averaged equations of motion for a variable-density fluid. Dynamically-coupled transport equations for turbulent kinetic energy, turbulent length scale, salinity and temperature are also solved. The EFDC model also simultaneously solves an arbitrary number of Eulerian transport-transformation equations for dissolved and suspended materials. The EFDC model allows for drying and wetting in shallow areas by a mass conservation scheme. The physics of the EFDC model and many aspects of the computational scheme are equivalent to the widely used Blumberg-Mellor model (Blumberg & Mellor, 1987) and U. S. Army Corps of Engineers' Chesapeake Bay model (Johnson, et al, 1993).

The water quality portion of the model simulates the spatial and temporal distributions of 21 water quality parameters including dissolved oxygen, suspended algae (3 groups), various components of carbon, nitrogen, phosphorus and silica cycles, and fecal coliform bacteria. Salinity, water temperature, and total suspended solids are needed for computation of the twenty-one state variables, and they are provided by the hydrodynamic model. The kinetic processes included in this model use the Chesapeake Bay three-dimensional water quality model, CE-QUAL.ICM (Cerco & Cole, 1994).

A sediment process model with 27 state variable is also included in the EFDC model. It uses a slightly modified version of the Chesapeake Bay three-dimensional model (DiToro & Fitzpatrick, 1993). The sediment process model, upon receiving the particulate organic matter deposited from the overlying water column, simulates their diagenesis and the resulting fluxes of inorganic substances (ammonium, nitrate, phosphate and silica) and sediment oxygen demand back to the water column. The coupling of the sediment process model with the water quality model not only enhances the model's predictive capability of water quality parameters but also enables it to simulate the long-term changes in water quality conditions in response to changes in nutrient loads.

Figure 3-1 shows a schematic of the various processes included in the EFDC water column simulation. This figure does not include the sediment component of the model.

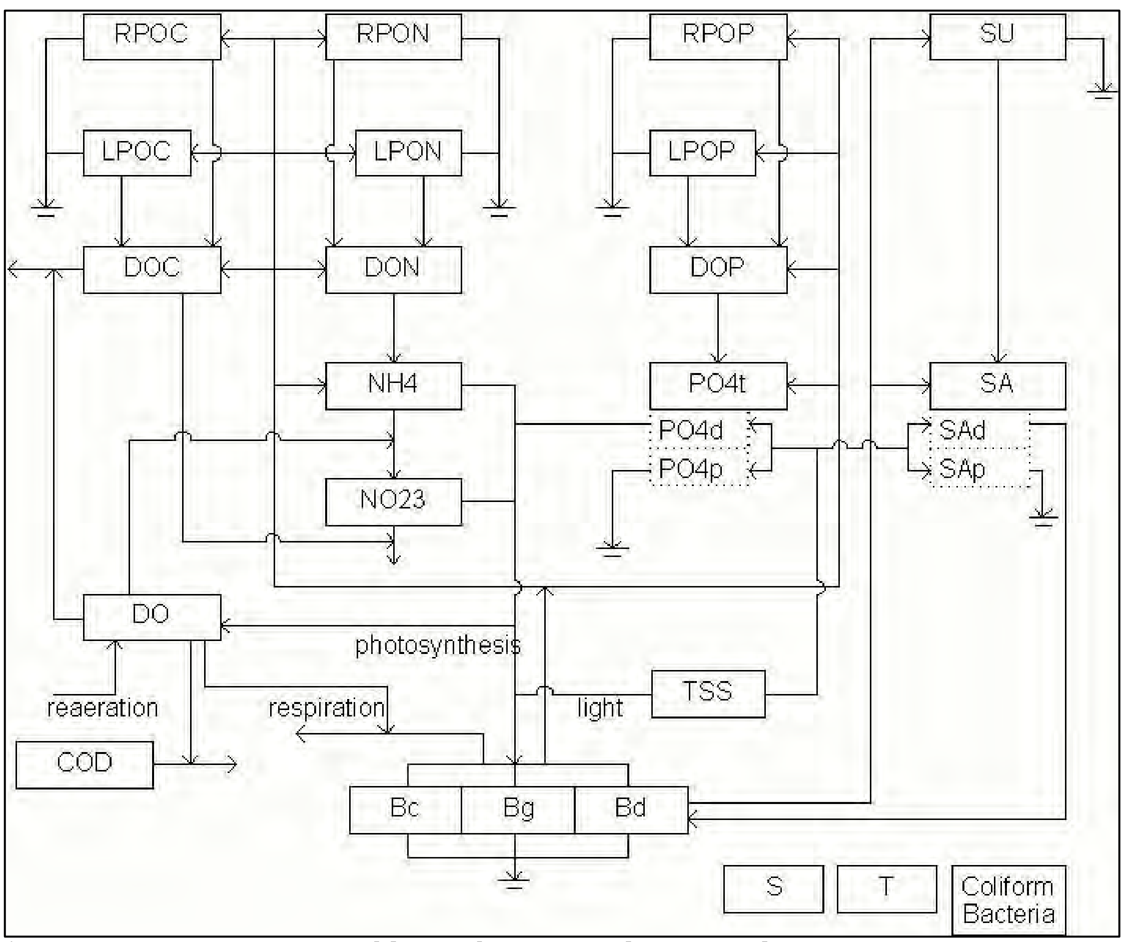

Figure 3-1. EFDC state variables in the water column simulation

3.3 Modeling Technique and Linkages

The watershed and bay models were developed separately, however they were designed to function together. Application of the models required division of the study area into discrete regions for model representation. Representation of the Mobile River basin using BASINS-NPSM required subdivision of the entire 43,000 mi^2 watershed into smaller hydrologic units. The watershed was therefore divided into 152 subwatersheds, in order to better represent land units draining into major rivers and Mobile Bay. The subdivision was based on elevation, stream connectivity, and the locations of monitoring stations.

Mobile Bay and tidally-influenced portions of the Mobile, Tensaw, and Middle Rivers were segmented into discrete cells for representation in the bay model. Over 1,000 three-dimensional cells were used to represent discrete regions of the bay and capture the variability of the bay's geometry.

The watershed model was configured to simulate nonpoint source flow and pollutant loadings for all subwatersheds, route flow and water quality through streams and rivers, and account for all major point source discharges in the basin. After configuration, the model was subjected to a rigorous testing process referred to as calibration. Once the model was calibrated and deemed acceptable for loading estimation purposes, it was run for a long-term historical period. Based on an analysis of historical hydrologic conditions, this period was selected as 1970 through 1995. The bay model was configured to receive time-variable output from the watershed model for use in simulating hydrodynamics, including water depth, velocities, salinity, temperature, and sediment for Mobile Bay. Figure 3-2 presents a map of the modeled area, including subwatersheds represented in the watershed model and cells represented in the bay model.

3.3.1 Watershed Segmentation

The Mobile River basin is comprised of 32 USGS 8-digit Cataloging Units. For modeling purposes, 30 of the 32 Cataloging Units in the basin were segmented into 104 subwatersheds. These 30 Cataloging Units represented the majority of the drainage area, excluding the immediate drainage area to Mobile Bay. The segmentation was based on the Cataloging Unit boundaries and the locations of major river systems. Further segmentation was required to appropriately represent major reservoirs and to align subwatershed outfalls with the locations of flow and water quality monitoring stations for calibration. The remaining two cataloging units, which make up the southern-most portion of the basin and are in closest proximity to Mobile Bay, were segmented into 48 subwatersheds. Segmentation of this area was performed at a higher resolution than in the remainder of the basin, to better represent immediate contributions to Mobile Bay. This segmentation was based on major river systems entering the bay.

By dividing the drainage area into multiple subwatersheds, the variability of land use, soils, meteorology, and other physical characteristics throughout the basin were represented. Each individual subwatershed was represented in the model with unique area, land use distribution, soils, and meteorological characteristics. Figure 3-2 shows the subwatersheds that were simulated in the watershed model. Appendix A contains enlarged images showing the subwatershed IDs for the upper and lower basin area.

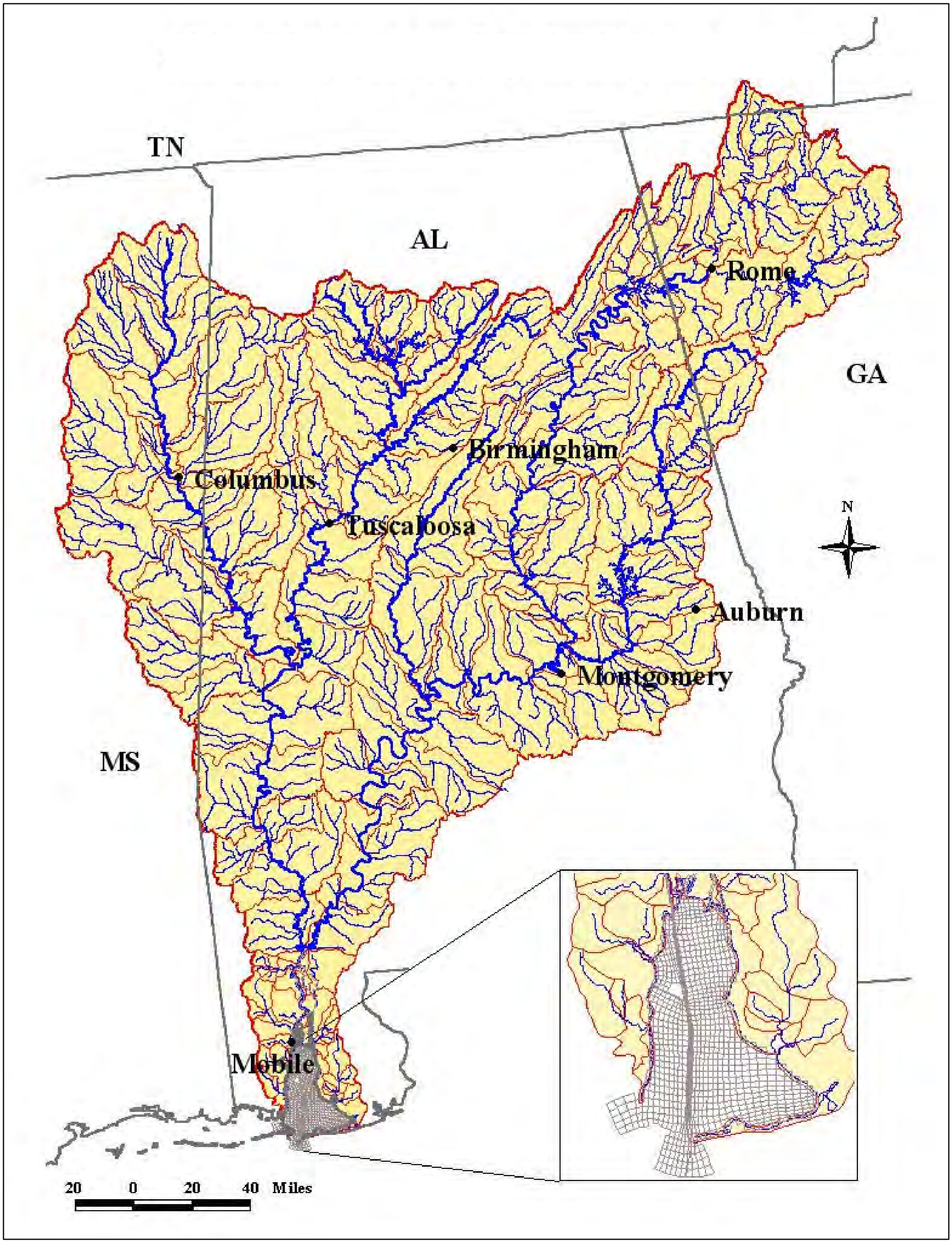

Figure 3-2. Modeling overview

3.3.2 Bay Segmentation

To simulate hydrodynamics in the bay and to enable future use of the model for water quality simulation, a 1,350-cell grid was developed. The grid represented Mobile Bay itself, from the city of Mobile in the north to south of Mobile Bay Point, as well as the tidally-influenced Mobile, Tensaw, and Middle Rivers.

All cells representing the bay portion of the grid were 3-dimensional (curvilinear with 4 vertical layers). The cells were configured such that large shallow areas of low bathymetric variability and deep and narrow navigation channels were represented. Simulating four vertical layers permitted representation of potential vertical stratification in the bay. Cells representing the tidally-influenced rivers feeding into the bay were represented in one dimension, due to predominantly longitudinal flow patterns. The Bay Model Section of this report provides more detail regarding cell representation and grid generation. Figure 3-3 shows the bay model grid.

Cells representing the outer extent of the bay and connections to major rivers received input from the watershed model. These inputs served as boundary conditions during simulation of the hydrodynamics in the bay.

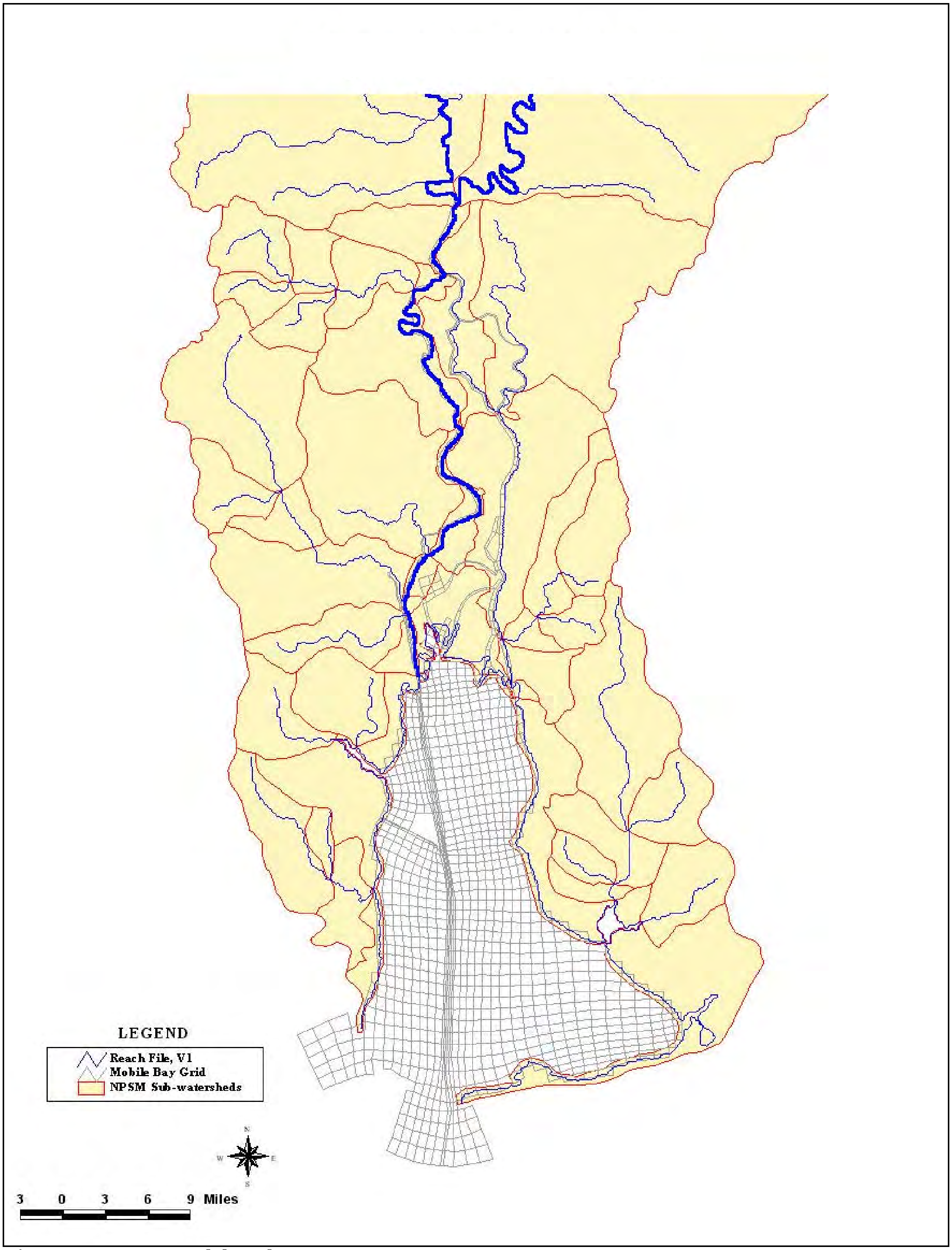

Figure 3-3. Bay model grid

4.0 Watershed Model

Development and application of the watershed model to address the project objectives involved a number of important steps:

1. Watershed Segmentation
2. Analysis of Hydrologic Conditions
3. Configuration of Key Model Components
4. Model Calibration and Validation
5. Model Execution for Existing Conditions
6. Model Execution for Future Conditions

Watershed segmentation was previously described in Section 3.3.1 and refers to the subdivision of the entire Mobile River basin into 152 subwatersheds for modeling and analysis. Another key step taken prior to configuring the model was to analyze hydrologic conditions. This was done to determine a modeling period representative of virtually all potential hydrologic conditions.

Configuration of the model itself involved consideration of five major components: meteorological data, land use representation, hydrologic and pollutant representation, stream and reservoir representation, and point sources. These components provide the basis for the model's ability to estimate flow and pollutant loadings. Meteorological data essentially drive the watershed model. Rainfall and other parameters are key inputs to HSPF's hydrologic algorithms. The land use representation provides the basis for distributing soils and pollutant loading characteristics throughout the basin. Hydrologic and pollutant representation refers to the HSPF modules or algorithms used to simulate hydrologic processes (e.g., surface runoff, evapotranspiration, and infiltration, and pollutant loading processes (primarily accumulation and washoff). Stream and reservoir representation refers to HSPF modules or algorithms used to simulate flow and pollutant transport through streams, rivers, and reservoirs. While nonpoint source contributions are represented through hydrologic and pollutant representation for the watershed, point source contributions are considered separately, as direct contributions to streams, rivers, and reservoirs.

After configuring the model, the model was tested for validity through a calibration and validation process. The calibrated and validated model was then run to simulate existing conditions and estimate flow and pollutant loads to Mobile Bay. After generating existing loads, estimates of the future land use distribution in the southern portion of the basin and permitted facility loads were made. The model was reconfigured and rerun to represent these future changes for a comparison to existing conditions.

4.1 Analysis of Hydrologic Conditions

Precipitation data, flow observation data, and Palmer Drought Indices were analyzed for the Mobile River basin in order to select a simulation period for the watershed model. The objective of the analysis was to identify time periods representing a wide range of hydrologic conditions, including mean, dry, and wet years, and seasonal extremes, including high winter-spring flows, low late summer flows, and a tropical storm condition. Results of the analysis indicated that the period 1970 through 1995 was appropriate for simulation. Table 4-1 summarizes the results of the hydrologic analysis through identification of conditions and corresponding time periods.

Table 4-1. Hydrologic conditions covered by the 1970 – 1995 modeling period

Hydrologic Condition	Representation Interval
Mean Year	October 1993 - September 1994
Wet Year	October 1989 - September 1990
Dry Year	October 1980 - September 1981
Seasonal Extreme - High Winter - Spring Flows	Winter - Spring of 1990
Seasonal Extreme - Low Late Summer Flows	Summer of 1988
Extreme Tropical Storm Condition	1979 (Hurricane Frederic, class 3) 1995 (Hurricane Opal, class 3)

4.2 Meteorological Data

Meteorological data are a critical component of the watershed model. Appropriate representation of precipitation, wind speed, potential evapotranspiration, cloud cover, temperature, and dew point are required to develop a valid model. These data provide necessary input to HSPF algorithms for hydrologic and water quality representation. Meteorological data were accessed from a number of sources in an effort to develop the most representative dataset for the Mobile River basin.

In general, hourly precipitation data are recommended for nonpoint source modeling. Therefore, only weather stations with hourly-recorded data were considered in development of a representative meteorological dataset. Long-term hourly precipitation data from twenty-one National Climatic Data Center (NCDC) weather stations located within or near the Mobile River basin were used to represent rainfall (Table 4-2). These stations sufficiently represent rainfall variability throughout the basin.

Long-term hourly wind speed, cloud cover, temperature, and dew point data were available for a subset of the weather stations used to represent rainfall in the region. Applicable data were obtained from Mobile, Montgomery, Meridian, and Birmingham. Hourly potential evapotranspiration data were calculated for each of these stations using the HSPF utility METCMP and the available meteorological data.

Table 4-2. Weather stations represented in the watershed model

Station Name	State	NCDC ID
ADDISON	AL	63
ALBERTA	AL	140
ATMORE	AL	407
BERRY 3 S	AL	748
BIRMINGHAM FAA ARPT	AL	831
DADEVILLE 2	AL	2124
DAUPHIN ISLAND #2	AL	2172
JACKSONVILLE	AL	4209
MIDWAY	AL	5397
MOBILE WSO ARPT	AL	5478
MONTGOMERY WSO ARPT	AL	5550
PETERMAN	AL	6370
THORSBY EXP STATION	AL	8209
WARRIOR LOCK AND DAM	AL	8673
CALHOUN EXP STATION	GA	1474
CANTON	GA	1585
CARROLLTON	GA	1640
ABERDEEN	MS	21
BOONEVILLE	MS	955
LOUISVILLE	MS	5247
MERIDIAN WSO ARPT	MS	5776

The 21 weather stations with rainfall data formed the basis of the meteorological dataset for the model. Meteorological data from the closest weather station with meteorological data were combined with rainfall data to create a complete dataset at each of the 21 locations. Data from each of these stations were applied to subwatersheds falling within the designated Thiessen polygons (Figure 4-1). All meteorological data were compiled into a watershed data management (WDM) file for use with the model. The WDM file is a mechanism for efficiently storing large time-series datasets.

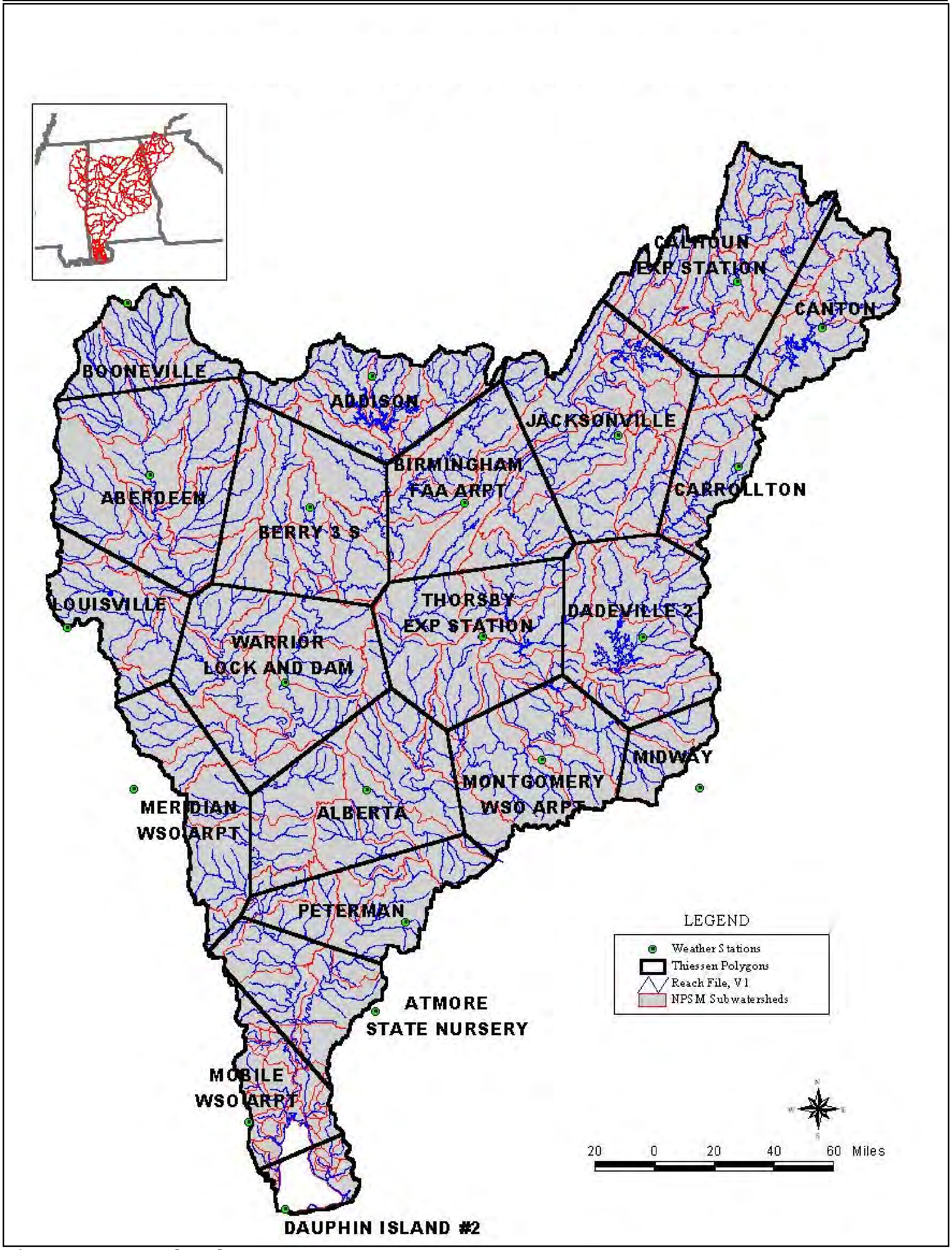

Figure 4-1. Weather data stations

4.3 Land Use Representation

The watershed model for the Mobile River basin required a basis for distributing hydrologic and pollutant loading parameters. This was necessary to appropriately represent hydrologic variability throughout the basin, which is influenced by land surface and subsurface characteristics. It was also necessary to represent variability in pollutant loading, which is highly correlated to land practices.

The USGS's Multi-Resolution Landuse Characterization (MRLC) data provided this basis. The MRLC dataset is a land use coverage with more than 25 classifications for urban and rural areas. The coverage represents land characteristics from the early to middle 1990's. The original land use categories from the MRLC dataset were reclassified into 10 categories for the watershed model. These categories were selected primarily to represent major contributing sources of nutrients and pollutants, as well as to represent hydrologic variability. The land use categories represented in the model are as follows:

- Urban
- Forest
- Wetlands
- Barren
- Pasture
- Cropland – cotton
- Cropland – soybeans
- Cropland – corn
- Cropland – hay
- Cropland – other

The distribution of the aforementioned land use categories was determined for each of the 152 subwatersheds in the Mobile River basin. The area of each category was determined directly from grouping MRLC categories (Table 4-3), except in the cases of pasture and cropland. Pasture and cropland categories were determined by using the MRLC data and 1992 Agricultural Census Data.

Table 4-3. MRLC land use codes and model grouping

Modeled Land Use	MRLC Land Use Code	MRLC Land Use
Forest	40	Natural Forested Upland (non-wet)
	41	Deciduous Forest
	42	Evergreen Forest
	43	Mixed Forest
	50	Natural Shrubland
	51	Deciduous Shrubland
	52	Evergreen Shrubland
	53	Mixed Shrubland
	70	Herbaceous Upland Natural/Semi-Natural Vegetation
	71	Grassland/Herbaceous Upland Natural
Wetland	90	Wetlands
	91	Woody Wetlands
	92	Emergent Herbaceous Wetlands
Pasture	81	Pasture/Hay
Cropland*	60	Non-natural Woody
	61	Planted/Cultivated (Orchards, vineyards, groves)
	82	Row Crops
	83	Small Grains
Barren	30	Barren
	31	Bare Rock/Sand/Clay
	32	Quarries/Strip Mines/Gravel Pits
	33	Transitional
	84	Bare Soil
Urban	20	Developed
	21	Low Intensity Residential
	22	High Intensity Residential
	23	High Intensity Commercial/Industrial/Transportation
	85	Other Grasses (Urban/Recreation)

* For modeling purposes, the Cropland category was distributed into Cropland-cotton, Cropland-soybeans, Cropland-corn, Cropland-hay, and Cropland-other using 1992 Agricultural Census Data.

4.4 Hydrology and Nonpoint Source Loading Representation

HSPF algorithms require that land use categories be divided into separate pervious and impervious land units for modeling. This division was made for the urban land use, in order to represent impervious and pervious areas separately. The division was based on typical impervious percentages associated with different land use types from the Soil Conservation Service's TR-55 Manual (Table 4-4). HSPF model algorithms simulating major hydrologic and pollutant loading processes were then applied to each pervious and impervious land unit.

Table 4-4. Imperviousness percentages used for pervious/impervious land unit division

MRLC Land Uses	% Imperviousness
Low Intensity Residential	15.5
High Intensity Residential	65
High Intensity Comm./Ind./Trans.	75

4.4.1 Hydrology Representation

The HSPF PWATER (water budget simulation for pervious land segments) and IWATER (water budget simulation for impervious land segments) modules were used to represent hydrology for all pervious and impervious land units. Designation of key hydrologic parameters in the PWATER and IWATER modules of HSPF was required. These parameters were associated with infiltration, groundwater flow, and overland flow. Key parameters are summarized in Table 4-5 and Table 4-6.

The STATSGO Soils Database included in BASINS served as a starting point for designation of infiltration and groundwater flow parameters. For parameter values not easily derived from STATSGO, documentation on past HSPF applications was accessed. Parameter values from these applications were used as a starting point for the model runs. Starting values for overland flow parameters were also derived from past HSPF applications (Nonpoint Source Pollutant Loading Evaluation – ACT & ACF Water Allocation Formula Environmental Impact Statements; Water Quality Improvements in the Lower Mississippi River Valley: Analysis of Nutrient and Sediment Loadings in the Yazoo River Basin), with the exception of subwatershed slopes, which were derived from Digital Elevation Model (DEM) data. Starting values were refined through the hydrologic calibration process. The calibration process is described in detail in Section 4.7 of this report.

Table 4-5. Key hydrologic parameters in HSPF—PWATER

HSPF Module	Data Group	Parameter	Definition	Units
PWATER	PWAT - PARM2	LZSN	lower zone nominal storage	in
		INFILT	index to the infiltration capacity of the soil	in/hr
		LSUR	length of the assumed overland flow plane	ft
		SLSUR	slope of assumed overland path	
		KVARY	parameter which affects the behavior of groundwater recession flow	1/in
		AGWRC	basic groundwater recession rate if KVARY is zero and there is no inflow to groundwater	1/day
	PWAT - PARM3	INFEXP	exponent in the infiltration equation	
		INFILD	ratio between the max and mean infiltration capacities over the PLS	
		DEEPFR	fraction of groundwater inflow which will enter deep (inactive) groundwater and be lost	
		BASETP	fraction of remaining potential E-T which can be satisfied from baseflow (groundwater outflow)	
		AGWETP	fraction of remaining potential E-T which can be satisfied from active groundwater storage if enough is available	
	PWAT - PARM4	INTFW	interflow inflow parameter	none
		IRC	interflow recession parameter	none 1/day
		MON - INTERCEP	monthly values of interception storage	in
		MON - MANNING	monthly values of Manning's constant for overland flow	
		MON - LZETPARM	monthly values of the lower zone ET parameter. It is an index to the density of deep-rooted vegetation.	

Table 4-6. Key hydrologic parameters in HSPF—IWATER

HSPF Module	Data Group	Parameter	Definition	Units
IWATER	IWAT-PARM2	LSUR	length of the assumed overland flow plane	none ft
		SLSUR	slope of the assumed overland flow plane	none

4.4.2 Nonpoint Source Loading Representation

Pollutants represented in the watershed model include:

- total nitrogen
- total phosphorus
- BOD_5
- zinc
- copper

- lead
- sediment

Pollutant loading processes for all pollutants except sediment were represented for each land unit using the HSPF PQUAL (simulation of quality constituents for pervious land segments) and IQUAL (simulation of quality constituents for impervious land segments) modules. These modules simulate the accumulation of pollutants during dry periods and the washoff of pollutants during storm events. Starting values for parameters relating to land-use-specific accumulation rates and buildup limits were derived from literature. These starting values were refined through the water quality calibration process. Key parameters are summarized in Tables 4-7 and 4-8. Although atmospheric deposition is not explicitly simulated in the current watershed model configuration, it is represented implicitly in the model through the land use- and pollutant-specific accumulation rates.

Table 4-7. Key water quality parameters in HSPF—PQUAL

HSPF Module	Data Group	Parameter	Definition	Units
PQUAL	QUAL - INPUT	POTFW	washoff potency factor	qty/ton
		POTFS	scour potency factor	qty/ton
		ACQOP	rate of accumulation of QUALOF	qty/ac/day
		SQOLIM	maximum storage of QUALOF	qty/ac
		WSQOP	rate of surface runoff which will remove 90 percent of stored QUALOF per hour	in/hr
		IOQC	concentration of the constituent in interflow outflow	qty/ft^3
		AOQC	concentration of the constituent in active groundwater outflow	qty/ft^3

Table 4-8. Key water quality parameters in HSPF—IQUAL

HSPF Module	Data Group	Parameter	Definition	Units
IQUAL	QUAL - INPUT	SQO	initial storae of QUALOF on the surface of the ILS	qty/ac
		POTFW	washoff potency factor	qty/ton
		ACQOP	rate of accumulation of QUALOF	qty/ac/day
		SQOLIM	maximum storage of QUALOF	qty/ac
		WSQOP	rate of surface runoff which will remove 90% of stored QUALOF per hour	in/hr

Sediment and solids accumulation and washoff were represented using the SEDMNT (production and removal of sediment for pervious areas) and SOLIDS (accumulation and removal of solids for impervious areas) modules of HSPF. Required parameters were derived from past studies and were refined through the water quality calibration process. Key parameters are summarized in Tables 4-9 and 4-10.

Table 4-9. Key sediment parameters in HSPF—SEDMNT

HSPF Module	Data Group	Parameter	Definition	Units
SEDMNT	SED - PARM2	SMPF	supporting management practice factor	
		KRER	coefficient in the soil detachment equation	
		JRER	exponent in the soil detachment equation	
		AFFIX	fraction by which detached sediment storage decreases each day, as a result of soil compaction	1/day
		COVER	fraction of land surface which is shielded from erosion by rainfall (not considering snow cover)	
		NVSI	rate at which sediment enters detached storage from the atmosphere	lb/ac/day
	SED - PARM3	KSER	coefficient in the detached sediment washoff equation	
		JSER	exponent in the detached sediment washoff equation	
		KGER	coefficient in the matrix soil scour equation (simulates gully erosion, etc.)	
		JGER	exponent in the matrix soil scour equation	

Table 4-10. Key sediment parameters in HSPF—SOLIDS

HSPF Module	Data Group	Parameter	Definition	Units
SOLIDS	SLD - PARM2	KEIM	coefficient in the solids washoff equation	
		JEIM	exponent in the solids washoff equation	
		ACCSDP	rate at which solids are placed on the land surface	tons/ac/day
		REMSDP	fraction of solids storage which is removed each day	1/day

4.5 Stream and Reservoir Representation

Modeling the entire Mobile River basin required routing flow and pollutants through numerous stream networks. These stream networks connected all of the subwatersheds represented in the watershed model. Routing required development of rating curves for major streams in the networks, in order for the model to simulate hydraulic processes. Hydraulic formulations typically estimate in-stream flow, water depth, and velocity using continuity and momentum equations.

Stream characteristics, including mean widths, depths, and slopes, from the Reach File, Version 1 database in BASINS were applied to development of rating curves. Streams were assumed to be completely-mixed, one-dimensional segments with a trapezoidal cross-section. The rating curves consisted of a representative depth-outflow-volume-surface area relationship for each major waterbody (one for each of the 152 subwatersheds).

Routing through major reservoirs in the basin was also necessary. Due to the scale of the analysis and the stated objectives, all reservoirs in the basin were also assumed to be completely-mixed, one-dimensional segments. Rating curves for these segments were developed in the same manner as for streams.

In-stream flow calculations were made using the HYDR (hydraulic behavior simulation) module in HSPF. In-stream pollutant transport was performed using the ADCALC (advective calculations for constituents), GQUAL (generalized quality constituent simulation), and SEDTRN (sediment simulation) modules. Key parameters are summarized in Tables 4-11 and 4-12.

Table 4-11. Key water quality parameters in HSPF—GQUAL

HSPF Module	Data Group	Parameter	Definition	Units
GQUAL	GQ – GEN DECAY	FSTDEC	first order decay rate for qual	1/day
		THFST	temperature correction coefficient for first order decay of qual	
	GQ – SED DECAY	KSUSP	decay rate for qual adsorbed to suspended sediment	1/day
		THSUSP	temperature correction for decay of qual on suspended sediment	
		KBED	decay rate for qual adsorbed to bed sediment	1/day
		THBED	temperature correction coefficient for decay of qual on bed sediment	

Table 4-12. Key sediment parameters in HSPF—SEDTRN

HSPF Module	Data Group	Parameter	Definition	Units
SEDTRN	SED – GEN PARM	BEDWID	width of the cross-section over which HSPF will assume bed sediment is deposited regardless of stage, top-width, etc.	ft
		POR	porosity of the bed (volume voids / total volume)	
	SED – HYD PARM	DB50	median diameter of bed sediment	in
	SAND - PM	D	effective diameter of the transported sand particles	in
		W	corresponding fall velocity in still water	in/sec
		RHO	density of the sand particles	gm/cm^3
		KSAND	coefficient in the sand load power function formula	
		EXPSND	exponent in the sandload power function formula	
	SILT - PM	D	effective diameter of the particles	in
		W	fall velocity in still water	in/sec
		RHO	density of the particles	gm/cm^3
		TAUCD	critical bed shear stress for deposition. Above this stress, there will be no deposition	lb/ft^2
		TAUCS	critical bed shear stress for scour. Below this value there will be no scour	lb/ft^2
		M	erodibility coefficient of the sediment	lb/ft^2/d
	CLAY - PM	D	effective diameter of the particles	in
		W	fall velocity in still water	in/sec
		RHO	density of the particles	gm/cm^3
		TAUCD	critical bed shear stress for deposition. Above this stress, there will be no deposition	lb/ft^2
		TAUCS	critical bed shear stress for scour. Below this valuek there will be no scour	lb/ft^2
		M	erodibility coefficient of the sediment	lb/ft^2/d

4.6 Point Sources

In order to analyze total pollutant contributions to Mobile Bay, it was necessary to consider contributions from major point source facilities. One hundred and seventy-six major point source facilities discharging within the basin were represented in the watershed model (Figure 4-2). These facilities were identified using EPA's Permit Compliance System (PCS) database. Monitored flow and pollutant concentrations were accessed from PCS and used to estimate typical flow and loading from each facility. In situations where discharge monitoring data were not available, the facility type (based on SIC code) was reviewed and typical pollutant contributions for that type of facility were assigned. Contributions from municipal facilities in Alabama were reviewed and updated by the Alabama Department of Environmental Management (ADEM) for incorporation into the model.

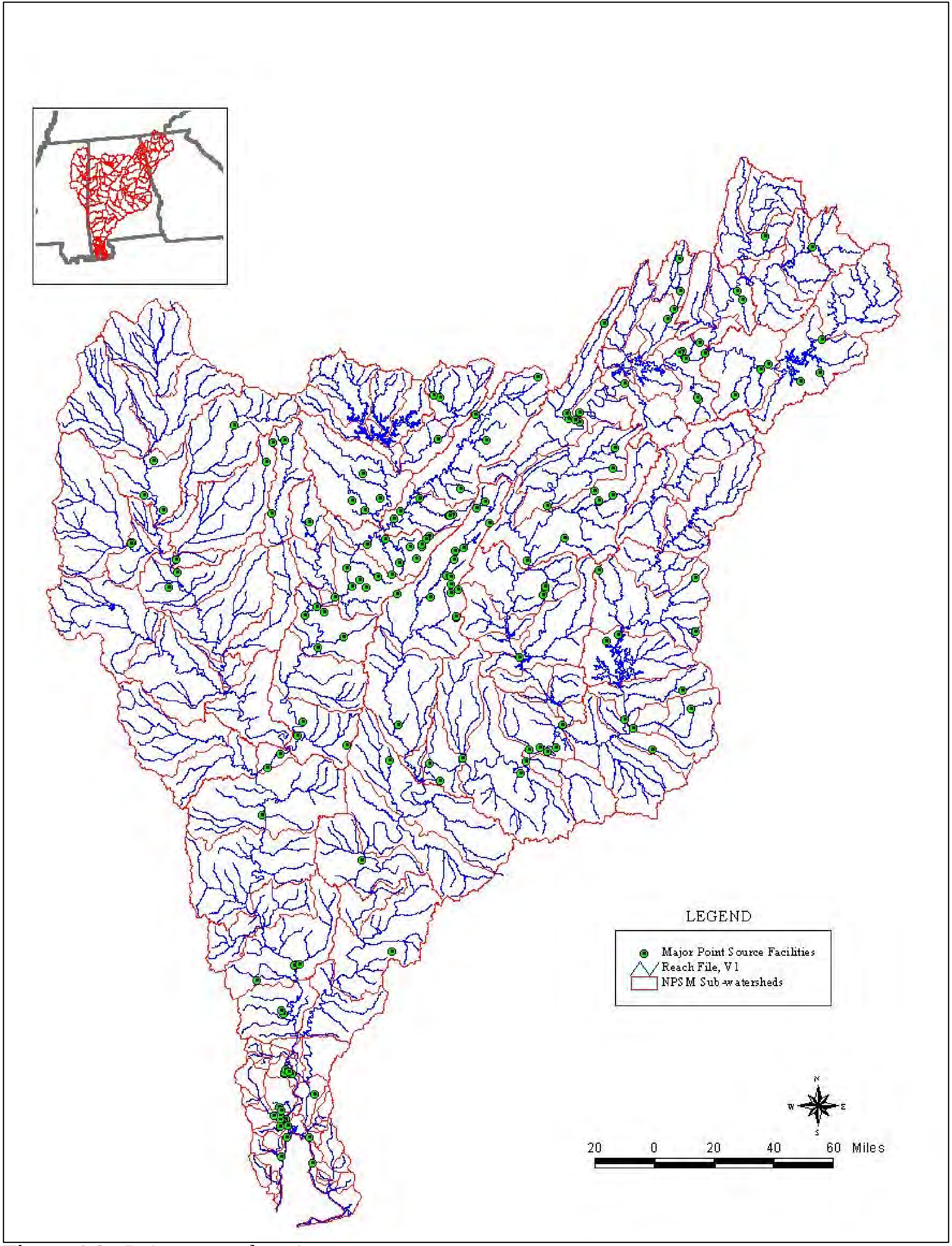

Figure 4-2. Point source locations

All facilities were represented as discharging constantly in the watershed model. A complete list of facilities located in the basin, the average loading used for the model, and the concentrations used to estimate loadings is included in Appendix B.

4.7 Model Calibration and Validation of the Watershed Model

After initially configuring the watershed model for the Mobile River basin, model calibration and validation were performed. Calibration refers to the adjustment or fine-tuning of modeling parameters to reproduce observations. The calibration was performed for different HSPF modules at multiple locations throughout the basin. This approach ensured that heterogeneities throughout the basin were accurately represented. The model validation was performed to test the calibrated parameters at different locations, without further adjustment. Upon completion of the calibration and validation at selected locations, a calibrated dataset containing parameter values for each modeled land use and pollutant was developed.

Calibration and validation were completed by comparing time-series model results to monitoring data. Output from the watershed model was in the form of daily average flow and daily average concentrations for total nitrogen, total phosphorus, BOD_5, zinc, copper, lead, iron, and sediment for each of the 152 streams (one for each subwatershed) representing the Mobile River basin. Flow monitoring data were available at USGS flow gauging stations located throughout the basin. Water quality monitoring data for selected stations were available from EPA's STORET database.

4.7.1 Hydrologic Calibration

Hydrology was the first model component calibrated. Hydrology for the Mobile River basin was calibrated through a comparison of observed data from in-stream USGS flow gauging stations to modeled in-stream flow by adjusting key hydrologic parameters (Tables 4-5 and 4-6). Seven locations were selected for hydrology calibration (Figure 4-3). These locations were selected to represent the major physiographic regions within the basin, with the exception of the Blue Ridge (which accounts for less than 1% of the basin's area) (Table 4-13). Physiographic regions represent areas with homogeneous physical properties, and these properties have a direct influence on hydrologic properties. The USGS gauging stations representing the selected subwatersheds also had sufficient data to perform the calibration. A summary of watershed characteristics influencing hydrology is presented for each of the calibration subwatersheds in Table 4-14.

Table 4-13. Subwatersheds and USGS gage stations used for hydrology calibration

Physiographic Region	Subwatershed	USGS Gage Station
Coastal Plain	50201034	02421000
	60101054	02431000
	60202004	02467500
	60204122	02471001
Appalachian Plateaus	60109008	02450000
Valley and Ridge	50101005	02387000
Piedmont	50104031	02392000

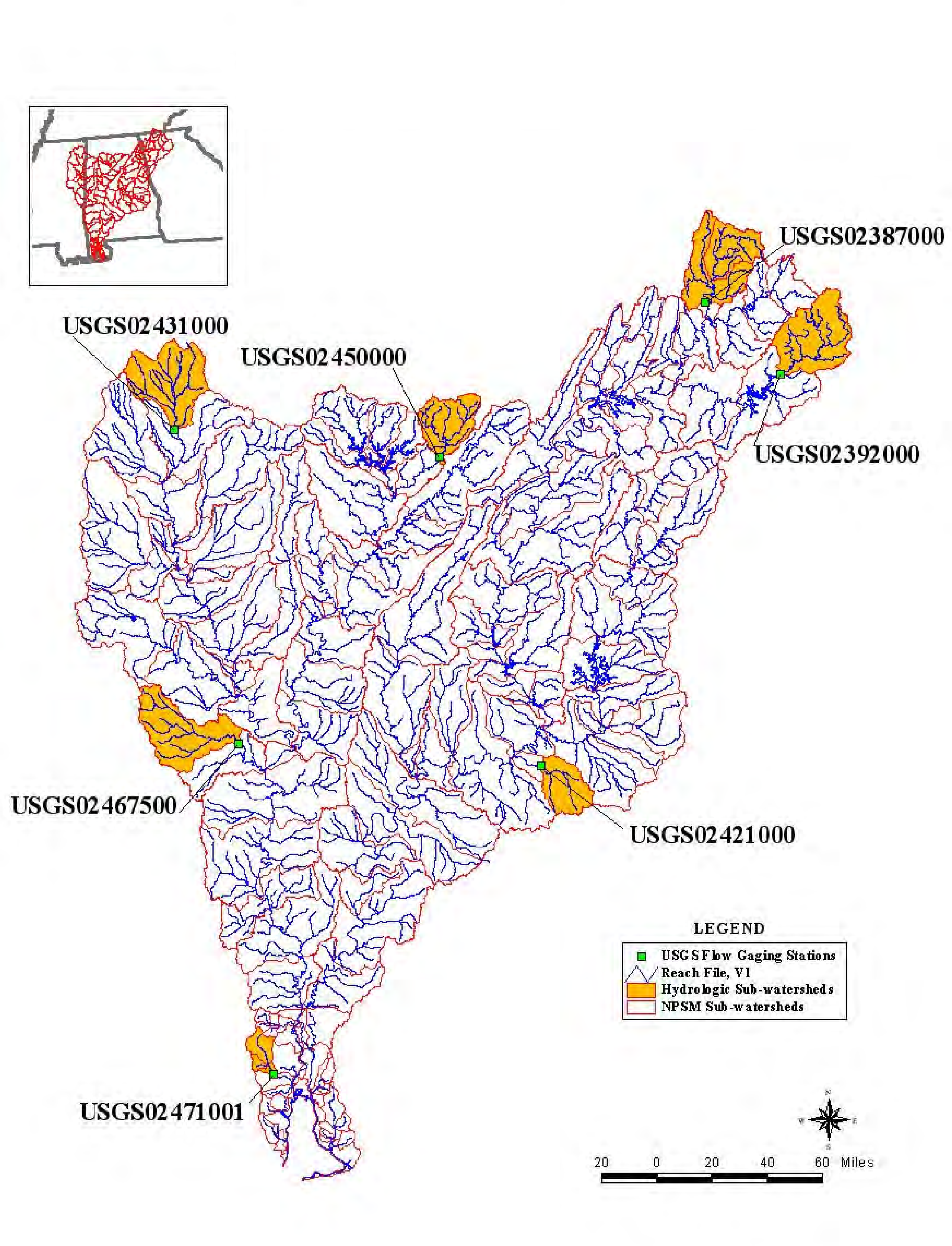

Figure 4-3. Hydrologic calibration locations

Table 4-14. Watershed characteristics influencing hydrology

USGS Gauge	02387000	02392000	02450000	02431000	02467500	02421000	02471001
Dams	No	No	No	No	No	No	No
Nearby Cities	No	No	No	No	No	Montgomery	No
Soil Type 1	80% B	50% B	80% B	80% C	40% B	100% C	100% D
Soil Type 2	20% C	50% C	20% D	20% B	40% C		
Soil Type 3					20% D		
Topography	Valley and Ridge	Piedmont	Appalachian Plateau	Coastal Plain	Coastal Plain	Coastal Plain	Coastal Plain
Subwatershed	50101005	50104031	60109008	60101054	60202004	50201034	60204122
% Forest	73.8%	88.8%	50.0%	63.2%	71.4%	48.6%	76.7%
% Urban	6.2%	0.9%	2.0%	0.8%	0.8%	4.0%	2.8%
% Water	0.2%	0.0%	0.6%	4.8%	9.7%	9.9%	8.8%
% Farmland	17.6%	8.8%	47.3%	26.5%	14.6%	35.2%	10.3%
% Other	2.2%	1.5%	0.1%	4.7%	3.5%	2.3%	1.4%

The calibration year was selected as October 1993 to September 1994 based upon an examination of annual precipitation variability and the availability of observation data. This period was determined to represent a range of hydrologic conditions: low, mean, and high flow conditions. Calibration for these conditions was necessary to ensure that the model would accurately predict a range of conditions for a longer period of time.

Key considerations in the hydrology calibration included the overall water balance, the high-flow-low-flow distribution, storm flows, and seasonal variation. Two criteria for goodness of fit were used for calibration: graphical comparison and the relative error method. Graphical comparisons are extremely useful for judging the results of model calibration (James and Burgess, 1982). Time-variable plots of observed versus modeled flow provide insight into the model's representation of storm hydrographs, baseflow recession, time distributions, and other pertinent factors often overlooked by statistical comparisons. The model's accuracy was primarily assessed through interpretation of the time-variable plots. The relative error method was used to support the goodness of fit evaluation through a quantitative comparison. The equation to calculate the relative error is as follows:

$$relative\ error(\%) = \frac{\sum(USGS\ observed\ daily\ flow) - \sum(NPSM\ simulated\ daily\ flow)}{\sum(USGS\ observed\ daily\ flow)} * 100$$

A small relative error indicates a better goodness of fit for calibration. Table 4-15 presents the relative error between observed data and model results for mean monthly flow at each of the hydrology calibration locations. It also presents comparisons of minimum and maximum flows for observed and modeled conditions. From this table, it is apparent that the relative error varies greatly by location. In some situations, the model overpredicts flow, while in others it underpredicts flow. On average the relative error is 7.64%. Appendix C presents the time-variable plots used to support hydrologic calibration assessment.

Table 4-15. Monthly average flow statistics for USGS and NPSM flows

Subwatershed	Observed (USGS)			Modeled			Relative Error (%) Between Mean Flow
	Min. Flow (cfs)	Max. Flow (cfs)	Mean Flow (cfs)	Min. Flow (cfs)	Max. Flow (cfs)	Mean Flow (cfs)	
50101005	96.45	4504.90	1389.80	51.03	4001.41	1091.41	21.47%
50104031	370.39	2206.45	1147.03	44.14	2224.64	925.71	19.30%
50201034	21.23	1710.10	433.65	101.35	1096.76	382.96	11.69%
50201054	142.6	2731.71	983.20	149.70	2185.76	903.51	8.10%
60109008	23.55	2624.86	800.96	119.96	2200.67	868.82	-8.47%
60202004	197.77	2424.61	918.74	114.79	2485.11	973.31	-5.94%
60204122	77.63	284.73	190.00	70.80	338.24	176.04	7.35%
Average							*7.64%*

4.7.2 Hydrologic Validation

After calibrating hydrology for multiple subwatersheds, independent sets of hydrologic parameters were developed and applied to the remaining subwatersheds in the basin. A validation of these hydrologic parameters was made through a comparison of model output to observed data at three additional locations in the basin (Figure 4-4). These validation locations represent larger watershed areas and essentially validate application of the hydrologic parameters derived from the calibration of smaller subwatersheds. Subwatersheds 50204034, 60106010, and 60201001 were validated to USGS gage stations 02428400, 02447025, and 02469761, respectively. Validation was assessed in a similar manner to calibration. Appendix D presents the comparison of the simulated flow to in-stream flow data.

4.7.3 Water Quality Calibration

After hydrology had been sufficiently calibrated, water quality calibration was performed. Modeled versus observed in-stream concentrations were directly compared during model calibration. The water quality calibration consisted of executing the watershed model, comparing water quality time series output to available water quality observation data, and adjusting pollutant loading and in-stream water quality parameters within a reasonable range.

The objective was to best simulate low flow, mean flow, and storm peaks at water quality monitoring stations representative of the physiographic regions. Representative stations were selected based on both location (distributed throughout the watershed) and long-term data availability. A long-term record of observations for the modeled parameters was not available for most monitoring stations in the basin. Table 4-16 presents the subwatersheds and the corresponding water quality stations used for the water quality calibration of the watershed model. A summary of watershed characteristics potentially influencing water quality is presented in Table 4-17 for selected locations. Figure 4-5 depicts the water quality calibration locations.

Adjusted water quality parameters included pollutant buildup, washoff, and subsurface concentrations. Water quality calibration adequacy was primarily assessed through review of time-series plots. Looking at a time series plot of modeled versus observed data provides more insight into the nature of the system and is more useful in water quality calibration than a

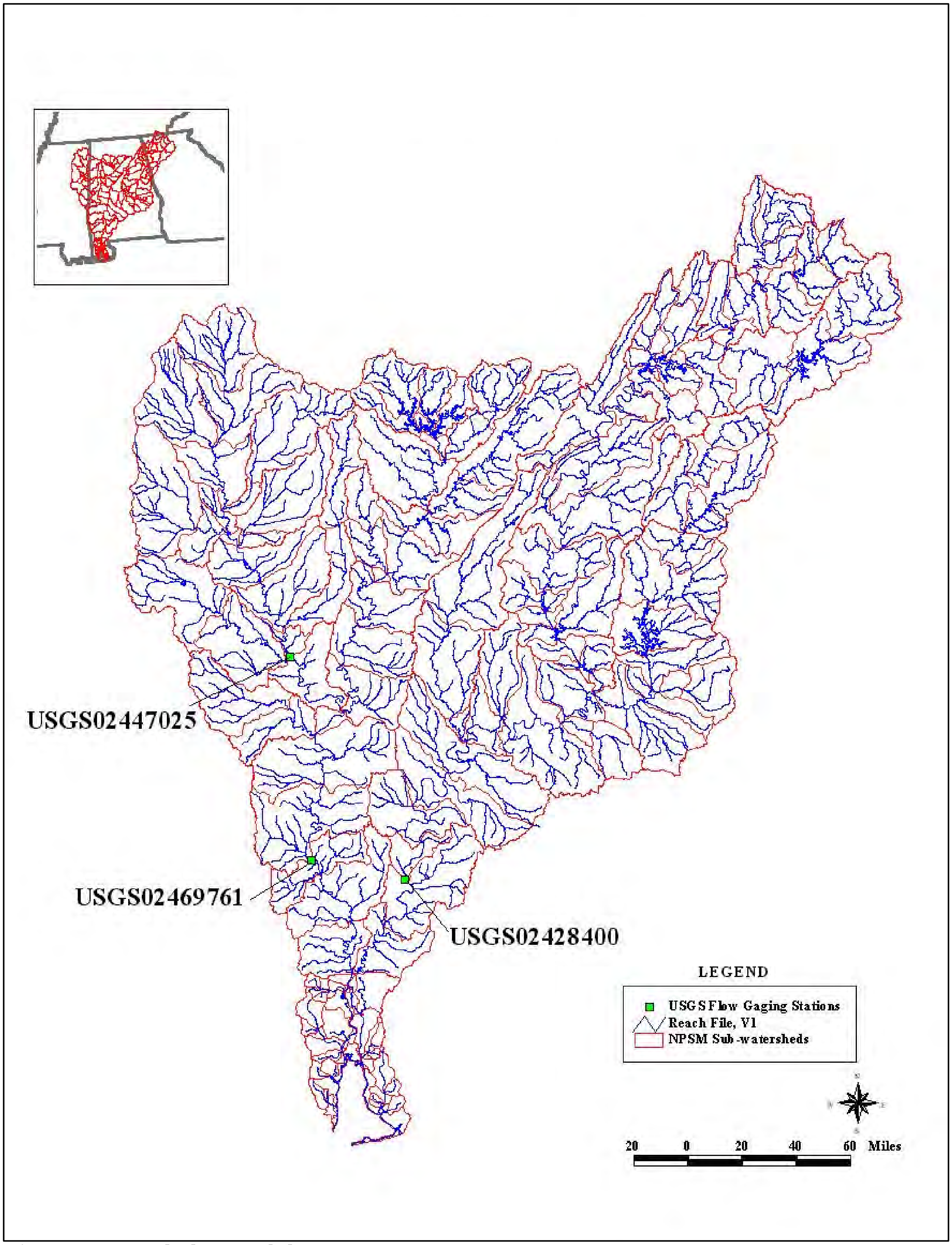

Figure 4-4. Hydrologic validation sites

statistical comparison. Flow (or rainfall) and water quality can be compared simultaneously, and thus can provide insight into conditions during the monitoring period (dry period versus storm event). The observed and modeled baseflow concentrations can be compared. The response of the model to storm events can also be studied and compared to observations (when available). There are times when the magnitude of the storm events may be too high, too low, or not coincide exactly in time with the observation. Ensuring that the storm events are represented within the range of the data over time is the most practical and meaningful means of assessing the quality of a calibration.

Time-variable model output and observed data comparisons are presented in Appendix E. It is also important to note that the plots in Appendix E represent a selected period of years, even though the model was typically run for a period of years prior to those plotted. For this reason, modeled concentrations typically start above zero.

Table 4-16. Subwatersheds and water quality stations used for water quality calibration

Subwatershed	Water Quality Station	Pollutants
50108025	112WRD 02412000	BOD_5 and Total Phosphorus
50108031	GAEPD 130300011 or 112WRD 02411930	$BOD_{5,}$ Total Phosphorus, Lead, and Zinc
50104031	GAEPD 14300001 or 112WRD 02392000	$BOD_{5,}$ Total Phosphorus, and Total Nitrogen
60205004	21AWIC WB1	$BOD_{5,}$ Total Phosphorus, Total Nitrogen, Lead, Copper, and Zinc
60205015	21AWIC FR1	$BOD_{5,}$ Total Phosphorus, Total Nitrogen, Lead, Copper, and Zinc
50201001	112WRD 02423000	Sediment
50202009	112WRD 02424590	Sediment
60106001	112WRD 02449000	Sediment
60112001	112WRD 02465000	Sediment

Table 4-17. Watershed characteristics influencing water quality

Water Quality Station	02412000	02411930	02392000	21AWIC WB1	21AWIC FR1
Point Sources	No	No	No	No	No
Point Sources within 5 miles	No	No	No	No	No
Nearby Cities	No	No	No	No	Mobile
Soil Type 1	90% C	80% C	50% B	80% B	50% D
Soil Type 2	10% B	20% B	50% C	20% A	50% C
Topography	Piedmont	Piedmont	Piedmont	Coastal Plain	Coastal Plain
Subwatershed	50108025	50108031	50104031	60205004	60205015
% Forest	87.1%	79.8%	88.8%	21.0%	51.5%
% Urban	0.9%	1.2%	0.9%	1.0%	1.9%
% Water	0.4%	1.8%	0.0%	8.2%	20.3%
% Farmland	9.1%	15.0%	8.8%	68.2%	20.7%
% Other	2.5%	2.2%	1.5%	1.6%	5.6%

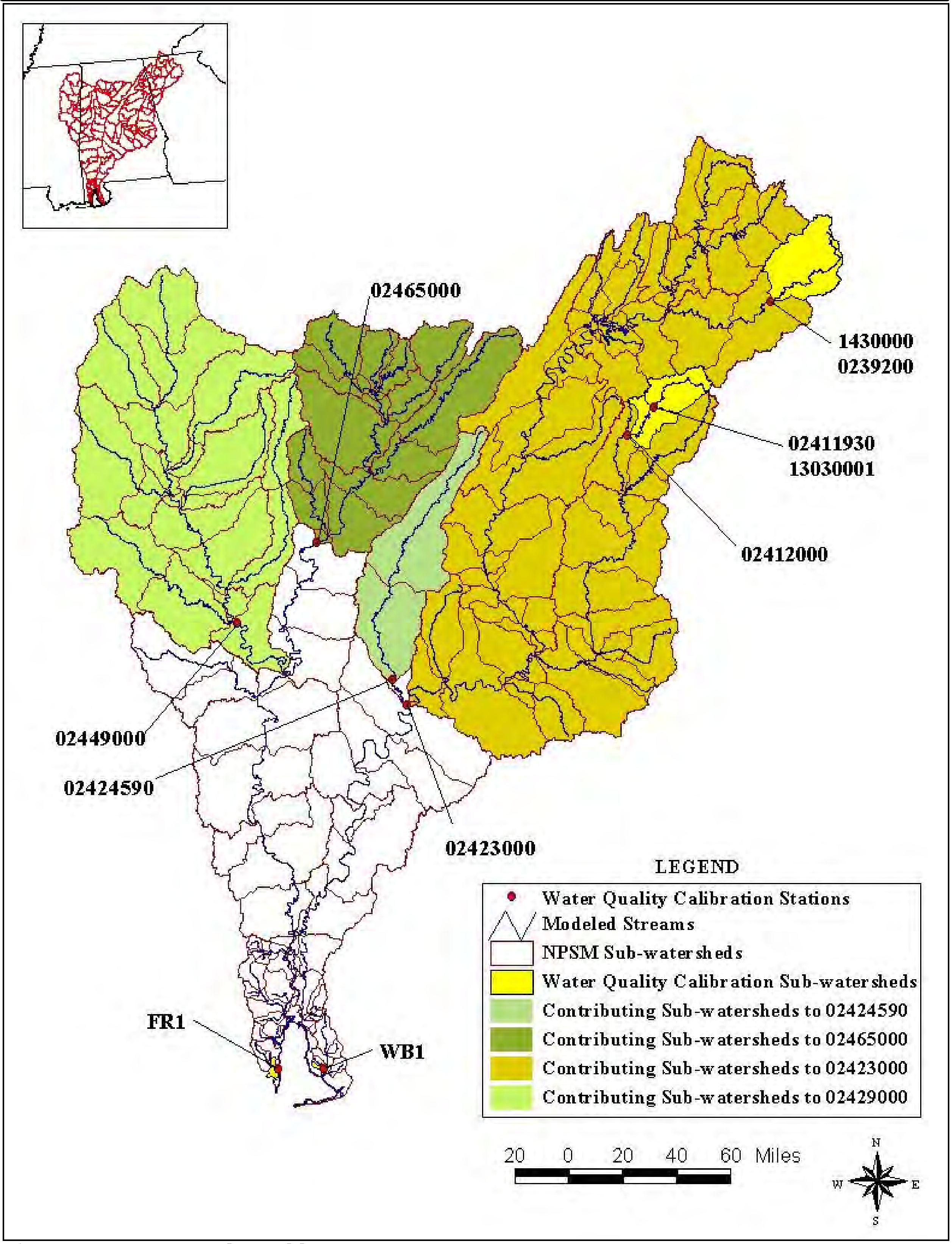

Figure 4-5. Water quality calibration sites

4.7.4 Water Quality Validation

Water quality parameters for the watershed model were validated through a comparison of observed water quality data to modeled in-stream values. The validation was performed in subwatersheds with sufficient water quality observation data located on major river systems in the basin. Table 4-18 presents the subwatersheds and the corresponding water quality stations used for validation purposes. Figure 4-6 shows the location of the water quality validation sites. Validation was assessed in a similar manner to calibration. Comparisons of the observed data and model output are in Appendix F.

Table 4-18. Subwatershed locations and water quality stations used for water quality validation

Subwatershed	Water Quality Station	Pollutants
50203001	21AWIC A3	BOD_5, Total Nitrogen, Total Phosphorus, Zinc, Copper, and Lead
50204034	112WRD 02429500	Sediment
60201001	112WRD 02469762	Total Nitrogen, Total Phosphorus, Zinc, Copper, Lead, and Sediment

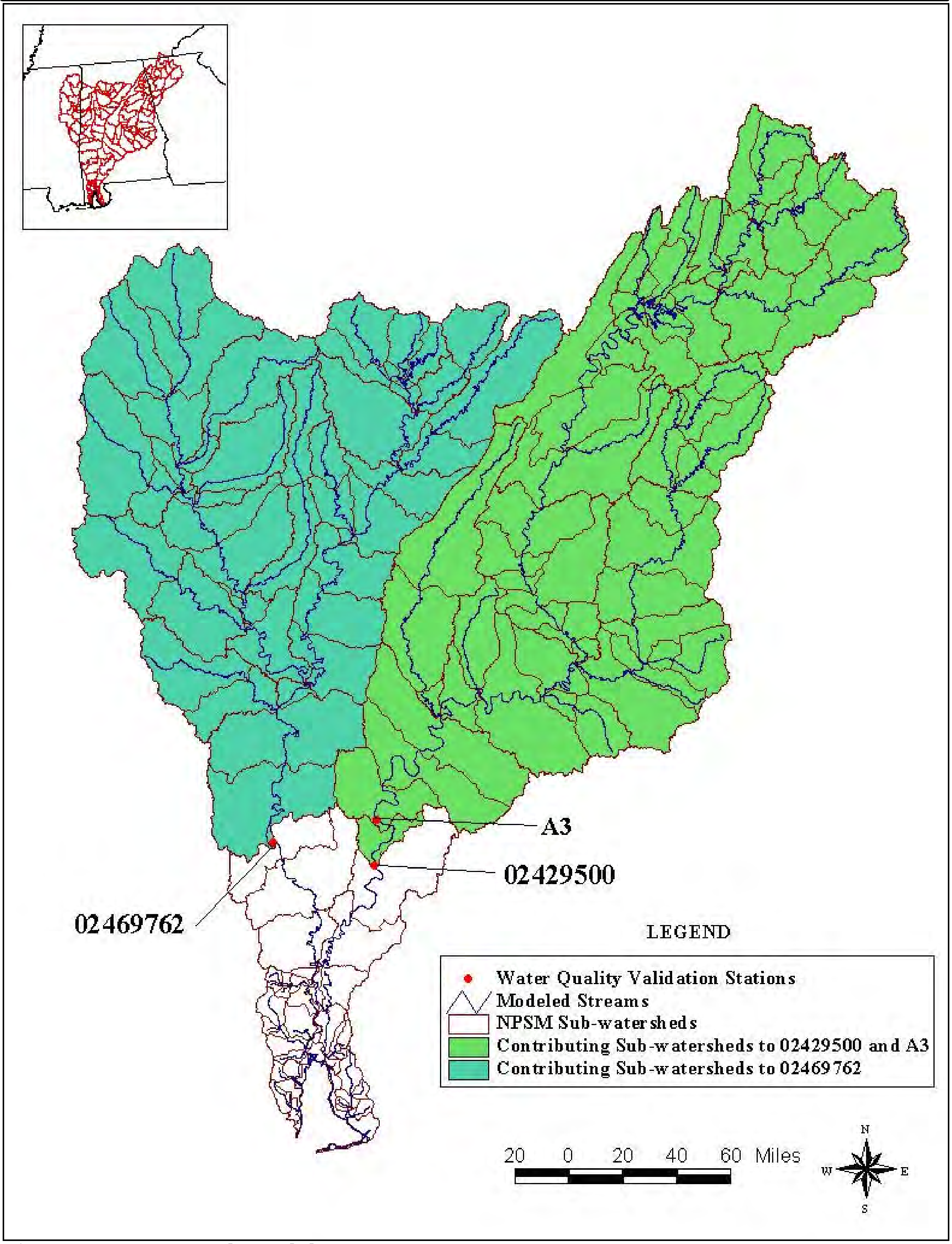

Figure 4-6. Water quality validation sites

4.8 Existing Conditions

The fully calibrated and validated watershed model was run for the period 1970 through 1995 to estimate contributions to Mobile Bay and characterize the distribution of pollutant loading throughout the Mobile River basin. The model was run on an hourly time step for total nitrogen, total phosphorus, BOD_5, zinc, copper, lead, and sediment. Toxic organic contaminants and mercury not explicitly represented in the watershed model due to insufficient monitoring data to support model calibration. These pollutants were addressed through separate analyses.

4.9 Future Conditions

In order to successfully protect water quality in Mobile Bay, it is important to consider the impacts of future changes in the contributing watershed. Future urban development and industry growth can often have a detrimental effect on water quality if appropriate protective measures are not defined. Using the same modeling period and pollutants as the existing conditions, the model was run for a set of future conditions, to assess the impacts of potential changes in the immediate vicinity of Mobile Bay on water quality. These conditions considered changes in land use distribution and point source loadings, and they were defined as follows:

- 2010 land use conditions/current point source discharges. For this scenario, land use conditions for 2010 in the Lower Mobile River basin (south of the Alabama and Tombigbee Rivers' confluence) were estimated from the Southern Alabama Regional Planning Commission (SARPC) 2010 land use estimates. The model was run using the future land use distribution while maintaining current point source discharges, in order to predict the effect of urbanization on flow and pollutant loadings to Mobile Bay.

  Land estimates were only available from SARPC for Baldwin County. Land use estimates for Mobile County were determined from a comparison of expected population growth in both Baldwin and Mobile counties. Estimates by the U.S. Census Bureau indicate that Baldwin County's population climbed from 98,280 in 1990 to 128, 842 in 1997. Baldwin County is the largest county by area and the second fastest growing county in the state. Mobile County is the second largest county by population and contains the city of Mobile, the second largest city in Alabama, with a population of 192, 278. The estimated population of the entire bay area is 325, 000 people. The expected change in Baldwin County's population is approximately six times greater than that of Mobile. The distribution of the state's population is 60 percent urban and 40 percent rural. Urban land uses in Baldwin County are expected to increase by approximately 27 percent. Urban land use areas in Mobile County, therefore were estimated to increase by 4 percent.

- 2010 land use conditions/maximum permitted point source discharges. For this scenario, 2010 land use conditions and maximum permit limits for point sources were used. Where permit limits were not available, the existing conditions discharge values were used. Tables B-3 and B-4 in Appendix B present the maximum daily loads and maximum concentrations, respectively, for the point sources in the Mobile River basin.

5.0 Bay Model

The bay model was configured separately from the watershed model, with the exception of defining upstream boundary conditions supplied by the watershed model. It was not required to generate load estimates to Mobile Bay, however it was used to test flow contributions estimated by the watershed model to the bay. Development and initial testing of the bay model provided a head start to assessing water quality within the bay itself and quantifying the impacts of the contributing watershed's contributions.

Configuration of the bay model required consideration of four components:

- Grid generation
- Cell representation
- Boundary condition representation
- Incorporation of watershed model output

After configuring the bay model, it was run for a one-year period to test hydrodynamics, primarily water surface elevations, flow directions, and salinity. The bay model is intended to be configured for water quality in the future. It is also expected to undergo a thorough hydrodynamic and water quality calibration and validation.

5.1 Grid Generation

Mobile Bay is characterized by deep and narrow navigation channels, large shallow areas of low bathymetric variability, and a complex multiple channel delta system (including the tidally influenced Mobile, Tensaw, and Middle Rivers). To implement the EFDC model, a curvilinear grid was generated to represent all of these components. The grid was generated based on NOAA bathymetric data for the bay, a detailed Mobile Bay navigation chart, and high-resolution shoreline and tributary data from the EPA Reach File, Version 3 stream network.

5.2 Cell Representation

The grid generated for Mobile Bay contains more than 1,000 grid cells in the horizontal plane and 4 vertical layers in each cell. The model incorporated 4 vertical layers to represent the vertical stratification that occurs in the bay. The narrow navigation channel, which stretches north to south across the length of the bay, was composed of five 150 meter wide cells. The cells that defined the shallow areas ranged in dimension from 0.5 to 2 kilometers in the horizontal plane.

The tidally-influenced Mobile River and Tensaw River and all major rivers inter-connecting the two rivers are represented by a one-dimensional grid. Minor tributaries are represented as discrete inputs into the model's cells.

5.3 Boundary Conditions

Boundary conditions were used to define hydrodynamic conditions at key locations. Two types of boundary conditions existed for the hydrodynamic model:

- Upstream boundary
- Outer bay boundary

The upstream boundary is located at the confluence of the Tombigbee River and the Alabama River (north of the bay). The upstream boundary conditions defined flow from the Mobile River basin stream network north of the bay, as well as flow from subwatersheds adjacent to the bay. Output from the watershed model was used for the upstream boundary conditions. The outer bay boundary conditions established tide-related settings for the model. The model was driven by fresh water output from NPSM at the upstream boundary, as well as tides, salinity, and water temperature at the two open boundaries near the mouth. Atmospheric time series data for dry and wet bulb temperature, rainfall, solar radiation, relative humidity, and wind speed and direction are used as atmospheric forcing functions at the surface boundary to simulate the hydrodynamics of the bay.

5.4 Incorporation of Watershed Model Output

The boundary cells of the bay model received output directly from the watershed model. The watershed model output was expressed as daily average flow. The freshwater output from NPSM was generated for 12 of the 152 total subwatersheds. These 12 routing flows were either directly applied to the bay grid cells (represented as direct discharge river connections), or evenly distributed along the river network and bay boundary (represented as lateral inflows).

5.5 Hydrodynamic Testing

The bay model was tested for hydrodynamic representation, however a full calibration was not performed. Output from the bay model was in the form of water elevations, flow velocities and direction, and salinity for each cell. Time-variable animations were generated for these outputs, in order to assess hydrodynamic representation. The animations suggested that the bay model accurately represented hydrodynamics for a typical tidally-influenced bay of its size. Before configuring the bay model for water quality and performing a detailed analysis based on the bay model results, further calibration is recommended.

6.0 Results

Assessing the total load of pollutants contributed to Mobile Bay and characterizing the distribution of sources and loads within the basin was addressed through two major techniques. The primary assessment method involved analyzing output from the watershed model. This addressed nutrients (total nitrogen and phosphorus), BOD_5, sediments, and selected metals (zinc, copper, and lead). The second technique involved assessment of watershed indicators, which are factors likely to influence water quality. This analysis looked into urban runoff potential, fertilizer and pesticide (toxic organic contaminant) application, silviculture practices, livestock distributions, and mercury. The watershed indicator analysis provided a means of assessing a number of pollutants for which insufficient monitoring data are available to support modeling: toxic organic contaminants and mercury.

6.1 Watershed Indicators

Watershed indicators are datasets indicative of potential pollution sources. They are a mechanism for identifying potential "trouble-spots," and they provide a relative means of comparison. Watershed indicators were assessed for both the entire Mobile River basin and the Lower Mobile River basin. Specific pollutants addressed include flow, nutrients, toxic organic contaminants, sediment, and mercury. Graphics showing the watershed indicators throughout the entire basin and the lower basin are in Appendix G.

6.1.1 Urban Runoff Potential

Imperviousness is a useful indicator in predicting impacts of land development on aquatic ecosystems. It has been shown that imperviousness can adversely affect hydrology, water quality, and biodiversity of aquatic ecosystems. Increased imperviousness increases the rate and volume of runoff, which in turn, decreases the flood capacity of receiving streams.

This indicator was developed using the MRLC urban land use distribution. Impervious proportions were assigned by the relative magnitude of urban development among the urban land use subcategories. The imperviousness percentages for the urban areas was derived from the Soil Conservation Service's TR-55 manual. All other land use categories were assumed to be pervious, therefore, they were weighted as 0 percent impervious when aggregating the areas. Table 6-1 presents the typical imperviousness values associated with each of the urban land uses.

Table 6-1. Urban land use imperviousness

MRLC Category	MRLC Subcategory	Percent Impervious
Low Intensity Residential	21	15.5 %
High Intensity Residential	22	65.0 %
Commercial/Industrial/Transportation	23	75.0 %

All the individual MRLC land use subcategories were aggregated at the subwatershed level to determine the percent imperviousness in each subwatershed. Subwatersheds with high percentage impervious areas are more vulnerable to urban expansion The highly impervious areas surrounding the bay result in large nonpoint source loadings directly to the bay. Appendix

G presents separate land imperviousness maps for the entire basin and the lower basin.

6.1.2 Total Applied Fertilizer

The total applied fertilizer indicator represents the amount of applied fertilizers (TN, TP, K_2O) in each subwatershed. It indicates which areas have the greatest potential for water quality problems due to fertilizer runoff. Subwatersheds with the highest amounts of applied fertilizers have a greater risk of water quality impairment from surface runoff than subwatersheds with lower amounts of applied fertilizer. The fertilizer rates were expressed as the total amount applied and as the amount applied per unit land area.

This indicator was constructed in three stages. First, the USGS Agricultural Chemical Data, reported at the county level as application rates (tons/mi^2), was applied to the MRLC agricultural land use subcategories (Table 6-2). Second, the resulting fertilizer quantities were summed by county in each subwatershed. Finally the sums were aggregated to the subwatershed level.

This procedure weighted each of the three fertilizers and land use subcategories equally. Since fertilizer application was expressed as a rate, the subwatersheds with larger land areas among the considered subcategories, and which had more area in counties with higher application rates, were expected to reflect higher amounts of applied fertilizers.

Appendix G presents the following maps for the entire basin and the lower basin:

- Total nitrogen fertilizer application
- Total nitrogen unit area loading (application normalized by area)
- Total phosphorus fertilizer application
- Total phosphorus unit area loading (application normalized by area)
- Potassium fertilizer application
- Potassium unit area loading (application normalized by area)

Table 6-2. Agricultural MRLC land uses

MRLC Category	MRLC Subcategory	Description
Cropland	82	Row Crops
	83	Small Grains
	60	Non-Natural Woody
	61	Planted/Cultivated (orchards, Vineyards, Groves)
	80	Herbaceous Planted/Cultivated
	81	Pasture/Hay
	85	Other Grasses (Urban/Recreation)

6.1.3 Total Applied Pesticides

The total applied pesticides indicator presents the total amount of applied pesticides in each subwatershed. It indicates which areas have the greatest potential for water quality problems associated with pesticide or toxic organic contaminant runoff. Subwatersheds with the highest amount of applied pesticides have a greater risk of water quality impairments from surface runoff than subwatersheds with lower amounts of applied pesticides.

This indicator was constructed in four stages. First, a composite application rate (lbs/mi^2) was developed by summing up all of the pesticide contributions at the county level. Second, the composite application rates were applied to the MRLC agricultural land use subcategories in Table 6-2. Next, the resulting pesticide quantities were summed by county in each subwatershed. Finally, the sums were aggregated to the subwatershed level. The 1989 USGS Agricultural Chemical Data reported 96 different potential herbicides and pesticides used in the different counties.

This procedure weighted each of the pesticides and land use subcategories equally, so the pesticides most commonly used play a larger role in the composite sum than the minor pesticides. This indicator does not directly indicate toxicity from the various pesticides. However, it does indicate which subwatersheds have the greatest potential for the movement of agricultural pesticides from farm fields through surface water runoff. Since pesticide application data were expressed as a rate, the subwatersheds with larger land areas, and which had more area with high application rates, were expected to reflect higher amounts of applied pesticides. Total basin pesticide application and pesticide applied to the lower basin are included in Appendix G in addition to the pesticide application rate per unit area for the entire basin and lower basin.

6.1.4 Total Livestock Numbers

The total livestock indicators estimate the total number of common livestock varieties within each subwatershed. The indicator can be used to identify which subwatersheds are more vulnerable to problems associated with manure disposal and manure land application, such as increased levels of nitrogen, phosphorus, BOD_5, COD, and fecal coliform. Subwatersheds with high livestock numbers have a greater risk of water quality impairment from agricultural runoff than subwatersheds with lower livestock numbers.

The livestock numbers indicators were constructed in four stages. First, the MRLC agricultural land use areas were summed at the county level to determine total agricultural land per county. Second, livestock densities (number/acre) for each county were calculated by uniformly distributing the Agricultural Census livestock numbers across the county agricultural land. Third, the county livestock densities were applied to MRLC land use for each county in a subwatershed. Finally, the livestock numbers were summed up at the subwatershed level. The 1997 U.S. Agricultural Census Data reported the numbers and varieties of livestock in each county. This indicator does not directly identify toxicity from the livestock manure runoff. It does indicate which subwatersheds have the greatest potential for the movement of livestock manure from farm fields through surface water runoff if insufficient agricultural management strategies prevail. Since animal numbers were converted to county densities, the subwatersheds with larger agricultural land areas, and which had more area with higher livestock numbers, were expected to reflect higher livestock counts. Figures showing the cattle, chicken, and hogs for the entire basin and the lower basin are included in Appendix G.

6.1.5 Silviculture

The silviculture indicator identifies which areas have the greatest potential for sediment problems associated with deforestation. Subwatersheds with high volumes of timber removed per year have a greater risk of water quality impairment associated with sediment runoff after deforestation.

The silviculture indicator was constructed in four stages. First, annual timber removal rates per county were calculated by dividing the total growth stock (ft^3) by total available timberland area (acres). Second, the percentage of timberland per forest was calculated at the county level. Third, the annual county timber removal rates (ft^3/acre) were applied to the estimated timberland portion of the total MRLC forestland for each county within a subwatershed. Finally, the volume of timber removed annually was summed at the subwatershed level. Table 6-3 shows the MRLC subcategories and descriptions associated with the forest land use classification. Figures showing the volume of lumber harvested in the entire basin and the lower portion of the basin are included in Appendix G.

Table 6-3. Forest MRLC land uses

MRLC Category	MRLC Subcategory	Description
Forest	40	Natural Forested Upland (not-wet)
	41	Deciduous Forest
	42	Evergreen Forest
	43	Mixed Forest

The volumes of timber removed were obtained from 1990 Alabama Forest Data, 1989 Mississippi Forest Data, 1994 Georgia Forest Data, and 1990 Tennessee Forest Data.

6.1.6 Mercury

The Mercury Deposition Network (MDN) atmospheric sampling stations in the region surrounding Mobile Bay estimate the average and seasonal patterns of mercury deposition in the basin. Emission of mercury to the atmosphere occurs from both natural and anthropogenic processes. Natural processes include volatilization of mercury in marine and freshwater environments, volatilization from vegetation, degassing of geologic materials (e.g., soils), and volcanic emissions (USEPA, 1987). Sources of anthropogenic mercury include both industrial manufacturing (i.e., chemical production, metal smelting), electric utilities, and incinerator facilities (i.e., municipal waste combustors).

Average and seasonal patterns of mercury deposition in the Mobile River basin are represented by MDN atmospheric sampling stations in the region. The MDN, part of the National Atmospheric Deposition Program (NADP), consists of 30 stations in the United States and is sponsored by numerous state, federal, and private agencies. Precipitation samples are collected at each station on a weekly basis. The MDN provides data on weekly total mercury and data are available for the years 1996-1997, depending on the individual station's period of operation. Some 1995 data, prior to the official operational status of the network, are available.

Three MDN stations (GA09, KY99, TX21) were selected based on data availability and spatial relation to the Mobile River basin (Figure 6-1). Weekly measurements of total mercury data for "wet events" at these stations were obtained for the years 1996-1997. Data from 1998 to the present are not currently available for these stations. Table 6-4 gives a summary of the total mercury data from stations GA09, KY99, and TX 21.

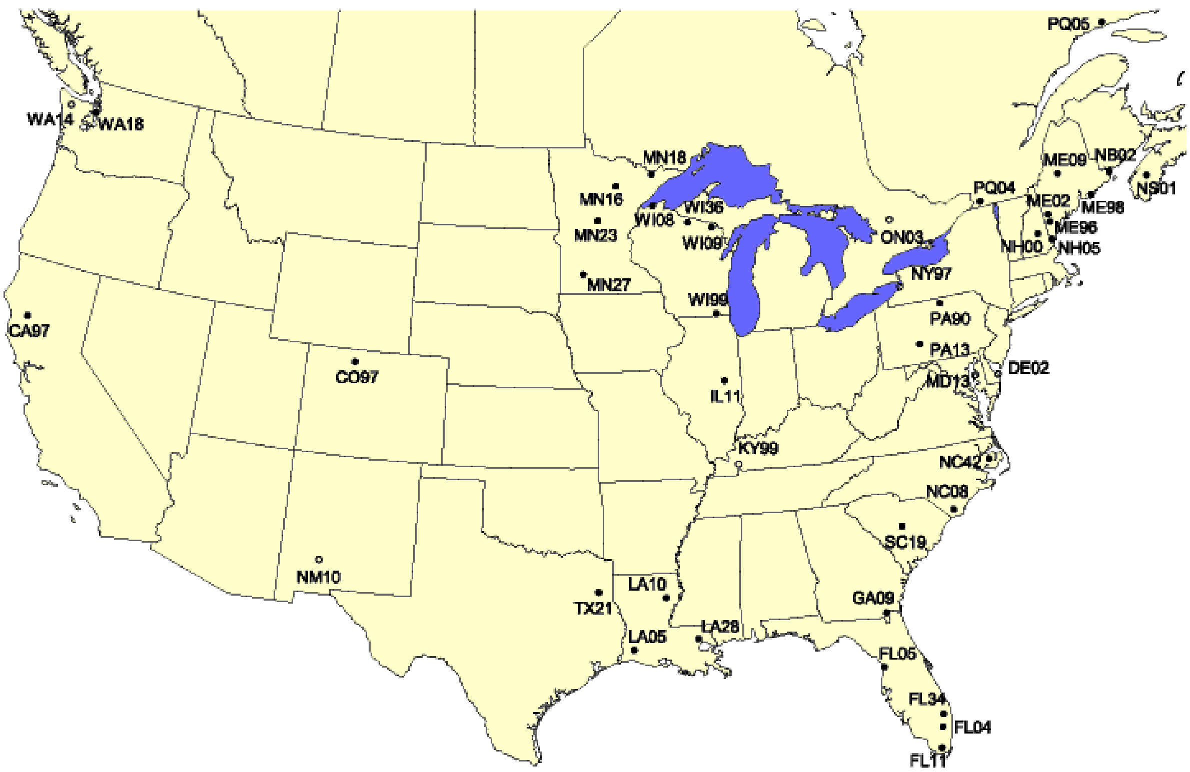

Figure 6-1. Mercury deposition stations

Table 6-4. Mercury deposition to the Mobile River basin

Station	Date of Operation	# of Obs.	Total Rainfall (mm)	Average Total Hg Conc. (ng/L)	Min. Total Hg Conc. (ng/L)	Max. Total Hg Conc. (ng/L)	Avg. Rate of Hg Deposition (ng/m^2*week)
TX21	01/09/96-12/30/97	99	2204	12.73	0	49	239.10
GA09	08/05/97-12/30/97	22	463	15.74	5	62	305.55
KY99	01/09/96-04/16/96	12	69	10.91	0	46	144.27

Deposition of mercury from the atmosphere can occur through one of several methods. Mercury can enter waterbodies directly from the atmosphere in the forms of Hg(II) and methylmercury during both wet and dry weather events. In addition, Hg(II) and methylmercury can also be delivered to water systems through overland runoff (bound to sediment particles and organic materials) and through leaching from groundwater flows (USEPA, 1987). Methylmercury is of primary concern in aquatic ecosystems since it is readily taken up by biota and travels efficiently through all trophic levels. Accumulation of methylmercury occurs rapidly in fish tissue and 100% of mercury found in fish tissue occurs in methylated form (Bloom, 1992). At the highest trophic levels in aquatic ecosystems (i.e., occupied by many types of common game fish), mercury in fish tissue can be passed to wildlife and humans (USEPA, 1987).

The locations of the MDN monitoring stations with relation to the Mobile River basin allow for the development of a "gross" representation of atmospheric mercury deposition patterns. Using the data in the table, a regional average deposition rate of 229.64 ng/(m^2-week) total mercury with an average mercury rainfall concentration of 13.13 ng/L is proposed for the Mobile River basin.

Mean monthly averages of total mercury deposition rates were compiled using data from the three MDN stations. The summer to early fall months (June-September) represent a period of high mercury deposition of 904-1796 ng/(m^2-month). During the months of October to May, mean monthly averages of total mercury deposition rates are lower and between 492-1080 ng/(m^2-month). Figure 6-2 presents the average monthly deposition rates of mercury.

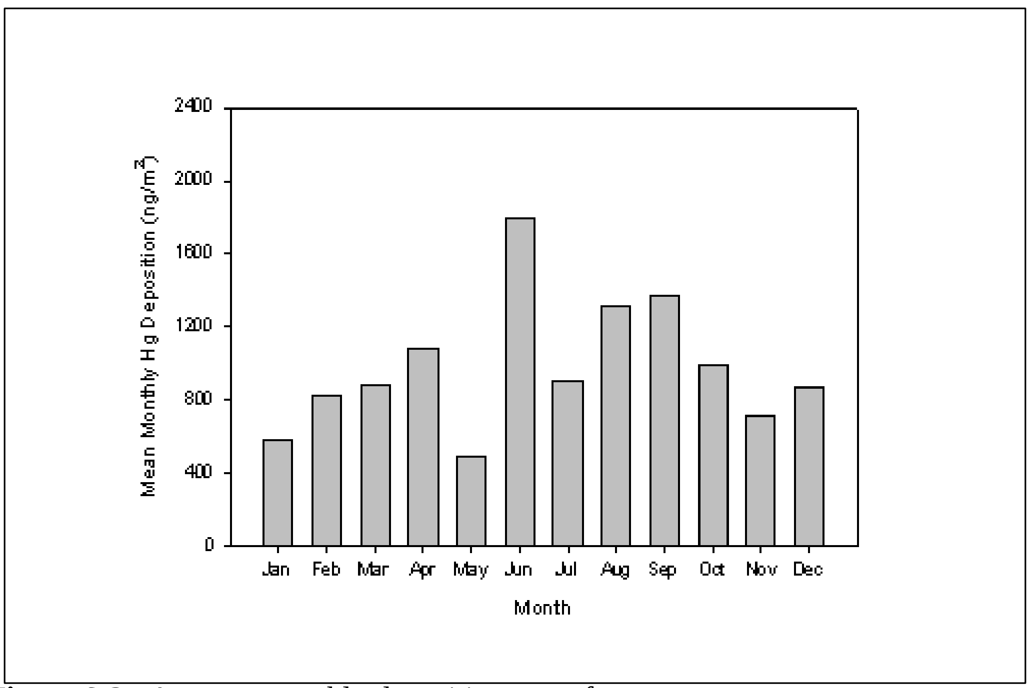

Figure 6-2. Average monthly deposition rate of mercury

6.2 Watershed Model Results - Existing Conditions

Flow and pollutant loads (total nitrogen, total phosphorus, BOD_5, zinc, copper, lead, and sediment) generated by the watershed model for existing conditions were summarized temporally, spatially, and by source. Graphics, or tables where appropriate, were prepared to show how the loadings varied. Model results were also compared to applicable loading estimations from the literature.

6.2.1 Temporal Analysis

The temporal analysis presents the variability in flow and pollutant loading for the entire Mobile River basin contributing to Mobile Bay over time. Annual results are provided for the mean, dry, and wet years during the simulation (specified in Section 4 of this report). These results provide a comparison of flow variability and loading variability for extreme and average annual conditions. Monthly results are provided for the mean, dry, and wet years, as well as for the seasonal extreme conditions (high winter-spring flows and low late summer flows). Results for the extreme tropical storm conditions are additionally presented.

6.2.1.a Annual Results

Water year 1994, which represents a mean year during the simulation period, exhibited the following conditions: an average annual modeled flow rate of 66,110 cfs, with a corresponding total nitrogen load of 68,644 tons, total phosphorus load of 5,344 tons, BOD_5 load of 120,207 tons, sediment load of 5,485,600 tons, zinc load of 4,711 tons, copper load of 6,388 tons, and a lead load of 1,072 tons.

Flow during dry and wet years ranged from 27 percent lower to 31 percent higher, respectively, than the mean year. Pollutant loads ranged similarly from 28 percent lower to 47 percent higher for dry and wet years, respectively, than the mean year. Table 6-5 shows the annual comparisons.

Table 6-5. Comparison of annual results

	Avg. Flow (cfs)	BOD_5 (ton/yr)	TN (ton/yr)	TP (ton/yr)	Zn (ton/yr)	Cu (ton/yr)	Pb (ton/yr)	Sediment (ton/yr)
Dry	48,105	86,143	48,277	3,729	3,428	4,654	768	3.875×10^6
Mean	66,110	120,207	68,644	5,344	4,711	6,388	1,072	5.486×10^6
Wet	96,444	177,952	99,183	8,168	6,066	8,163	1,412	9.505×10^6

6.2.1.b Monthly Results

Model output was also plotted on a monthly basis for the mean, dry, and wet years, as well as for the seasonal extreme conditions. These plots provide a comparison of flow and loads throughout the year and are indicative of the expected time-varying nature of water quality levels occurring in the bay. Appendix H contains the results for flow and the other modeled parameters during mean, dry, and wet years. It is important to note that these results represent model output for individual water years (mean-1994, dry-1990, wet-1981) and not statistically-based calculations.

For example, flow from some months for the dry year may exceed flow for the same months for the mean year. Appendix I contains the results for the seasonal extreme conditions (high winter-spring and low late summer flows

For the mean water year, flow and pollutant loads were lowest in October and highest from January through April. Average monthly flow ranged from 9,776 cfs in October to 142,253 cfs in March. Pollutant loadings were lowest in October (BOD_5 = 1,683 tons, TN = 571 tons, TP = 27 tons, Zn = 44 tons, Cu = 64 tons, Pb = 14 tons, Fe = 465 tons, and Sediment = 52,200 tons) and highest in February and March (BOD_5 = 25,183 tons, TN = 13,440 tons, TP = 1,317 tons, Zn = 1,055 tons, Cu = 1,422 tons, Pb = 216 tons, Fe = 8,813 tons, and Sediment = 1,337,200 tons).

6.2.1.c Extreme Tropical Storm Conditions

Monthly flow and pollutant loading model output were compiled for Hurricanes Frederic (1979) and Opal (1995) to represent extreme storm conditions. Hurricane Frederic resulted in a 61 percent higher average flow rate for the month of September than the mean year, and from 73 to 95 percent higher pollutant loadings for the same month. Hurricane Opal resulted in a 93 percent higher flow rate for the month of October than the mean year, and from 92 percent to 98 percent higher pollutant loadings for the same month. Table 6-6 summarizes the results of flow and pollutant loading relevant to these two storms.

Table 6-6. Flow and pollutant loading during Hurricanes Frederic and Opal

		Avg. Flow (cfs)	BOD_5 (ton)	TN (ton)	TP (ton)	Zn (ton)	Cu (ton)	Pb (ton)	Sediment (ton)
Hurricane Frederic	**Sep-79**	78,727	12,861	6,839	705	503	682	124	909,600
	Oct-79	50,230	5,188	3,492	224	270	367	38	110,500
Hurricane Opal	**Sep-95**	12,181	1,614	905	29	67	93	17	78,700
	Oct-95	134,643	21,441	12,195	1,504	889	1,193	138	1,483,300

6.2.2 Spatial Analysis

The spatial analysis provides insight into the distribution of flow and pollutants throughout the Mobile River basin. It presents the variation in magnitude of nonpoint source pollutant loading throughout the Lower Mobile River basin and includes a comparison of total loads from the lower to the upper basin.

6.2.2.a Nonpoint Source Loadings

The magnitude of nonpoint source loadings varied widely throughout the Lower Mobile River basin. Nutrient and sediment nonpoint source loadings were typically higher on the east side of the bay, in Baldwin County, while nonpoint source metals contributions were higher on the west side of the bay. Appendix J presents the distribution of the pollutants throughout the Lower Mobile River basin for the mean year. Table 6-7 presents loadings data by subwatershed in a tabular format.

Table 6-7. Subwatershed loadings from nonpoint sources

Subwatershed	BOD_5 (ton/yr)	TN (ton/yr)	TP (ton/yr)	Zinc (ton/yr)	Copper (ton/yr)	Lead (ton/yr)	Sediment (ton/yr)
60204001	17.95	4.89	0.53	0.34	0.55	0.19	115
60204002	130.54	43.15	3.74	2.49	3.69	1.21	797
60204003	27.00	9.50	0.80	0.70	0.96	0.28	146
60204004	63.05	25.99	2.00	1.40	1.85	0.54	624
60204005	153.57	58.77	4.71	3.32	4.56	1.42	1,922
60204006	306.16	127.24	11.54	9.61	12.76	3.87	6,076
60204007	947.36	387.02	26.02	20.87	27.54	8.94	11,551
60204008	28.73	12.78	2.59	3.37	4.44	1.28	672
60204009	160.07	66.81	4.88	3.43	4.65	1.53	1,878
60204010	66.49	19.84	2.68	2.45	3.56	1.12	300
60204011	128.38	29.30	3.51	2.23	3.90	1.39	293
60204012	9.29	3.28	0.35	0.18	0.28	0.10	29
60204013	3.08	1.37	0.22	0.25	0.32	0.09	37
60204014	11.63	5.09	0.95	1.21	1.60	0.46	176
60204015	10.92	5.19	0.52	0.47	0.62	0.20	88
60204016	121.31	48.17	3.96	3.01	4.08	1.25	2,256
60204017	69.19	31.03	2.59	1.71	2.27	0.72	2,039
60204018	138.54	61.05	4.97	3.07	4.13	1.32	3,440
60204019	74.28	29.53	2.30	1.59	2.17	0.64	570
60204020	83.60	36.63	2.97	2.02	2.68	0.86	2,751
60204021	507.96	196.17	17.28	12.35	17.23	5.37	6,497
60204022	628.67	203.13	19.19	12.03	18.56	6.26	5,197
60204023	462.42	202.60	15.89	10.34	13.74	4.30	10,412
60204024	129.52	55.10	4.09	2.65	3.53	1.07	1,544
60204025	529.08	126.03	14.45	9.47	16.17	5.67	1,332
60204105	187.24	77.29	6.34	4.21	5.71	1.97	6,370
60204114	242.38	103.10	8.89	6.43	8.64	2.71	6,184
60204122	91.81	36.48	2.86	1.98	2.71	0.85	859
60205001	668.60	282.89	19.74	9.97	13.54	4.71	6,013
60205002	412.64	184.83	13.07	4.37	6.02	2.25	2,883
60205003	54.54	23.47	1.53	0.65	0.88	0.31	362
60205004	97.41	45.55	3.34	1.02	1.39	0.51	676
60205005	299.94	134.58	9.82	3.55	4.89	1.77	2,519
60205006	348.38	160.86	11.53	3.62	4.92	1.81	2,273
60205007	666.88	281.65	21.54	9.22	12.67	4.45	7,545
60205008	147.08	61.18	3.85	1.71	2.35	0.88	1,018
60205009	417.12	152.88	10.97	6.94	9.89	3.33	2,224
60205010	155.76	36.98	4.20	2.86	4.83	1.68	231
60205011	570.18	131.20	15.30	10.34	17.69	6.17	944
60205012	3.69	1.07	0.10	0.08	0.12	0.04	2,447
60205013	271.98	90.04	8.20	5.02	7.70	2.58	1,868
60205014	327.98	102.72	9.79	6.50	10.02	3.40	159
60205015	162.08	66.92	4.84	3.35	4.54	1.52	2,778
60205016	51.99	20.03	1.24	0.83	1.14	0.40	389
60205017	308.58	126.17	9.00	4.79	6.73	2.28	2,145
60205018	26.90	10.92	1.06	0.88	1.20	0.36	101
60205020	63.32	25.98	2.61	1.55	2.23	0.91	280

6.2.2.b Upper Versus Lower Mobile River Basin

A comparison was made between the total loads contributed by the Upper Mobile River basin to Mobile Bay and those contributed by the Lower Mobile River basin to Mobile Bay. Loads contributed by the Upper Mobile River basin to the bay were determined by removing all contributions from the Lower Mobile River basin in the model, and simply routing flow and pollutants from the Alabama and Tombigbee Rivers through main-stem rivers feeding into the bay. Contributions from the Lower Mobile River basin were determined by essentially canceling out the contribution of flow and pollutants from the Alabama and Tombigbee Rivers in the model.

Contributions from the upper watershed were estimated to be significantly higher than those from the immediate bay area. In general, the difference is most pronounced for nutrients, while less pronounced for BOD_5 and metals. The results of this comparison, for the mean year, are presented in Appendix K.

6.2.3 Source Analysis

The source analysis compares nonpoint source contributions to point source contributions in the Lower Mobile River basin. A comparison between mean annual nonpoint source loads and point source loads was made for all pollutants represented in the watershed model. The comparisons focus only on loadings in the Lower Mobile River basin and are presented in Appendix L.

Modeled nonpoint source flow and pollutant loads were considerably higher than point source loads. The greatest deviation was for metals and sediment. The smallest deviation was for total phosphorus.

6.2.4 Comparisons to Literature Estimations

Comparisons were made between the watershed model results and pollutant loading estimations presented in the literature. The watershed model results were compared to USGS estimates for the simulation period between 1972 and 1993 and values referenced in the *Preliminary Characterization of Water Quality of the Mobile Bay National Estuary Program (MBNEP) Study Area* report. Table 6-8 shows a comparison of results for the Tombigbee and Alabama Rivers to USGS data.

Table 6-8. Comparison of model loadings to USGS observed loadings

	Tombigbee			Alabama		
	Flow (cfs)	TN (tons)	TP (tons)	Flow (cfs)	TN (tons)	TP (tons)
USGS [a]	32,322	27,500	3,540	34,946	22,200	2,570
Model	34,648	43,110	3,956	36,649	36,138	2,900
% Difference	7.2%	36.2%	10.51%	4.6%	38.6%	11.4%
USGS temporal trend significance	p > 0.10	p > 0.10	p < 0.05	P > 0.10	p > 0.10	p < 0.05

[a] Source: USGS Water Resources Investigations Report 96-4113

The average modeled flows closely match the average USGS observed flows. Due to the variability of assumptions, sampling times, locations, and frequencies, nutrient load estimates are typically more difficult to compare. Modeled nutrients were higher than USGS estimates, with total phosphorus (TP) slightly higher and total nitrogen (TN) significantly higher. Trend analysis by the USGS showed the total phosphorus observations were within the 95 percent confidence interval. Furthermore, there was a small percent difference in modeled estimates versus USGS estimates. Since phosphorus is more conservative than nitrogen, the similarity in phosphorus estimates verifies the modeled estimates.

Differences in TN estimates can be attributed to differing assumptions on runoff potential and the significance of nitrogen decay and uptake processes. The modeled estimates are not unreasonable compared to USGS estimations, which showed TN estimates higher than 40,000 tons in the Tombigbee River for 5 of 22 years and higher than 30,000 tons in the Alabama River for 9 of 22 years.

Regarding sediment loads to the bay, Baya et al. (1998) stated that Isphording reported mean annual sediment loading estimates of 4.5 million metric tonnes for Mobile Bay. Modeling results are consistent with this estimate: from 3.875 million tons (3.515 million metric tonnes) for a dry year to as high as 9.505 million tons (8.621 million metric tonnes) for a wet year. Sediment estimates to Mobile Bay for the year selected to represent mean or typical conditions were on the order of 5.486 million tons (4.976 million metric tones).

A comparison of model results to the 208 report for the Mobile area was not made for a number of reasons:

- The 208 study involved small catchment basins in specific locations near Mobile, AL.
- Runoff data reported represents conditions in the late 1970's.
- The study involved monitoring specific storm events at discrete locations in the small catchments

Parameters for the watershed model developed over the course of this project were derived to characterize general runoff patterns and total loadings from each and all land sources to the rivers, tributaries, and ultimately, to the bay itself. Model results were compared to in-stream flow and water quality monitoring data during calibration.

These aspects could have been compared, but with some reservation:

- Accumulation rates used in the HSPF model for the various pollutants can be compared to those published in the study.
- Likewise, unit area loadings calculated during individual storms can be compared to those published in the study.

The results from such comparisons, however, may not be meaningful because of the variability of the lot characteristics as described in the 208 study. Percent imperviousness, varying hydrologic representation due to small-scale soil variability, and changes in landuse since the time of the study (late 1970s) are among the factors that make direct area-for-area runoff comparisons between the current modeled results and the published data in the study less meaningful. In summary, the spatial scale and the highly varied timing of the two studies do not match significantly enough to allow for meaningful comparison.

6.3 Watershed Model Results - Future Conditions

Running the watershed model to represent future conditions was intended to provide an estimate of how flow and loads contributed to Mobile Bay may change over the next decade. Results from the two future conditions scenarios (2010 land use/current point source discharges and 2010 land use/permit point source conditions) are presented in terms of flow and loading comparisons.

6.3.1 2010 Land Use Scenario/Current Point Source Discharges

6.3.1.a Lower Basin Nonpoint Source Comparison

A comparison of future condition nonpoint source contributions to existing conditions was made for the Lower Mobile River basin. Nonpoint source flows were estimated to increase by less than 0.2% for the mean water year, while pollutant loads were estimated to both decrease (by 0.1% percent for sediment) and increase (by as much as 3.1% for lead). Table 6-9 compares the results of the 2010 land use conditions and existing conditions.

Table 6-9. Nonpoint source loadings in the lower basin for existing and future conditions

		Avg. flow (cfs)	BOD_5 (ton/yr)	TN (ton/yr)	TP (ton/yr)	Zn (ton/yr)	Cu (ton/yr)	Pb (ton/yr)	Sediment (ton/yr)
Dry	**Existing Conditions**	2,151	5,332	1,924	175	110	159	52	92,920
	2010 LU	2,154	5,419	1,945	178	112	163	54	92,820
	Percent Change	0.15%	1.62%	1.12%	1.8%	1.93%	2.28%	2.97%	-0.110%
Mean	**Existing Conditions**	2,053	5,949	2,179	192	120	173	57	94,940
	2010 LU	2,057	6,042	2,200	195	122	177	59	94,860
	Percent Change	0.18%	1.56%	0.98%	1.87%	2.05%	2.41%	3.08%	-0.084%
Wet	**Existing Conditions**	3,604	9,192	3,467	312	225	314	95	159,840
	2010 LU	3,604	9,295	3,492	317	228	318	97	159,720
	Percent Change	0%	1.12%	0.72%	1.39%	1.14%	1.39%	2.24%	-0.075%

6.3.1.b Entire Basin Comparison

In a similar fashion, the flow and pollutant contributions from the entire Mobile River basin to Mobile Bay were output and compared to existing conditions. These contributions represent contributions from all nonpoint and point sources in the basin, and they take into account the effects of routing flow and pollutants through the major rivers. The results showed a minor increase for the future land use scenario over the existing land use conditions simulation, with the exception of sediment, which was negligible. The comparisons are shown in Table 6-10.

Table 6-10. Loadings to Mobile Bay under existing and future land use conditions

		Avg. flow (cfs)	BOD_5 (ton/yr)	TN (ton/yr)	TP (ton/yr)	Zn (ton/yr)	Cu (ton/yr)	Pb (ton/yr)	Sediment (ton/yr)
Dry	**Existing Conditions**	48,187	87,530	49,326	3,875	3,435	4,656	769	3,875,100
	2010 LU	48,196	87,675	49,376	3,881	3,440	4,663	772	3,875,000
	Percent Change	0.02%	0.17%	0.10%	0.16%	0.13%	0.16%	0.44%	-0.003%
Mean	**Existing Conditions**	66,192	121,594	69,693	5,489	4,718	6,389	1074	5,485,600
	2010 LU	66,201	121,742	69,738	5,495	4,723	6,397	1077	5,485,500
	Percent Change	0.01%	0.12%	0.06%	0.12%	0.10%	0.12%	0.33%	-0.001%
Wet	**Existing Conditions**	96,525	179,339	100,232	8,313	6,073	8,165	1413	9,504,700
	2010 LU	96,533	179,500	100,283	8,321	6,078	8,173	1417	9,504,600
	Percent Change	0.01%	0.09%	0.05%	0.10%	0.08%	0.10%	0.30%	-0.001%

6.3.2 2010 Land Use Scenario/Permitted Point Source Discharges

6.3.2.a Point Source Comparison

Contributions from point source facilities represented in the model for the existing and future conditions (permit limits) varied greatly. The variability was based entirely on the difference between monitored and permitted discharge values. In most cases, monitored facility discharges were at or under the permitted limits, however, there were situations where facilities were exceeding permitted limits.

Table 6-11 presents the point source contributions for existing and future conditions (permit limits) for the entire basin. Table 6-12 presents the point source contributions for existing and future conditions (permit limits) for only the lower basin. It is important to note that these loads represent the end-of-pipe loads summed for all facilities. They do not represent the effects of routing the discharged pollutants through the waterbodies to Mobile Bay. Therefore, the magnitude of contributions may appear large for some pollutants.

Table 6-11. Comparison of point source contributions for existing and future conditions (entire basin)

	Avg. flow (cfs)	BOD5 (ton/yr)	TN (ton/yr)	TP (ton/yr)	Zn (ton/yr)	Cu (ton/yr)	Pb (ton/yr)	Sediment (ton/yr)
Existing Conditions	1,750	25,056	6,533	1,281	191	174	73	29,047
Permit Limits	1,805	35,579	7,317	1,345	233	228	84	46,704
Percent Change	3%	42%	12%	5%	22%	31%	15%	36%

Table 6-12. Comparison of point source contributions for existing and future conditions (lower basin)

	Avg. flow (cfs)	BOD5 (ton/yr)	TN (ton/yr)	TP (ton/yr)	Zn (ton/yr)	Cu (ton/yr)	Pb (ton/yr)	Sediment (ton/yr)
Existing Conditions	81	1,387	1,049	145	6.7	1.6	1.1	1,571
Permit Limits	83	2,053	1,699	205	8.6	2.6	1.7	2,168
Percent Change	2%	48%	62%	41%	29%	61%	55%	38%

6.3.2.b Entire Basin Comparison

The overall contribution to Mobile Bay was also compared for the future land use condition/permitted point source discharge condition. As with the first future scenario, only a minor difference between contributions for existing conditions and the future scenario was noticed. Table 6-13 presents a comparison of all flow and load (nonpoint and point source) contributed to the bay under existing conditions and the 2010 land use/permitted point source contributions conditions. These contributions represent contributions from all nonpoint and point sources in the basin, and they take into account the effects of routing flow and pollutants through the major rivers.

Table 6-13. Loadings to Mobile Bay under existing and future land use/permitted point source conditions

		Avg. flow (cfs)	BOD_5 (ton/yr)	TN (ton/yr)	TP (ton/yr)	Zn (ton/yr)	Cu (ton/yr)	Pb (ton/yr)	Sediment (ton/yr)
Dry	**Existing Conditions**	48,187	87,530	49,326	3,875	3,435	4,656	769	3,875,100
	2010 LU/Permit Limits	48,196	94,827	54,031	4,195	3,627	4,831	846	3,876,600
	Percent Change	0.02%	8.34%	9.54%	8.26%	5.60%	3.77%	9.94%	0.038%
Mean	**Existing Conditions**	66,192	121,594	69,693	5,489	4,718	6,389	1,074	5,485,600
	2010 LU/Permit Limits	66,201	129,340	74,641	5,845	4,916	6,569	1,153	5,487,100
	Percent Change	0.01%	6.37%	7.10%	6.48%	4.20%	2.82%	7.38%	0.027%
Wet	**Existing Conditions**	96,525	179,339	100,232	8,313	6,073	8,165	1,413	9,504,700
	2010 LU/Permit Limits	96,533	187,338	105,161	8,715	6,266	8,341	1,490	9,506,100
	Percent Change	0.01%	4.46%	4.92%	4.83%	3.17%	2.16%	5.46%	0.015%

7.0 Discussion and Conclusions

7.1 Overview

In order to meet the defined objectives of this project, a watershed model was developed to represent the Mobile River basin. The model simulated contributions from nonpoint and point sources and routed flow and water quality through major stream networks to Mobile Bay. Flow and pollutant loadings to Mobile Bay were estimated, as well as their distribution throughout the contributing drainage area. In addition to the watershed model, a hydrodynamic model of Mobile Bay was configured. This model was intended to be a starting point for analyzing hydrodynamics and ultimately water quality within the bay. The bay model was developed in parallel with the watershed model, in order to set in place critical linkages between the models.

7.2 Data Limitations and Recommendations

The watershed model, in its current state, is capable of estimating flow, total nitrogen, total phosphorus, $BOD_{5,}$ zinc, copper, lead, and sediment. Estimates generated by the model are directly a result of calibrations and validations performed at multiple locations in the basin and available point source discharge data. For many parameters, particularly sediment and metals, insufficient in-stream monitoring data were available throughout the basin to perform a thorough calibration and validation. It is recommended that additional monitoring data be identified and/or collected to support further model calibration. Recommended monitoring data include, but are not limited to the following:

- <u>Baseflow samples</u>. Baseflow samples should include flow and water quality samples (for all parameters of interest) representing baseflow conditions throughout the basin. For watersheds containing no point sources, these samples provide insight into low-flow/background conditions. In watersheds with point sources, the samples support assessment of point source influences.
- <u>Storm samples</u>. Storm samples should include flow and water quality samples (for all parameters of interest) representing storms of varying magnitude. It is recommended that multiple samples be taken to accurately represent storm pollutographs. Storm samples support assignment of nonpoint source-related model parameters and are used to test the model under different hydrologic conditions.
- <u>Land use-specific samples</u>. Calibrating the watershed model requires assignment of hydrologic and water quality samples for different land uses. Monitoring data representing small watersheds of predominantly a single land use type are useful in assessing contributions from different nonpoint sources and designating model parameters.

Further model calibration with additional data will ultimately improve the model's load estimation capabilities.

7.3 Future Modeling

Federal and state agencies intend to build on the existing comprehensive modeling framework in place to address key water quality issues in Mobile Bay. One likely step will be to further calibrate and validate hydrodynamics for the bay model and configure the model to represent water quality parameters of interest. This effort will require that flow and water quality loads from the watershed model be applied directly to cells in the bay model.

In fully calibrating and validating the bay model to replicate hydrodynamic and water quality observations, it is expected that the watershed model loads will need to be revisited. The ability of the bay model to accurately represent observations in the bay will be based directly on the accuracy of the watershed model to simulate contributions to the bay. Where insufficient monitoring data were available to support a thorough calibration and validation of the watershed model, as in the case of sediment, the bay model will likely indicate necessary changes.

References

Baya, E., L. Yokel, C. Pineyard III, E. Blancher, S. Skelnar, and W. Isphording. 1998. Preliminary Characterization of Water Quality of the Mobile Bay National Estuary Program (MBNEP) Study Area. Thompson Engineering/TAI Environmental Sciences.

Bicknell, B.R., J.C. Imhoff, Kittle, Jr., A.S. Donigan, and R.C. Johanson. 1996. Hydrological Simulation Program—FORTRAN (HSPF) User's Manual for Release 11. Environmental Research Laboratory, Office of Research and Development, USEPA, Athens, GA.

Bloom, N.S. 1992. On the chemical form of mercury in edible fish and marine invertebrate tissue. Can. J. Fish. Aquat. Sci. 49:1010-1017

Blumberg, A.F. and G.L. Mellor. 1987. A description of a three-dimensional coastal ocean circulation model. In: *Three-dimensional coastal and ocean models, coastal and estuarine science*, Vol. 4. American Geographical Union, pp. 1-19

Cerco, C.F. and Cole, T.M. 1994. Three-dimensional eutrophication model of Chesapeake Bay: Volume 1, main report. Technical Report EL-94-4, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

DiToro, D.M. and Fitzpatrick, J.J. 1993. Chesapeake Bay sediment flux model. Contract Report EL-93-2, US Army Engineer Waterways Experiment Station, Vicksburg, MS, 316 pp.

Hamrick, J.M. 1992(a). A Three-dimensional Environmental Fluid Dynamics Computer Code: Theoretical and Computational Aspects. The College of William and Mary, Virginia Institute of Marine Science. Special report 317, 63 pp.

Hamrick, J.M. 1996. User's Manual for the Environmental Fluid Dynamics Computer Code. Special Report No. 331 in Applied Marine Science and Ocean Engineering, Department of Physical sciences, School of Marine Sciences, Virginia Institute of Marine Sciences.

James, L.D. and Burgess, S.J. 1982. Selection, calibration, and testing of hydrologic models. In *Hydrologic modeling of small watersheds,* ed. C.T. Hahn, H.P. Johnson, and D.L. Brakensiek, pp. 435-472. American Society of Agricultural Engineers, St. Joseph, Michigan.

Johnson, B.H., K.W. Kim, R.E. Heath, B.B. Hsieh, and H.L. Butler. 1993. Validation of three-dimensional hydrodynamic model of Chesapeake Nay. *J. Hyd. Engrg*. 119:2-20.

Soil Conservation Service. 1986. Urban Hydrology for Small Watersheds, Technical Release 55. United States Department of Agriculture.

Tetra Tech, Inc. 1998. Nonpoint source pollutant loading evaluation ACT & ACF water allocation formula environmental impact statements. Prepared for United States Army Corps of Engineers Mobile District. Mobile, AL.

Tetra Tech, Inc. 1999. Water quality improvements in the Lower Mississippi river valley: Analysis of nutrient loading in the Yazoo River basin. Prepared for the United States Environmental Protection Agency, Region 4, Gulf of Mexico Program, Mississippi Department of Environmental Quality.

USEPA. 1987. Mercury Study Report to Congress. EPA-452/R-97-003. U.S. Environmental Protection Agency, Washington, D.C.

USEPA. 1998. Better Assessment Science Integrating Point and Nonpoint Sources. BASINS, Version 2.0 User's Manual. EPA-823-B-98-006. United States Environmental Protection Agency, Office of Water. November 1998.

USGS. 1998. National Water-Quality Assessment (NAWQA) Program Mobile River Basin. http://tenn.er.usgs.gov/MOBL/basin-description.html.

Appendix A

Subwatershed IDs for the Upper and Lower Basin Areas

Figure A-1. Subwatershed IDs for the upper basin

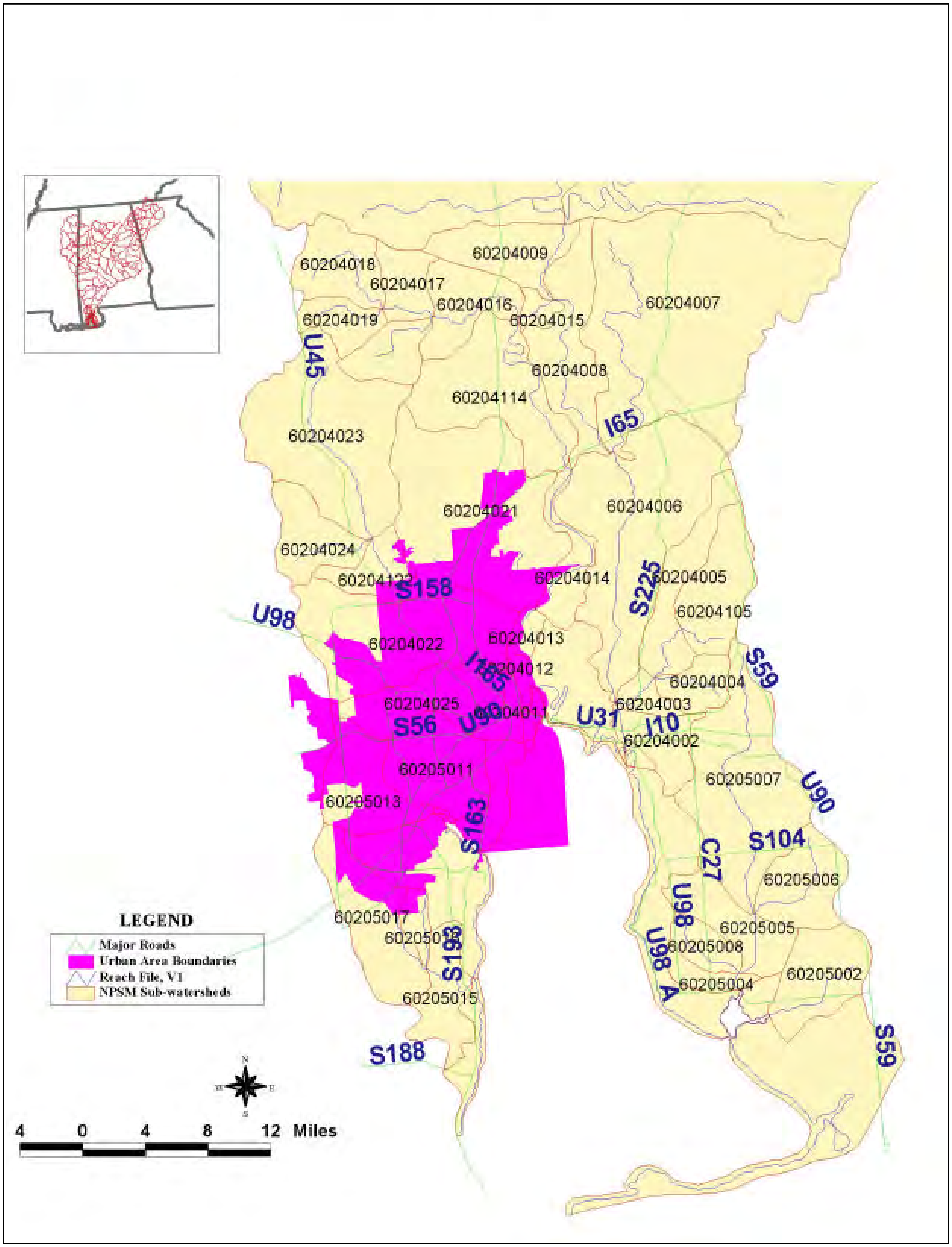

Figure A-2. Subwatershed IDs for the lower basin

Appendix B

Average and Maximum Loadings and Concentrations for Point Source Facilities Located in the Mobile River Basin

Table B-1. Average loadings from point sources used in the watershed model

Facility	Sub-watershed ID	Flow (cfs)	BOD_5 (lb/hr)	Copper (lb/hr)	Lead (lb/hr)	Total N (lb/hr)	Total P (lb/hr)	TSS (lb/hr)	Zinc (lb/hr)
AL0000680	60112012	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AL0000973	60113026	0.85	1.60	0.00	0.00	2.82	0.00	4.46	0.01
AL0001449	60111009	1.68	2.39	0.02	0.02	0.35	0.09	3.78	0.04
AL0001597	60204114	0.97	2.00	0.16	0.04	0.33	0.00	11.38	0.12
AL0001627	50107049	1.96	0.75	0.05	0.01	0.36	0.00	2.60	0.44
AL0001767	60112002	0.22	0.81	0.00	0.00	1.77	0.00	0.96	0.00
AL0001945	60203001	5.42	20.09	0.41	0.20	0.00	0.00	51.28	0.24
AL0001961	60204114	1.32	1.24	0.19	0.04	0.00	0.00	3.32	0.14
AL0001970	60204114	0.72	5.40	0.11	0.02	0.96	0.00	6.19	0.08
AL0002097	60111001	0.09	0.24	0.00	0.00	0.40	0.00	0.26	0.00
AL0002631	50202017	12.96	0.00	0.05	0.04	0.00	0.00	8.75	0.18
AL0002658	50106001	0.39	0.55	0.07	0.03	0.06	0.00	3.72	0.01
AL0002666	60204022	2.34	3.97	0.19	0.96	2.53	0.13	57.53	0.52
AL0002674	50203001	29.24	354.94	0.12	0.07	0.00	0.00	464.27	0.45
AL0002755	60203007	29.60	108.34	0.12	0.07	0.00	0.00	80.31	0.46
AL0002780	60204013	46.06	499.04	0.19	0.10	0.00	0.00	1283.44	0.71
AL0002801	60204022	111.12	584.99	0.45	0.25	0.00	0.00	1055.09	1.71
AL0002828	60201033	24.91	113.94	0.10	0.06	0.00	0.00	164.11	0.38
AL0002879	60204114	40.60	0.00	0.82	0.09	0.00	0.00	24.73	0.03
AL0002887	50106041	7.82	0.00	1.75	0.02	0.00	0.00	11.72	1.23
AL0002909	50202009	19.25	0.00	4.31	0.04	0.00	0.00	21.70	2.40
AL0002917	60113001	7.33	0.00	0.15	0.02	0.00	0.00	7.19	0.24
AL0003018	50201006	57.09	687.98	0.23	0.13	0.00	0.05	893.81	0.88
AL0003026	60204114	15.71	62.14	4.49	0.99	0.00	0.00	103.47	0.17
AL0003085	60204114	1.22	2.11	0.09	0.02	0.68	0.00	11.95	0.07
AL0003093	60203001	13.15	36.96	1.64	0.36	3.51	0.00	79.15	1.19
AL0003115	50201006	44.25	380.97	0.18	0.10	0.00	0.00	360.45	0.68
AL0003140	50107049	34.49	0.00	7.72	0.08	0.00	0.00	0.00	5.43
AL0003158	50106001	76.25	330.61	0.31	0.17	0.00	0.00	317.78	1.18
AL0003221	60112012	0.02	0.03	0.00	0.00	0.01	0.00	0.08	0.00
AL0003247	60111001	11.84	137.45	0.12	0.93	5.49	0.00	39.63	0.83
AL0003301	60201016	74.88	319.24	0.31	0.17	0.00	0.00	186.66	1.15
AL0003336	50202017	1.47	0.00	0.01	0.00	0.00	0.00	4.51	0.02
AL0003379	60111001	0.34	0.00	0.00	0.00	0.00	0.00	1.99	0.01
AL0003395	50202017	1.88	1.56	0.02	0.02	0.13	0.62	6.57	0.04
AL0003417	60111001	0.39	0.00	0.00	0.00	3.75	0.00	7.36	0.01
AL0003514	60204022	0.57	0.27	0.11	0.00	0.27	0.00	14.54	0.01
AL0003620	60112012	0.01	0.02	0.00	0.00	0.00	0.00	0.03	0.00
AL0003646	60112012	30.48	104.76	0.72	0.09	103.38	0.00	877.08	0.72
AL0003662	50107049	4.97	0.00	0.00	0.00	0.00	0.00	11.55	0.00
AL0003671	60203007	0.01	0.07	0.07	0.00	0.00	0.00	0.09	0.07
AL0003794	60109001	1.82	0.00	0.02	0.02	0.00	0.00	2.39	0.04
AL0003930	50106001	0.85	10.23	0.00	0.00	0.36	0.00	16.19	0.01
AL0020001	50107049	3.35	7.06	0.01	0.01	8.40	1.18	8.52	0.06
AL0020141	50109017	1.29	0.75	0.00	0.00	9.69	1.65	4.22	0.02
AL0020486	50110028	1.63	4.37	0.01	0.00	3.52	0.36	16.44	0.03

Facility	Sub-watershed ID	Flow (cfs)	BOD_5 (lb/hr)	Copper (lb/hr)	Lead (lb/hr)	Total N (lb/hr)	Total P (lb/hr)	TSS (lb/hr)	Zinc (lb/hr)
AL0020842	60110003	2.44	2.65	0.01	0.01	0.04	0.00	9.79	0.05
AL0020869	60203007	0.93	9.43	0.00	0.00	0.49	0.00	13.75	0.02
AL0020885	60204022	1.48	9.84	0.01	0.00	0.08	0.00	25.28	0.03
AL0021156	50109001	2.06	1.44	0.01	0.01	4.75	0.50	2.73	0.04
AL0021971	60112012	0.22	0.00	0.00	0.00	0.00	0.00	0.70	0.00
AL0022136	50203022	1.35	0.48	0.01	0.00	0.16	0.00	3.96	0.03
AL0022195	50106001	15.54	18.81	0.06	0.04	41.19	23.14	15.26	0.29
AL0022225	50201037	20.00	65.41	0.08	0.05	61.18	12.59	73.61	0.37
AL0022241	50201037	3.73	6.93	0.01	0.01	10.05	1.91	14.20	0.07
AL0022357	50106001	4.48	3.74	0.02	0.01	10.71	1.42	11.83	0.08
AL0022578	50201001	5.74	30.48	0.02	0.01	14.69	3.07	17.61	0.11
AL0022586	50106019	3.32	11.31	0.01	0.01	6.17	2.97	3.06	0.06
AL0022659	50106040	6.55	20.28	0.03	0.02	16.46	3.40	20.14	0.12
AL0022713	60113026	29.66	27.51	0.11	0.07	77.23	6.18	70.51	0.55
AL0022926	60111009	7.30	4.87	0.03	0.02	18.27	0.81	7.67	0.14
AL0022934	50202017	3.30	0.71	0.01	0.01	8.55	0.80	7.30	0.06
AL0023027	50202017	14.51	4.01	0.06	0.04	37.44	5.59	10.20	0.27
AL0023078	60110014	3.28	12.99	0.01	0.01	7.89	0.80	8.64	0.06
AL0023086	60110014	39.19	195.85	0.15	0.10	155.23	21.61	201.43	0.73
AL0023094	60109005	20.69	58.16	0.08	0.05	61.40	8.50	56.73	0.39
AL0023116	50202017	2.03	0.98	0.01	0.01	4.46	2.27	1.00	0.04
AL0023205	60204025	5.82	24.66	0.02	0.01	1.03	0.00	11.69	0.11
AL0023272	60203007	7.22	2.42	0.23	0.05	4.99	0.00	15.43	0.16
AL0023311	50106040	5.41	15.53	0.02	0.01	0.66	0.00	11.60	0.10
AL0023400	60105003	0.52	0.83	0.00	0.00	0.50	0.00	3.96	0.01
AL0023418	60109001	6.27	7.12	0.02	0.02	1.48	0.00	14.59	0.12
AL0023647	50202017	57.60	17.14	0.22	0.14	148.38	14.86	120.13	1.07
AL0023655	60112012	76.32	23.75	0.29	0.19	196.10	20.48	125.17	1.42
AL0023892	60111001	1.27	0.00	0.00	0.00	0.00	0.00	2.31	0.00
AL0024252	50202017	0.03	0.02	0.00	0.00	0.00	0.00	0.05	0.00
AL0024376	50105001	2.04	8.11	0.01	0.01	0.00	0.00	0.00	0.04
AL0024457	50202017	0.83	0.00	0.00	0.00	0.00	0.00	1.51	0.01
AL0024520	50106019	2.99	2.16	0.01	0.01	7.48	3.14	4.62	0.06
AL0025828	50202017	3.06	7.27	0.01	0.01	9.08	5.14	2.26	0.06
AL0025968	60113001	85.10	699.95	0.35	0.19	4.80	0.00	1909.47	1.31
AL0025984	50110020	1.93	3.47	0.01	0.00	0.38	0.00	5.96	0.04
AL0026590	60112002	2.86	0.00	0.03	0.03	0.00	0.00	7.50	0.06
AL0026654	50201037	2.69	1.56	0.01	0.01	6.93	3.37	3.97	0.05
AL0026832	60109008	1.25	2.21	0.01	0.01	0.52	0.00	4.95	0.03
AL0026913	60111001	26.25	20.84	0.10	0.06	66.51	6.59	23.02	0.49
AL0026921	60113026	0.16	4.44	0.03	0.01	0.00	0.00	3.15	0.02
AL0027146	60111001	7.35	0.00	3.96	0.02	0.00	0.00	25.54	0.20
AL0027561	60204002	3.17	1.79	0.01	0.01	7.93	1.39	10.92	0.06
AL0027723	50201037	2.77	7.14	0.01	0.01	5.66	2.18	6.56	0.05
AL0027782	50204010	1.11	0.72	0.00	0.00	0.15	0.00	3.18	0.02
AL0027863	50201037	32.37	26.05	0.12	0.08	93.01	12.76	0.00	0.60
AL0029181	60112002	63.37	0.00	0.57	0.71	0.00	0.00	325.56	1.42

Facility	Sub-watershed ID	Flow (cfs)	BOD_5 (lb/hr)	Copper (lb/hr)	Lead (lb/hr)	Total N (lb/hr)	Total P (lb/hr)	TSS (lb/hr)	Zinc (lb/hr)
AL0029432	60112012	1.71	0.00	0.02	0.02	0.00	0.00	2.81	0.04
AL0029475	60112002	33.49	0.00	0.30	0.38	0.00	0.00	123.83	0.75
AL0030546	60112025	31.60	0.00	0.28	0.36	0.00	0.00	116.45	0.71
AL0040843	60109005	0.80	5.43	0.00	0.00	0.52	0.36	14.41	0.08
AL0041653	50202017	2.05	0.98	0.01	0.01	5.23	1.07	1.10	0.04
AL0041866	60107007	0.53	0.00	0.00	0.01	0.00	0.00	1.30	0.01
AL0042447	60204114	1.09	2.10	0.05	0.05	0.38	0.00	8.70	0.04
AL0043168	60201033	2.99	28.68	0.01	0.01	5.88	0.00	13.42	0.06
AL0043176	50201001	1.18	0.31	0.00	0.00	0.03	0.00	0.73	0.02
AL0045969	50202017	1.88	0.42	0.01	0.00	5.08	1.44	0.58	0.04
AL0045993	50106019	2.67	1.93	0.01	0.01	6.68	1.55	3.03	0.05
AL0048372	60103002	0.98	0.98	0.00	0.00	2.19	0.10	3.45	0.02
AL0048763	50110020	1.64	1.36	0.01	0.00	1.59	2.00	3.27	0.03
AL0048861	50109001	8.26	7.27	0.03	0.02	21.10	5.35	31.06	0.15
AL0049549	60111009	1.90	6.79	0.01	0.00	0.76	0.00	11.53	0.04
AL0049603	60111009	4.43	2.42	0.02	0.01	1.84	0.00	9.22	0.08
AL0050237	50110024	6.67	3.74	0.03	0.02	16.87	1.65	10.28	0.12
AL0050245	50110028	2.50	1.77	0.01	0.01	6.54	0.85	2.49	0.05
AL0050423	60109008	5.63	7.20	0.02	0.01	14.08	5.07	15.09	0.10
AL0052264	60113026	1.13	1.61	0.01	0.01	0.00	0.00	0.00	0.03
AL0053201	50106040	14.35	44.63	0.05	0.04	35.38	7.27	43.56	0.27
AL0054399	60204006	0.81	0.00	0.00	0.00	0.00	0.00	16.37	0.01
AL0054631	50107019	2.40	1.31	0.01	0.01	4.24	1.01	4.63	0.04
AL0054640	60107007	2.93	4.48	0.01	0.01	7.33	2.80	9.20	0.05
AL0054666	50202017	2.40	0.70	0.01	0.01	6.01	1.18	1.77	0.04
AL0054704	50201006	3.71	5.99	1.25	0.27	0.00	0.00	10.10	0.88
AL0055204	60204022	1.03	5.58	0.00	0.00	0.48	0.00	3.99	0.02
AL0055239	50106040	122.93	0.00	3.12	2.51	14.12	0.00	359.74	0.06
AL0055786	60204021	1.84	2.63	0.01	0.00	4.96	0.86	3.02	0.03
AL0055859	60204022	0.34	0.53	0.00	0.00	0.09	0.00	2.14	0.01
AL0056758	60109001	0.43	0.00	0.00	0.00	0.00	0.00	0.91	0.01
AL0057037	60112002	1.05	1.21	0.01	0.01	0.00	0.00	0.00	0.02
AL0057193	60113001	1.98	10.22	0.01	0.00	3.44	0.00	21.07	0.04
AL0057657	50106040	3.00	11.02	0.01	0.01	5.81	1.39	21.72	0.06
AL0058408	50106001	3.43	3.14	0.01	0.01	8.59	7.91	17.23	0.06
AL0060216	60113026	1.09	0.89	0.01	0.01	0.00	0.00	0.00	0.02
AL0060798	60112002	2.75	2.09	0.02	0.03	0.00	0.00	0.00	0.06
AL0061786	50202017	0.46	0.00	0.00	0.01	0.00	0.00	2.24	0.01
AL0062421	60112012	15.79	0.00	0.14	0.18	0.00	0.00	51.80	0.36
AL0062430	60112012	0.12	0.14	0.00	0.00	0.00	0.00	0.00	0.00
AL0062715	50109017	0.62	3.47	0.00	0.00	0.44	0.00	7.92	0.01
AL0062723	50105001	0.99	4.17	0.00	0.00	2.48	0.61	10.49	0.02
AL0062839	50109017	0.55	0.28	0.00	0.00	1.70	0.21	0.96	0.01
AL0064025	50107001	3.20	1.98	0.01	0.01	8.53	4.27	12.96	0.06
AL0064394	60112001	4.37	3.07	0.02	0.01	11.38	0.96	0.00	0.08
AL0066869	60109001	0.71	0.00	0.01	0.01	0.00	0.00	1.62	0.02
AL0067067	50202017	3.04	0.31	0.01	0.01	7.63	0.28	0.00	0.06

Facility	Sub-watershed ID	Flow (cfs)	BOD_5 (lb/hr)	Copper (lb/hr)	Lead (lb/hr)	Total N (lb/hr)	Total P (lb/hr)	TSS (lb/hr)	Zinc (lb/hr)
AL0067253	50202017	0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00
GA0000329	50103002	0.21	0.44	0.00	0.00	0.48	0.00	0.82	0.00
GA0001104	50105019	9.65	26.40	0.04	0.02	0.00	2.76	108.05	0.15
GA0001708	50105019	0.41	1.83	0.02	0.02	0.44	0.07	4.89	0.18
GA0020982	50108031	0.54	0.00	0.00	0.00	0.00	0.00	0.00	0.01
GA0021369	50102021	2.63	12.75	0.01	1.68	4.66	0.93	12.54	0.48
GA0024074	50105019	3.08	5.99	0.01	0.01	0.62	1.84	6.28	0.06
GA0024091	50104001	11.10	18.94	0.04	0.09	7.72	0.00	28.58	0.21
GA0024104	50105029	3.14	14.99	0.03	0.04	0.00	7.53	24.21	0.07
GA0024112	50105019	19.17	35.86	0.07	0.05	3.76	9.69	45.69	0.36
GA0024155	50105019	1.63	0.00	0.04	0.24	0.00	0.02	0.00	0.36
GA0024341	50105019	1.54	0.62	0.24	0.48	0.18	0.33	2.09	0.03
GA0024988	50104013	13.01	0.00	0.08	0.10	1.03	1.83	8.50	0.30
GA0025607	50105032	6.73	25.37	0.03	0.02	2.21	0.91	71.24	0.13
GA0025674	50104013	1.38	4.72	0.01	0.72	0.59	1.21	5.41	0.24
GA0025704	50105029	2.72	0.00	0.01	0.01	0.31	4.14	5.90	0.05
GA0025712	50105032	3.71	3.34	0.03	0.03	0.30	3.60	17.45	0.19
GA0026026	50104013	0.38	0.00	0.00	0.00	0.00	0.00	0.00	0.01
GA0026042	50104001	1.74	5.13	0.01	0.00	5.04	3.07	6.65	0.03
GA0030333	50103002	14.89	60.91	0.06	0.04	4.25	32.31	80.00	0.28
GA0032492	50101005	2.57	3.44	0.01	1.68	0.18	3.93	5.42	1.15
GA0046035	50103002	0.21	0.00	0.00	0.00	0.00	0.00	0.00	0.00
GA0046451	50104013	1.60	0.00	0.01	0.00	0.00	0.00	0.00	0.03
GA0046761	50104013	5.02	0.00	0.02	0.01	0.50	0.63	2.53	0.09
MS0001783	60104001	3.66	3.22	0.00	0.00	0.93	0.00	10.77	0.00
MS0001970	60101004	1.82	5.92	0.02	0.01	0.26	0.00	7.92	0.18
MS0002232	60101004	7.53	0.00	0.03	0.02	1.58	0.00	9.14	0.10
MS0003158	60101004	0.24	0.00	0.00	0.00	0.00	0.02	0.60	0.01
MS0020788	60104001	2.64	9.81	0.01	0.01	0.50	0.00	14.71	0.08
MS0023868	60105001	10.84	9.25	0.04	0.03	3.92	0.00	11.46	0.20
MS0024783	60101004	0.65	0.00	0.00	0.00	0.00	0.00	0.00	0.01
MS0036111	60102001	8.15	0.00	0.03	0.02	0.00	0.00	0.00	0.15
MS0036145	60108009	7.25	0.00	0.03	0.02	0.00	0.00	0.00	0.14
MS0036412	60106025	33.57	140.75	0.14	0.08	0.00	0.00	280.93	0.52
MS0040215	60106025	0.10	0.00	1.04	0.00	0.00	0.00	0.19	0.00
MS0045489	60101009	1.53	0.00	0.01	0.00	0.00	0.00	0.00	0.03

Table B-2. Average concentrations from point sources used in the watershed model

Facility	Sub-watershed ID	Flow (cfs)	BOD_5 (mg/L)	Copper (mg/L)	Lead (mg/L)	Total N (mg/L)	Total P (mg/L)	TSS (mg/L)	Zinc (mg/L)
AL0000680	60112012	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AL0000973	60113026	0.85	8.38	0.02	0.01	14.78	0.00	23.40	0.07
AL0001449	60111009	1.68	6.37	0.04	0.05	0.93	0.24	10.06	0.10
AL0001597	60204114	0.97	9.23	0.74	0.16	1.54	0.00	52.39	0.53
AL0001627	50107049	1.96	1.71	0.11	0.03	0.81	0.00	5.92	1.00
AL0001767	60112002	0.22	16.88	0.02	0.01	36.72	0.00	20.05	0.07
AL0001945	60203001	5.42	16.57	0.34	0.16	0.00	0.00	42.30	0.20
AL0001961	60204114	1.32	4.21	0.65	0.14	0.00	0.00	11.22	0.47
AL0001970	60204114	0.72	33.52	0.70	0.15	5.99	0.00	38.38	0.51
AL0002097	60111001	0.09	11.96	0.02	0.01	19.73	0.00	12.93	0.07
AL0002631	50202017	12.96	0.00	0.02	0.01	0.00	0.00	3.02	0.06
AL0002658	50106001	0.39	6.35	0.80	0.30	0.67	0.00	42.93	0.10
AL0002666	60204022	2.34	7.59	0.37	1.83	4.83	0.24	109.83	0.99
AL0002674	50203001	29.24	54.23	0.02	0.01	0.00	0.00	70.93	0.07
AL0002755	60203007	29.60	16.35	0.02	0.01	0.00	0.00	12.12	0.07
AL0002780	60204013	46.06	48.40	0.02	0.01	0.00	0.00	124.48	0.07
AL0002801	60204022	111.12	23.52	0.02	0.01	0.00	0.00	42.42	0.07
AL0002828	60201033	24.91	20.43	0.02	0.01	0.00	0.00	29.43	0.07
AL0002879	60204114	40.60	0.00	0.09	0.01	0.00	0.00	2.72	0.00
AL0002887	50106041	7.82	0.00	1.00	0.01	0.00	0.00	6.69	0.70
AL0002909	50202009	19.25	0.00	1.00	0.01	0.00	0.00	5.03	0.56
AL0002917	60113001	7.33	0.00	0.09	0.01	0.00	0.00	4.38	0.15
AL0003018	50201006	57.09	53.83	0.02	0.01	0.00	0.00	69.94	0.07
AL0003026	60204114	15.71	17.67	1.28	0.28	0.00	0.00	29.42	0.05
AL0003085	60204114	1.22	7.71	0.32	0.07	2.50	0.00	43.75	0.24
AL0003093	60203001	13.15	12.56	0.56	0.12	1.19	0.00	26.89	0.40
AL0003115	50201006	44.25	38.46	0.02	0.01	0.00	0.00	36.39	0.07
AL0003140	50107049	34.49	0.00	1.00	0.01	0.00	0.00	0.00	0.70
AL0003158	50106001	76.25	19.37	0.02	0.01	0.00	0.00	18.62	0.07
AL0003221	60112012	0.02	5.30	0.02	0.01	1.35	0.00	16.50	0.21
AL0003247	60111001	11.84	51.88	0.04	0.35	2.07	0.00	14.96	0.31
AL0003301	60201016	74.88	19.05	0.02	0.01	0.00	0.00	11.14	0.07
AL0003336	50202017	1.47	0.00	0.02	0.01	0.00	0.00	13.70	0.06
AL0003379	60111001	0.34	0.00	0.04	0.05	0.00	0.00	26.11	0.10
AL0003395	50202017	1.88	3.71	0.04	0.05	0.30	1.47	15.61	0.10
AL0003417	60111001	0.39	0.00	0.02	0.01	43.25	0.00	84.97	0.07
AL0003514	60204022	0.57	2.10	0.87	0.01	2.10	0.00	113.99	0.06
AL0003620	60112012	0.01	6.74	0.04	0.05	0.00	0.00	15.63	0.10
AL0003646	60112012	30.48	15.35	0.11	0.01	15.15	0.00	128.55	0.11
AL0003662	50107049	4.97	0.00	0.00	0.00	0.00	0.00	10.38	0.00
AL0003671	60203007	0.01	29.96	30.95	0.01	0.00	0.00	40.84	30.95
AL0003794	60109001	1.82	0.00	0.04	0.05	0.00	0.00	5.88	0.10
AL0003930	50106001	0.85	53.72	0.02	0.01	1.89	0.00	84.99	0.07
AL0020001	50107049	3.35	9.41	0.02	0.01	11.19	1.57	11.35	0.08
AL0020141	50109017	1.29	2.59	0.02	0.01	33.46	5.69	14.56	0.08
AL0020486	50110028	1.63	11.98	0.02	0.01	9.65	0.99	45.09	0.08

Facility	Sub-watershed ID	Flow (cfs)	BOD_5 (mg/L)	Copper (mg/L)	Lead (mg/L)	Total N (mg/L)	Total P (mg/L)	TSS (mg/L)	Zinc (mg/L)
AL0020842	60110003	2.44	4.84	0.02	0.01	0.08	0.00	17.90	0.08
AL0020869	60203007	0.93	45.31	0.02	0.01	2.34	0.00	66.04	0.08
AL0020885	60204022	1.48	29.71	0.02	0.01	0.24	0.00	76.35	0.08
AL0021156	50109001	2.06	3.13	0.02	0.01	10.33	1.10	5.93	0.08
AL0021971	60112012	0.22	0.00	0.04	0.05	0.00	0.00	14.26	0.10
AL0022136	50203022	1.35	1.59	0.02	0.01	0.54	0.00	13.09	0.08
AL0022195	50106001	15.54	5.41	0.02	0.01	11.84	6.65	4.39	0.08
AL0022225	50201037	20.00	14.61	0.02	0.01	13.67	2.81	16.45	0.08
AL0022241	50201037	3.73	8.29	0.02	0.01	12.03	2.29	16.99	0.08
AL0022357	50106001	4.48	3.73	0.02	0.01	10.69	1.42	11.80	0.08
AL0022578	50201001	5.74	23.73	0.02	0.01	11.44	2.39	13.72	0.08
AL0022586	50106019	3.32	15.21	0.02	0.01	8.29	3.99	4.12	0.08
AL0022659	50106040	6.55	13.83	0.02	0.01	11.23	2.32	13.74	0.08
AL0022713	60113026	29.66	4.14	0.02	0.01	11.63	0.93	10.62	0.08
AL0022926	60111009	7.30	2.98	0.02	0.01	11.18	0.49	4.69	0.08
AL0022934	50202017	3.30	0.96	0.02	0.01	11.57	1.08	9.87	0.08
AL0023027	50202017	14.51	1.24	0.02	0.01	11.53	1.72	3.14	0.08
AL0023078	60110014	3.28	17.71	0.02	0.01	10.75	1.09	11.78	0.08
AL0023086	60110014	39.19	22.32	0.02	0.01	17.69	2.46	22.96	0.08
AL0023094	60109005	20.69	12.56	0.02	0.01	13.26	1.83	12.25	0.08
AL0023116	50202017	2.03	2.15	0.02	0.01	9.81	4.98	2.19	0.08
AL0023205	60204025	5.82	18.93	0.02	0.01	0.79	0.00	8.97	0.08
AL0023272	60203007	7.22	1.50	0.14	0.03	3.09	0.00	9.55	0.10
AL0023311	50106040	5.41	12.82	0.02	0.01	0.54	0.00	9.58	0.08
AL0023400	60105003	0.52	7.20	0.02	0.01	4.31	0.00	34.27	0.08
AL0023418	60109001	6.27	5.07	0.02	0.01	1.05	0.00	10.39	0.08
AL0023647	50202017	57.60	1.33	0.02	0.01	11.51	1.15	9.32	0.08
AL0023655	60112012	76.32	1.39	0.02	0.01	11.48	1.20	7.33	0.08
AL0023892	60111001	1.27	0.00	0.00	0.00	0.00	0.00	8.13	0.00
AL0024252	50202017	0.03	3.26	0.02	0.01	0.00	0.00	7.98	0.06
AL0024376	50105001	2.04	17.73	0.02	0.01	0.00	0.00	0.00	0.08
AL0024457	50202017	0.83	0.00	0.02	0.01	0.00	0.00	8.11	0.06
AL0024520	50106019	2.99	3.22	0.02	0.01	11.18	4.70	6.90	0.08
AL0025828	50202017	3.06	10.60	0.02	0.01	13.24	7.50	3.30	0.08
AL0025968	60113001	85.10	36.75	0.02	0.01	0.25	0.00	100.24	0.07
AL0025984	50110020	1.93	8.04	0.02	0.01	0.88	0.00	13.82	0.08
AL0026590	60112002	2.86	0.00	0.04	0.05	0.00	0.00	11.72	0.10
AL0026654	50201037	2.69	2.59	0.02	0.01	11.52	5.61	6.60	0.08
AL0026832	60109008	1.25	7.88	0.04	0.05	1.87	0.00	17.66	0.10
AL0026913	60111001	26.25	3.55	0.02	0.01	11.32	1.12	3.92	0.08
AL0026921	60113026	0.16	126.92	0.79	0.17	0.00	0.00	89.95	0.57
AL0027146	60111001	7.35	0.00	2.40	0.01	0.00	0.00	15.52	0.12
AL0027561	60204002	3.17	2.53	0.02	0.01	11.18	1.96	15.40	0.08
AL0027723	50201037	2.77	11.52	0.02	0.01	9.12	3.52	10.58	0.08
AL0027782	50204010	1.11	2.89	0.02	0.01	0.60	0.00	12.81	0.08
AL0027863	50201037	32.37	3.60	0.02	0.01	12.84	1.76	0.00	0.08
AL0029181	60112002	63.37	0.00	0.04	0.05	0.00	0.00	22.95	0.10

Facility	Sub-watershed ID	Flow (cfs)	BOD_5 (mg/L)	Copper (mg/L)	Lead (mg/L)	Total N (mg/L)	Total P (mg/L)	TSS (mg/L)	Zinc (mg/L)
AL0029432	60112012	1.71	0.00	0.04	0.05	0.00	0.00	7.34	0.10
AL0029475	60112002	33.49	0.00	0.04	0.05	0.00	0.00	16.52	0.10
AL0030546	60112025	31.60	0.00	0.04	0.05	0.00	0.00	16.46	0.10
AL0040843	60109005	0.80	30.17	0.00	0.00	2.91	2.00	80.04	0.43
AL0041653	50202017	2.05	2.14	0.02	0.01	11.37	2.32	2.38	0.08
AL0041866	60107007	0.53	0.00	0.04	0.05	0.00	0.00	10.98	0.10
AL0042447	60204114	1.09	8.61	0.22	0.22	1.56	0.00	35.66	0.16
AL0043168	60201033	2.99	42.87	0.02	0.01	8.79	0.00	20.05	0.08
AL0043176	50201001	1.18	1.16	0.02	0.01	0.13	0.00	2.77	0.08
AL0045969	50202017	1.88	1.00	0.02	0.01	12.06	3.43	1.39	0.08
AL0045993	50106019	2.67	3.23	0.02	0.01	11.18	2.59	5.07	0.08
AL0048372	60103002	0.98	4.50	0.02	0.01	10.02	0.46	15.75	0.08
AL0048763	50110020	1.64	3.69	0.02	0.01	4.33	5.44	8.88	0.08
AL0048861	50109001	8.26	3.93	0.02	0.01	11.42	2.89	16.80	0.08
AL0049549	60111009	1.90	15.98	0.02	0.01	1.80	0.00	27.13	0.08
AL0049603	60111009	4.43	2.44	0.02	0.01	1.86	0.00	9.29	0.08
AL0050237	50110024	6.67	2.51	0.02	0.01	11.30	1.11	6.89	0.08
AL0050245	50110028	2.50	3.17	0.02	0.01	11.69	1.52	4.44	0.08
AL0050423	60109008	5.63	5.72	0.02	0.01	11.18	4.02	11.98	0.08
AL0052264	60113026	1.13	6.37	0.04	0.05	0.00	0.00	0.00	0.10
AL0053201	50106040	14.35	13.90	0.02	0.01	11.01	2.26	13.56	0.08
AL0054399	60204006	0.81	0.00	0.02	0.02	0.00	0.00	90.27	0.06
AL0054631	50107019	2.40	2.45	0.02	0.01	7.90	1.88	8.63	0.08
AL0054640	60107007	2.93	6.84	0.02	0.01	11.18	4.27	14.03	0.08
AL0054666	50202017	2.40	1.30	0.02	0.01	11.18	2.20	3.30	0.08
AL0054704	50201006	3.71	7.21	1.50	0.32	0.00	0.00	12.15	1.05
AL0055204	60204022	1.03	24.15	0.02	0.01	2.09	0.00	17.26	0.08
AL0055239	50106040	122.93	0.00	0.11	0.09	0.51	0.00	13.07	0.00
AL0055786	60204021	1.84	6.37	0.02	0.01	12.01	2.08	7.32	0.08
AL0055859	60204022	0.34	7.02	0.02	0.01	1.21	0.00	28.16	0.07
AL0056758	60109001	0.43	0.00	0.04	0.05	0.00	0.00	9.48	0.10
AL0057037	60112002	1.05	5.16	0.04	0.05	0.00	0.00	0.00	0.10
AL0057193	60113001	1.98	23.10	0.02	0.01	7.79	0.00	47.64	0.08
AL0057657	50106040	3.00	16.43	0.02	0.01	8.66	2.07	32.39	0.08
AL0058408	50106001	3.43	4.09	0.02	0.01	11.19	10.30	22.44	0.08
AL0060216	60113026	1.09	3.64	0.04	0.05	0.00	0.00	0.00	0.10
AL0060798	60112002	2.75	3.40	0.04	0.05	0.00	0.00	0.00	0.10
AL0061786	50202017	0.46	0.00	0.04	0.05	0.00	0.00	21.79	0.10
AL0062421	60112012	15.79	0.00	0.04	0.05	0.00	0.00	14.66	0.10
AL0062430	60112012	0.12	5.33	0.04	0.05	0.00	0.00	0.00	0.10
AL0062715	50109017	0.62	24.87	0.02	0.01	3.17	0.00	56.74	0.08
AL0062723	50105001	0.99	18.81	0.02	0.01	11.18	2.73	47.25	0.08
AL0062839	50109017	0.55	2.28	0.02	0.01	13.67	1.67	7.78	0.08
AL0064025	50107001	3.20	2.77	0.02	0.01	11.93	5.97	18.11	0.08
AL0064394	60112001	4.37	3.14	0.02	0.01	11.64	0.98	0.00	0.08
AL0066869	60109001	0.71	0.00	0.04	0.05	0.00	0.00	10.18	0.10
AL0067067	50202017	3.04	0.45	0.02	0.01	11.23	0.41	0.00	0.08

Facility	Sub-watershed ID	Flow (cfs)	BOD_5 (mg/L)	Copper (mg/L)	Lead (mg/L)	Total N (mg/L)	Total P (mg/L)	TSS (mg/L)	Zinc (mg/L)
AL0067253	50202017	0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00
GA0000329	50103002	0.21	9.30	0.02	0.01	10.22	0.00	17.52	0.10
GA0001104	50105019	9.65	12.22	0.02	0.01	0.00	1.28	50.02	0.07
GA0001708	50105019	0.41	19.93	0.26	0.16	4.80	0.72	53.27	1.96
GA0020982	50108031	0.54	0.00	0.02	0.01	0.00	0.00	0.00	0.08
GA0021369	50102021	2.63	21.66	0.02	2.85	7.91	1.58	21.29	0.82
GA0024074	50105019	3.08	8.68	0.02	0.01	0.91	2.67	9.11	0.08
GA0024091	50104001	11.10	7.62	0.02	0.04	3.11	0.00	11.50	0.08
GA0024104	50105029	3.14	21.33	0.04	0.05	0.00	10.71	34.45	0.10
GA0024112	50105019	19.17	8.36	0.02	0.01	0.88	2.26	10.65	0.08
GA0024155	50105019	1.63	0.00	0.10	0.66	0.00	0.05	0.00	1.00
GA0024341	50105019	1.54	1.79	0.70	1.39	0.52	0.94	6.08	0.08
GA0024988	50104013	13.01	0.00	0.03	0.04	0.35	0.63	2.92	0.10
GA0025607	50105032	6.73	16.84	0.02	0.01	1.47	0.60	47.29	0.08
GA0025674	50104013	1.38	15.26	0.02	2.33	1.90	3.92	17.51	0.78
GA0025704	50105029	2.72	0.00	0.02	0.01	0.50	6.80	9.69	0.08
GA0025712	50105032	3.71	4.02	0.04	0.04	0.36	4.33	21.01	0.23
GA0026026	50104013	0.38	0.00	0.02	0.01	0.00	0.00	0.00	0.08
GA0026042	50104001	1.74	13.16	0.02	0.01	12.94	7.88	17.07	0.08
GA0030333	50103002	14.89	18.27	0.02	0.01	1.28	9.69	24.00	0.08
GA0032492	50101005	2.57	5.98	0.02	2.92	0.32	6.83	9.42	2.01
GA0046035	50103002	0.21	0.00	0.02	0.01	0.00	0.00	0.00	0.08
GA0046451	50104013	1.60	0.00	0.02	0.01	0.00	0.00	0.00	0.08
GA0046761	50104013	5.02	0.00	0.02	0.01	0.45	0.56	2.25	0.08
MS0001783	60104001	3.66	3.93	0.00	0.00	1.14	0.00	13.14	0.00
MS0001970	60101004	1.82	14.53	0.05	0.02	0.64	0.00	19.44	0.44
MS0002232	60101004	7.53	0.00	0.02	0.01	0.94	0.00	5.43	0.06
MS0003158	60101004	0.24	0.00	0.04	0.03	0.00	0.33	11.14	0.11
MS0020788	60104001	2.64	16.60	0.01	0.01	0.85	0.00	24.89	0.13
MS0023868	60105001	10.84	3.81	0.02	0.01	1.61	0.00	4.72	0.08
MS0024783	60101004	0.65	0.00	0.02	0.01	0.00	0.00	0.00	0.08
MS0036111	60102001	8.15	0.00	0.02	0.01	0.00	0.00	0.00	0.08
MS0036145	60108009	7.25	0.00	0.02	0.01	0.00	0.00	0.00	0.08
MS0036412	60106025	33.57	18.73	0.02	0.01	0.00	0.00	37.38	0.07
MS0040215	60106025	0.10	0.00	46.39	0.01	0.00	0.00	8.40	0.06
MS0045489	60101009	1.53	0.00	0.02	0.01	0.00	0.00	0.00	0.08

Table B-3. Maximum loadings from point sources used in the watershed model

Facility	Sub-watershed ID	Flow (cfs)	BOD_5 (lb/hr)	Copper (lb/hr)	Lead (lb/hr)	Total N (lb/hr)	Total P (lb/hr)	TSS (lb/hr)	Zinc (lb/hr)
AL0000680	60112012	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AL0000973	60113026	0.85	2.39	0.01	0.00	5.63	0.00	8.92	0.03
AL0001449	60111009	1.68	3.59	0.03	0.04	0.70	0.18	7.56	0.08
AL0001597	60204114	0.97	3.01	0.32	0.07	0.67	0.00	22.75	0.23
AL0001627	50107049	1.96	1.13	0.10	0.02	0.72	0.00	5.21	0.88
AL0001767	60112002	0.22	1.22	0.00	0.00	3.54	0.00	1.93	0.01
AL0001945	60203001	5.42	30.13	0.82	0.40	0.00	0.00	102.56	0.48
AL0001961	60204114	1.32	1.87	0.39	0.09	0.00	0.00	6.63	0.28
AL0001970	60204114	0.72	8.10	0.23	0.05	1.93	0.00	12.37	0.16
AL0002097	60111001	0.09	0.36	0.00	0.00	0.79	0.00	0.52	0.00
AL0002631	50202017	12.96	0.00	0.11	0.08	0.00	0.00	17.50	0.35
AL0002658	50106001	0.39	0.82	0.14	0.05	0.12	0.00	7.43	0.02
AL0002666	60204022	2.34	5.96	0.38	1.92	5.06	0.25	115.05	1.04
AL0002674	50203001	29.24	532.41	0.24	0.13	0.00	0.00	928.55	0.90
AL0002755	60203007	29.60	162.52	0.24	0.13	0.00	0.00	160.63	0.91
AL0002780	60204013	46.06	748.57	0.38	0.21	0.00	0.00	2566.89	1.42
AL0002801	60204022	111.12	877.49	0.91	0.50	0.00	0.00	2110.18	3.43
AL0002828	60201033	24.91	170.90	0.20	0.11	0.00	0.00	328.23	0.77
AL0002879	60204114	40.60	0.00	1.64	0.18	0.00	0.00	49.46	0.07
AL0002887	50106041	7.82	0.00	3.50	0.04	0.00	0.00	23.43	2.46
AL0002909	50202009	19.25	0.00	8.62	0.09	0.00	0.00	43.39	4.80
AL0002917	60113001	7.33	0.00	0.30	0.03	0.00	0.00	14.39	0.48
AL0003018	50201006	57.09	1031.98	0.47	0.26	0.00	0.11	1787.61	1.76
AL0003026	60204114	15.71	93.20	8.98	1.98	0.00	0.00	206.94	0.35
AL0003085	60204114	1.22	3.16	0.18	0.04	1.36	0.00	23.90	0.13
AL0003093	60203001	13.15	55.44	3.28	0.72	7.01	0.00	158.30	2.38
AL0003115	50201006	44.25	571.45	0.36	0.20	0.00	0.00	720.89	1.36
AL0003140	50107049	34.49	0.00	15.44	0.16	0.00	0.00	0.00	10.86
AL0003158	50106001	76.25	495.92	0.62	0.34	0.00	0.00	635.55	2.35
AL0003221	60112012	0.02	0.04	0.00	0.00	0.01	0.00	0.16	0.00
AL0003247	60111001	11.84	206.18	0.23	1.85	10.98	0.00	79.26	1.65
AL0003301	60201016	74.88	478.87	0.61	0.34	0.00	0.00	373.32	2.31
AL0003336	50202017	1.47	0.00	0.01	0.01	0.00	0.00	9.01	0.04
AL0003379	60111001	0.34	0.00	0.01	0.01	0.00	0.00	3.97	0.02
AL0003395	50202017	1.88	2.34	0.03	0.04	0.25	1.23	13.14	0.08
AL0003417	60111001	0.39	0.00	0.00	0.00	7.49	0.00	14.71	0.01
AL0003514	60204022	0.57	0.40	0.22	0.00	0.54	0.00	29.09	0.02
AL0003620	60112012	0.01	0.02	0.00	0.00	0.00	0.00	0.07	0.00
AL0003646	60112012	30.48	157.14	1.44	0.18	206.76	0.00	1754.16	1.43
AL0003662	50107049	4.97	0.00	0.00	0.00	0.00	0.00	23.09	0.00
AL0003671	60203007	0.01	0.10	0.14	0.00	0.00	0.00	0.18	0.14
AL0003794	60109001	1.82	0.00	0.03	0.04	0.00	0.00	4.79	0.08
AL0003930	50106001	0.85	15.35	0.01	0.00	0.72	0.00	32.38	0.03
AL0020001	50107049	3.35	10.60	0.03	0.02	16.79	2.36	17.04	0.13
AL0020141	50109017	1.29	1.13	0.01	0.01	19.39	3.30	8.44	0.05
AL0020486	50110028	1.63	6.55	0.01	0.01	7.04	0.72	32.89	0.06

Facility	Sub-watershed ID	Flow (cfs)	BOD_5 (lb/hr)	Copper (lb/hr)	Lead (lb/hr)	Total N (lb/hr)	Total P (lb/hr)	TSS (lb/hr)	Zinc (lb/hr)
AL0020842	60110003	2.44	3.97	0.02	0.01	0.09	0.00	19.58	0.09
AL0020869	60203007	0.93	14.15	0.01	0.00	0.97	0.00	27.49	0.03
AL0020885	60204022	1.48	14.76	0.01	0.01	0.16	0.00	50.56	0.06
AL0021156	50109001	2.06	2.16	0.02	0.01	9.51	1.01	5.46	0.08
AL0021971	60112012	0.22	0.00	0.00	0.00	0.00	0.00	1.40	0.01
AL0022136	50203022	1.35	0.72	0.01	0.01	0.33	0.00	7.92	0.05
AL0022195	50106001	15.54	28.22	0.12	0.08	82.39	46.27	30.53	0.58
AL0022225	50201037	20.00	98.11	0.15	0.10	122.36	25.19	147.23	0.75
AL0022241	50201037	3.73	10.40	0.03	0.02	20.11	3.82	28.41	0.14
AL0022357	50106001	4.48	5.61	0.03	0.02	21.42	2.84	23.65	0.17
AL0022578	50201001	5.74	45.71	0.04	0.03	29.38	6.14	35.23	0.21
AL0022586	50106019	3.32	16.97	0.03	0.02	12.34	5.94	6.13	0.12
AL0022659	50106040	6.55	30.42	0.05	0.03	32.92	6.80	40.28	0.24
AL0022713	60113026	29.66	41.27	0.23	0.15	154.45	12.35	141.02	1.11
AL0022926	60111009	7.30	7.31	0.06	0.04	36.55	1.62	15.34	0.27
AL0022934	50202017	3.30	1.07	0.03	0.02	17.10	1.60	14.59	0.12
AL0023027	50202017	14.51	6.02	0.11	0.07	74.88	11.18	20.41	0.54
AL0023078	60110014	3.28	19.49	0.03	0.02	15.78	1.61	17.28	0.12
AL0023086	60110014	39.19	293.77	0.30	0.19	310.46	43.21	402.86	1.46
AL0023094	60109005	20.69	87.23	0.16	0.10	122.80	17.00	113.46	0.77
AL0023116	50202017	2.03	1.47	0.02	0.01	8.93	4.54	1.99	0.08
AL0023205	60204025	5.82	36.98	0.04	0.03	2.05	0.00	23.38	0.22
AL0023272	60203007	7.22	3.63	0.45	0.10	9.98	0.00	30.87	0.33
AL0023311	50106040	5.41	23.29	0.04	0.03	1.32	0.00	23.19	0.20
AL0023400	60105003	0.52	1.25	0.00	0.00	1.00	0.00	7.93	0.02
AL0023418	60109001	6.27	10.68	0.05	0.03	2.96	0.00	29.18	0.23
AL0023647	50202017	57.60	25.71	0.44	0.28	296.76	29.71	240.25	2.15
AL0023655	60112012	76.32	35.63	0.58	0.38	392.19	40.97	250.34	2.85
AL0023892	60111001	1.27	0.00	0.00	0.00	0.00	0.00	4.62	0.00
AL0024252	50202017	0.03	0.03	0.00	0.00	0.00	0.00	0.11	0.00
AL0024376	50105001	2.04	12.16	0.02	0.01	0.00	0.00	0.00	0.08
AL0024457	50202017	0.83	0.00	0.01	0.00	0.00	0.00	3.01	0.02
AL0024520	50106019	2.99	3.23	0.02	0.01	14.96	6.28	9.23	0.11
AL0025828	50202017	3.06	10.90	0.02	0.02	18.16	10.29	4.53	0.11
AL0025968	60113001	85.10	1049.93	0.70	0.38	9.61	0.00	3818.94	2.62
AL0025984	50110020	1.93	5.20	0.01	0.01	0.76	0.00	11.92	0.07
AL0026590	60112002	2.86	0.00	0.05	0.06	0.00	0.00	15.00	0.13
AL0026654	50201037	2.69	2.34	0.02	0.01	13.85	6.74	7.94	0.10
AL0026832	60109008	1.25	3.32	0.02	0.03	1.05	0.00	9.91	0.06
AL0026913	60111001	26.25	31.27	0.20	0.13	133.01	13.17	46.04	0.98
AL0026921	60113026	0.16	6.66	0.06	0.01	0.00	0.00	6.29	0.04
AL0027146	60111001	7.35	0.00	7.91	0.03	0.00	0.00	51.07	0.40
AL0027561	60204002	3.17	2.69	0.02	0.02	15.86	2.78	21.83	0.12
AL0027723	50201037	2.77	10.71	0.02	0.01	11.31	4.36	13.12	0.10
AL0027782	50204010	1.11	1.07	0.01	0.01	0.30	0.00	6.36	0.04
AL0027863	50201037	32.37	39.07	0.25	0.16	186.03	25.52	0.00	1.21
AL0029181	60112002	63.37	0.00	1.14	1.42	0.00	0.00	651.11	2.85

Facility	Sub-watershed ID	Flow (cfs)	BOD_5 (lb/hr)	Copper (lb/hr)	Lead (lb/hr)	Total N (lb/hr)	Total P (lb/hr)	TSS (lb/hr)	Zinc (lb/hr)
AL0029432	60112012	1.71	0.00	0.03	0.04	0.00	0.00	5.62	0.08
AL0029475	60112002	33.49	0.00	0.60	0.75	0.00	0.00	247.66	1.51
AL0030546	60112025	31.60	0.00	0.57	0.71	0.00	0.00	232.90	1.42
AL0040843	60109005	0.80	8.15	0.00	0.00	1.05	0.72	28.83	0.16
AL0041653	50202017	2.05	1.47	0.02	0.01	10.45	2.13	2.19	0.08
AL0041866	60107007	0.53	0.00	0.01	0.01	0.00	0.00	2.61	0.02
AL0042447	60204114	1.09	3.15	0.11	0.11	0.76	0.00	17.40	0.08
AL0043168	60201033	2.99	43.03	0.02	0.01	11.76	0.00	26.83	0.11
AL0043176	50201001	1.18	0.46	0.01	0.01	0.07	0.00	1.46	0.04
AL0045969	50202017	1.88	0.63	0.01	0.01	10.15	2.88	1.17	0.07
AL0045993	50106019	2.67	2.90	0.02	0.01	13.36	3.10	6.06	0.10
AL0048372	60103002	0.98	1.48	0.01	0.00	4.39	0.20	6.89	0.04
AL0048763	50110020	1.64	2.04	0.01	0.01	3.19	4.01	6.54	0.06
AL0048861	50109001	8.26	10.90	0.06	0.04	42.20	10.69	62.12	0.31
AL0049549	60111009	1.90	10.19	0.01	0.01	1.53	0.00	23.06	0.07
AL0049603	60111009	4.43	3.63	0.03	0.02	3.68	0.00	18.44	0.17
AL0050237	50110024	6.67	5.61	0.05	0.03	33.74	3.31	20.57	0.25
AL0050245	50110028	2.50	2.66	0.02	0.01	13.08	1.70	4.97	0.09
AL0050423	60109008	5.63	10.80	0.04	0.03	28.17	10.14	30.17	0.21
AL0052264	60113026	1.13	2.42	0.02	0.03	0.00	0.00	0.00	0.05
AL0053201	50106040	14.35	66.95	0.11	0.07	70.75	14.54	87.11	0.54
AL0054399	60204006	0.81	0.00	0.01	0.01	0.00	0.00	32.74	0.02
AL0054631	50107019	2.40	1.97	0.02	0.01	8.47	2.01	9.26	0.09
AL0054640	60107007	2.93	6.73	0.02	0.01	14.66	5.59	18.40	0.11
AL0054666	50202017	2.40	1.05	0.02	0.01	12.03	2.36	3.55	0.09
AL0054704	50201006	3.71	8.98	2.49	0.53	0.00	0.00	20.20	1.75
AL0055204	60204022	1.03	8.37	0.01	0.01	0.96	0.00	7.97	0.04
AL0055239	50106040	122.93	0.00	6.24	5.02	28.25	0.00	719.47	0.13
AL0055786	60204021	1.84	3.94	0.01	0.01	9.91	1.72	6.04	0.07
AL0055859	60204022	0.34	0.80	0.00	0.00	0.18	0.00	4.29	0.01
AL0056758	60109001	0.43	0.00	0.01	0.01	0.00	0.00	1.82	0.02
AL0057037	60112002	1.05	1.82	0.02	0.02	0.00	0.00	0.00	0.05
AL0057193	60113001	1.98	15.33	0.02	0.01	6.89	0.00	42.14	0.07
AL0057657	50106040	3.00	16.52	0.02	0.01	11.62	2.78	43.44	0.11
AL0058408	50106001	3.43	4.71	0.03	0.02	17.18	15.81	34.47	0.13
AL0060216	60113026	1.09	1.33	0.02	0.02	0.00	0.00	0.00	0.05
AL0060798	60112002	2.75	3.14	0.05	0.06	0.00	0.00	0.00	0.12
AL0061786	50202017	0.46	0.00	0.01	0.01	0.00	0.00	4.49	0.02
AL0062421	60112012	15.79	0.00	0.28	0.36	0.00	0.00	103.60	0.71
AL0062430	60112012	0.12	0.21	0.00	0.00	0.00	0.00	0.00	0.01
AL0062715	50109017	0.62	5.21	0.00	0.00	0.88	0.00	15.84	0.02
AL0062723	50105001	0.99	6.26	0.01	0.00	4.96	1.21	20.97	0.04
AL0062839	50109017	0.55	0.42	0.00	0.00	3.39	0.41	1.93	0.02
AL0064025	50107001	3.20	2.97	0.02	0.02	17.06	8.54	25.91	0.12
AL0064394	60112001	4.37	4.60	0.03	0.02	22.76	1.92	0.00	0.16
AL0066869	60109001	0.71	0.00	0.01	0.02	0.00	0.00	3.24	0.03
AL0067067	50202017	3.04	0.46	0.02	0.02	15.26	0.55	0.00	0.11

Facility	Sub-watershed ID	Flow (cfs)	BOD_5 (lb/hr)	Copper (lb/hr)	Lead (lb/hr)	Total N (lb/hr)	Total P (lb/hr)	TSS (lb/hr)	Zinc (lb/hr)
AL0067253	50202017	0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00
GA0000329	50103002	0.21	0.66	0.00	0.00	0.96	0.00	1.65	0.01
GA0001104	50105019	9.65	39.61	0.08	0.04	0.00	5.51	216.10	0.30
GA0001708	50105019	0.41	2.74	0.05	0.03	0.88	0.13	9.78	0.36
GA0020982	50108031	0.54	0.00	0.00	0.00	0.00	0.00	0.00	0.02
GA0021369	50102021	2.63	19.13	0.02	3.36	9.31	1.86	25.07	0.96
GA0024074	50105019	3.08	8.98	0.02	0.02	1.25	3.68	12.56	0.11
GA0024091	50104001	11.10	28.40	0.08	0.18	15.44	0.00	57.16	0.41
GA0024104	50105029	3.14	22.48	0.06	0.07	0.00	15.05	48.43	0.14
GA0024112	50105019	19.17	53.79	0.15	0.09	7.52	19.38	91.38	0.72
GA0024155	50105019	1.63	0.00	0.07	0.48	0.00	0.04	0.00	0.73
GA0024341	50105019	1.54	0.93	0.48	0.96	0.36	0.65	4.19	0.06
GA0024988	50104013	13.01	0.00	0.17	0.21	2.06	3.66	17.01	0.61
GA0025607	50105032	6.73	38.05	0.05	0.03	4.42	1.82	142.47	0.25
GA0025674	50104013	1.38	7.07	0.01	1.44	1.17	2.42	10.82	0.48
GA0025704	50105029	2.72	0.00	0.02	0.01	0.61	8.28	11.80	0.10
GA0025712	50105032	3.71	5.00	0.06	0.06	0.59	7.19	34.90	0.38
GA0026026	50104013	0.38	0.00	0.00	0.00	0.00	0.00	0.00	0.01
GA0026042	50104001	1.74	7.69	0.01	0.01	10.08	6.14	13.30	0.06
GA0030333	50103002	14.89	91.37	0.11	0.07	8.51	64.62	160.01	0.56
GA0032492	50101005	2.57	5.16	0.02	3.36	0.37	7.86	10.84	2.31
GA0046035	50103002	0.21	0.00	0.00	0.00	0.00	0.00	0.00	0.01
GA0046451	50104013	1.60	0.00	0.01	0.01	0.00	0.00	0.00	0.06
GA0046761	50104013	5.02	0.00	0.04	0.02	1.00	1.27	5.06	0.19
MS0001783	60104001	3.66	4.83	0.00	0.00	1.86	0.00	21.53	0.00
MS0001970	60101004	1.82	8.88	0.04	0.01	0.52	0.00	15.84	0.36
MS0002232	60101004	7.53	0.00	0.06	0.05	3.15	0.00	18.29	0.21
MS0003158	60101004	0.24	0.00	0.00	0.00	0.00	0.04	1.20	0.01
MS0020788	60104001	2.64	14.72	0.02	0.01	1.00	0.00	29.42	0.15
MS0023868	60105001	10.84	13.87	0.08	0.05	7.84	0.00	22.91	0.40
MS0024783	60101004	0.65	0.00	0.00	0.00	0.00	0.00	0.00	0.02
MS0036111	60102001	8.15	0.00	0.06	0.04	0.00	0.00	0.00	0.30
MS0036145	60108009	7.25	0.00	0.06	0.04	0.00	0.00	0.00	0.27
MS0036412	60106025	33.57	211.12	0.27	0.15	0.00	0.00	561.85	1.04
MS0040215	60106025	0.10	0.00	2.08	0.00	0.00	0.00	0.38	0.00
MS0045489	60101009	1.53	0.00	0.01	0.01	0.00	0.00	0.00	0.06

Table B-4. Maximum concentrations from point sources used in the watershed model

Facility	Sub-watershed ID	Flow (cfs)	BOD_5 (mg/L)	Copper (mg/L)	Lead (mg/L)	Total N (mg/L)	Total P (mg/L)	TSS (mg/L)	Zinc (mg/L)
AL0000680	60112012	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AL0000973	60113026	0.85	12.57	0.03	0.01	29.56	0.00	46.80	0.15
AL0001449	60111009	1.68	9.55	0.08	0.10	1.86	0.48	20.12	0.20
AL0001597	60204114	0.97	13.84	1.48	0.33	3.08	0.00	104.78	1.07
AL0001627	50107049	1.96	2.56	0.23	0.05	1.63	0.00	11.84	2.00
AL0001767	60112002	0.22	25.32	0.04	0.03	73.45	0.00	40.09	0.14
AL0001945	60203001	5.42	24.86	0.67	0.33	0.00	0.00	84.61	0.40
AL0001961	60204114	1.32	6.32	1.31	0.29	0.00	0.00	22.44	0.95
AL0001970	60204114	0.72	50.28	1.40	0.31	11.97	0.00	76.76	1.01
AL0002097	60111001	0.09	17.93	0.03	0.03	39.45	0.00	25.85	0.13
AL0002631	50202017	12.96	0.00	0.04	0.03	0.00	0.00	6.03	0.12
AL0002658	50106001	0.39	9.52	1.61	0.60	1.34	0.00	85.85	0.20
AL0002666	60204022	2.34	11.38	0.73	3.67	9.66	0.48	219.65	1.99
AL0002674	50203001	29.24	81.34	0.04	0.02	0.00	0.00	141.86	0.14
AL0002755	60203007	29.60	24.53	0.04	0.02	0.00	0.00	24.24	0.14
AL0002780	60204013	46.06	72.60	0.04	0.02	0.00	0.00	248.96	0.14
AL0002801	60204022	111.12	35.28	0.04	0.02	0.00	0.00	84.84	0.14
AL0002828	60201033	24.91	30.65	0.04	0.02	0.00	0.00	58.86	0.14
AL0002879	60204114	40.60	0.00	0.18	0.02	0.00	0.00	5.44	0.01
AL0002887	50106041	7.82	0.00	2.00	0.02	0.00	0.00	13.39	1.41
AL0002909	50202009	19.25	0.00	2.00	0.02	0.00	0.00	10.07	1.11
AL0002917	60113001	7.33	0.00	0.18	0.02	0.00	0.00	8.77	0.29
AL0003018	50201006	57.09	80.75	0.04	0.02	0.00	0.01	139.88	0.14
AL0003026	60204114	15.71	26.50	2.55	0.56	0.00	0.00	58.85	0.10
AL0003085	60204114	1.22	11.57	0.64	0.14	5.00	0.00	87.51	0.48
AL0003093	60203001	13.15	18.83	1.11	0.25	2.38	0.00	53.77	0.81
AL0003115	50201006	44.25	57.69	0.04	0.02	0.00	0.00	72.78	0.14
AL0003140	50107049	34.49	0.00	2.00	0.02	0.00	0.00	0.00	1.41
AL0003158	50106001	76.25	29.06	0.04	0.02	0.00	0.00	37.24	0.14
AL0003221	60112012	0.02	7.95	0.03	0.03	2.69	0.00	33.00	0.41
AL0003247	60111001	11.84	77.82	0.09	0.70	4.14	0.00	29.91	0.62
AL0003301	60201016	74.88	28.57	0.04	0.02	0.00	0.00	22.27	0.14
AL0003336	50202017	1.47	0.00	0.04	0.03	0.00	0.00	27.40	0.12
AL0003379	60111001	0.34	0.00	0.08	0.10	0.00	0.00	52.22	0.20
AL0003395	50202017	1.88	5.57	0.08	0.10	0.60	2.93	31.22	0.20
AL0003417	60111001	0.39	0.00	0.04	0.03	86.51	0.00	169.95	0.14
AL0003514	60204022	0.57	3.16	1.74	0.03	4.21	0.00	227.99	0.12
AL0003620	60112012	0.01	10.12	0.08	0.10	0.00	0.00	31.25	0.20
AL0003646	60112012	30.48	23.03	0.21	0.03	30.31	0.00	257.10	0.21
AL0003662	50107049	4.97	0.00	0.00	0.00	0.00	0.00	20.76	0.00
AL0003671	60203007	0.01	44.95	61.90	0.02	0.00	0.00	81.67	61.90
AL0003794	60109001	1.82	0.00	0.08	0.10	0.00	0.00	11.76	0.20
AL0003930	50106001	0.85	80.58	0.04	0.02	3.79	0.00	169.99	0.14
AL0020001	50107049	3.35	14.12	0.03	0.02	22.37	3.14	22.70	0.17
AL0020141	50109017	1.29	3.89	0.03	0.02	66.92	11.38	29.12	0.17
AL0020486	50110028	1.63	17.97	0.03	0.02	19.29	1.97	90.18	0.17

Facility	Sub-watershed ID	Flow (cfs)	BOD_5 (mg/L)	Copper (mg/L)	Lead (mg/L)	Total N (mg/L)	Total P (mg/L)	TSS (mg/L)	Zinc (mg/L)
AL0020842	60110003	2.44	7.26	0.03	0.02	0.16	0.00	35.81	0.17
AL0020869	60203007	0.93	67.96	0.03	0.02	4.68	0.00	132.08	0.17
AL0020885	60204022	1.48	44.57	0.03	0.02	0.49	0.00	152.71	0.17
AL0021156	50109001	2.06	4.69	0.03	0.02	20.65	2.19	11.86	0.17
AL0021971	60112012	0.22	0.00	0.08	0.10	0.00	0.00	28.51	0.20
AL0022136	50203022	1.35	2.39	0.03	0.02	1.08	0.00	26.19	0.17
AL0022195	50106001	15.54	8.11	0.03	0.02	23.68	13.30	8.77	0.17
AL0022225	50201037	20.00	21.92	0.03	0.02	27.34	5.63	32.89	0.17
AL0022241	50201037	3.73	12.44	0.03	0.02	24.05	4.57	33.98	0.17
AL0022357	50106001	4.48	5.60	0.03	0.02	21.38	2.83	23.60	0.17
AL0022578	50201001	5.74	35.60	0.03	0.02	22.88	4.78	27.43	0.17
AL0022586	50106019	3.32	22.81	0.03	0.02	16.59	7.98	8.24	0.17
AL0022659	50106040	6.55	20.75	0.03	0.02	22.46	4.64	27.48	0.17
AL0022713	60113026	29.66	6.22	0.03	0.02	23.26	1.86	21.24	0.17
AL0022926	60111009	7.30	4.47	0.03	0.02	22.37	0.99	9.39	0.17
AL0022934	50202017	3.30	1.44	0.03	0.02	23.14	2.17	19.74	0.17
AL0023027	50202017	14.51	1.85	0.03	0.02	23.05	3.44	6.28	0.17
AL0023078	60110014	3.28	26.57	0.03	0.02	21.51	2.19	23.56	0.17
AL0023086	60110014	39.19	33.48	0.03	0.02	35.39	4.93	45.92	0.17
AL0023094	60109005	20.69	18.83	0.03	0.02	26.51	3.67	24.50	0.17
AL0023116	50202017	2.03	3.23	0.03	0.02	19.62	9.97	4.38	0.17
AL0023205	60204025	5.82	28.39	0.03	0.02	1.58	0.00	17.95	0.17
AL0023272	60203007	7.22	2.24	0.28	0.06	6.18	0.00	19.10	0.20
AL0023311	50106040	5.41	19.23	0.03	0.02	1.09	0.00	19.15	0.17
AL0023400	60105003	0.52	10.80	0.03	0.02	8.63	0.00	68.53	0.17
AL0023418	60109001	6.27	7.61	0.03	0.02	2.11	0.00	20.78	0.17
AL0023647	50202017	57.60	1.99	0.03	0.02	23.02	2.30	18.63	0.17
AL0023655	60112012	76.32	2.09	0.03	0.02	22.96	2.40	14.65	0.17
AL0023892	60111001	1.27	0.00	0.00	0.00	0.00	0.00	16.26	0.00
AL0024252	50202017	0.03	4.89	0.04	0.03	0.00	0.00	15.96	0.12
AL0024376	50105001	2.04	26.59	0.03	0.02	0.00	0.00	0.00	0.17
AL0024457	50202017	0.83	0.00	0.04	0.03	0.00	0.00	16.22	0.12
AL0024520	50106019	2.99	4.83	0.03	0.02	22.37	9.39	13.80	0.17
AL0025828	50202017	3.06	15.90	0.03	0.02	26.47	15.00	6.60	0.17
AL0025968	60113001	85.10	55.12	0.04	0.02	0.50	0.00	200.49	0.14
AL0025984	50110020	1.93	12.06	0.03	0.02	1.77	0.00	27.65	0.17
AL0026590	60112002	2.86	0.00	0.08	0.10	0.00	0.00	23.44	0.20
AL0026654	50201037	2.69	3.89	0.03	0.02	23.04	11.21	13.20	0.17
AL0026832	60109008	1.25	11.82	0.08	0.10	3.74	0.00	35.31	0.20
AL0026913	60111001	26.25	5.32	0.03	0.02	22.64	2.24	7.83	0.17
AL0026921	60113026	0.16	190.37	1.57	0.35	0.00	0.00	179.91	1.14
AL0027146	60111001	7.35	0.00	4.81	0.02	0.00	0.00	31.04	0.24
AL0027561	60204002	3.17	3.80	0.03	0.02	22.37	3.93	30.80	0.17
AL0027723	50201037	2.77	17.28	0.03	0.02	18.24	7.04	21.17	0.17
AL0027782	50204010	1.11	4.33	0.03	0.02	1.19	0.00	25.63	0.17
AL0027863	50201037	32.37	5.39	0.03	0.02	25.68	3.52	0.00	0.17
AL0029181	60112002	63.37	0.00	0.08	0.10	0.00	0.00	45.90	0.20

Facility	Sub-watershed ID	Flow (cfs)	BOD_5 (mg/L)	Copper (mg/L)	Lead (mg/L)	Total N (mg/L)	Total P (mg/L)	TSS (mg/L)	Zinc (mg/L)
AL0029432	60112012	1.71	0.00	0.08	0.10	0.00	0.00	14.69	0.20
AL0029475	60112002	33.49	0.00	0.08	0.10	0.00	0.00	33.04	0.20
AL0030546	60112025	31.60	0.00	0.08	0.10	0.00	0.00	32.93	0.20
AL0040843	60109005	0.80	45.25	0.00	0.00	5.81	4.00	160.07	0.87
AL0041653	50202017	2.05	3.21	0.03	0.02	22.74	4.63	4.77	0.17
AL0041866	60107007	0.53	0.00	0.08	0.10	0.00	0.00	21.97	0.20
AL0042447	60204114	1.09	12.91	0.44	0.45	3.11	0.00	71.31	0.32
AL0043168	60201033	2.99	64.30	0.03	0.02	17.58	0.00	40.10	0.17
AL0043176	50201001	1.18	1.74	0.03	0.02	0.26	0.00	5.53	0.17
AL0045969	50202017	1.88	1.50	0.03	0.02	24.13	6.85	2.77	0.17
AL0045993	50106019	2.67	4.85	0.03	0.02	22.37	5.19	10.14	0.17
AL0048372	60103002	0.98	6.75	0.03	0.02	20.05	0.92	31.49	0.17
AL0048763	50110020	1.64	5.54	0.03	0.02	8.66	10.88	17.76	0.17
AL0048861	50109001	8.26	5.90	0.03	0.02	22.83	5.79	33.61	0.17
AL0049549	60111009	1.90	23.97	0.03	0.02	3.59	0.00	54.26	0.17
AL0049603	60111009	4.43	3.65	0.03	0.02	3.71	0.00	18.59	0.17
AL0050237	50110024	6.67	3.76	0.03	0.02	22.61	2.22	13.78	0.17
AL0050245	50110028	2.50	4.76	0.03	0.02	23.37	3.04	8.89	0.17
AL0050423	60109008	5.63	8.58	0.03	0.02	22.37	8.05	23.96	0.17
AL0052264	60113026	1.13	9.55	0.08	0.10	0.00	0.00	0.00	0.20
AL0053201	50106040	14.35	20.84	0.03	0.02	22.03	4.53	27.12	0.17
AL0054399	60204006	0.81	0.00	0.04	0.04	0.00	0.00	180.55	0.13
AL0054631	50107019	2.40	3.67	0.03	0.02	15.80	3.75	17.27	0.17
AL0054640	60107007	2.93	10.26	0.03	0.02	22.37	8.54	28.07	0.17
AL0054666	50202017	2.40	1.95	0.03	0.02	22.37	4.39	6.60	0.17
AL0054704	50201006	3.71	10.81	3.00	0.64	0.00	0.00	24.31	2.11
AL0055204	60204022	1.03	36.22	0.03	0.02	4.17	0.00	34.52	0.17
AL0055239	50106040	122.93	0.00	0.23	0.18	1.03	0.00	26.15	0.00
AL0055786	60204021	1.84	9.55	0.03	0.02	24.01	4.16	14.64	0.17
AL0055859	60204022	0.34	10.53	0.03	0.01	2.42	0.00	56.32	0.15
AL0056758	60109001	0.43	0.00	0.08	0.10	0.00	0.00	18.95	0.20
AL0057037	60112002	1.05	7.74	0.08	0.10	0.00	0.00	0.00	0.20
AL0057193	60113001	1.98	34.65	0.03	0.02	15.57	0.00	95.28	0.17
AL0057657	50106040	3.00	24.64	0.03	0.02	17.33	4.14	64.77	0.17
AL0058408	50106001	3.43	6.14	0.03	0.02	22.37	20.59	44.88	0.17
AL0060216	60113026	1.09	5.45	0.08	0.10	0.00	0.00	0.00	0.20
AL0060798	60112002	2.75	5.10	0.08	0.10	0.00	0.00	0.00	0.20
AL0061786	50202017	0.46	0.00	0.08	0.10	0.00	0.00	43.59	0.20
AL0062421	60112012	15.79	0.00	0.08	0.10	0.00	0.00	29.31	0.20
AL0062430	60112012	0.12	8.00	0.08	0.10	0.00	0.00	0.00	0.20
AL0062715	50109017	0.62	37.31	0.03	0.02	6.34	0.00	113.49	0.17
AL0062723	50105001	0.99	28.21	0.03	0.02	22.37	5.46	94.51	0.17
AL0062839	50109017	0.55	3.43	0.03	0.02	27.34	3.33	15.56	0.17
AL0064025	50107001	3.20	4.15	0.03	0.02	23.85	11.94	36.23	0.17
AL0064394	60112001	4.37	4.71	0.03	0.02	23.28	1.97	0.00	0.17
AL0066869	60109001	0.71	0.00	0.08	0.10	0.00	0.00	20.36	0.20
AL0067067	50202017	3.04	0.68	0.03	0.02	22.46	0.82	0.00	0.17

Facility	Sub-watershed ID	Flow (cfs)	BOD_5 (mg/L)	Copper (mg/L)	Lead (mg/L)	Total N (mg/L)	Total P (mg/L)	TSS (mg/L)	Zinc (mg/L)
AL0067253	50202017	0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00
GA0000329	50103002	0.21	13.94	0.04	0.02	20.45	0.00	35.03	0.20
GA0001104	50105019	9.65	18.34	0.04	0.02	0.00	2.55	100.04	0.14
GA0001708	50105019	0.41	29.89	0.53	0.33	9.59	1.43	106.54	3.93
GA0020982	50108031	0.54	0.00	0.03	0.02	0.00	0.00	0.00	0.17
GA0021369	50102021	2.63	32.49	0.03	5.71	15.82	3.16	42.58	1.63
GA0024074	50105019	3.08	13.02	0.03	0.02	1.81	5.33	18.22	0.17
GA0024091	50104001	11.10	11.43	0.03	0.07	6.21	0.00	23.01	0.17
GA0024104	50105029	3.14	31.99	0.08	0.10	0.00	21.42	68.90	0.20
GA0024112	50105019	19.17	12.53	0.03	0.02	1.75	4.52	21.29	0.17
GA0024155	50105019	1.63	0.00	0.20	1.32	0.00	0.11	0.00	1.99
GA0024341	50105019	1.54	2.69	1.39	2.78	1.05	1.89	12.15	0.17
GA0024988	50104013	13.01	0.00	0.06	0.07	0.71	1.26	5.84	0.21
GA0025607	50105032	6.73	25.26	0.03	0.02	2.93	1.21	94.57	0.17
GA0025674	50104013	1.38	22.90	0.03	4.66	3.80	7.83	35.02	1.55
GA0025704	50105029	2.72	0.00	0.03	0.02	1.01	13.60	19.38	0.17
GA0025712	50105032	3.71	6.03	0.07	0.07	0.72	8.66	42.02	0.46
GA0026026	50104013	0.38	0.00	0.03	0.02	0.00	0.00	0.00	0.17
GA0026042	50104001	1.74	19.75	0.03	0.02	25.87	15.77	34.15	0.17
GA0030333	50103002	14.89	27.41	0.03	0.02	2.55	19.39	48.01	0.17
GA0032492	50101005	2.57	8.97	0.03	5.84	0.64	13.66	18.84	4.01
GA0046035	50103002	0.21	0.00	0.03	0.02	0.00	0.00	0.00	0.17
GA0046451	50104013	1.60	0.00	0.03	0.02	0.00	0.00	0.00	0.17
GA0046761	50104013	5.02	0.00	0.03	0.02	0.89	1.13	4.50	0.17
MS0001783	60104001	3.66	5.89	0.00	0.00	2.27	0.00	26.28	0.00
MS0001970	60101004	1.82	21.79	0.10	0.04	1.27	0.00	38.88	0.89
MS0002232	60101004	7.53	0.00	0.04	0.03	1.87	0.00	10.85	0.12
MS0003158	60101004	0.24	0.00	0.08	0.07	0.00	0.67	22.28	0.22
MS0020788	60104001	2.64	24.91	0.03	0.02	1.69	0.00	49.79	0.26
MS0023868	60105001	10.84	5.72	0.03	0.02	3.23	0.00	9.44	0.17
MS0024783	60101004	0.65	0.00	0.03	0.02	0.00	0.00	0.00	0.17
MS0036111	60102001	8.15	0.00	0.03	0.02	0.00	0.00	0.00	0.17
MS0036145	60108009	7.25	0.00	0.03	0.02	0.00	0.00	0.00	0.17
MS0036412	60106025	33.57	28.10	0.04	0.02	0.00	0.00	74.77	0.14
MS0040215	60106025	0.10	0.00	92.78	0.03	0.00	0.00	16.80	0.12
MS0045489	60101009	1.53	0.00	0.03	0.02	0.00	0.00	0.00	0.17

Appendix C

Hydrology Calibration Results

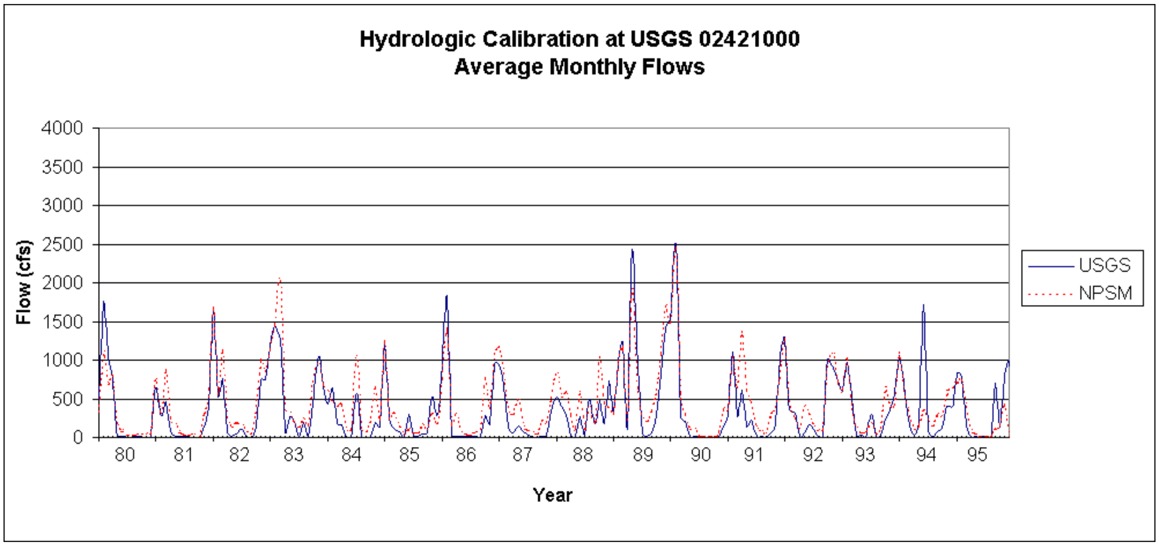

Figure C-1. Hydrologic calibration at USGS gage 02421000—Coastal Plains

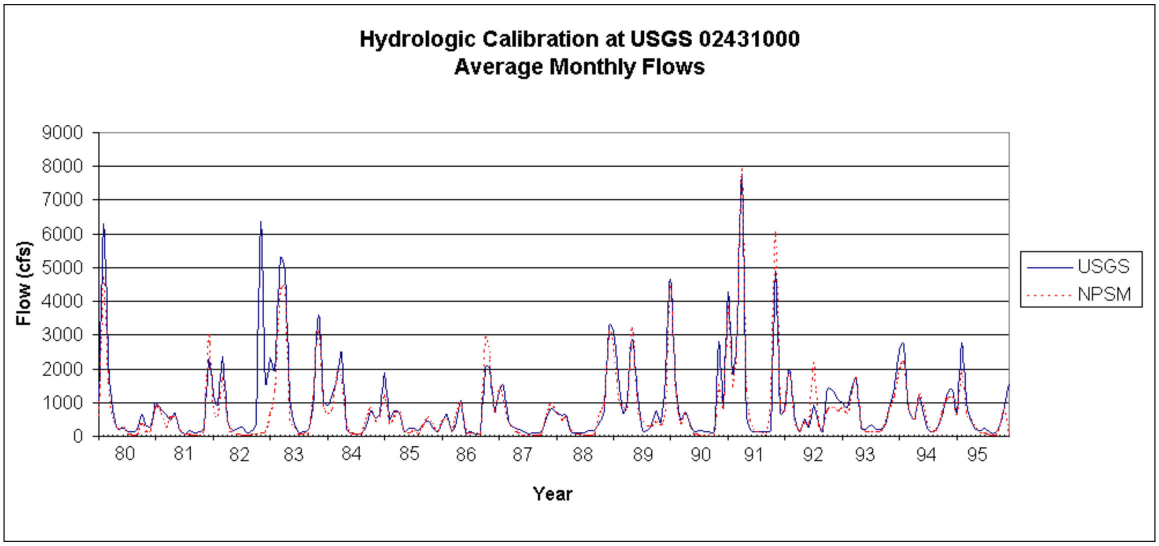

Figure C-2. Hydrologic calibration at USGS gage 02431000—Coastal Plains

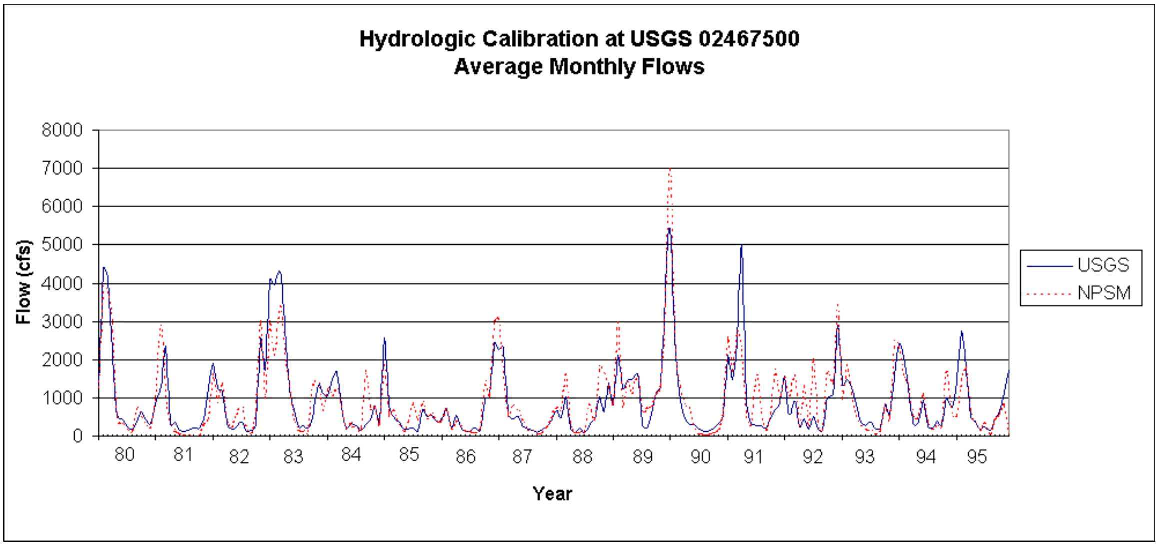

Figure C-3. Hydrologic calibration at USGS gage 02437500—Coastal Plains

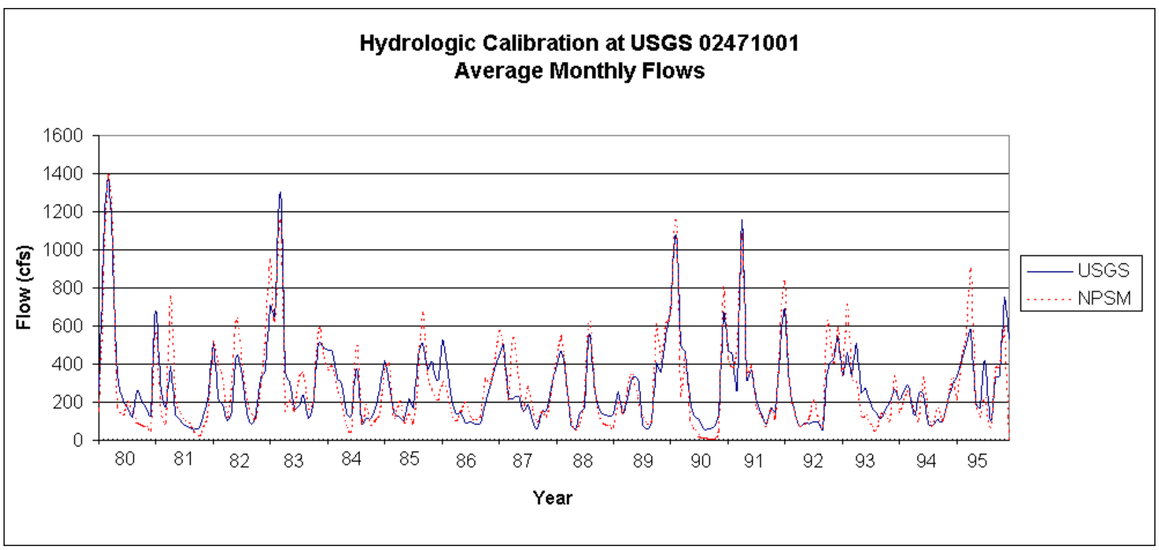

Figure C-4. Hydrologic calibration at USGS gage 02471001—Appalachian Plateaus

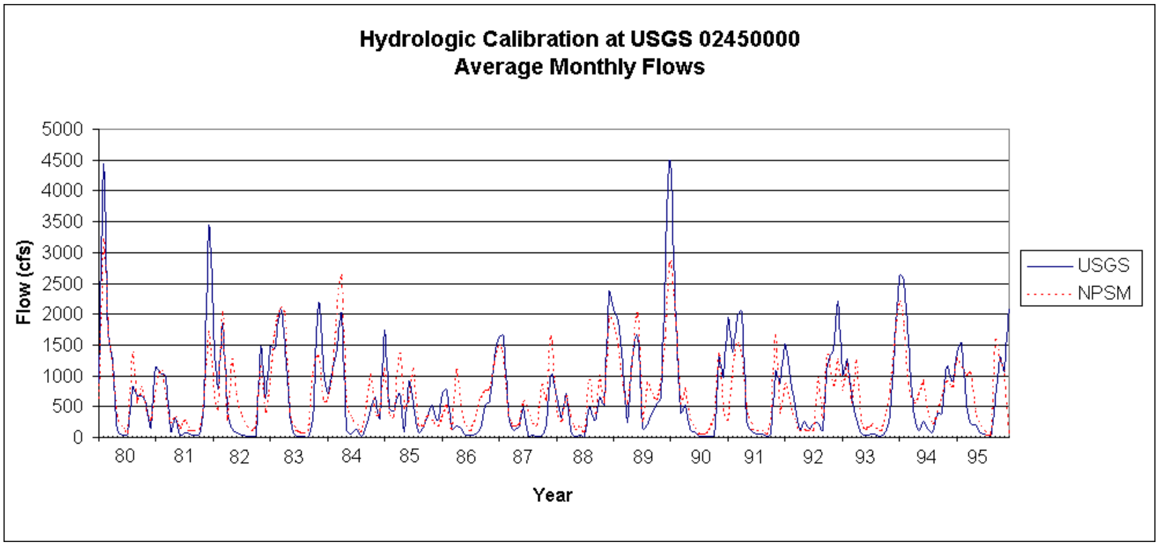

Figure C-5. Hydrologic calibration at USGS gage 02450000—Appalachian Plateaus

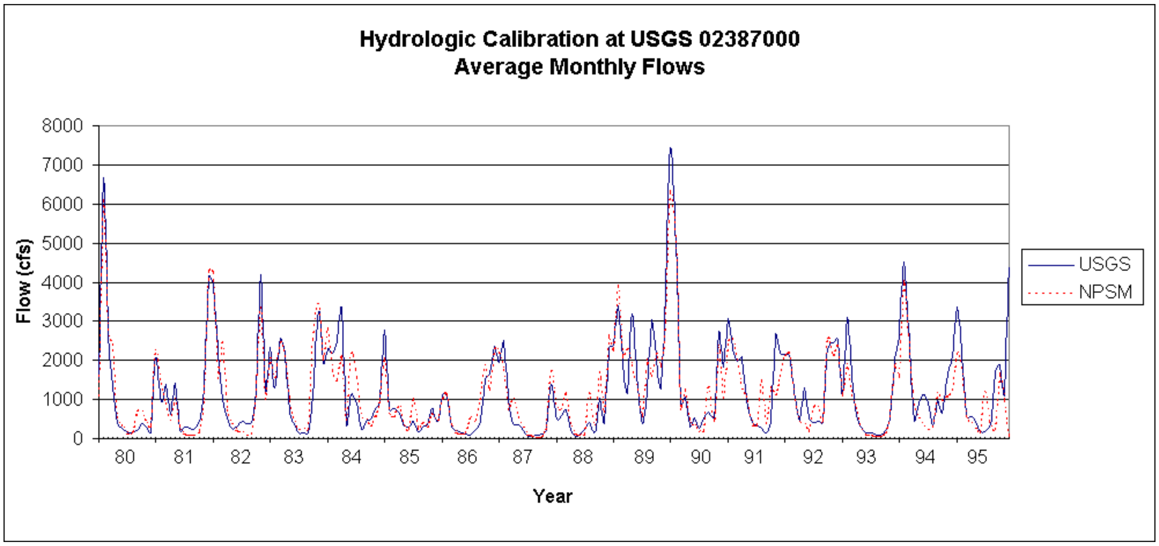

Figure C-6. Hydrologic calibration at USGS gage 02387000—Valley and Ridge

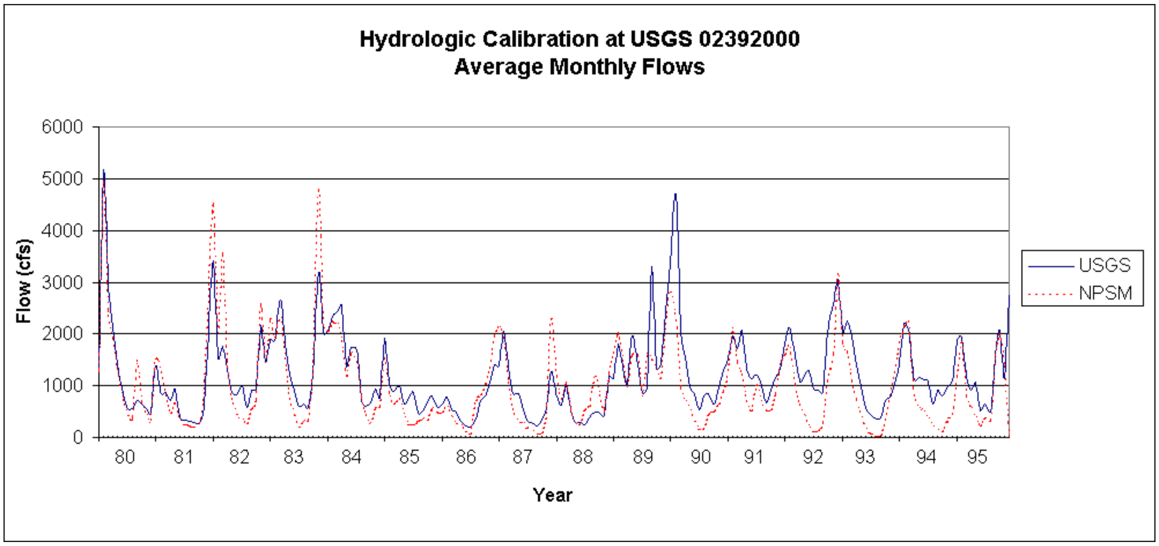

Figure C-7. Hydrologic calibration at USGS gage 02392000—Piedmont

Appendix D

Hydrology Validation Results

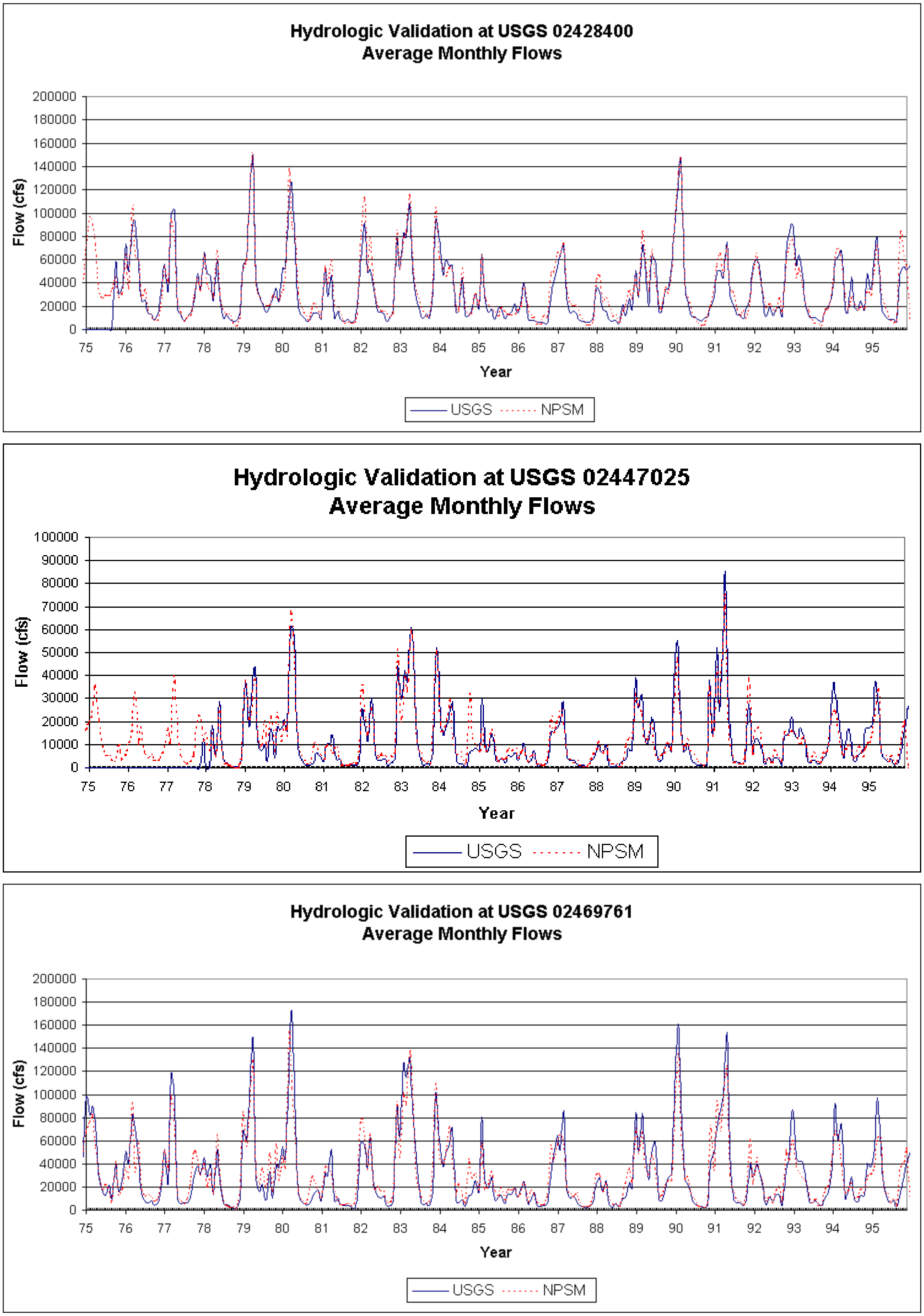

Figure D-1. Hydrologic validation at USGS gage stations 02428400, 02447025, and 02469761

Appendix E

Water Quality Calibration Results

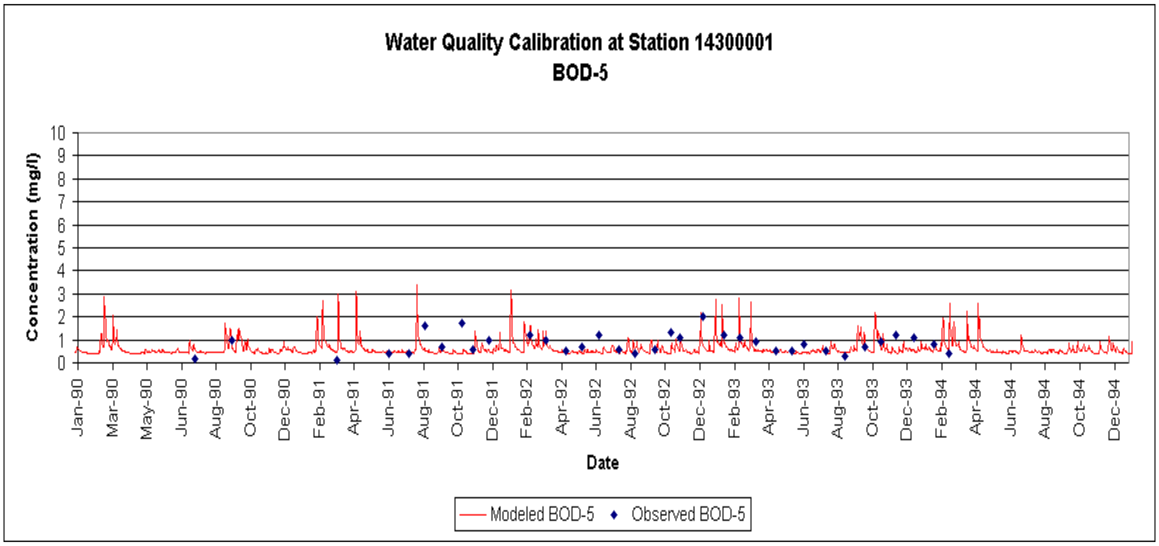

Figure E-1. Water quality calibration for BOD_5 at station 14300001

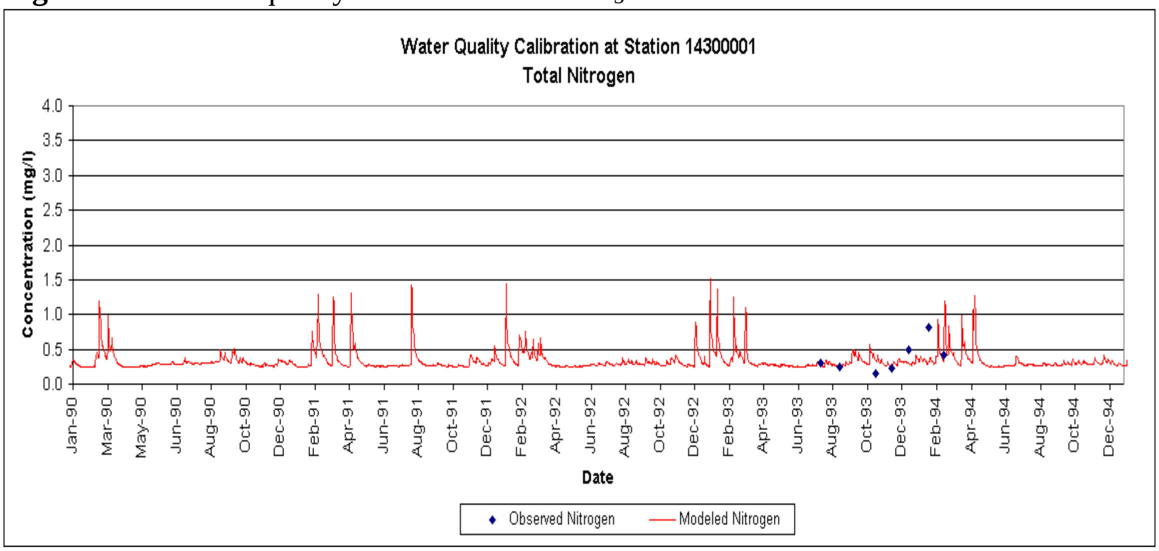

Figure E-2. Water quality calibration for total nitrogen at station 14300001

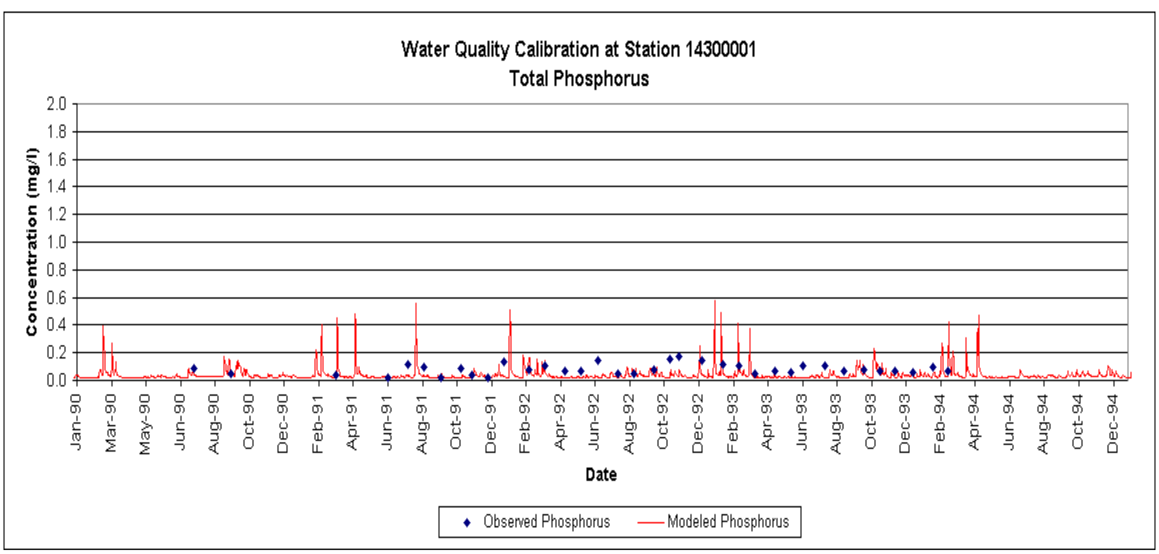

Figure E-3. Water quality calibration for total phosphorus at station 14300001

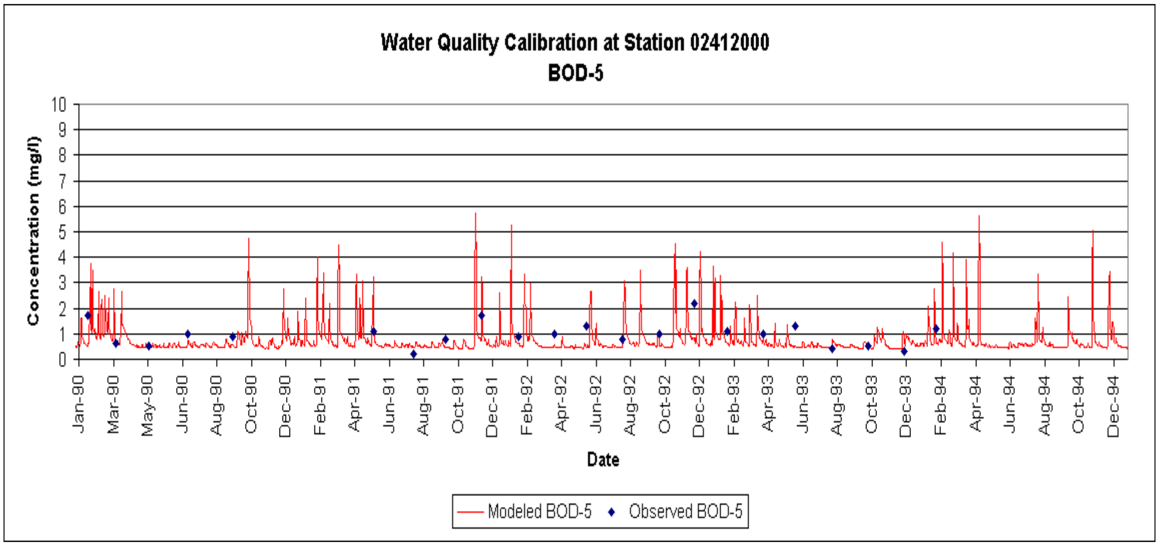

Figure E-4. Water quality calibration for BOD_5 at station 02412000

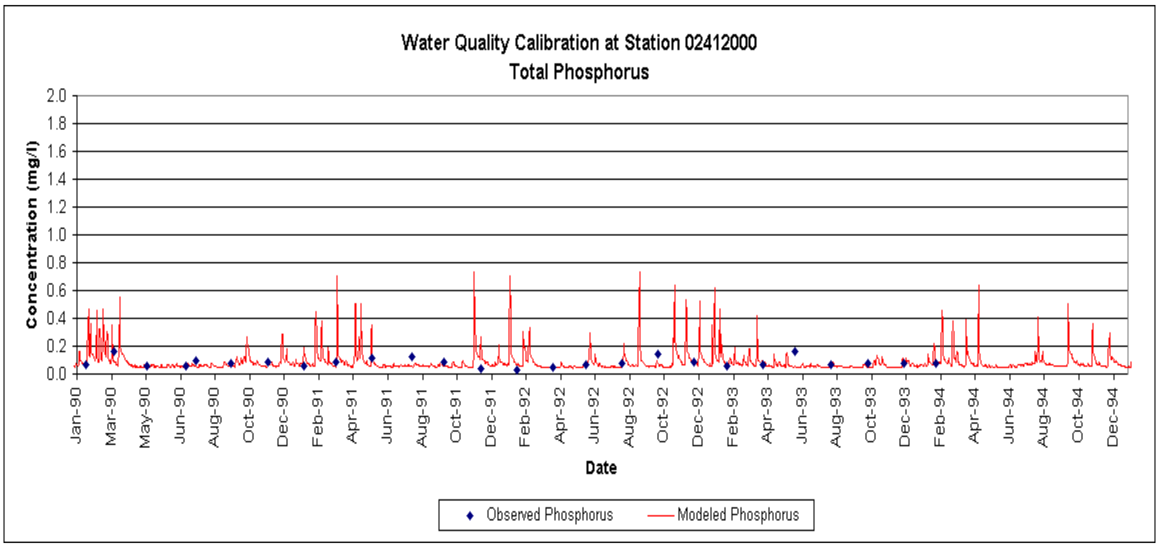

Figure E-5. Water quality calibration for total phosphorus at station 02412000

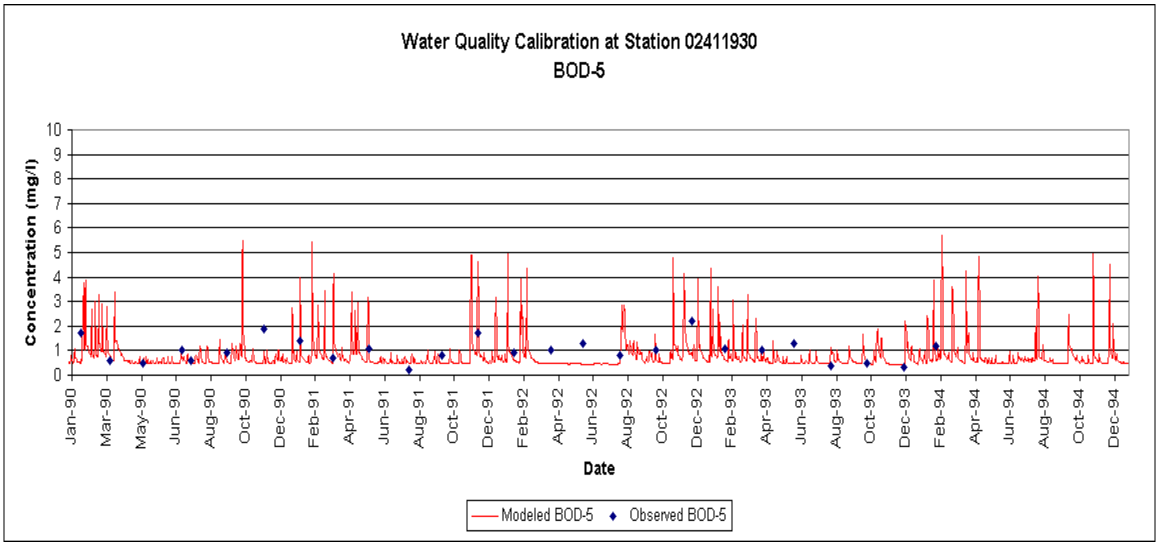

Figure E-6. Water quality calibration for BOD_5 at station 02411930

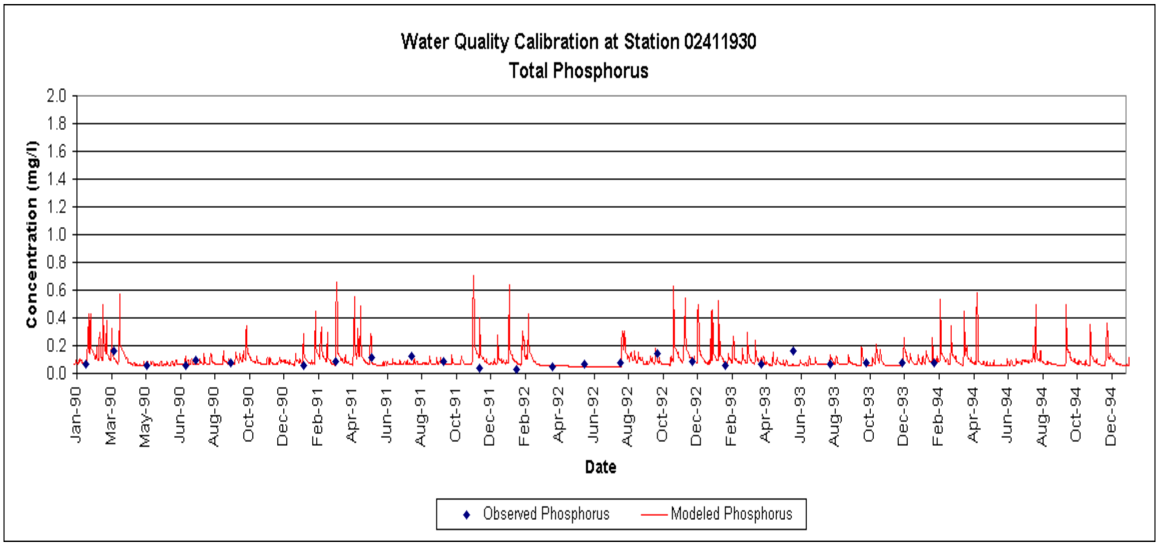

Figure E-7. Water quality calibration for total phosphorus at station 02411930

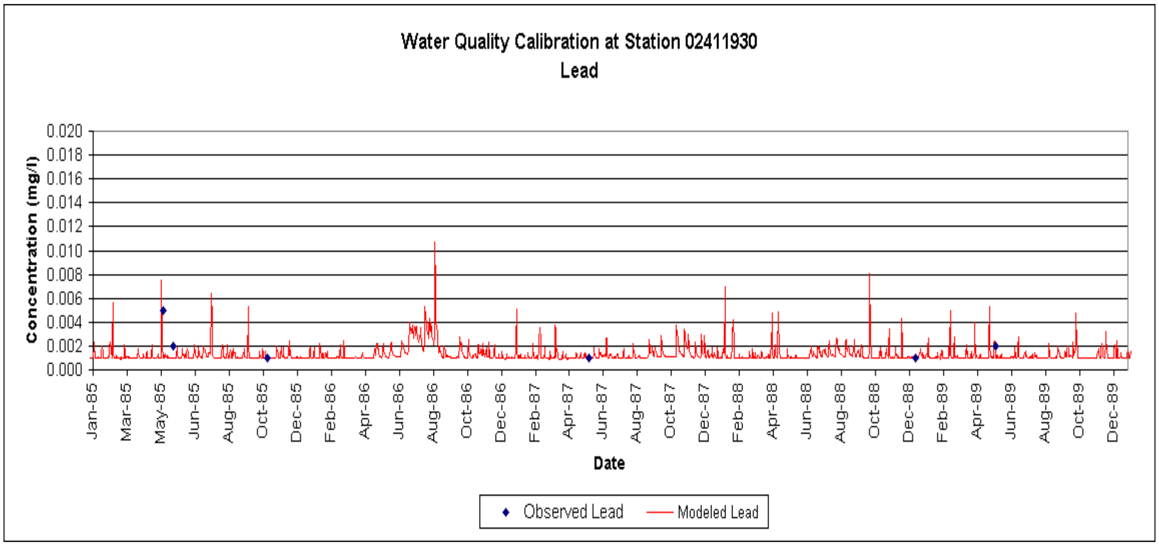

Figure E-8. Water quality calibration for lead at station 02411930

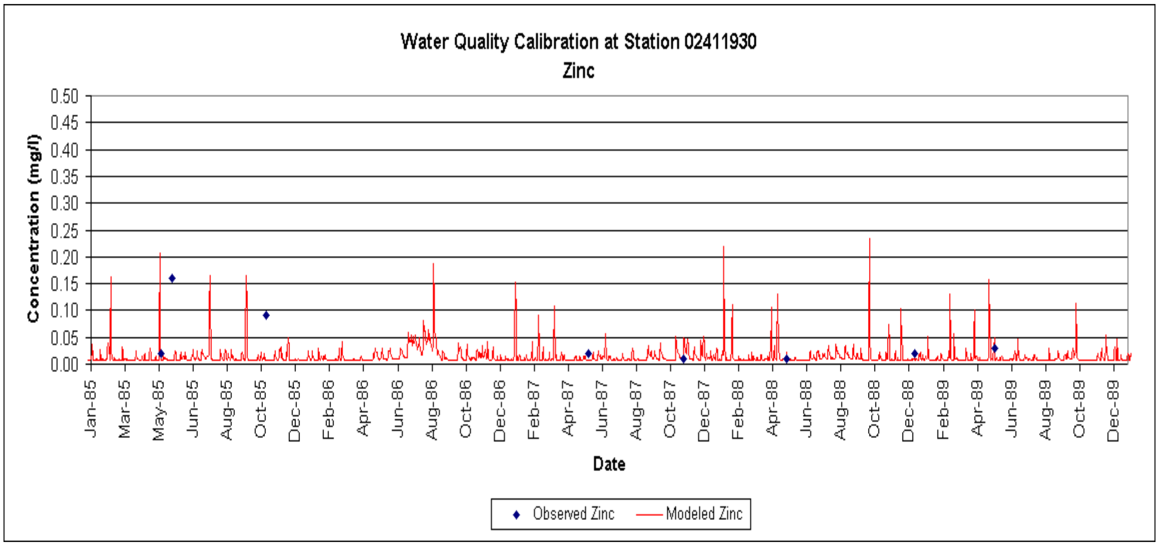

Figure E-9. Water quality calibration for zinc at station 02411930

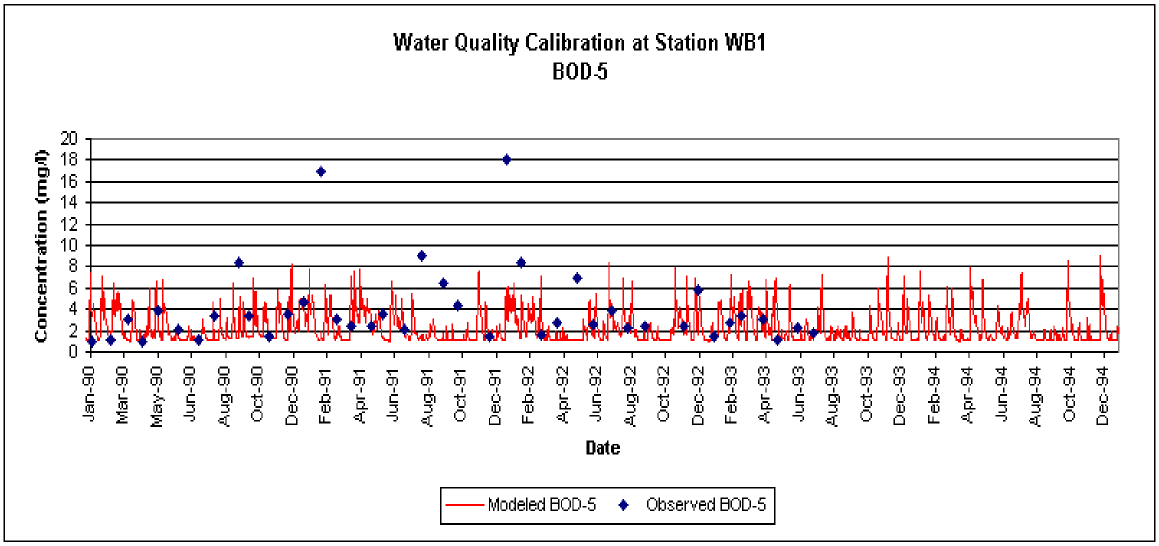

Figure E-10. Water quality calibration for BOD_5 at station WB1

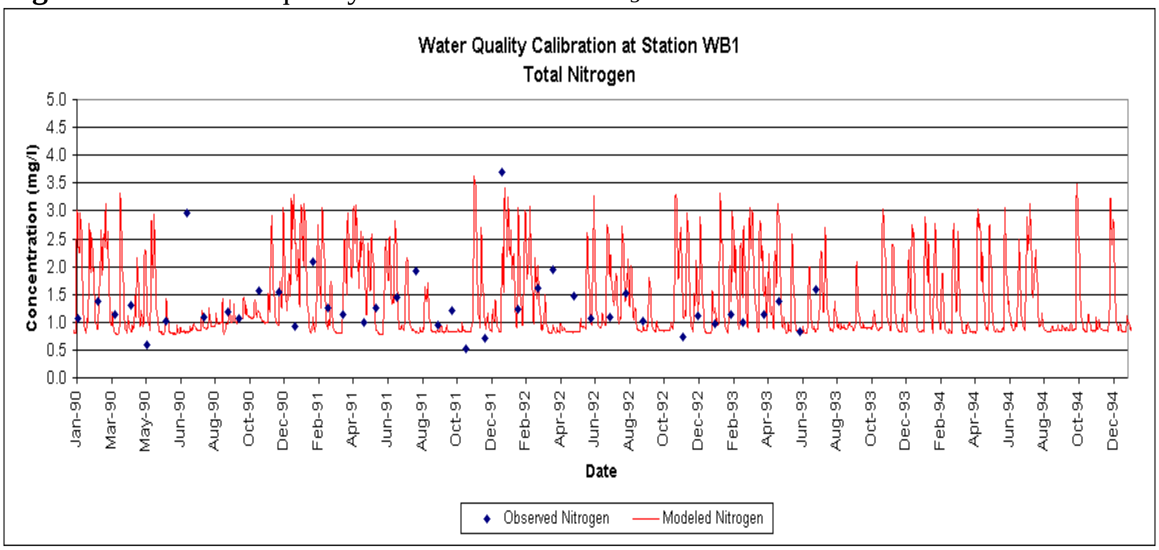

Figure E-11. Water quality calibration for total nitrogen at station WB1

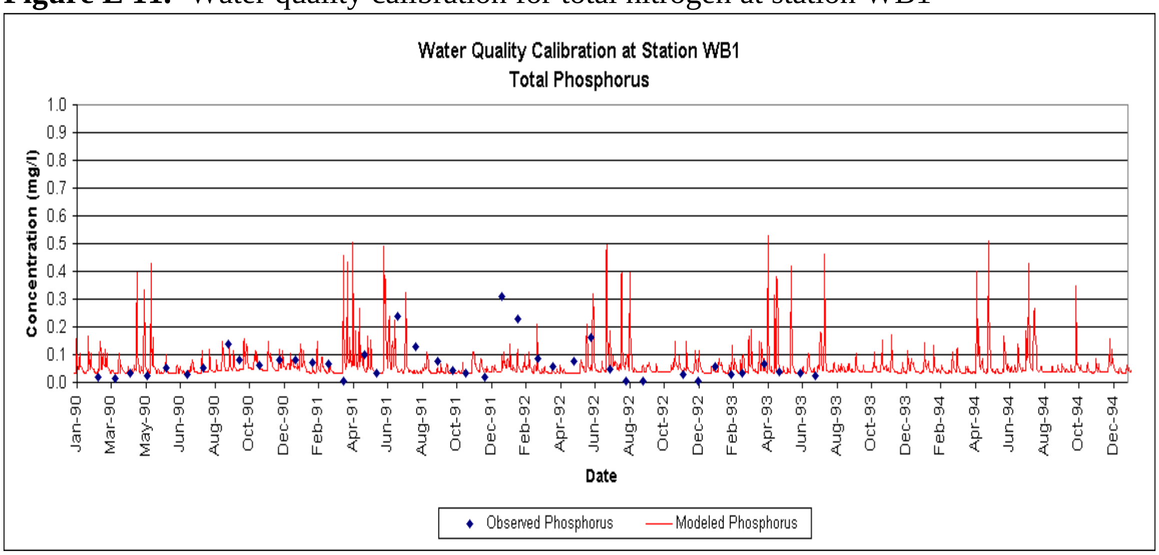

Figure E-12. Water quality calibration for total phosphorus at station WB1

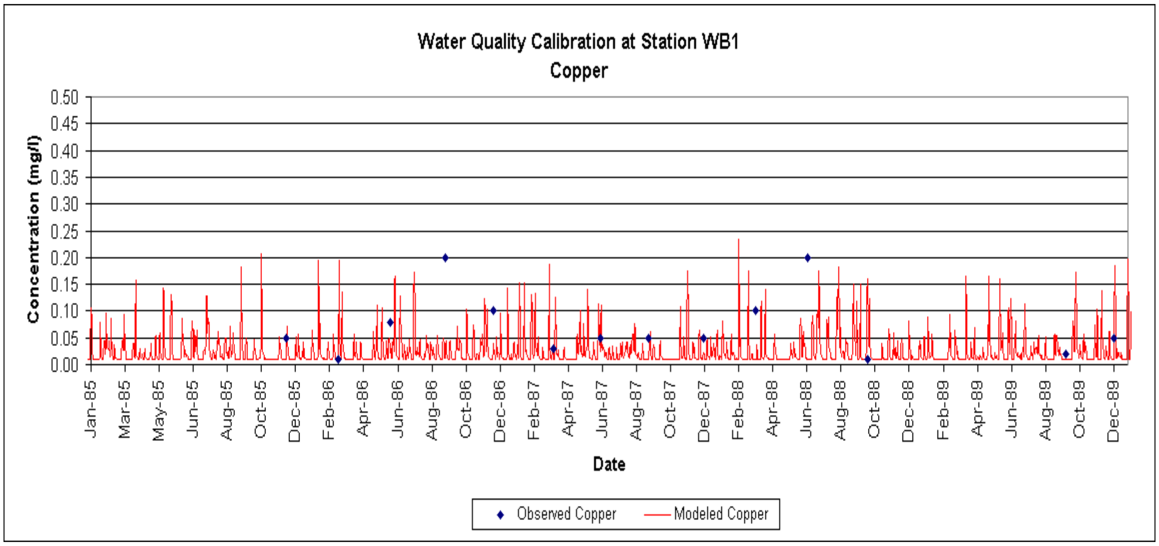

Figure E-13. Water quality calibration for copper at station WB1

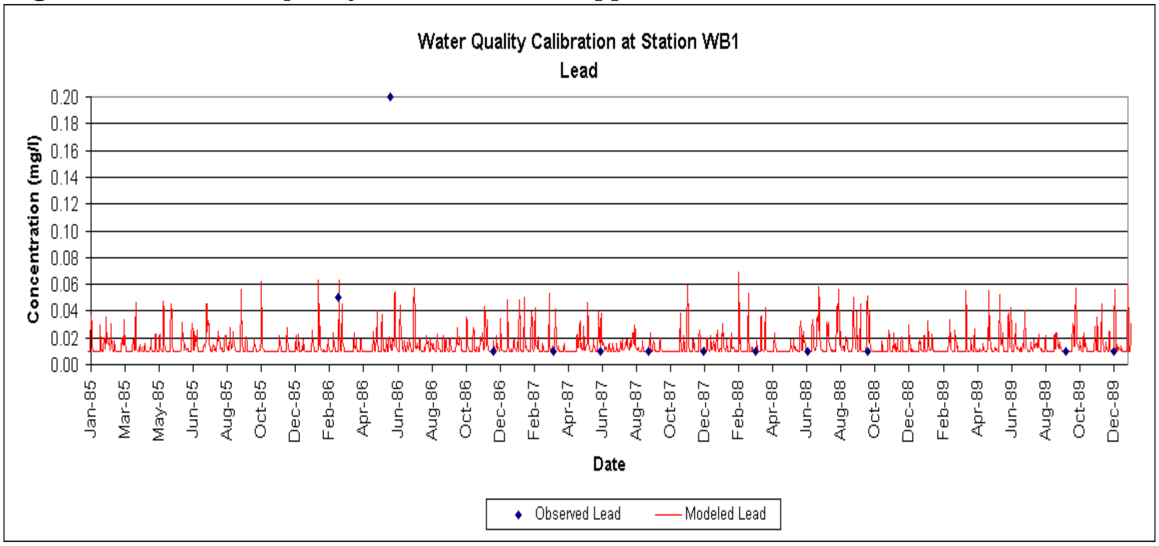

Figure E-14. Water quality calibration for lead at station WB1

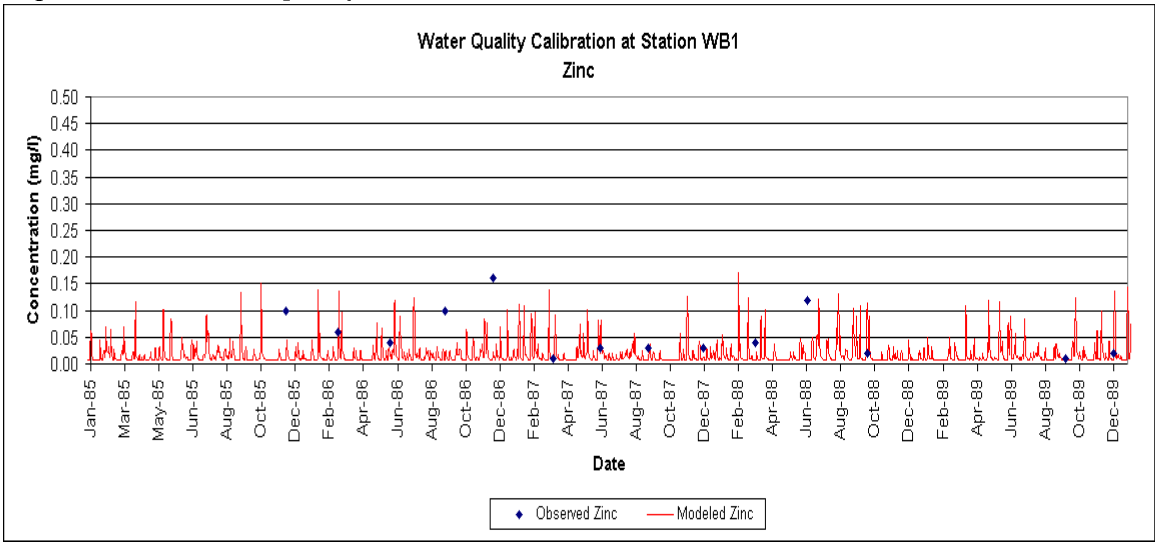

Figure E-15. Water quality calibration for zinc at station WB1

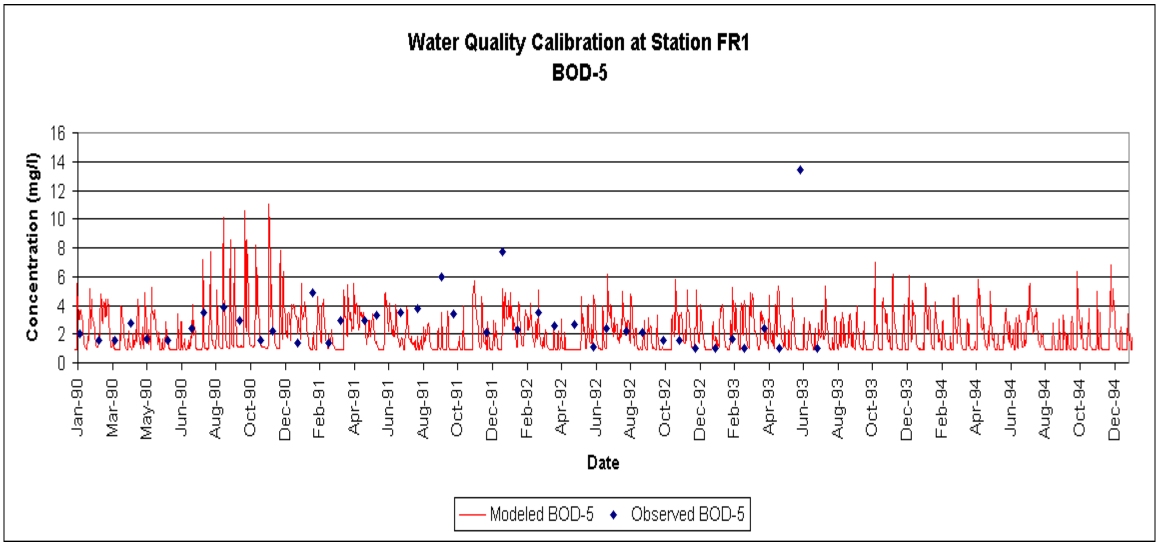

Figure E-16. Water quality calibration for BOD_5 at station FR1

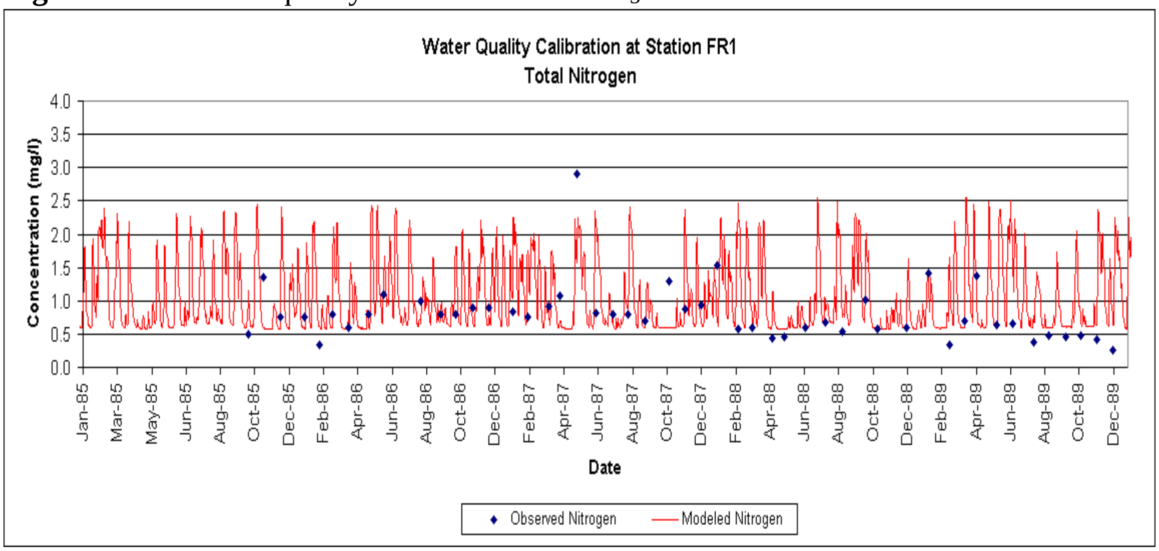

Figure E-17. Water quality calibration for total nitrogen at station FR1

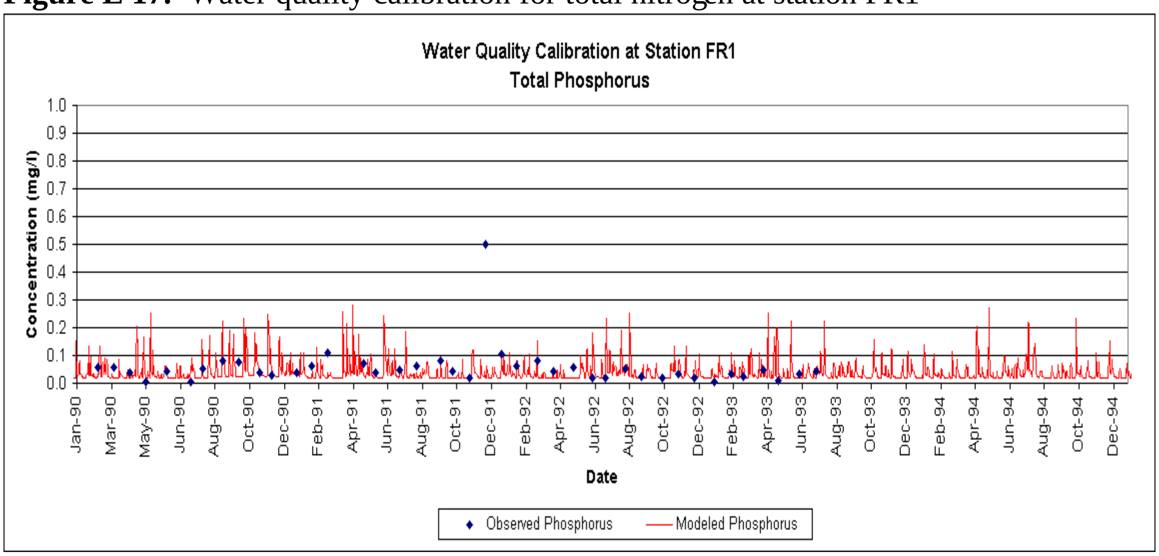

Figure E-18. Water quality calibration for total phosphorus at station FR1

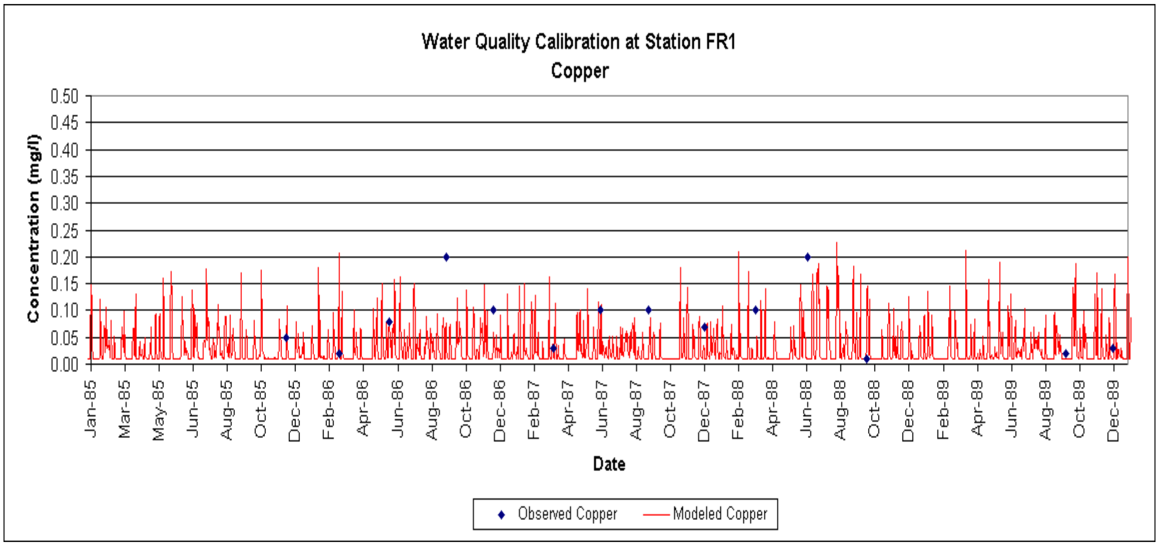

Figure E-19. Water quality ycalibration for copper at station FR1

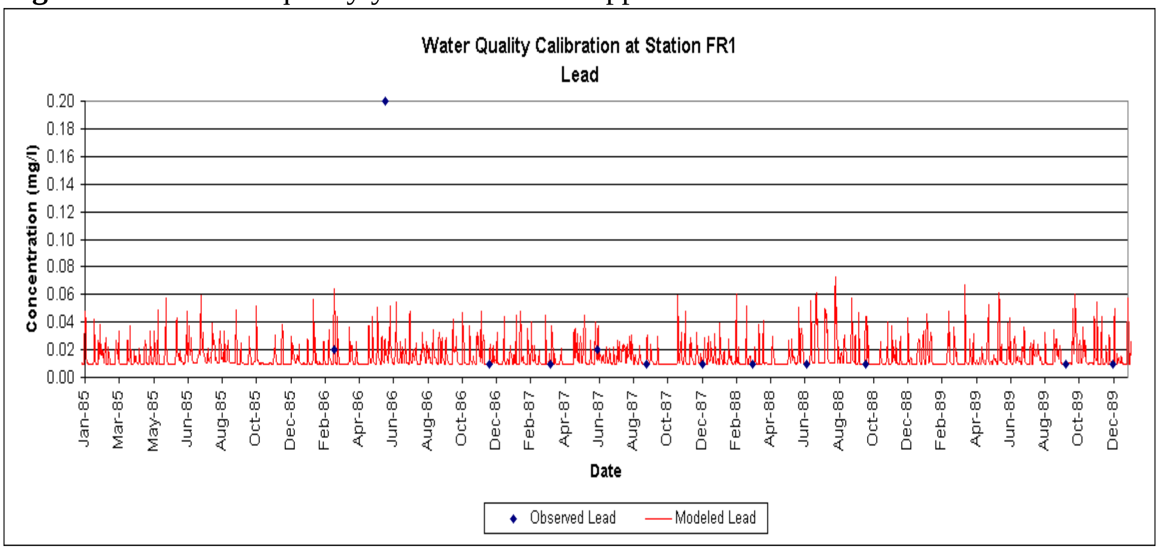

Figure E-20. Water quality calibration for lead at station FR1

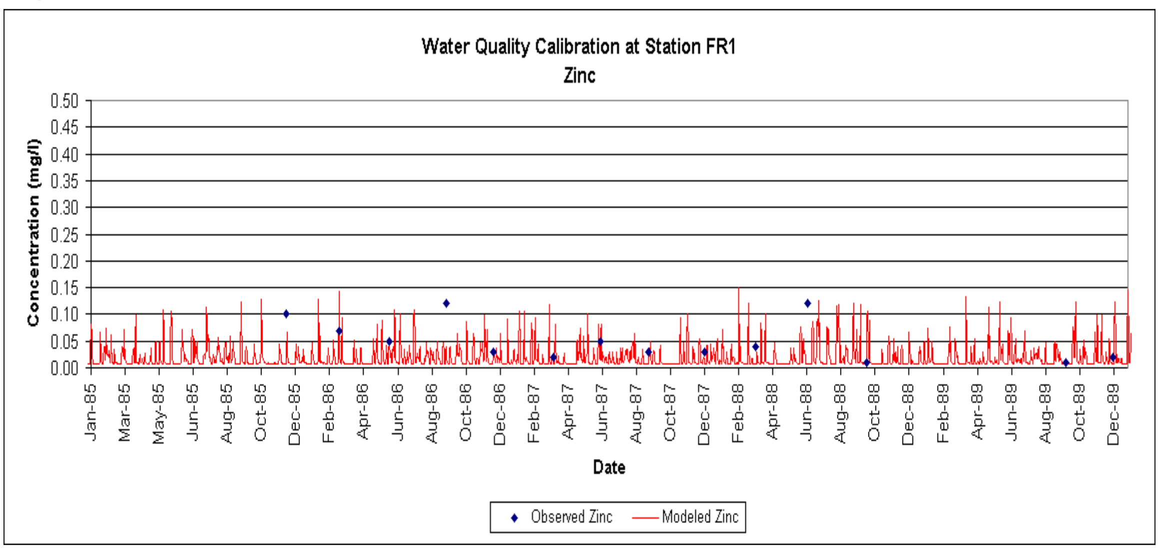

Figure E-21. Water quality calibration for zinc at station FR1

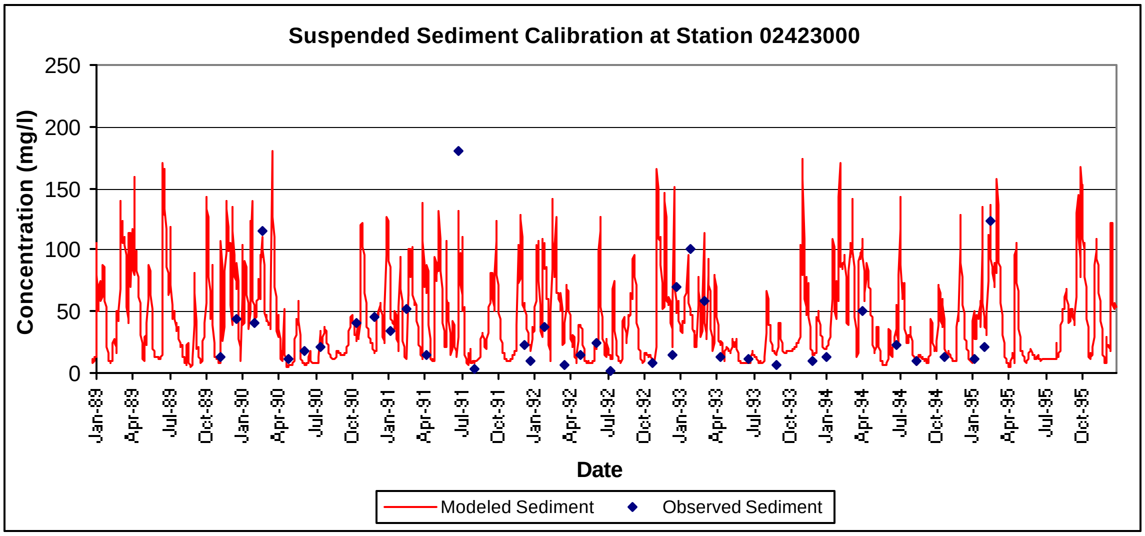

Figure E-22. Water quality calibration for sediment at station 02423000

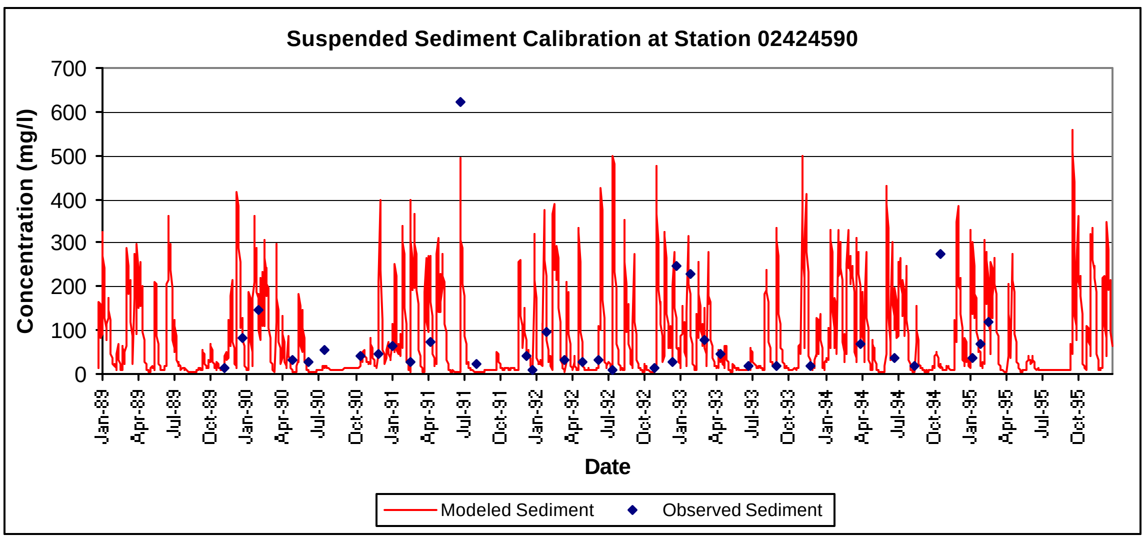

Figure E-23. Water quality calibration for sediment at station 02424590

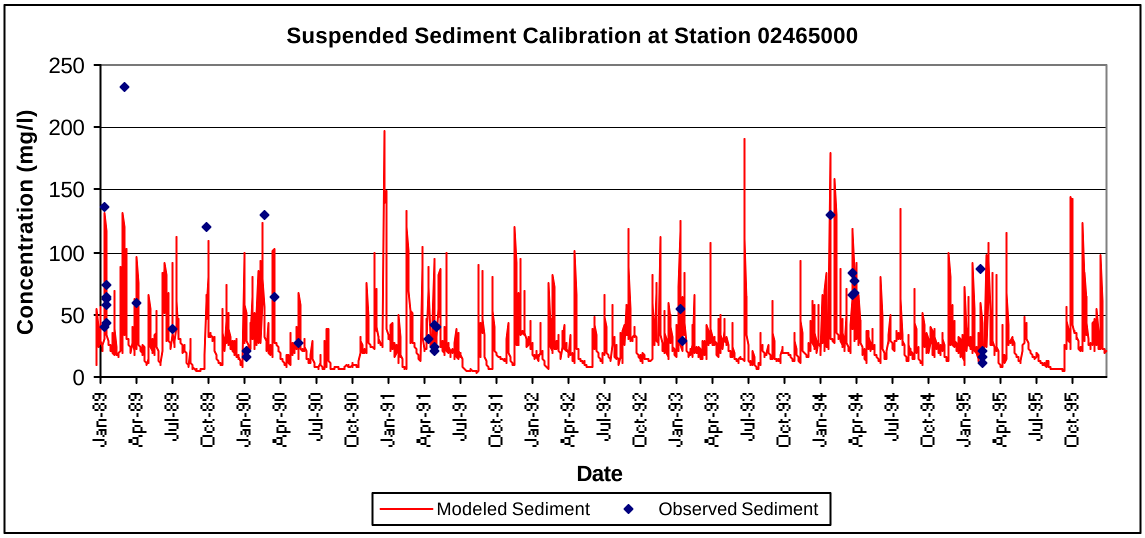

Figure E-24. Water quality calibration for sediment at station 02465000

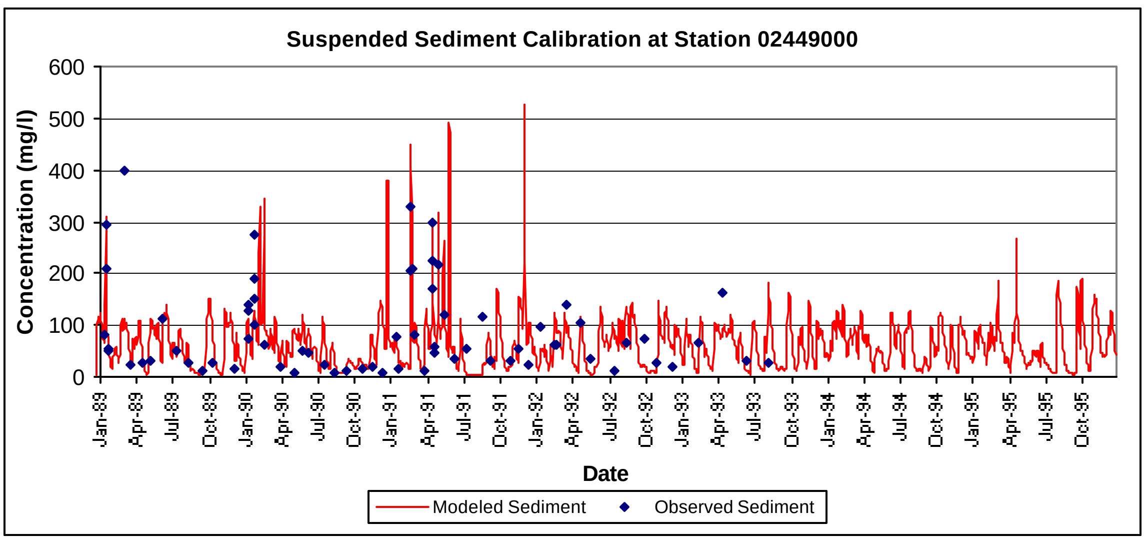

Figure E-25. Water quality calibration for sediment at station 02449000

Appendix F

Water Quality Validation Results

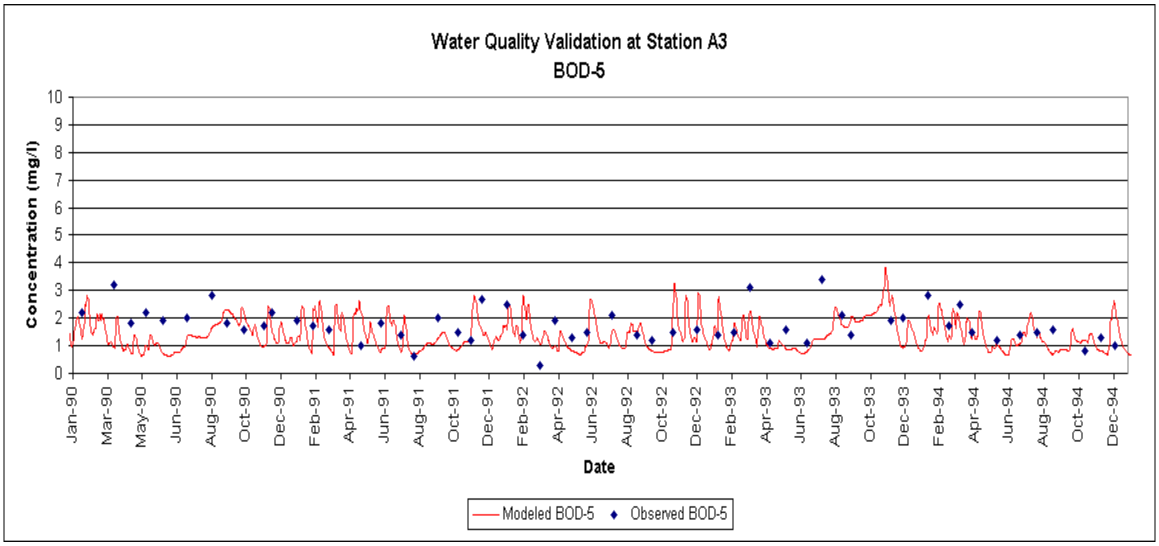

Figure F-1. Water quality validation for BOD_5 at station A3

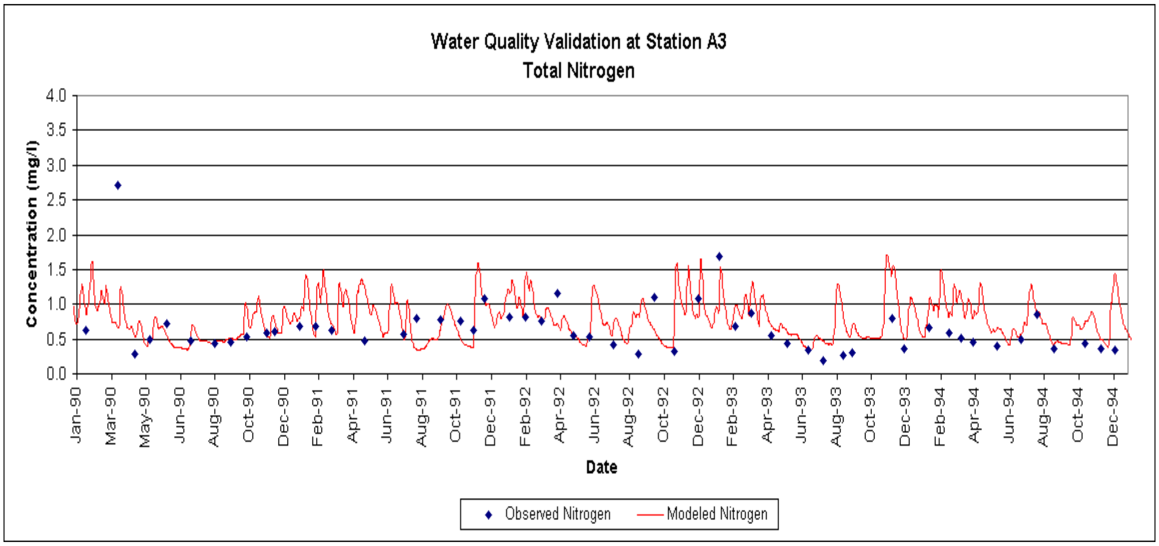

Figure F-2. Water quality validation for total nitrogen at station A3

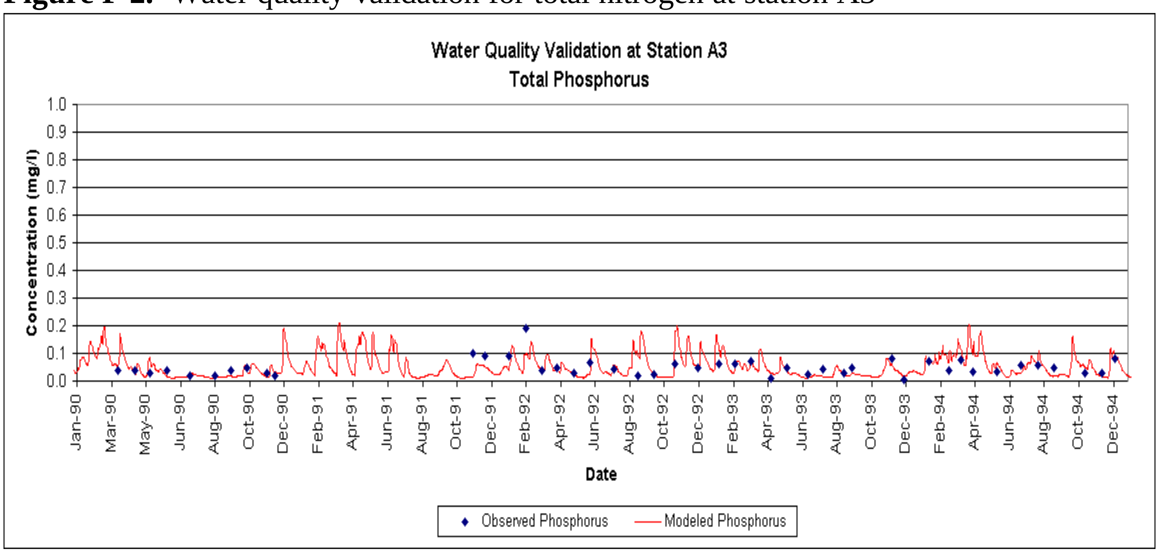

Figure F-3. Water quality validation for total phosphorus at station A3

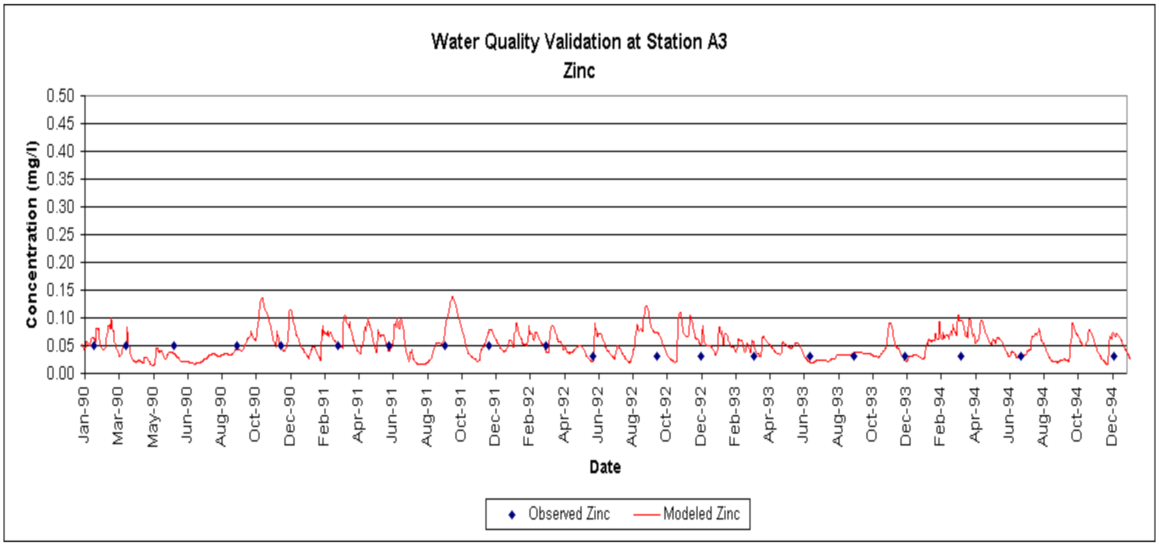

Figure F-4. Water quality validation for zinc at station A3

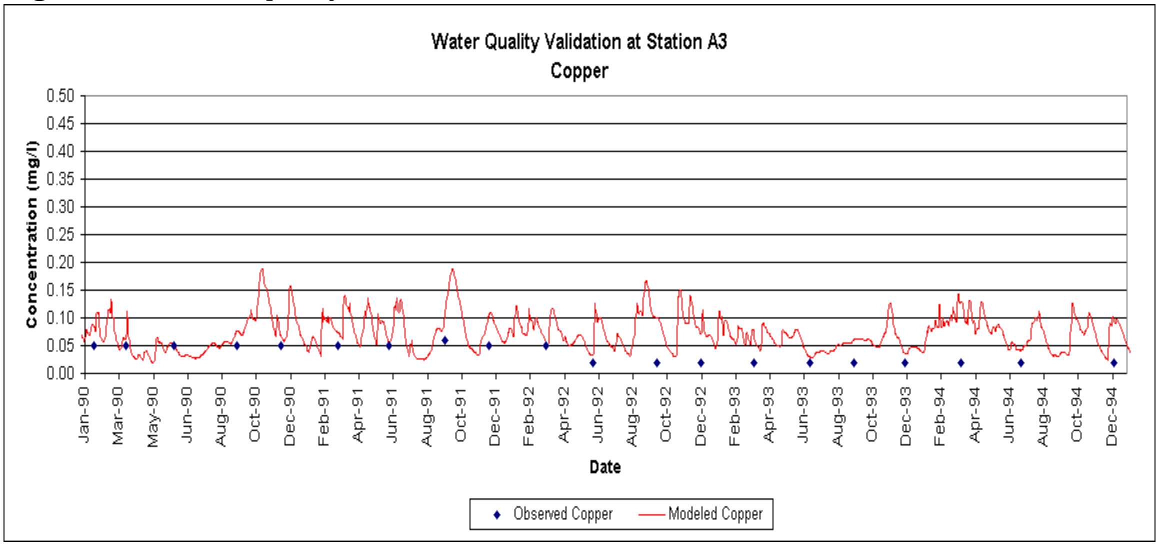

Figure F-5. Water quality validation for copper at station A3

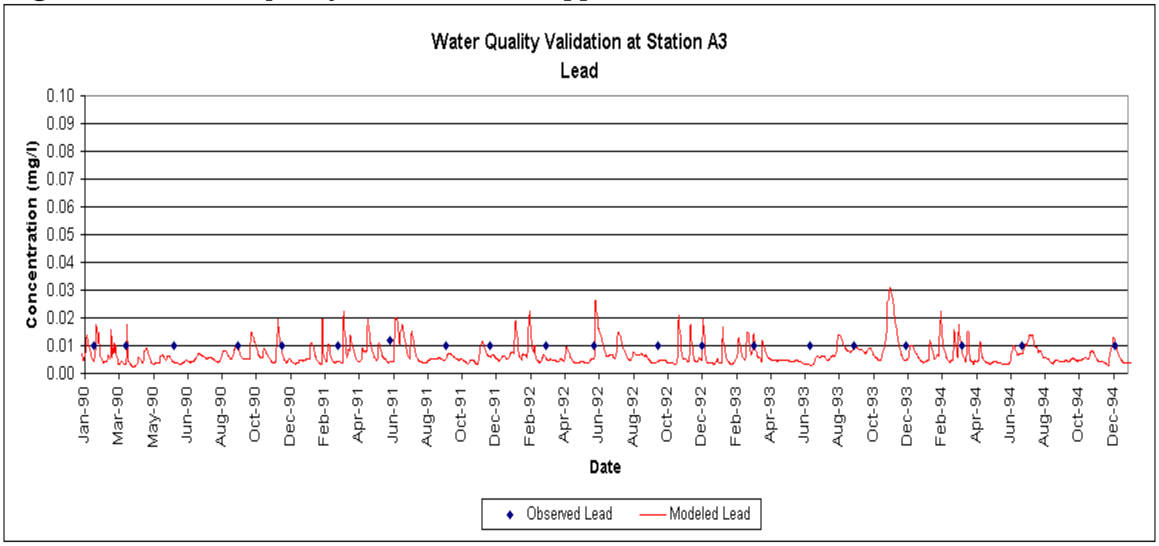

Figure F-6. Water quality validation for lead at station A3

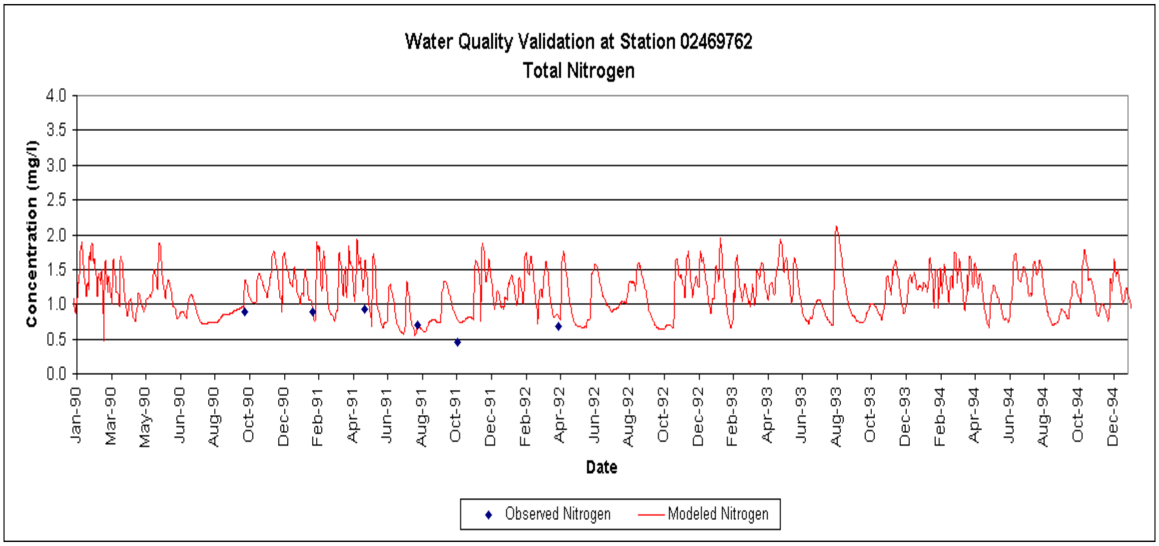

Figure F-7. Water quality validation for total nitrogen at station 02469762

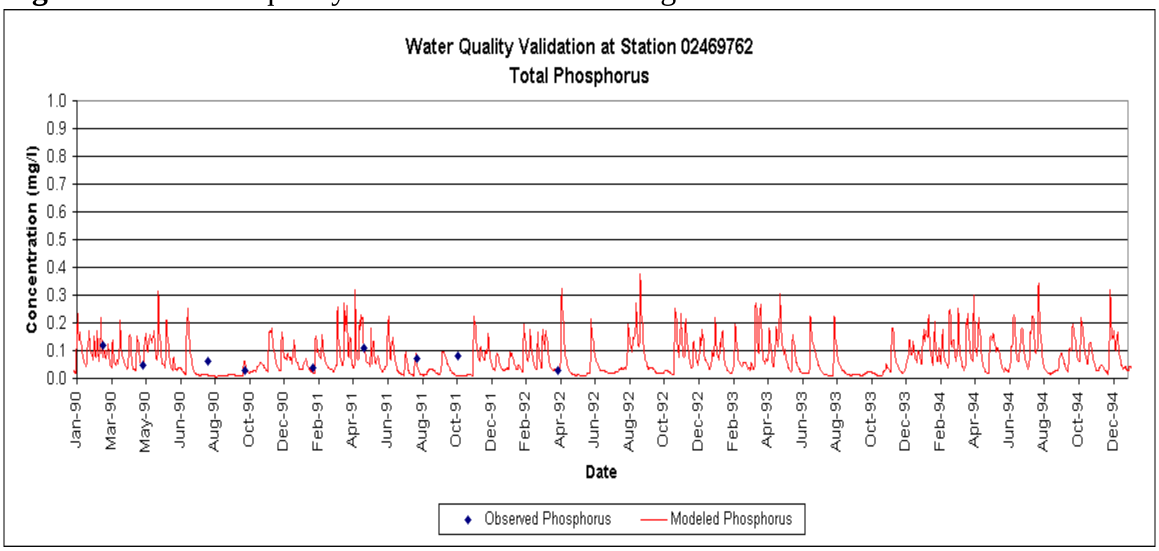

Figure F-8. Water quality validation for total phosphorus at station 02469762

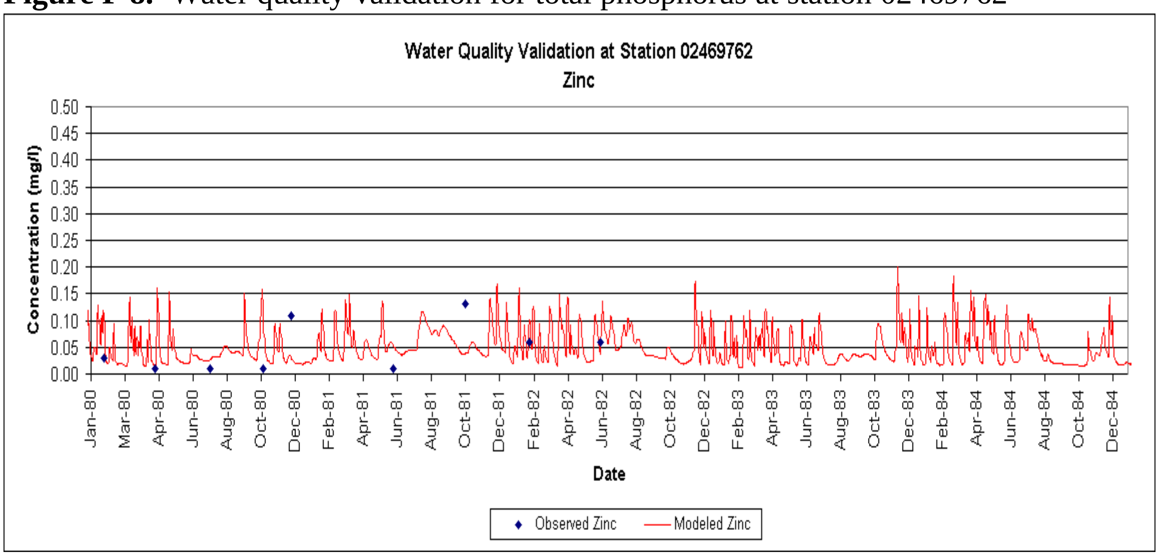

Figure F-9. Water quality validation for zinc at station 02469762

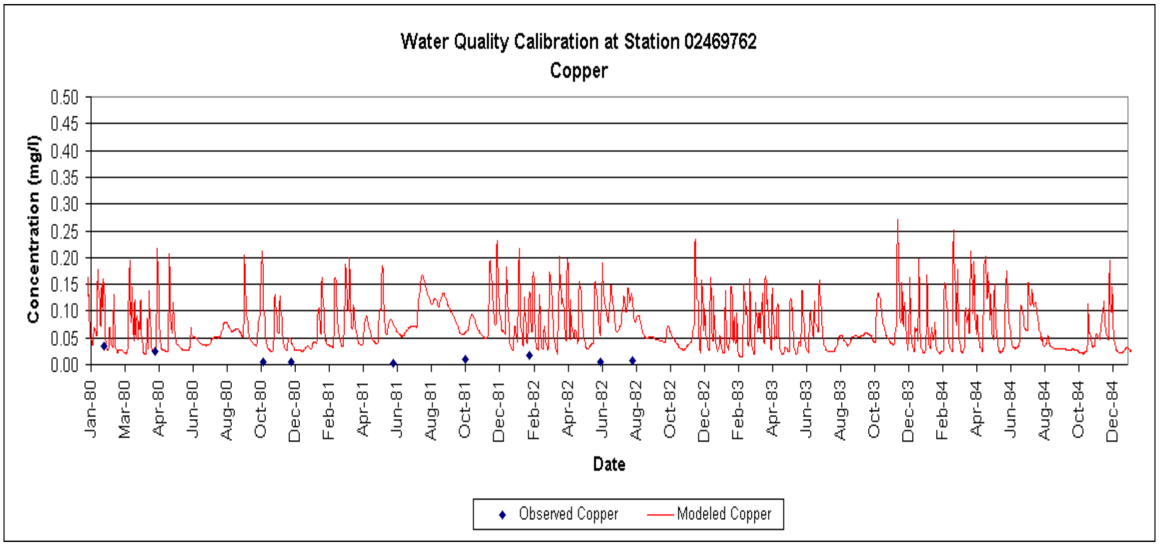

Figure F-10. Water quality validation for copper at station 02469762

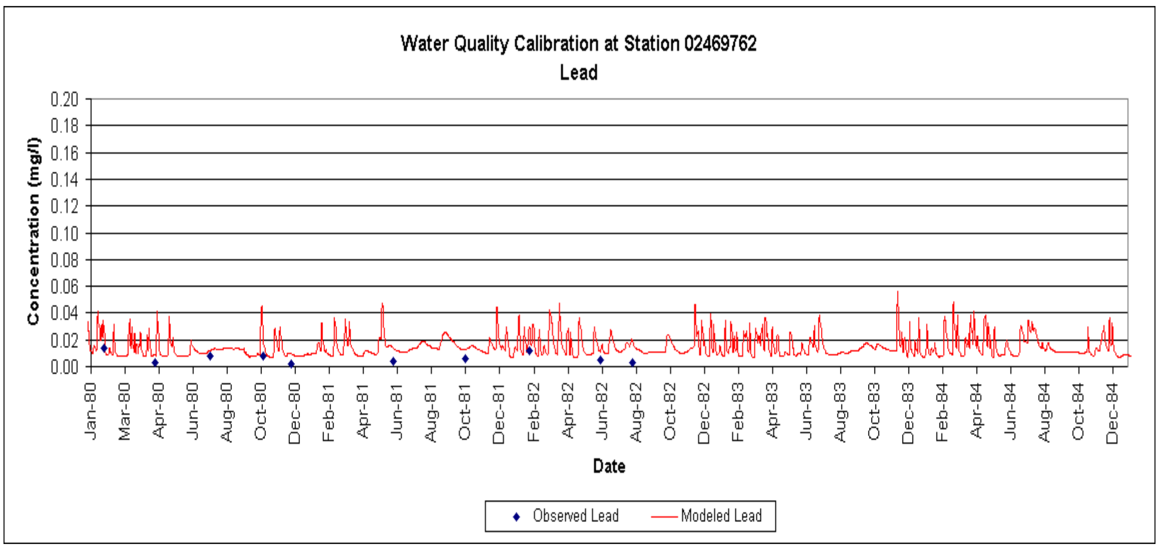

Figure F-11. Water quality validation for lead at station 02469762

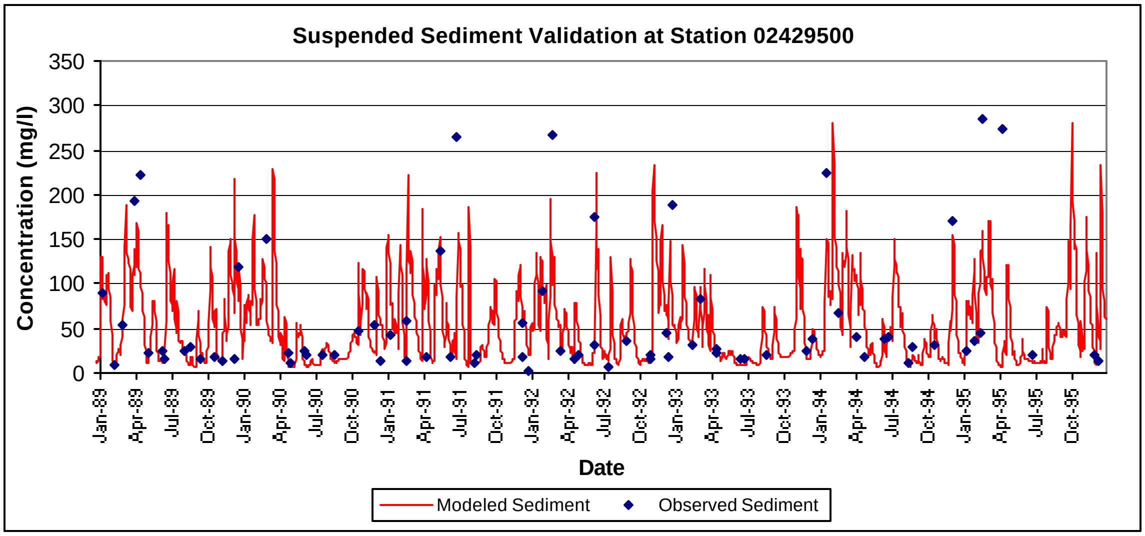

Figure F-12. Water quality validation for sediment at station 02429500

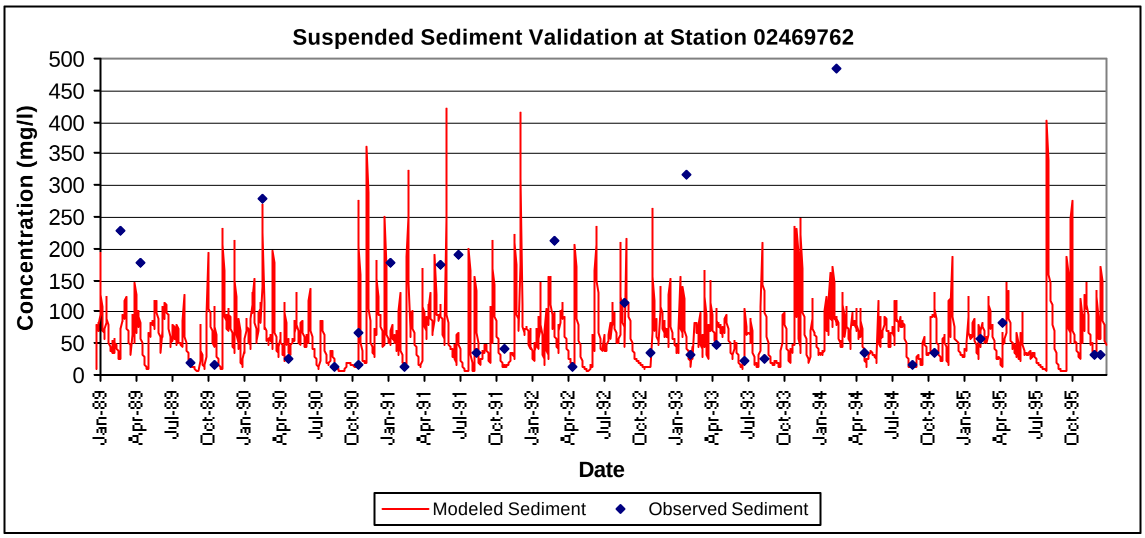

Figure F-13. Water quality validation for sediment at station 02469762

Appendix G

Watershed Indicators

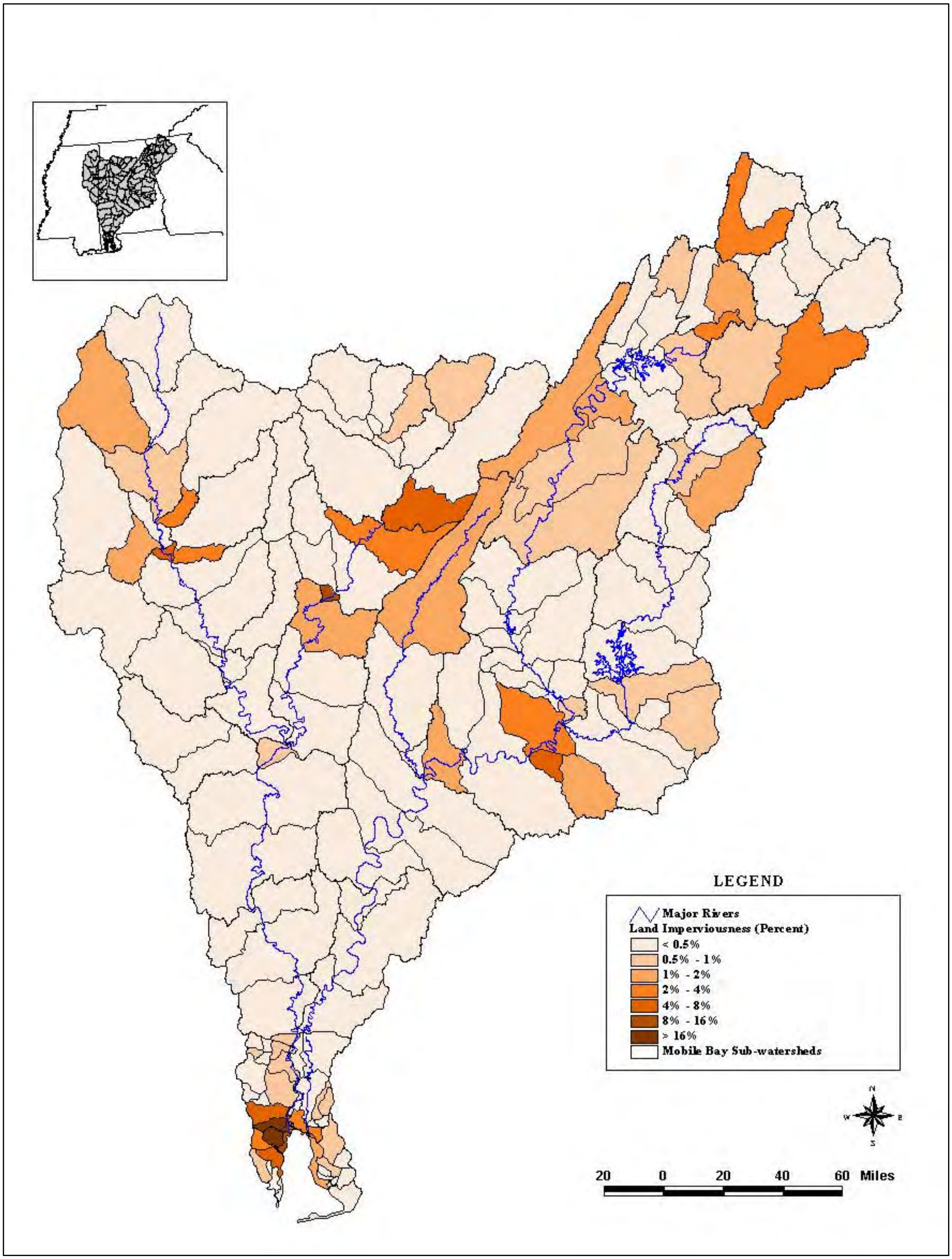

Figure G-1. Land imperviousness for the Upper Mobile River basin

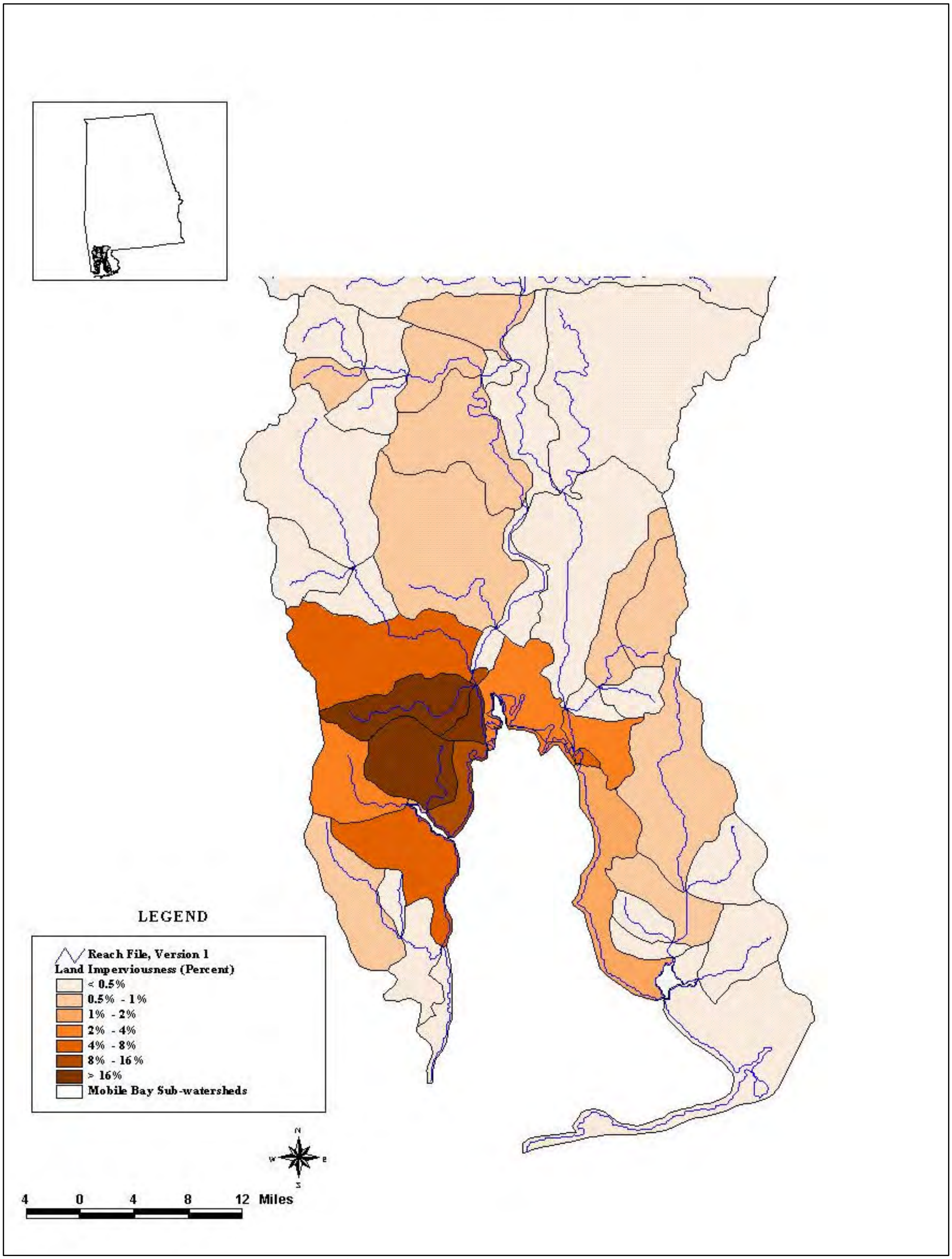

Figure G-2. Land imperviousness for the Lower Mobile River basin

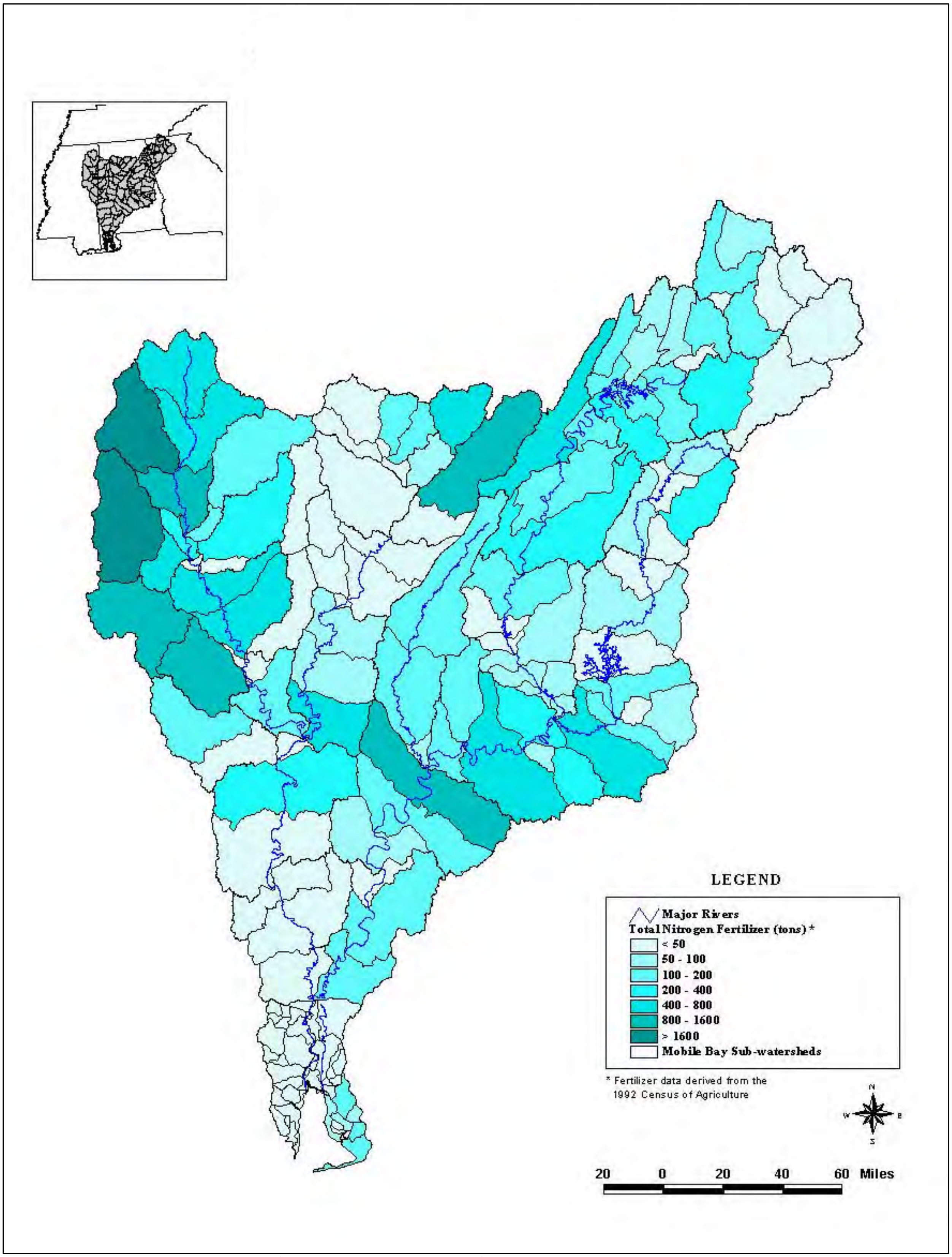

Figure G-3. Total nitrogen fertilizer application for the Upper Mobile River basin

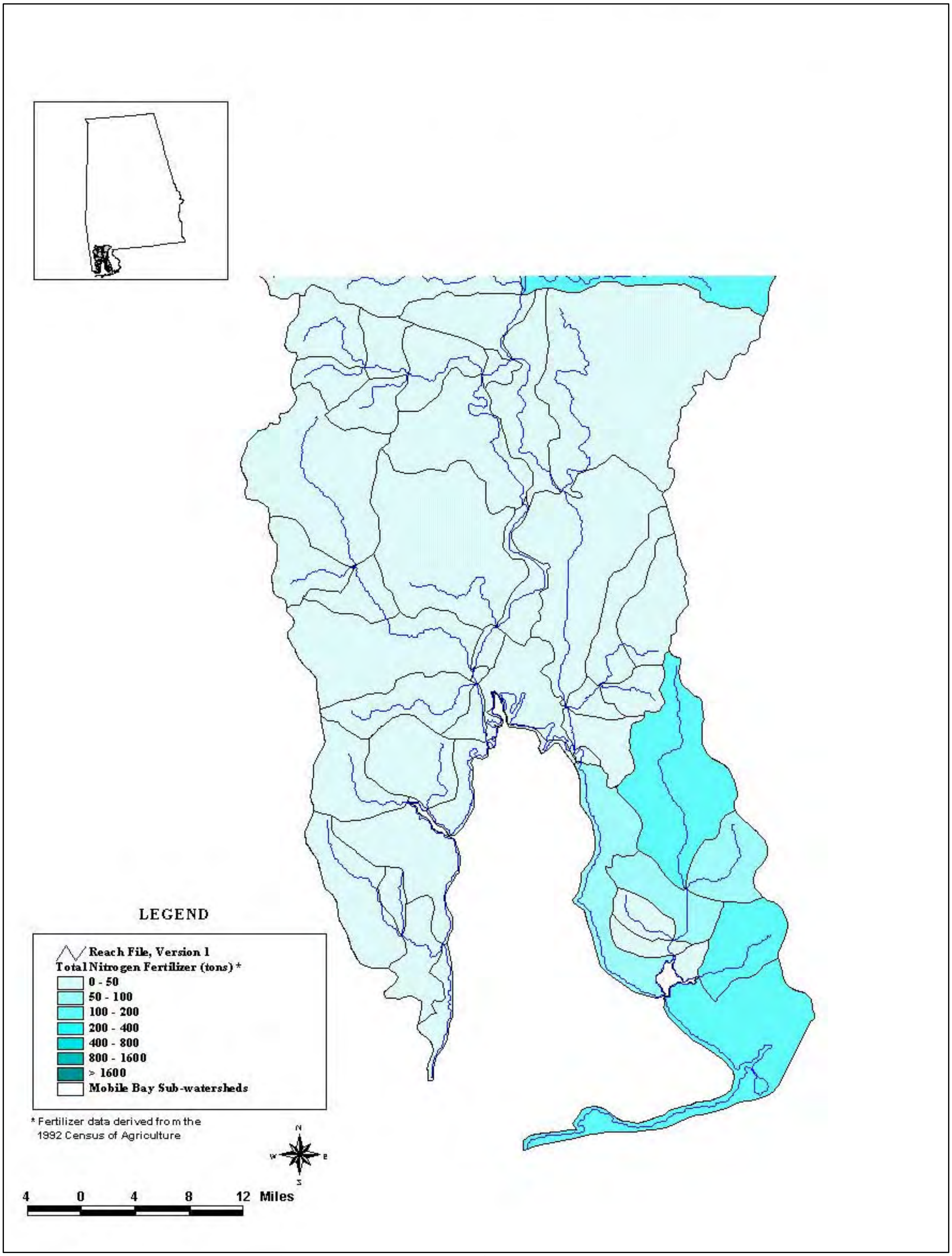

Figure G-4. Total nitrogen fertilizer application for the Lower Mobile River basin

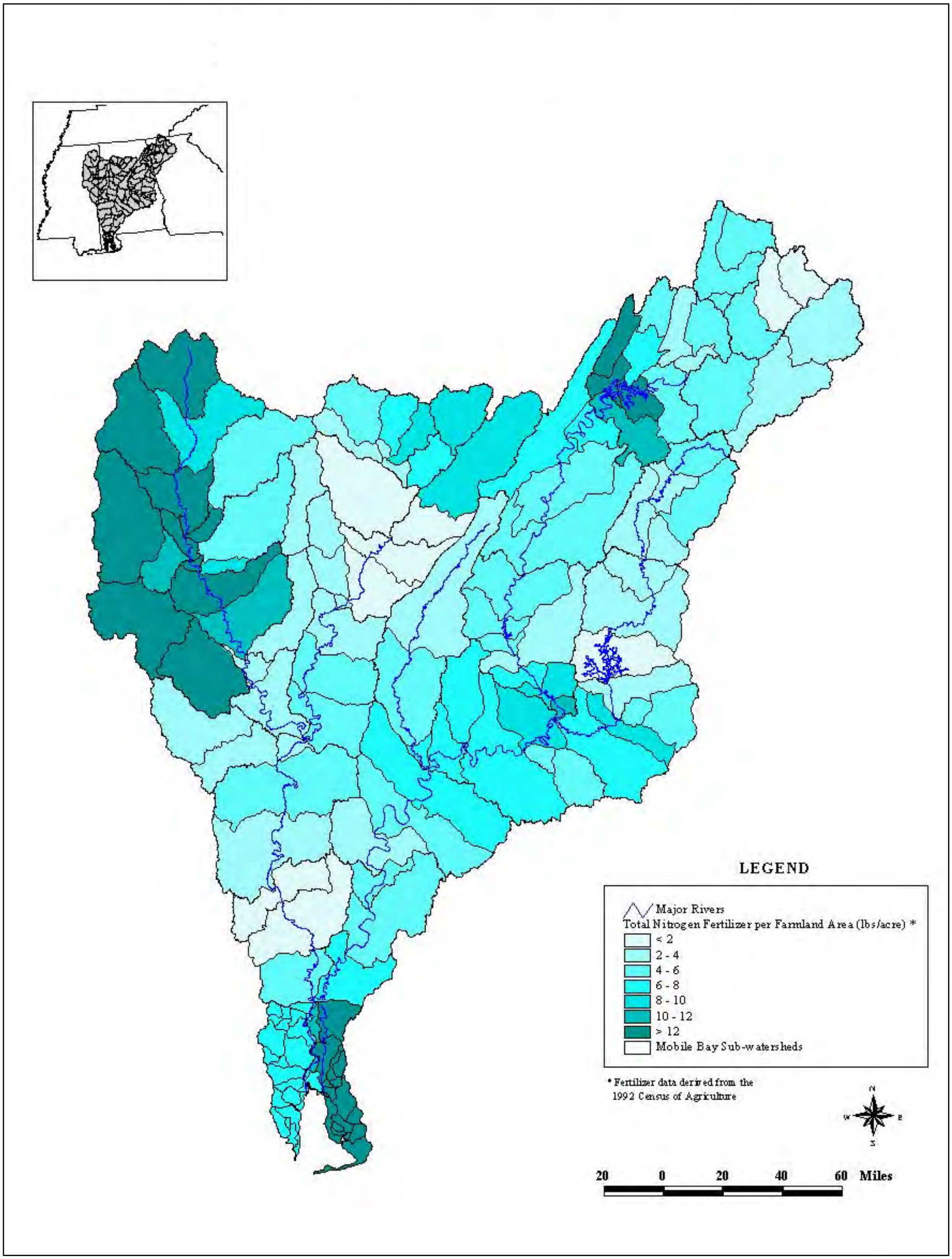

Figure G-5. Total nitrogen fertilizer unit area loading for the Upper Mobile River basin

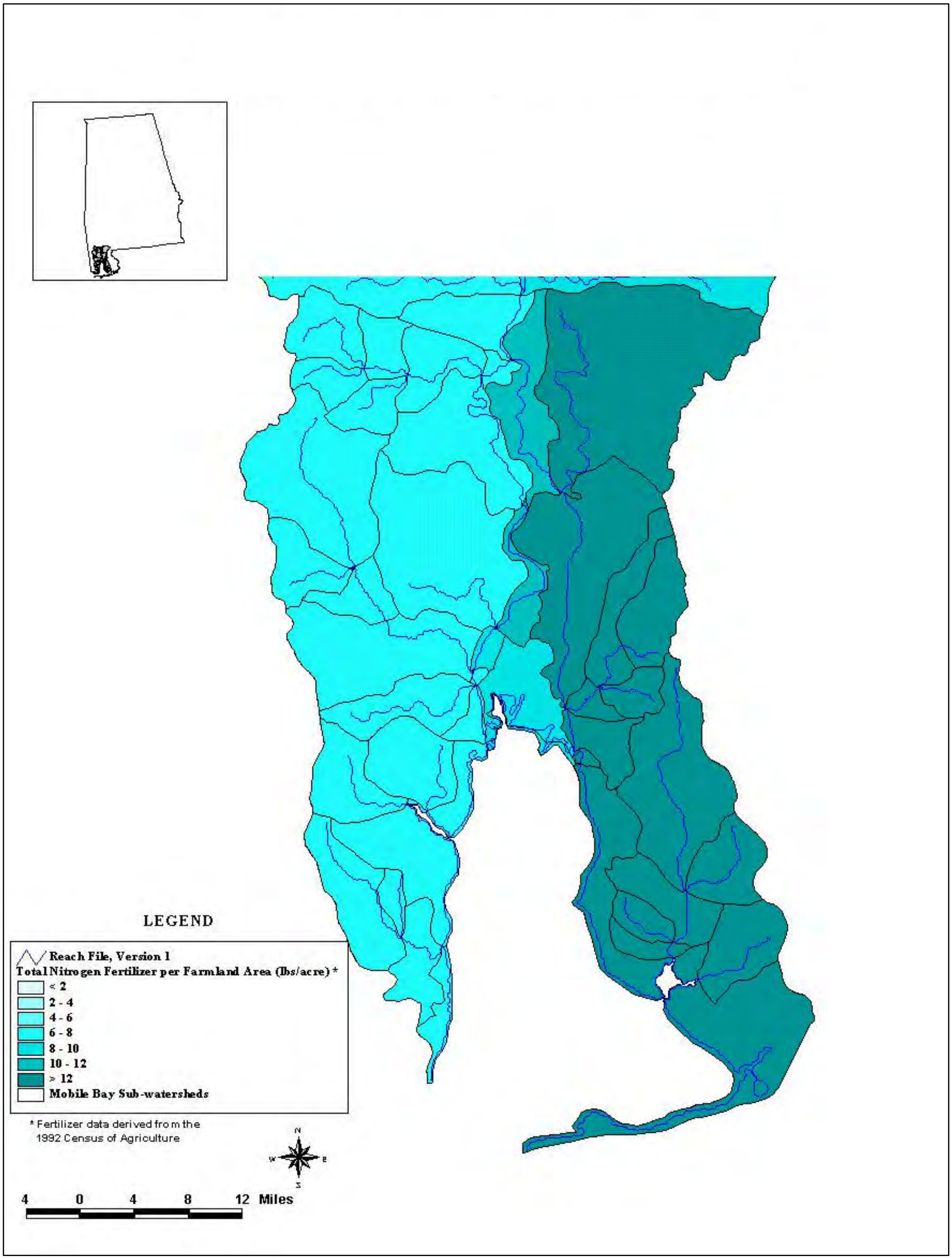

Figure G-6. Total nitrigen fertilizer unit area loading for the Lower Mobile River basin

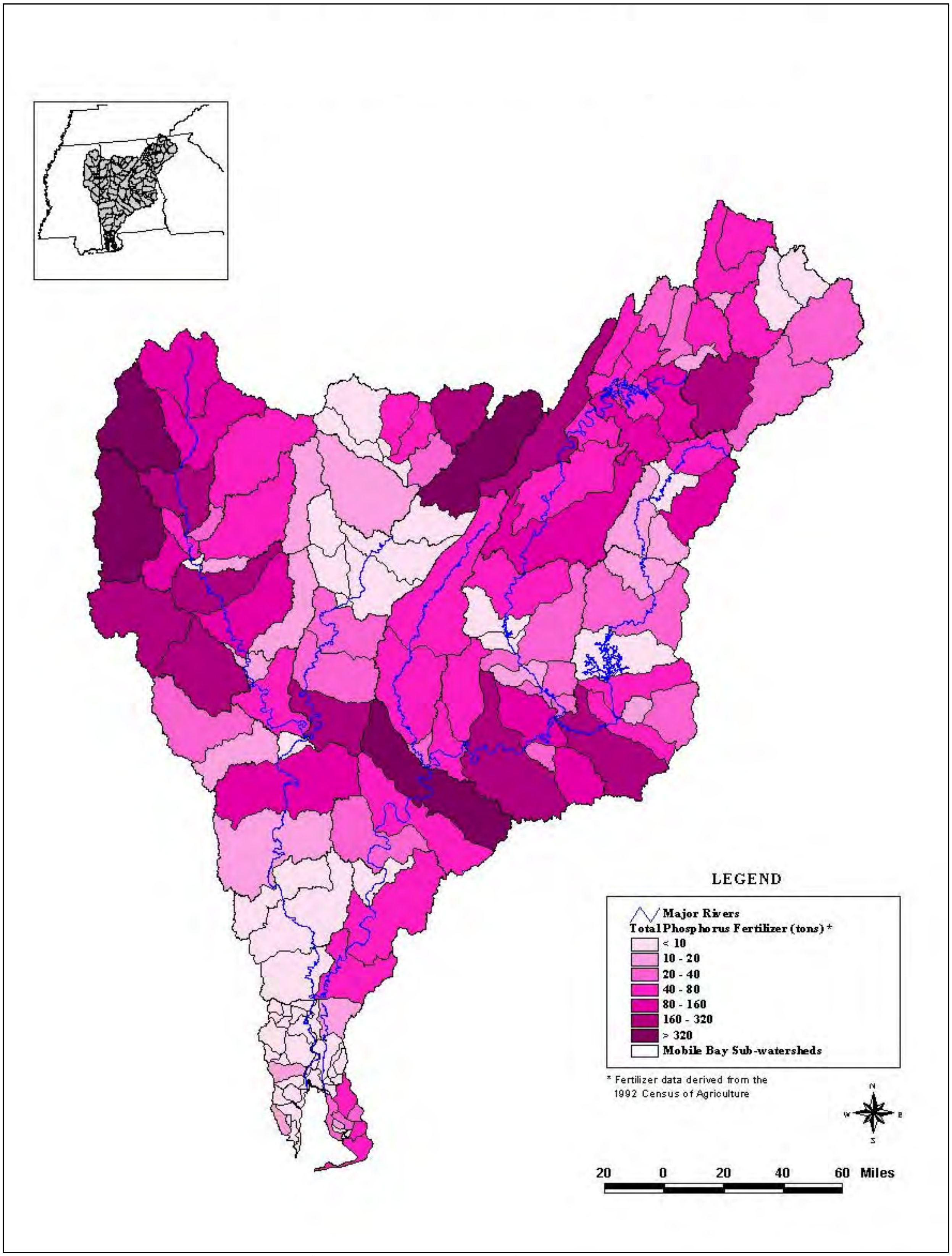

Figure G-7. Total phosphorus fertilizer application for the Upper Mobile River basin

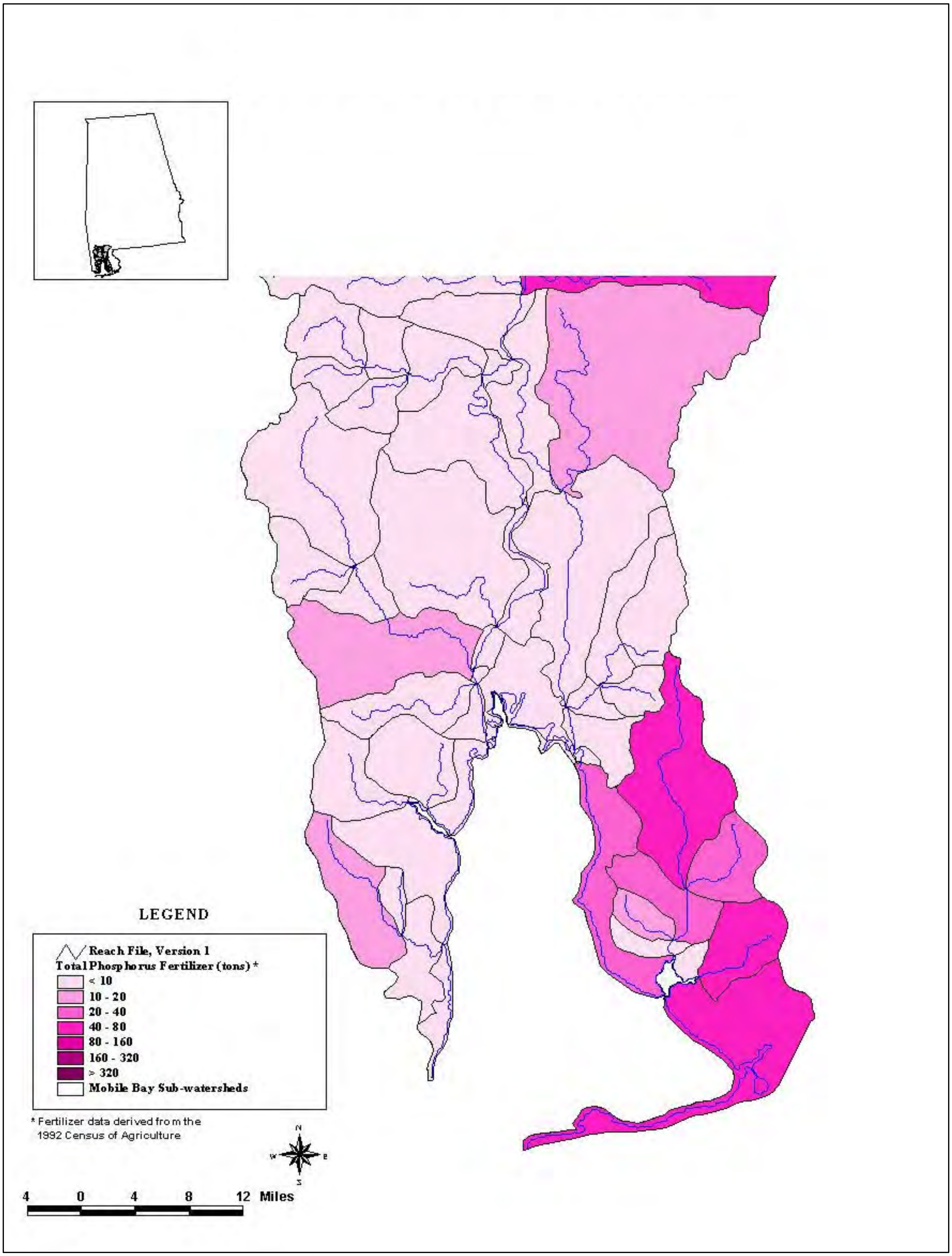

Figure G-8. Total phosphorus fertilizer application for the Lower Mobile River basin

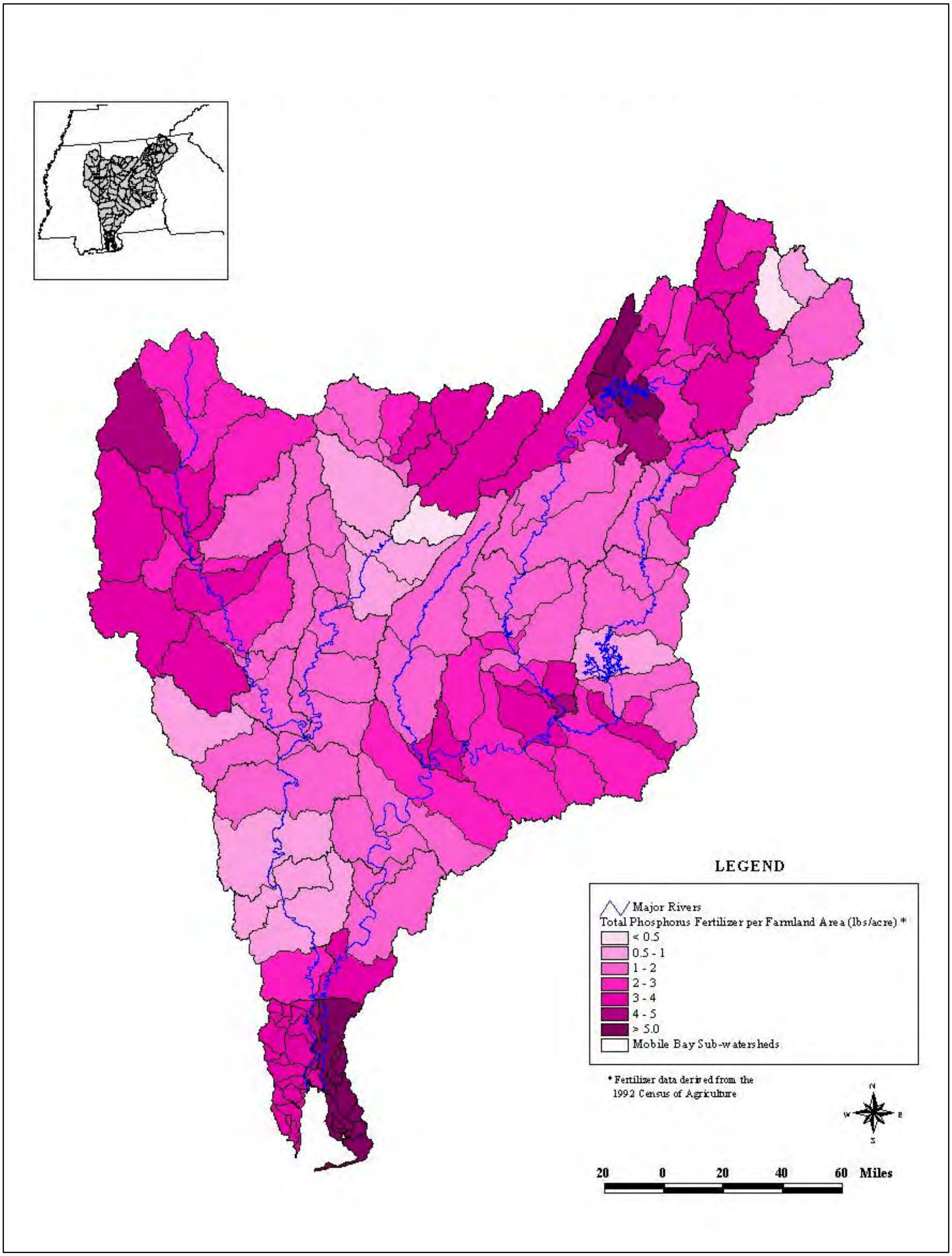

Figure G-9. Total phosphorus fertilizer unit area loading for the Upper Mobile River basin

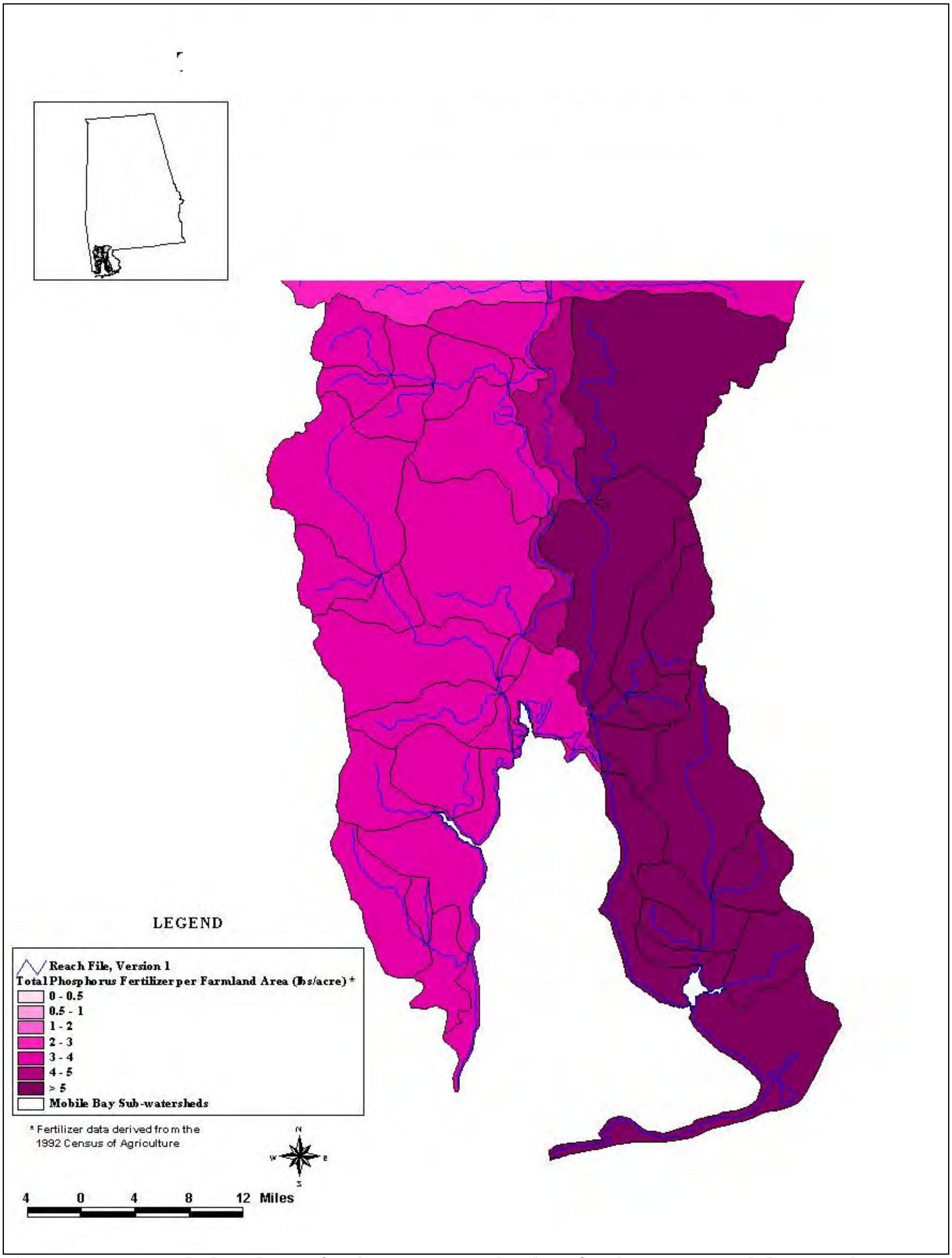

Figure G-10. Total phosphorus fertilizer unit area loading for the Lower Mobile River basin

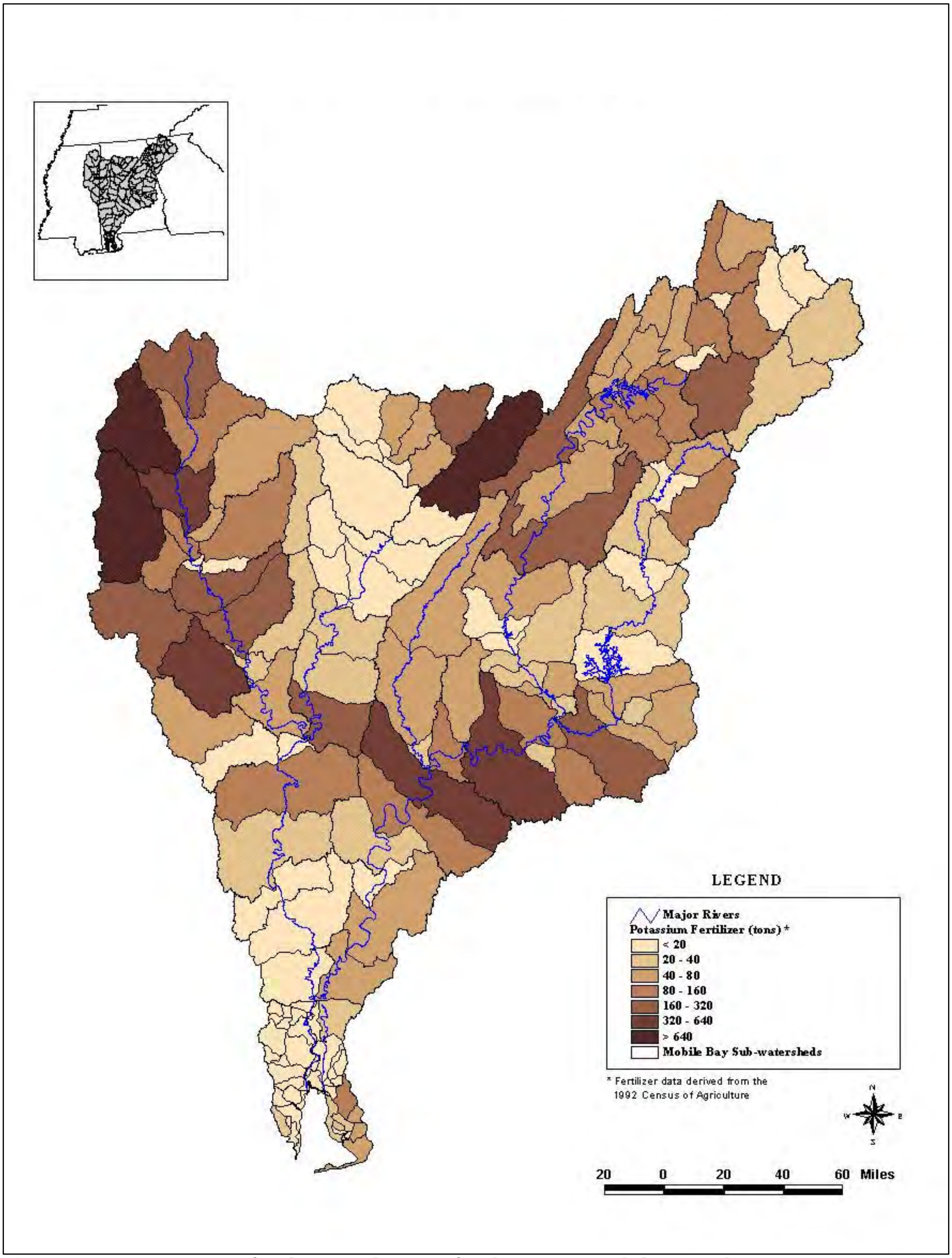

Figure G-11. Potassium fertilizer application for the Upper Mobile River basin

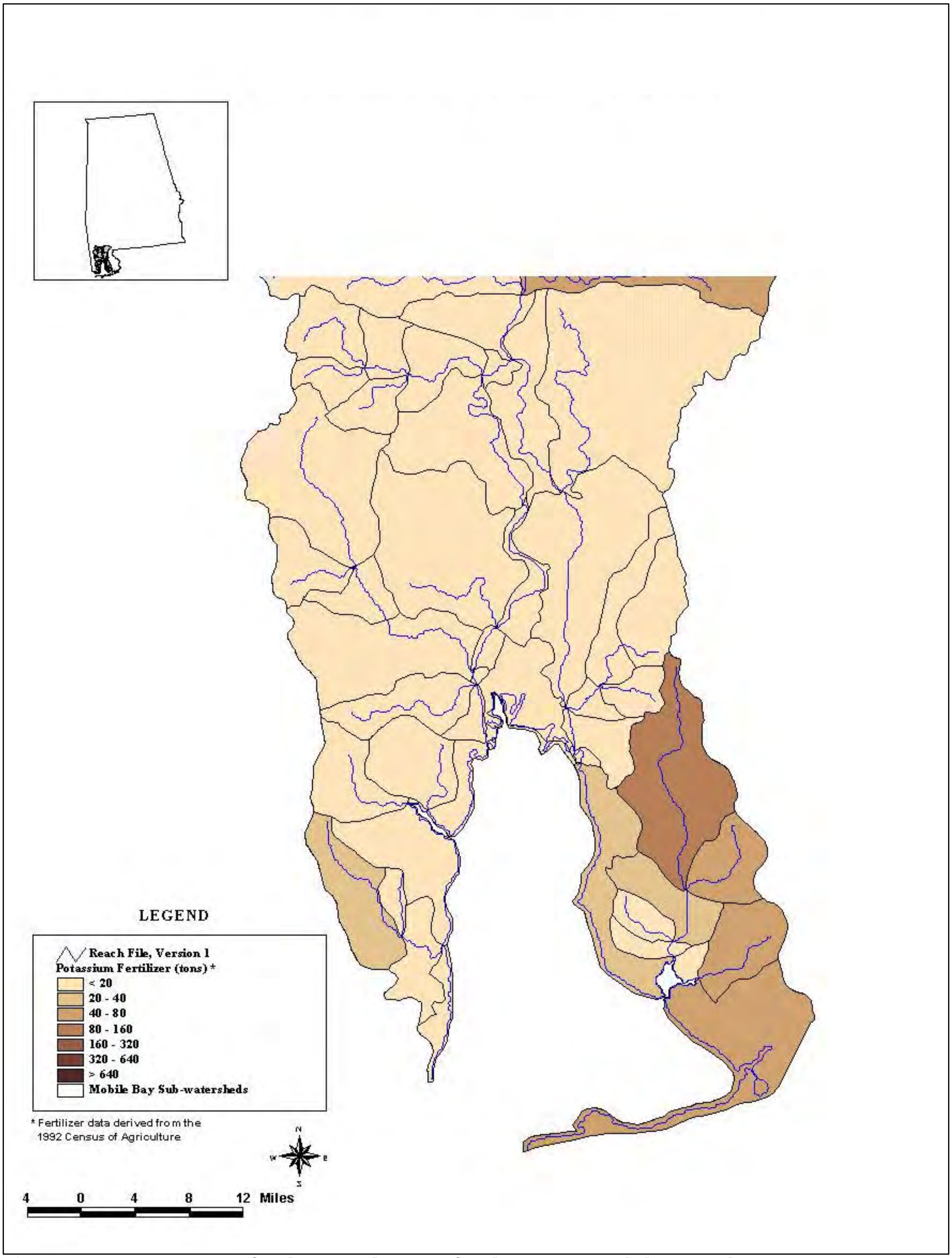

Figure G-12. Potassium fertilizer application for the Lower Mobile River basin

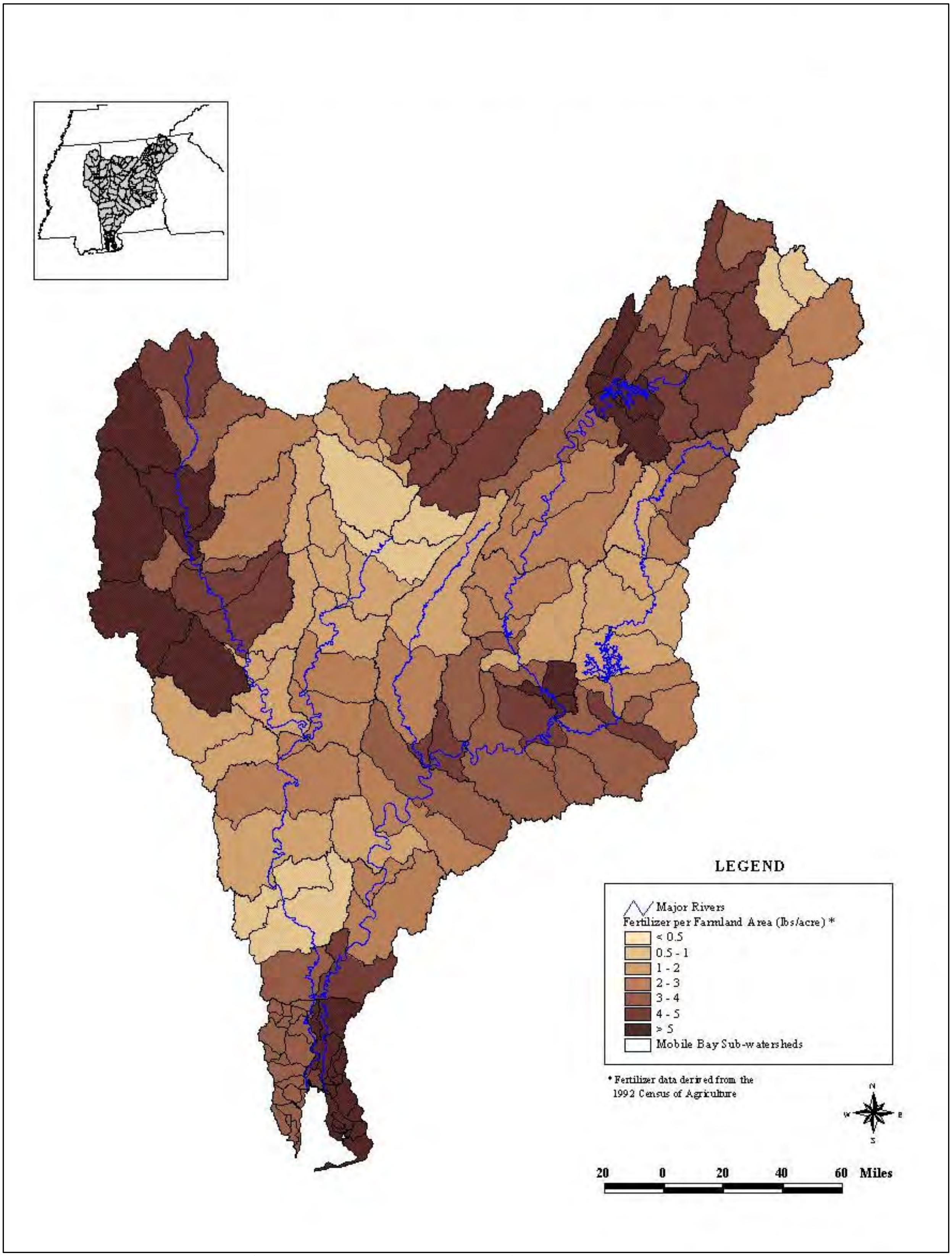

Figure G-13. Potassium fertilizer unit area loading for the Upper Mobile River basin

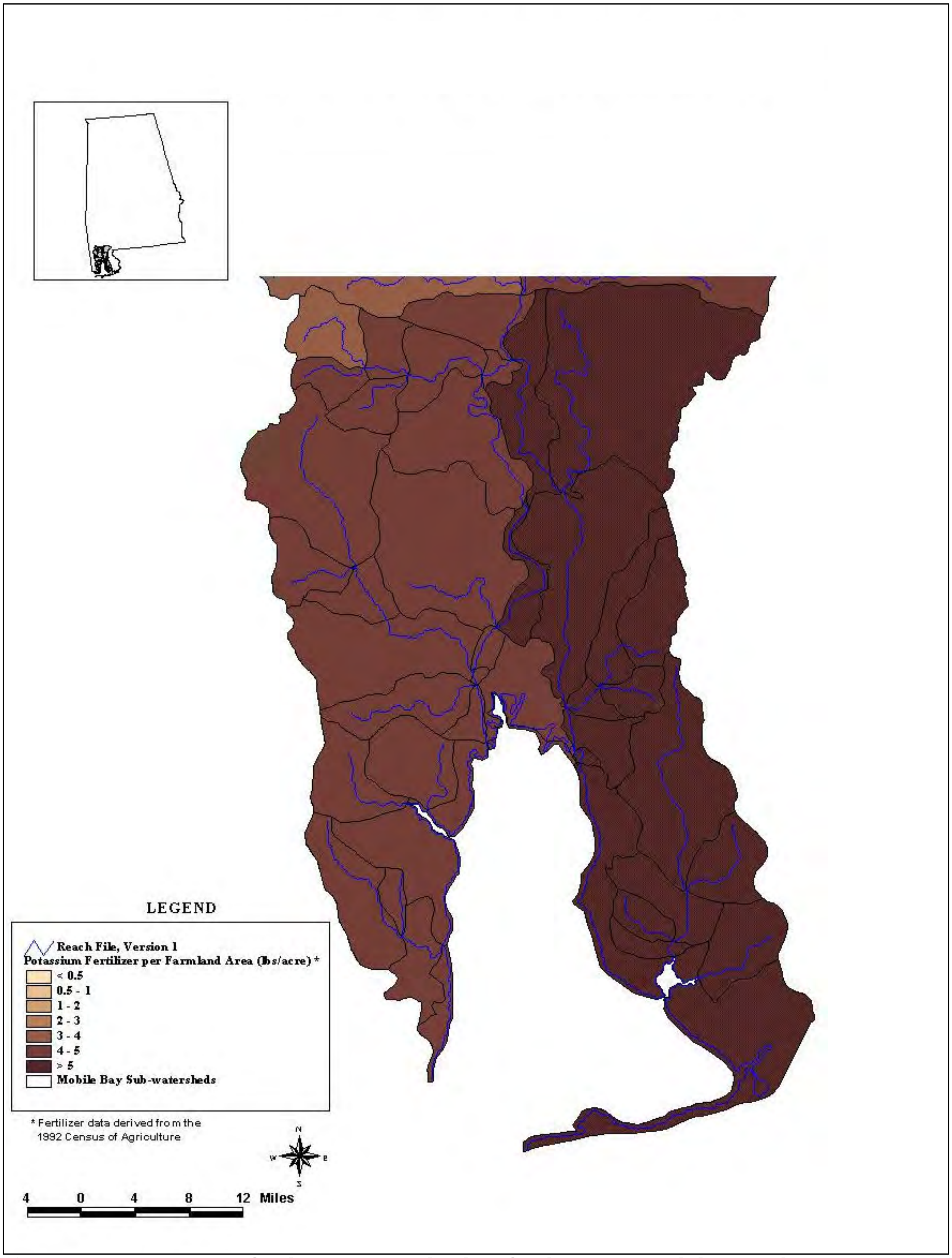

Figure G-14. Potassium fertilizer unit area loading for the Lower Mobile River basin

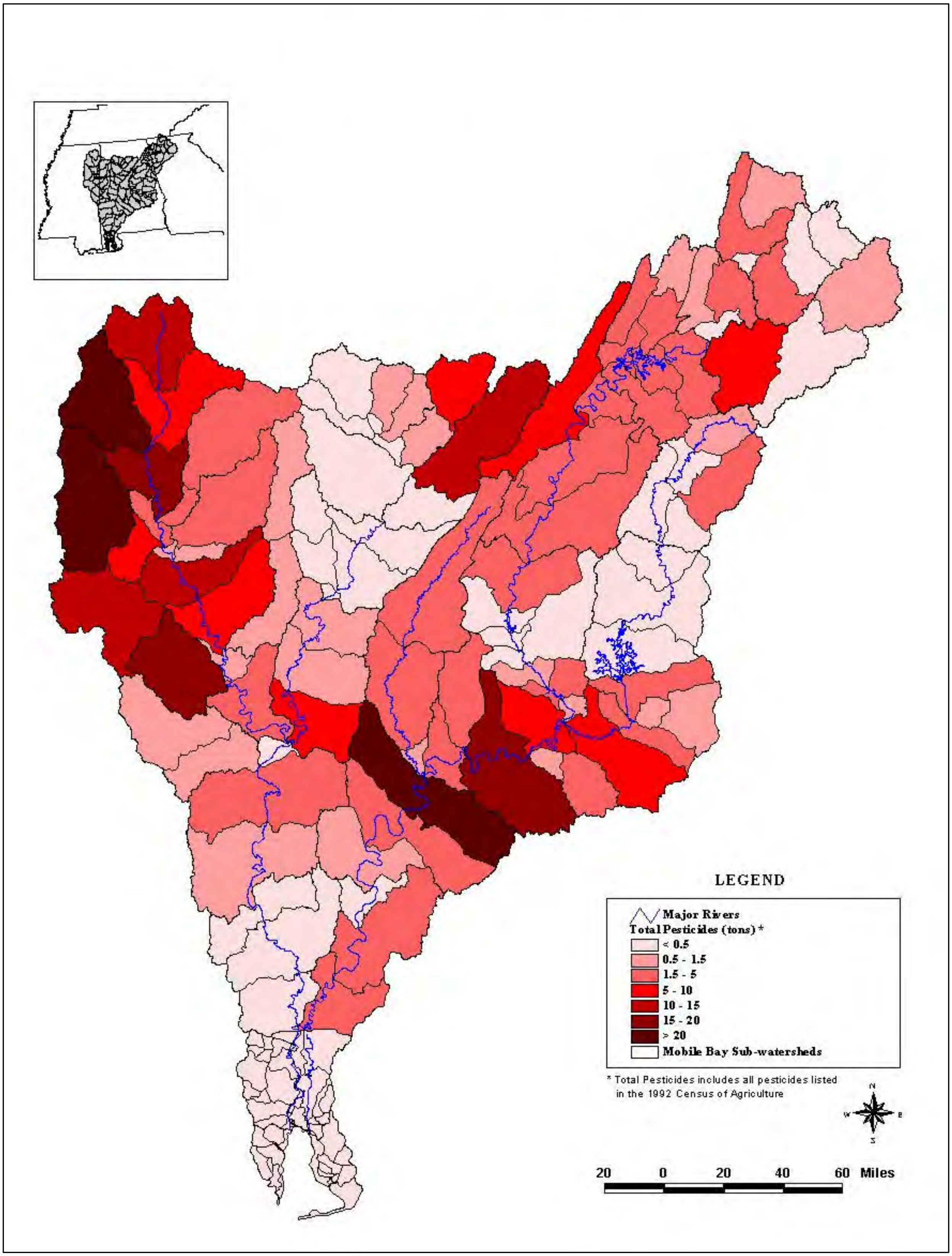

Figure G-15. Pesticide application for the Upper Mobile River basin

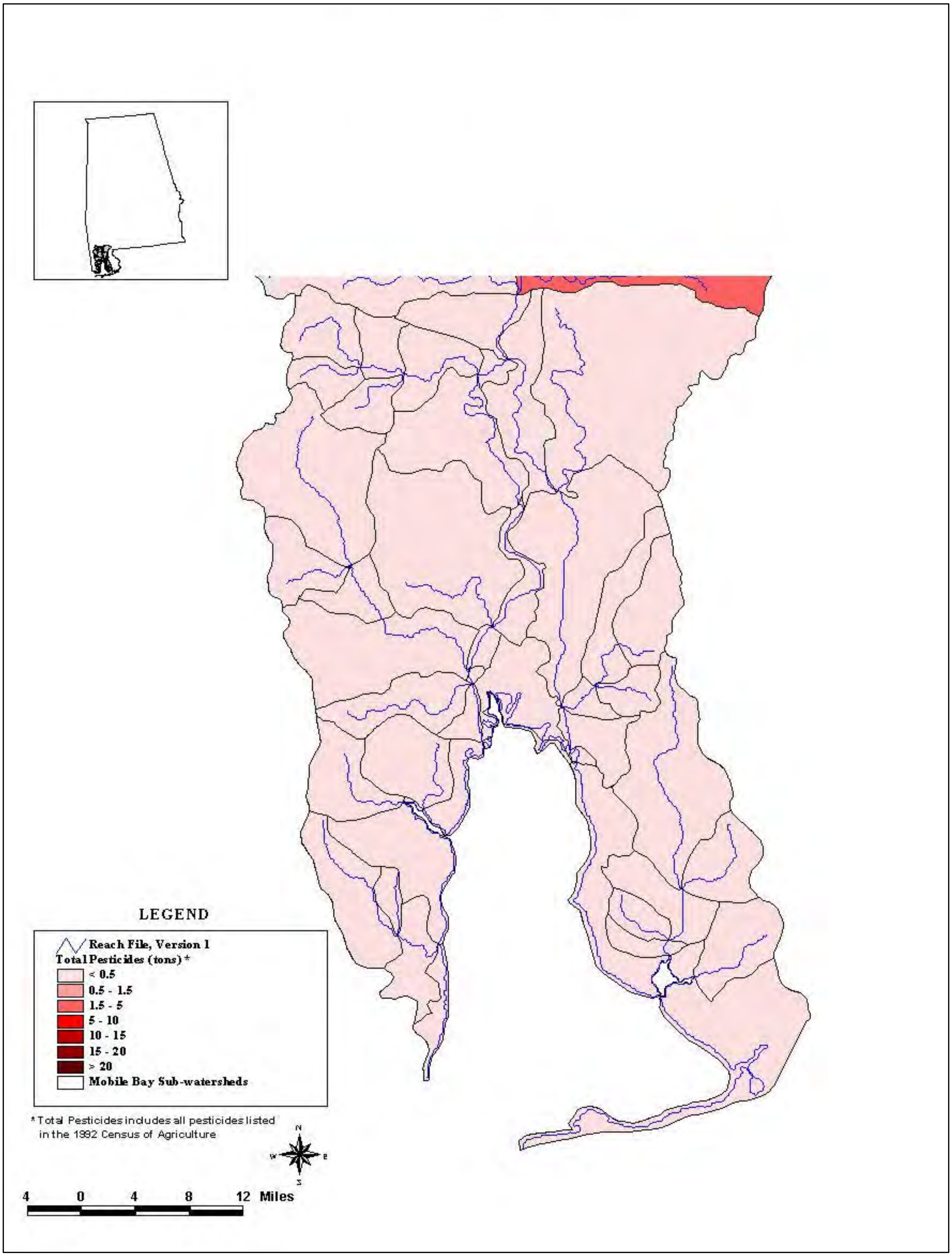

Figure G-16. Pesticide application for the Lower Mobile River basin

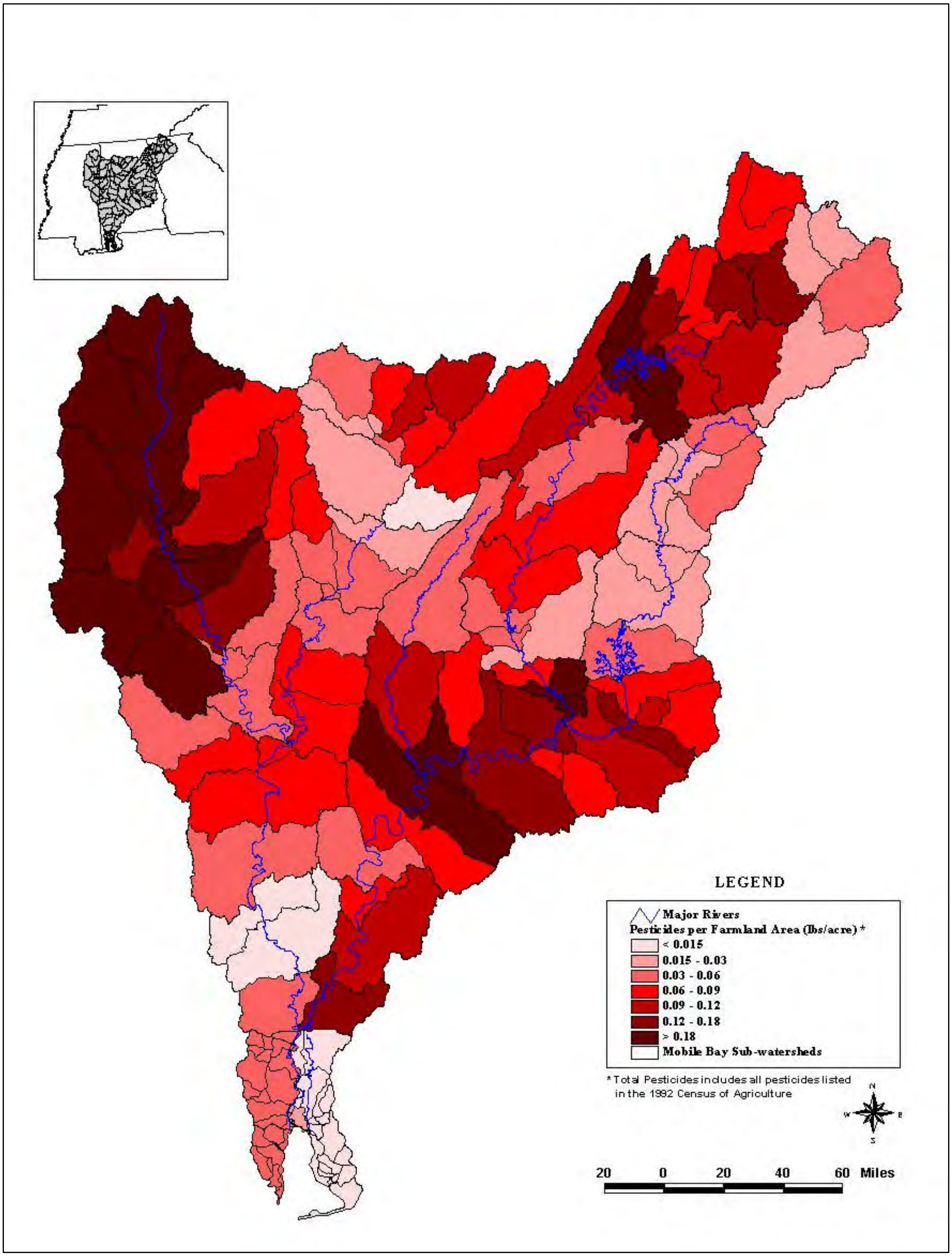

Figure G-17. Pesticide unit area loading for the Upper Mobile River basin

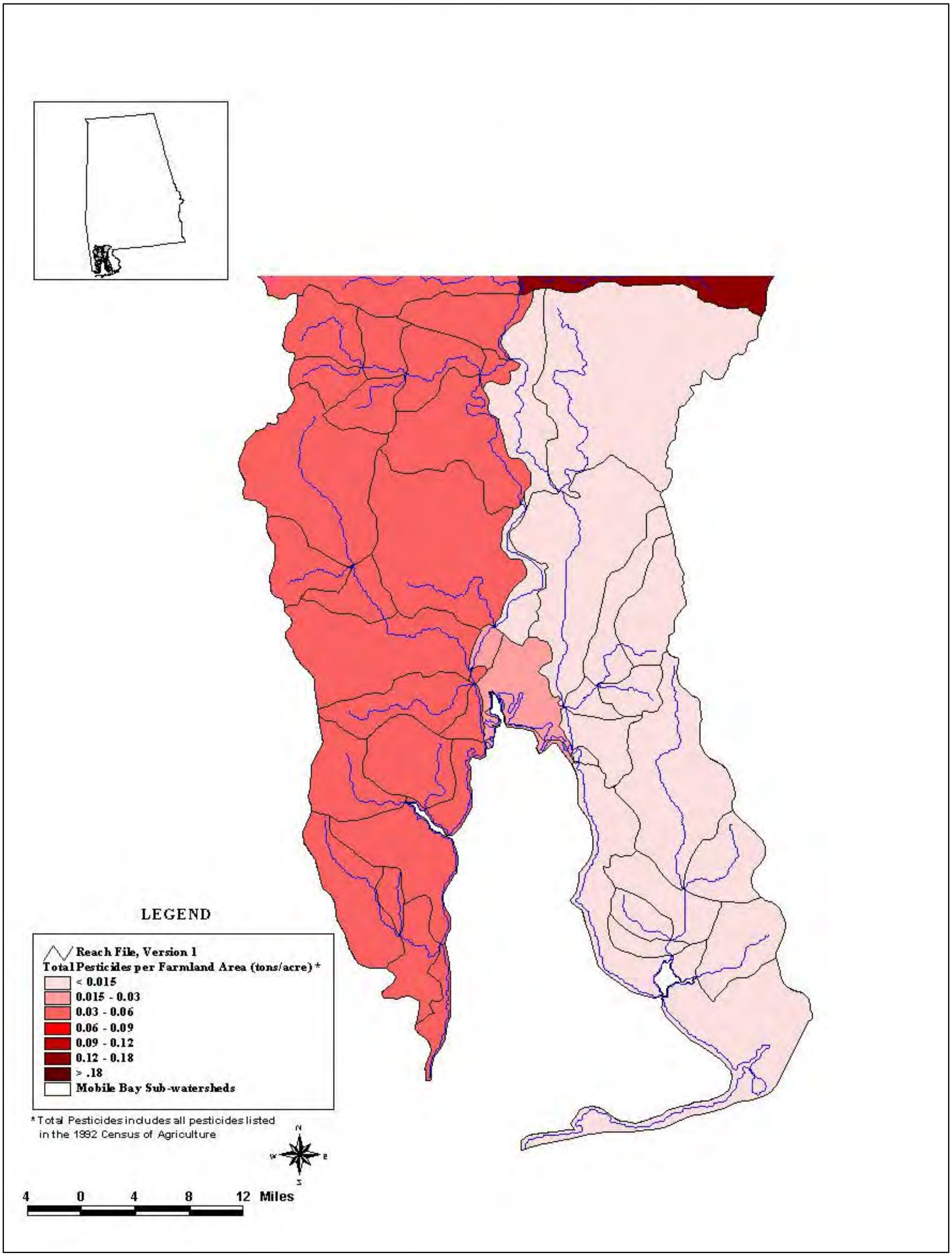

Figure G-18. Pesticide unit area loading for the Lower Mobile River basin

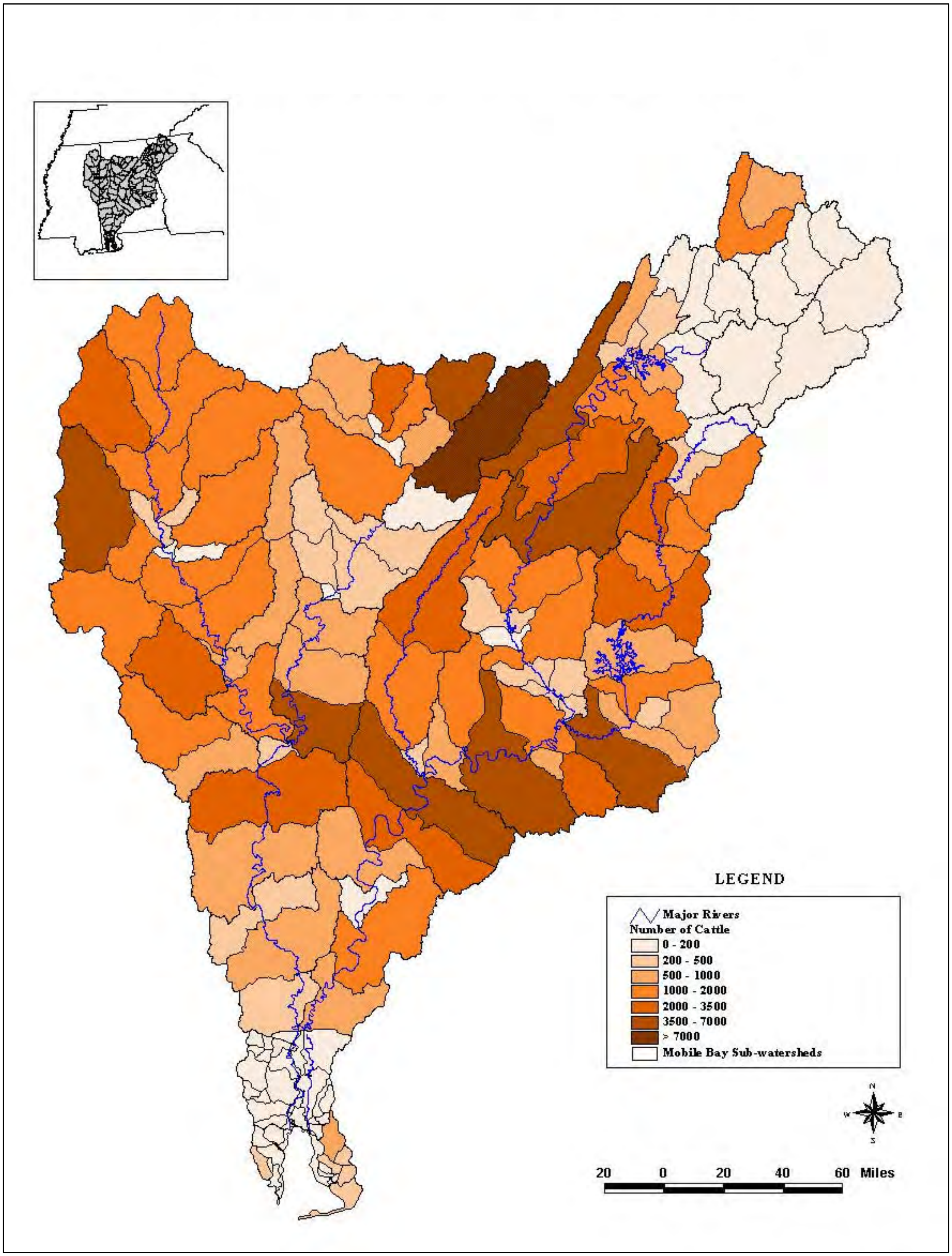

Figure G-19. Cattle distribution in the Upper Mobile River basin

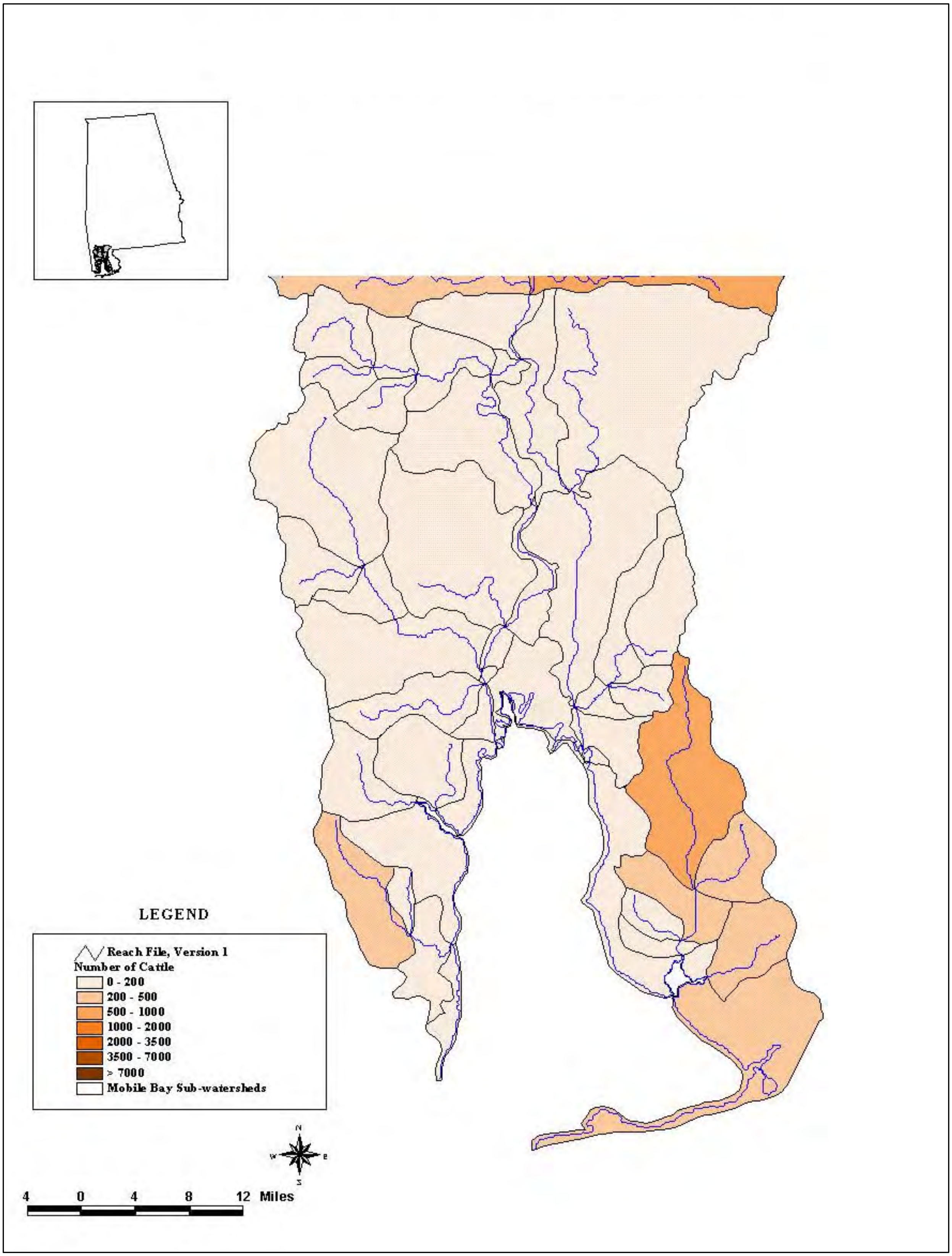

Figure G-20. Cattle distribution in the Lower Mobile River basin

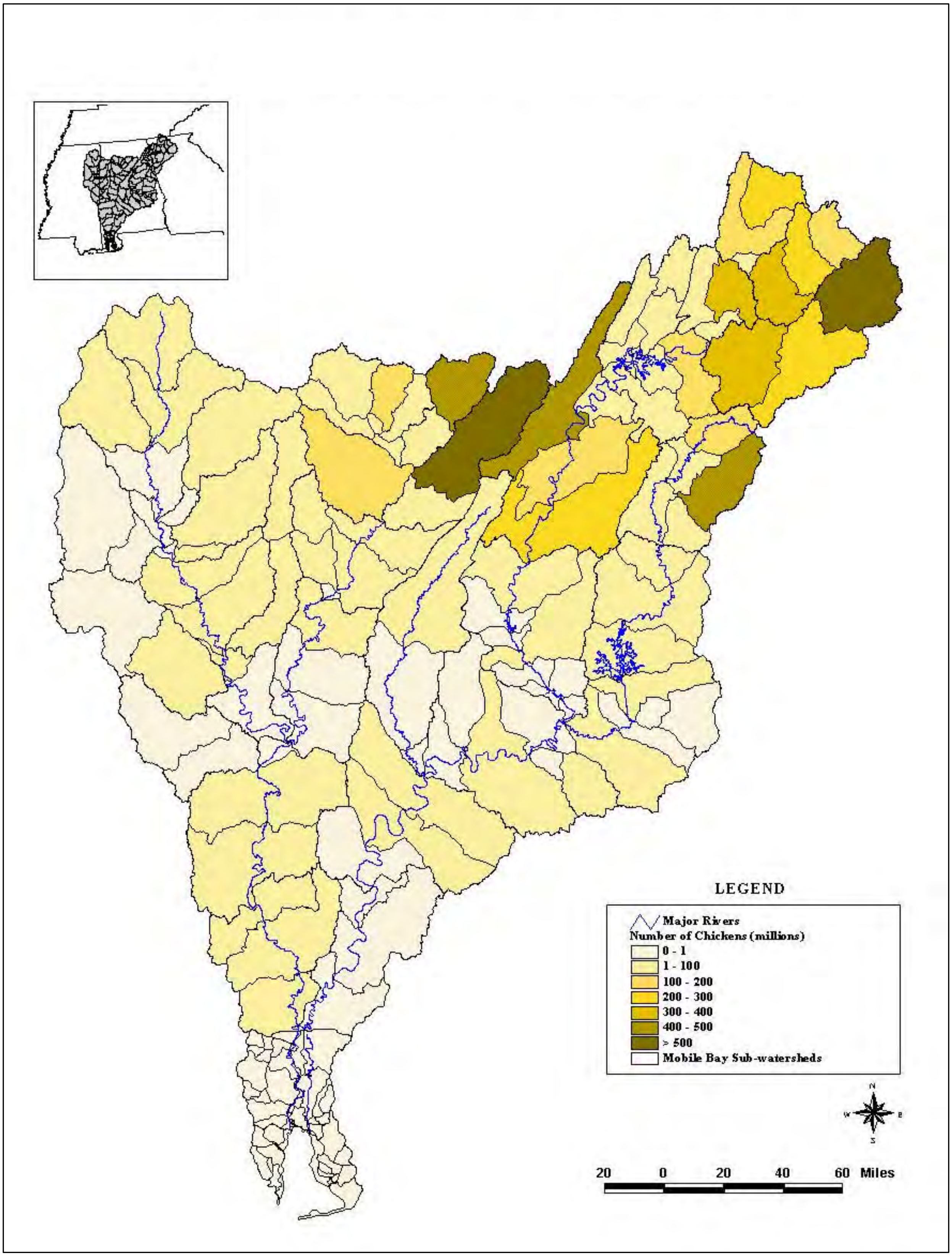

Figure G-21. Chicken distribution in the Upper Mobile River basin

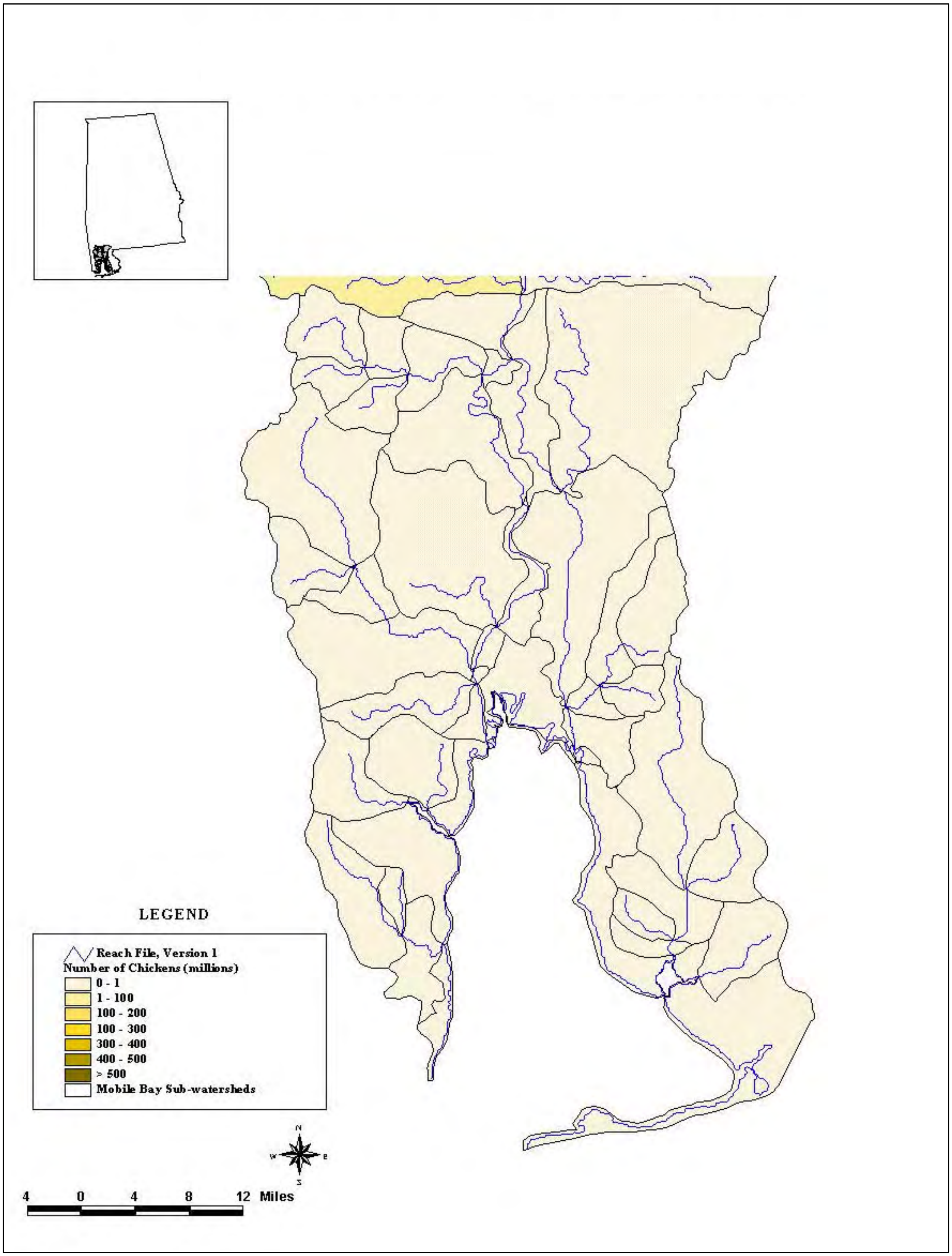

Figure G-22. Chicken distribution in the Lower Mobile River basin

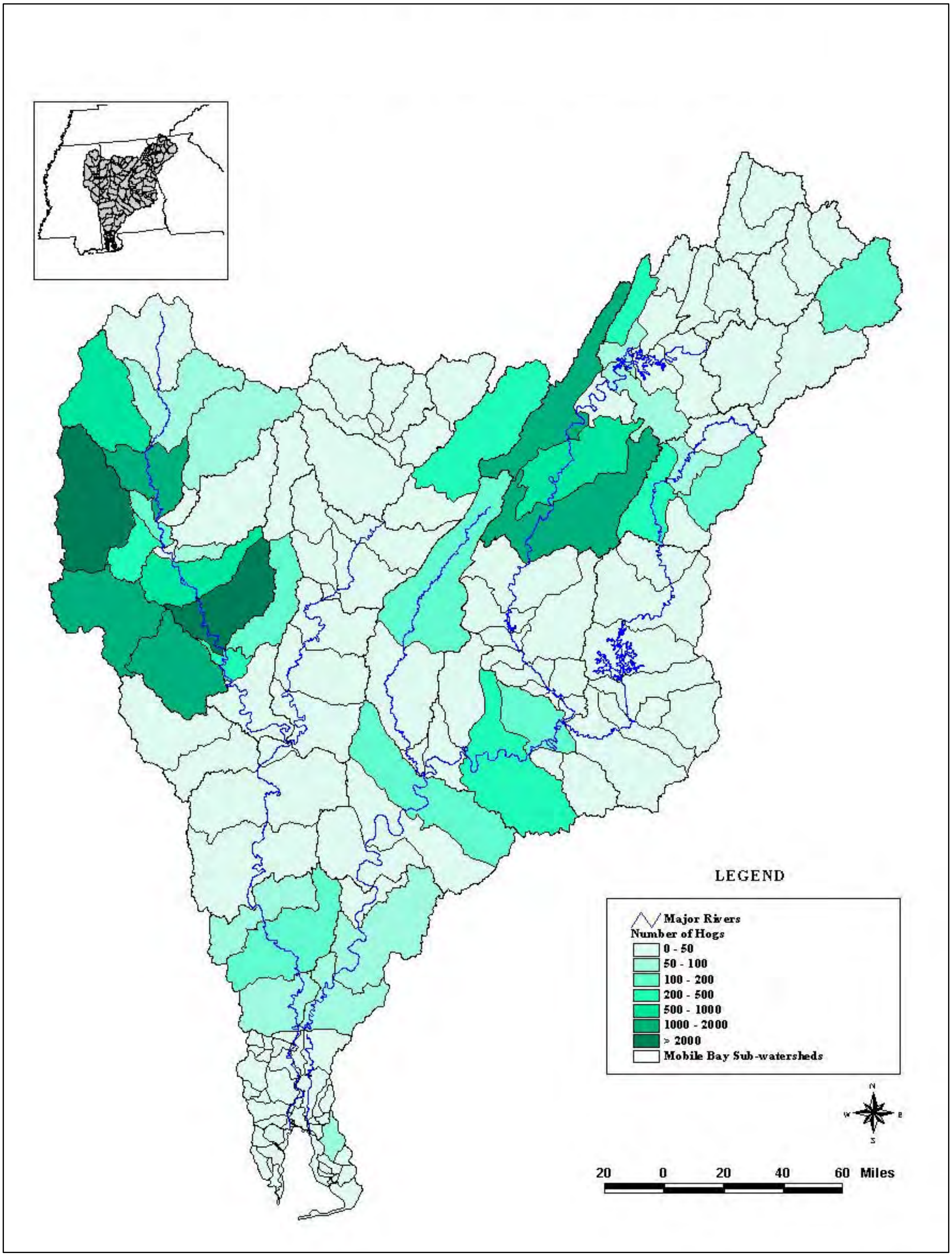

Figure G-23. Hog distribution in the Upper Mobile River basin

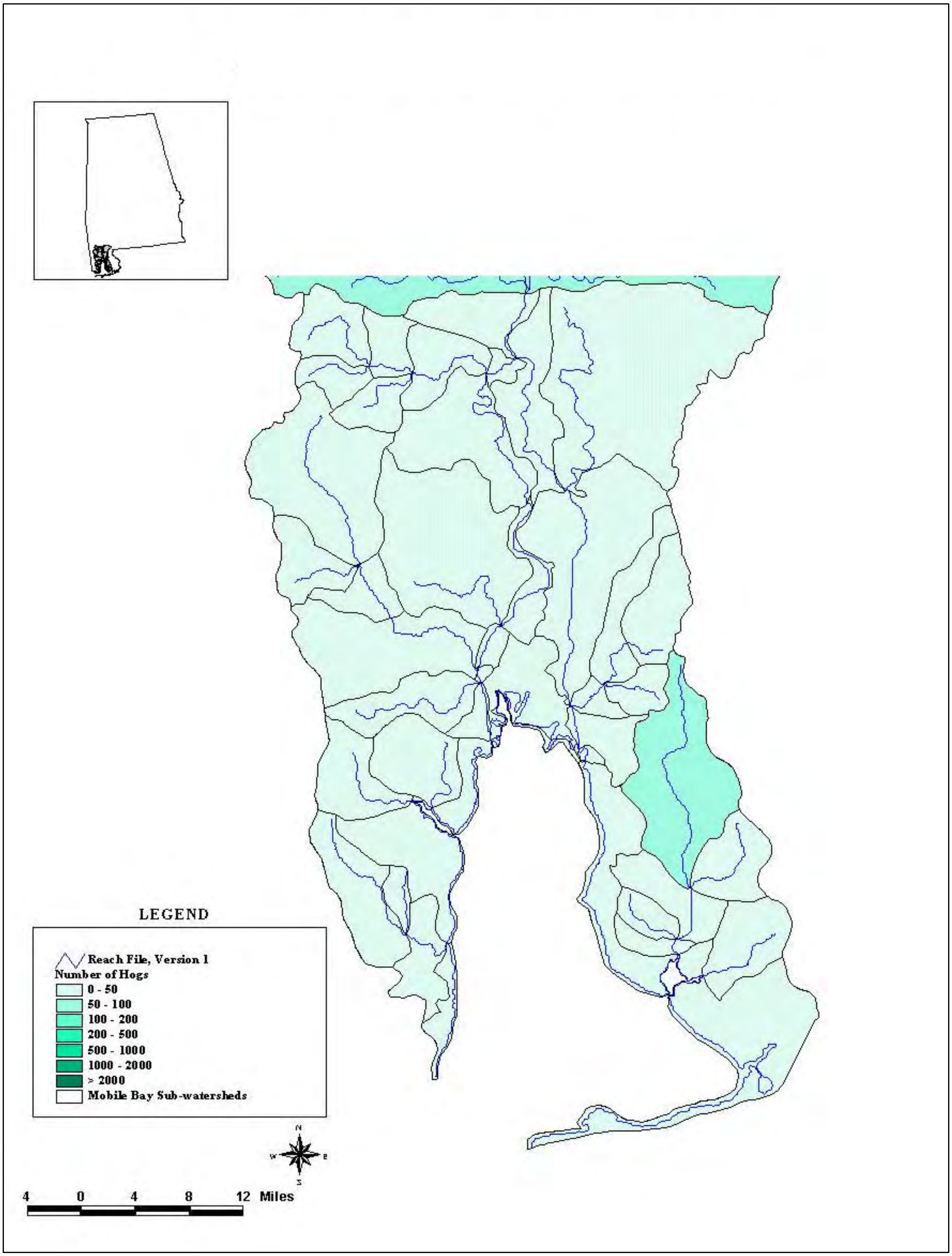

Figure G-24. Hog distribution in the Lower Mobile River basin

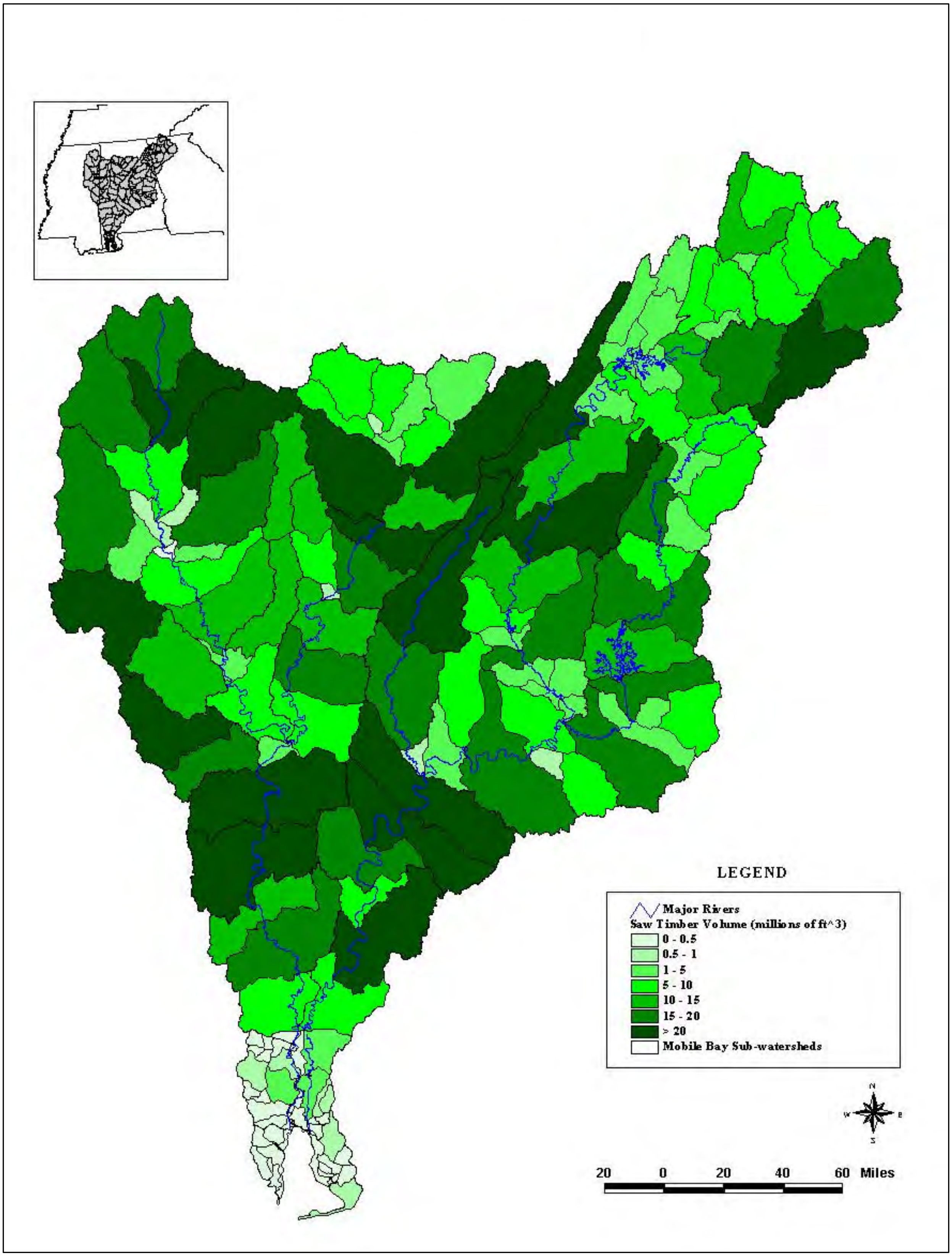

Figure G-25. Saw timber volume in the Upper Mobile River basin

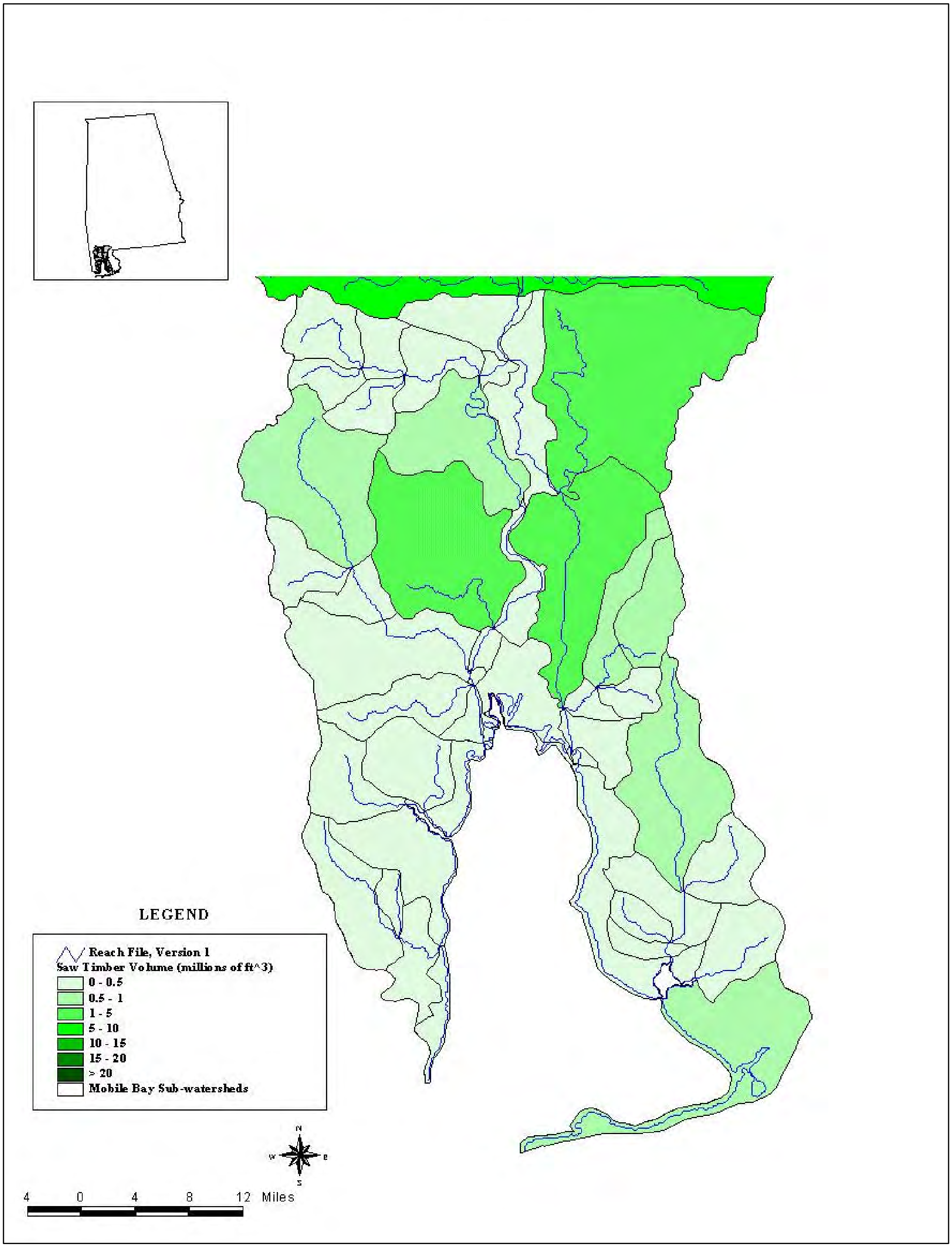

Figure G-26. Saw timber volume in the Lower Mobile River basin

Appendix H

Monthly Results – Mean, Dry, and Wet Years

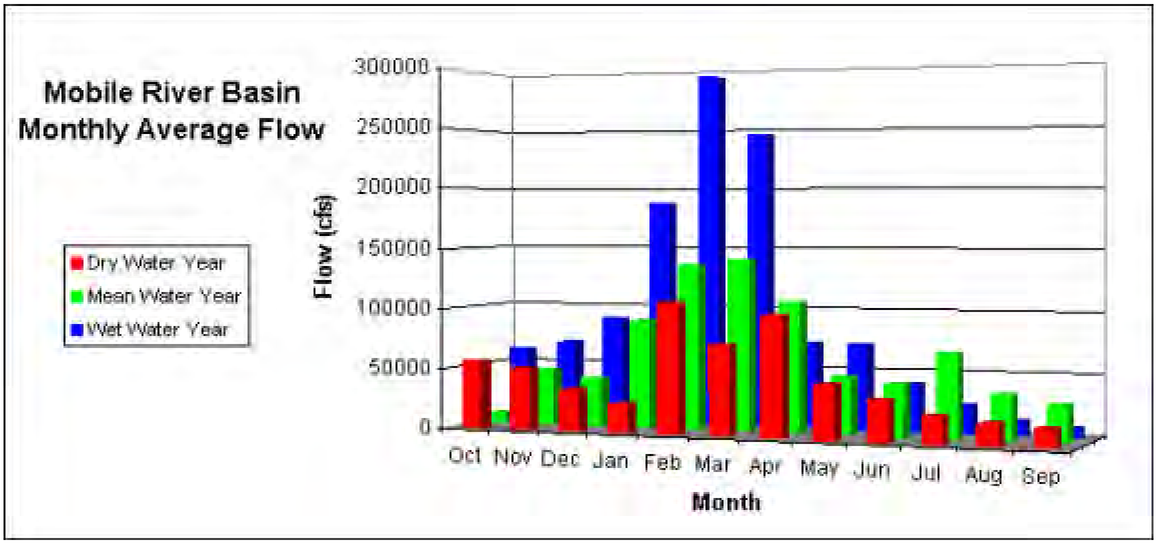

Figure H-1. Monthly average flow in the Mobile River basin

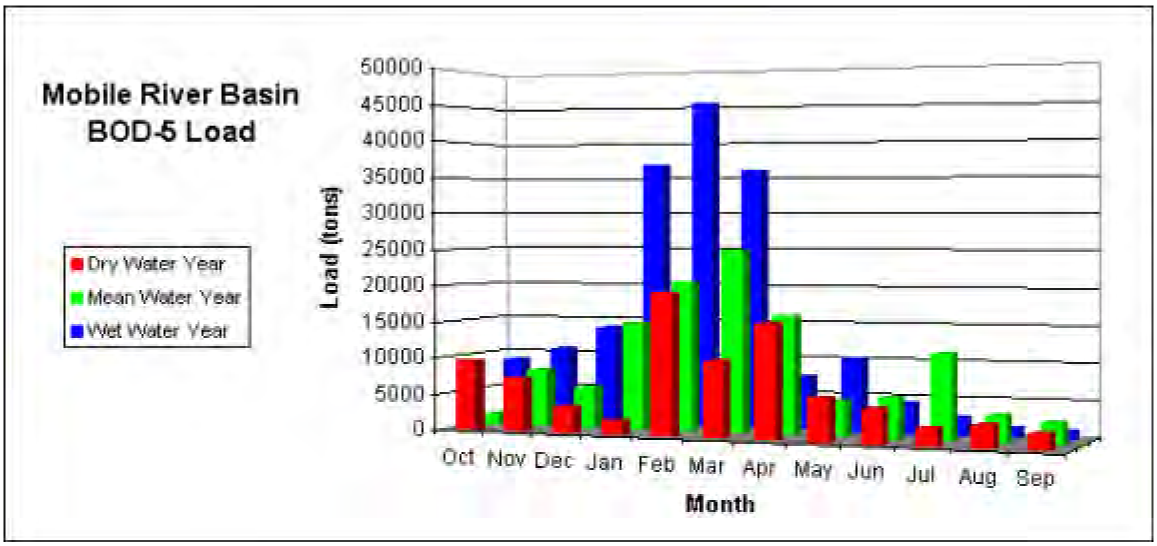

Figure H-2. Monthly BOD_5 loadings in the Mobile River basin

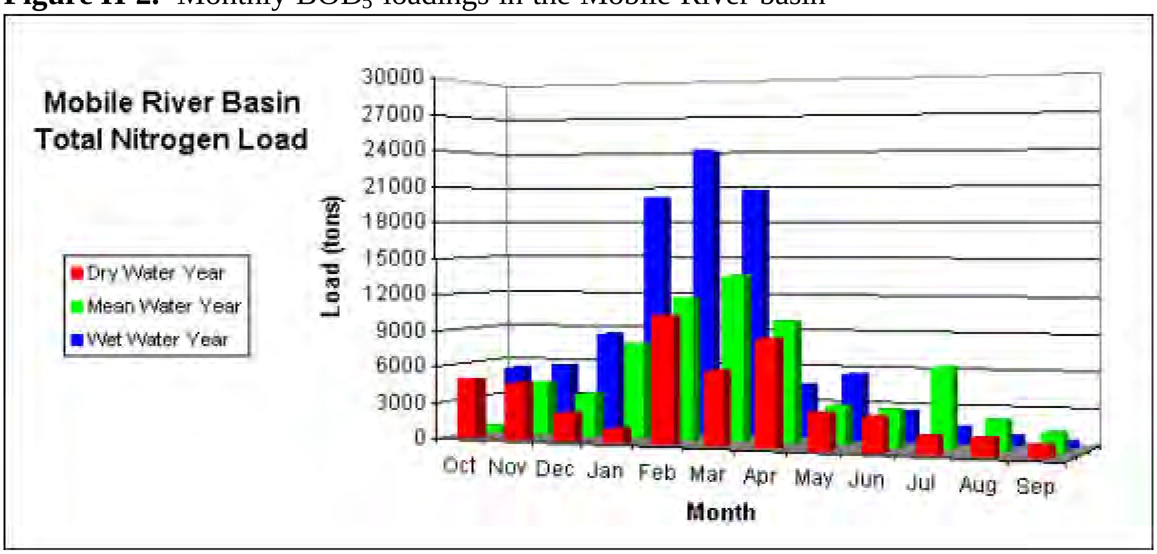

Figure H-3. Monthly total nitrogen loading in the Mobile River basin

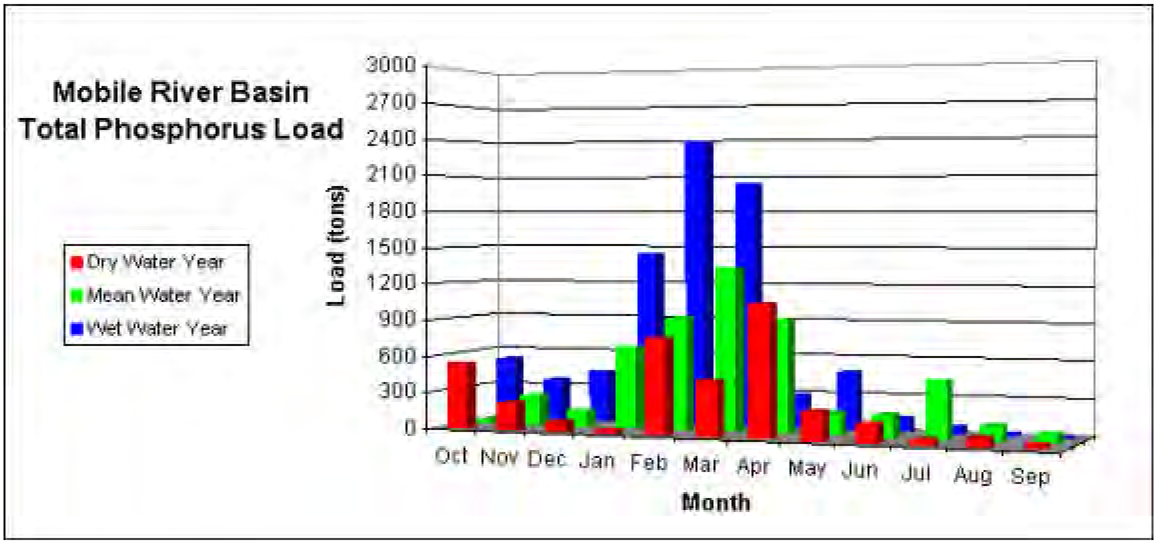

Figure H-4. Monthly total phosphorus loading in the Mobile River basin

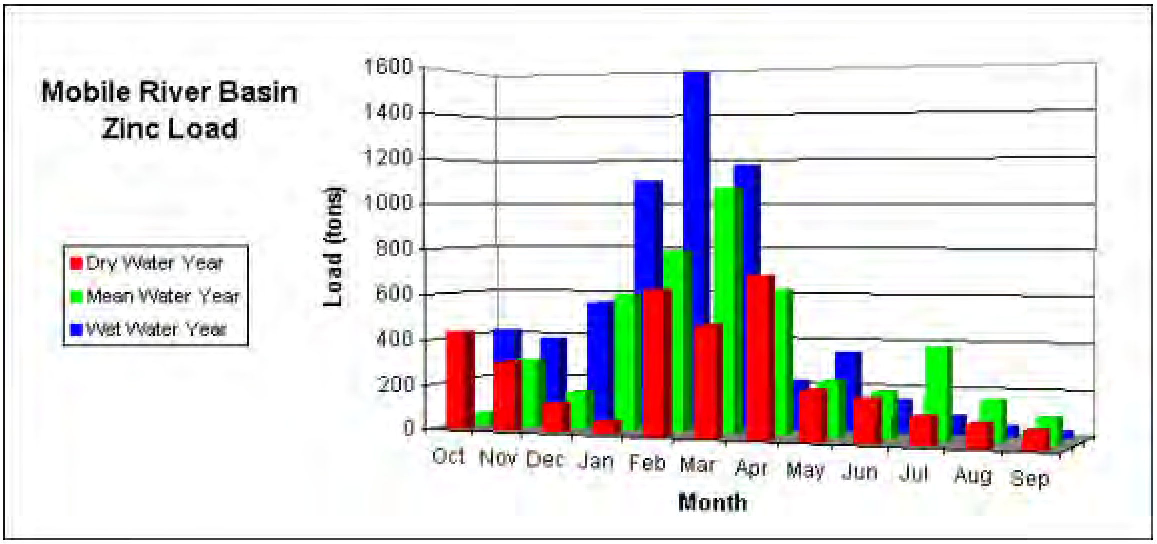

Figure H-5. Monthly zinc loading in the Mobile River basin

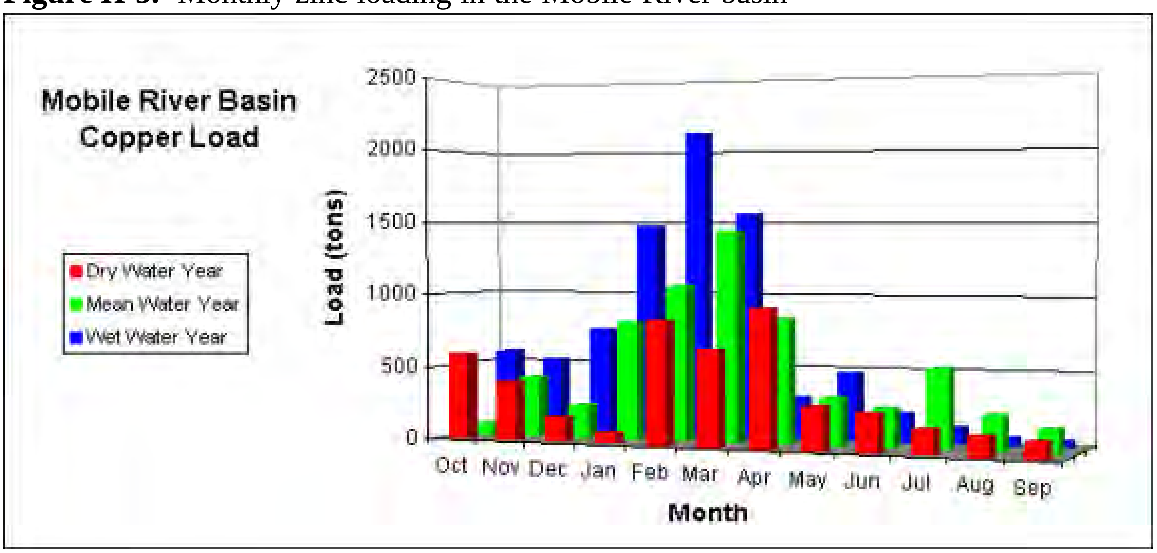

Figure H-6. Monthly copper loading in the Mobile River basin

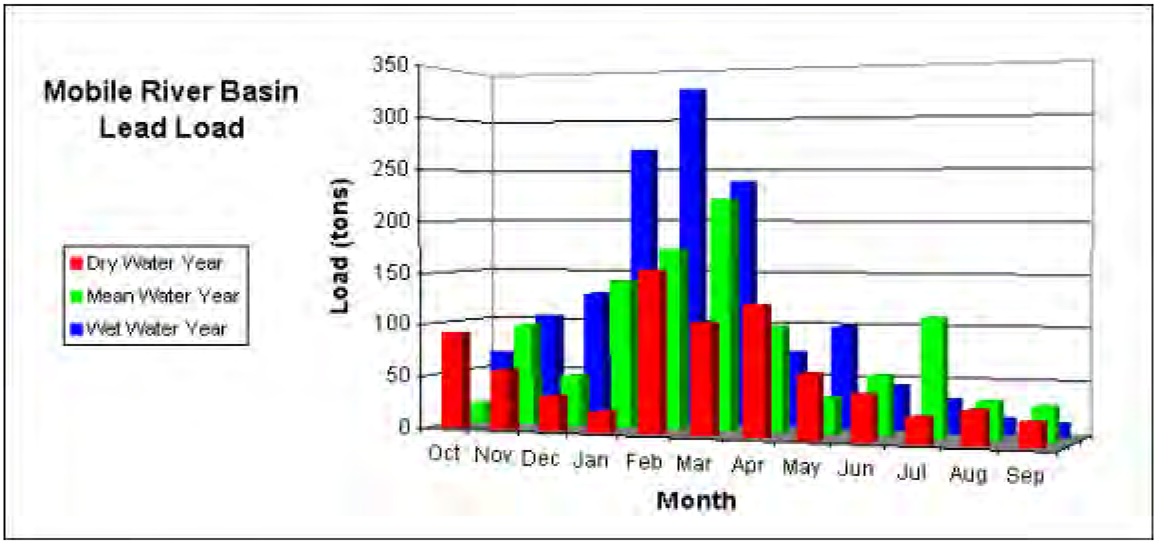

Figure H-7. Monthly lead loading in the Mobile River basin

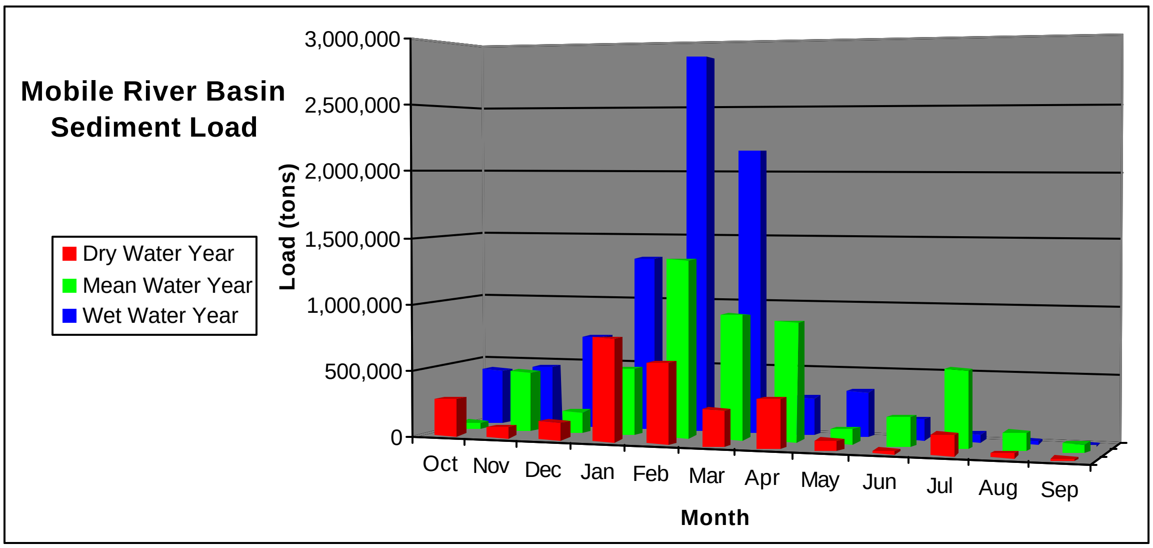

Figure H-8. Monthly sediment loading in the Mobile River basin

Appendix I

Monthly Plots - Seasonal Extreme Conditions

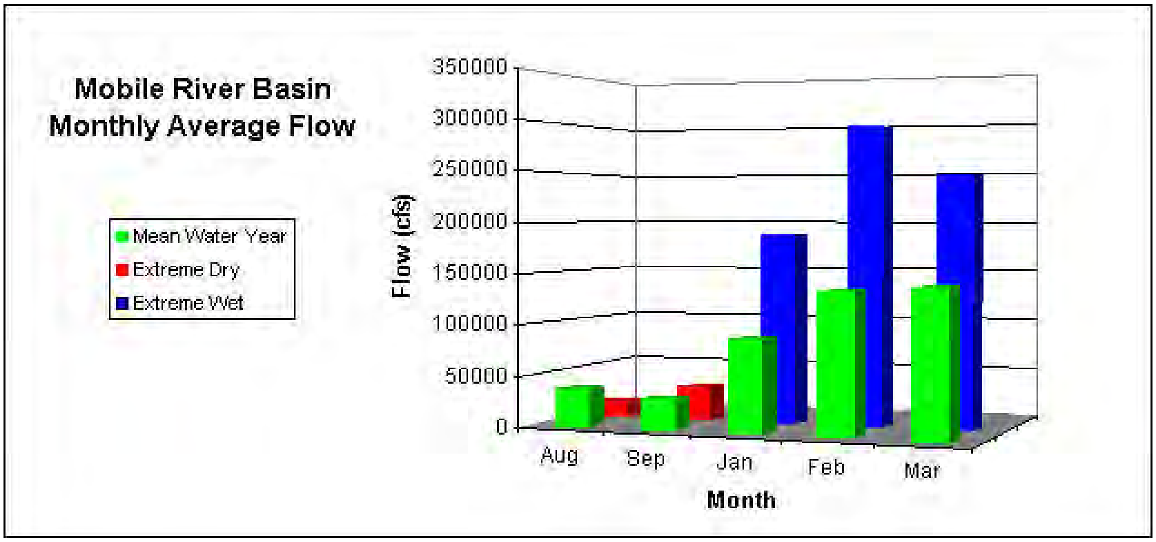

Figure I-1. Flow under extreme conditions in the Mobile River basin

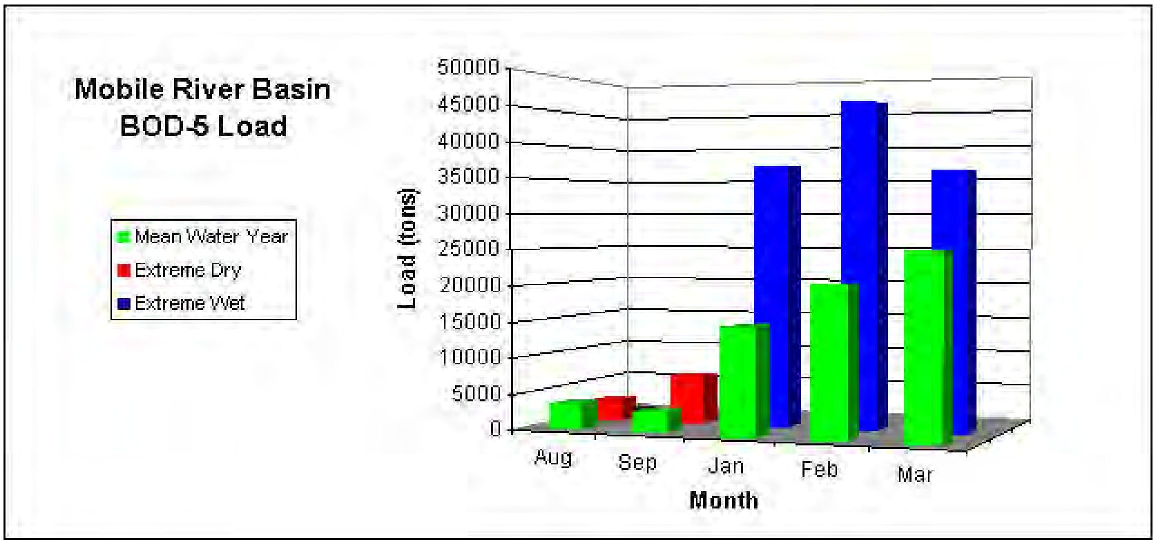

Figure I-2. BOD_5 loading under extreme conditions in the Mobile River basin

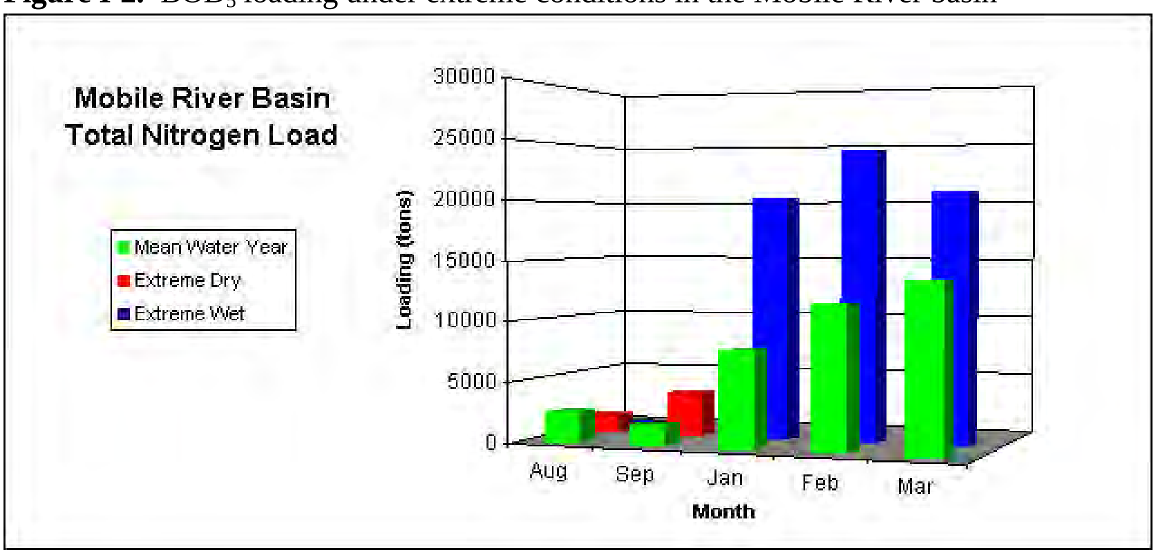

Figure I-3. Total nitrogen loading under extreme conditions in the Mobile River basin

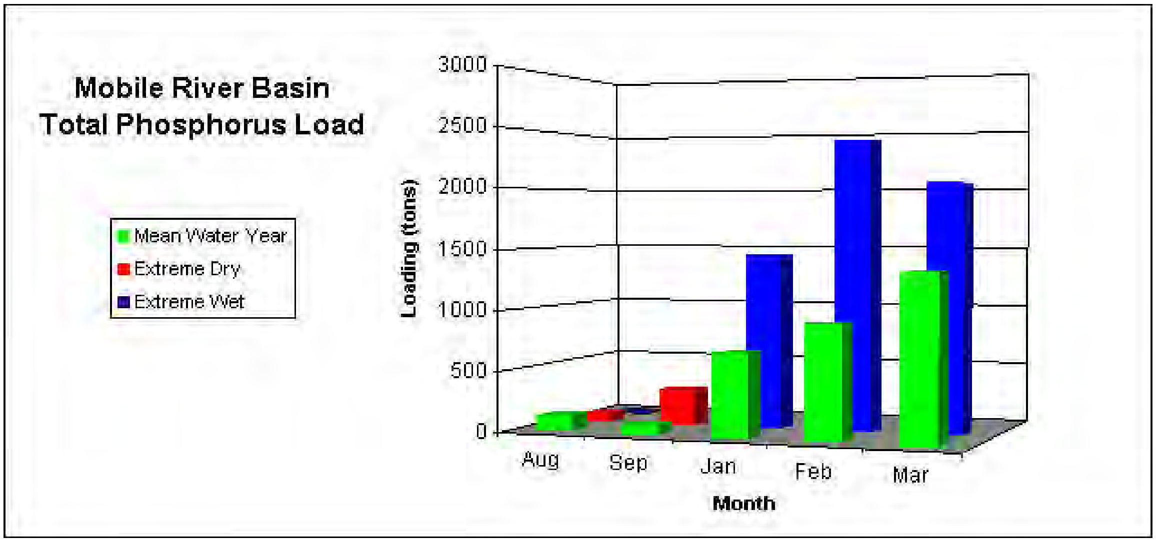

Figure I-4. Total phosphorus loading under extreme conditions in the Mobile River basin

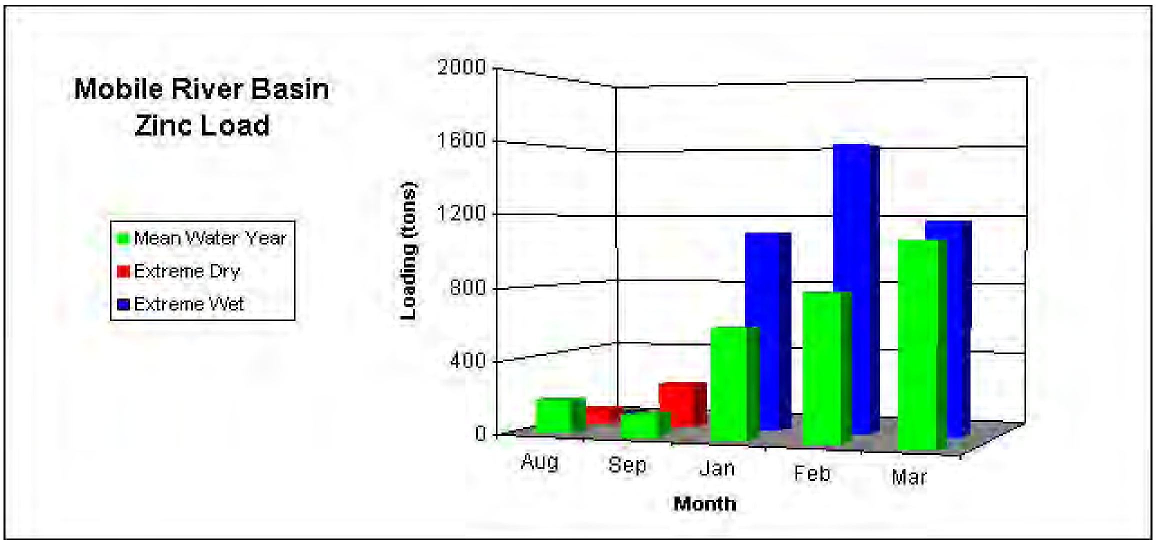

Figure I-5. Zinc loading under extreme conditions in the Mobile River basin

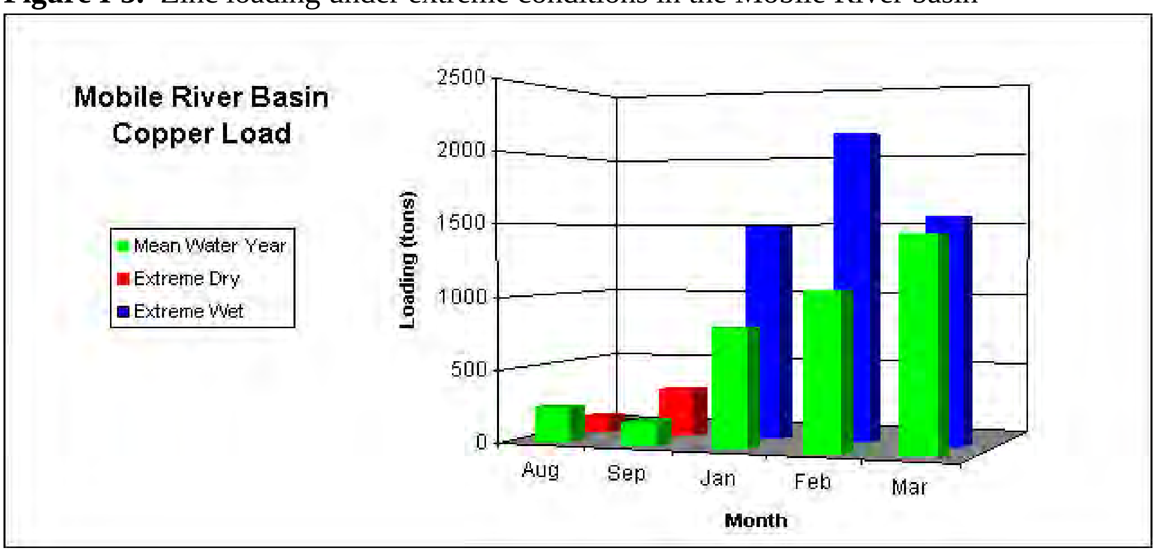

Figure I-6. Copper loading under extreme conditions in the Mobile River basin

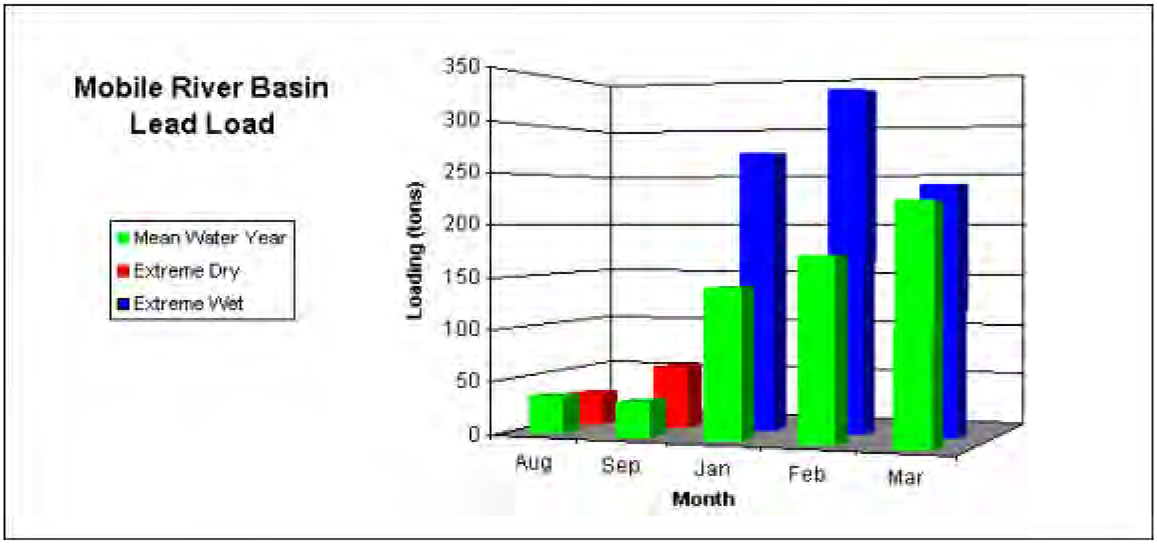

Figure I-7. Lead loading under extreme conditions in the Mobile River basin

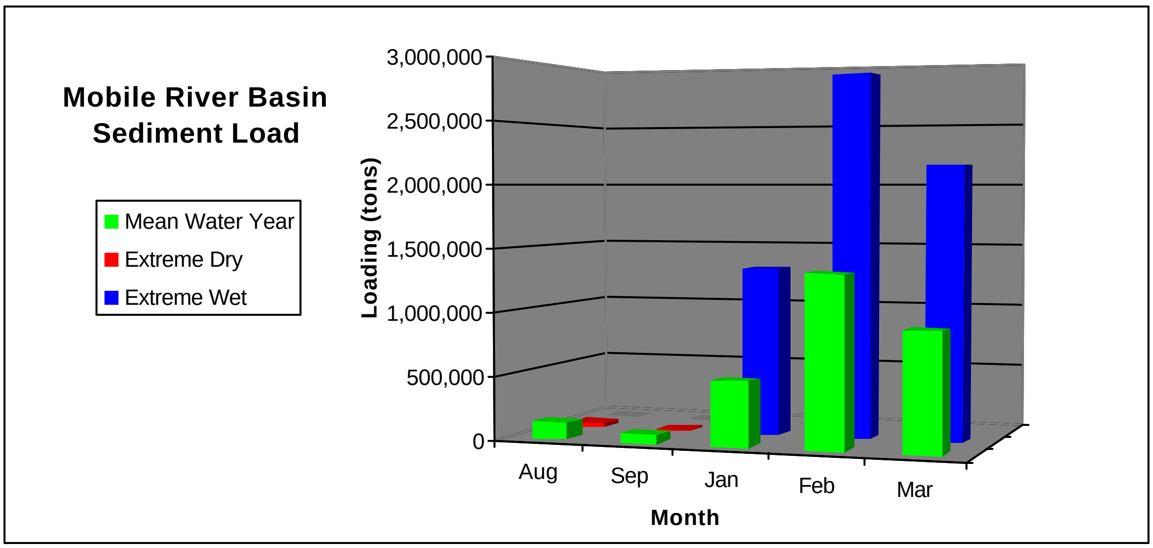

Figure I-8. Sediment loading under extreme conditions in the Mobile River basin

Appendix J

Nonpoint Source Loadings in the Lower Mobile River Basin

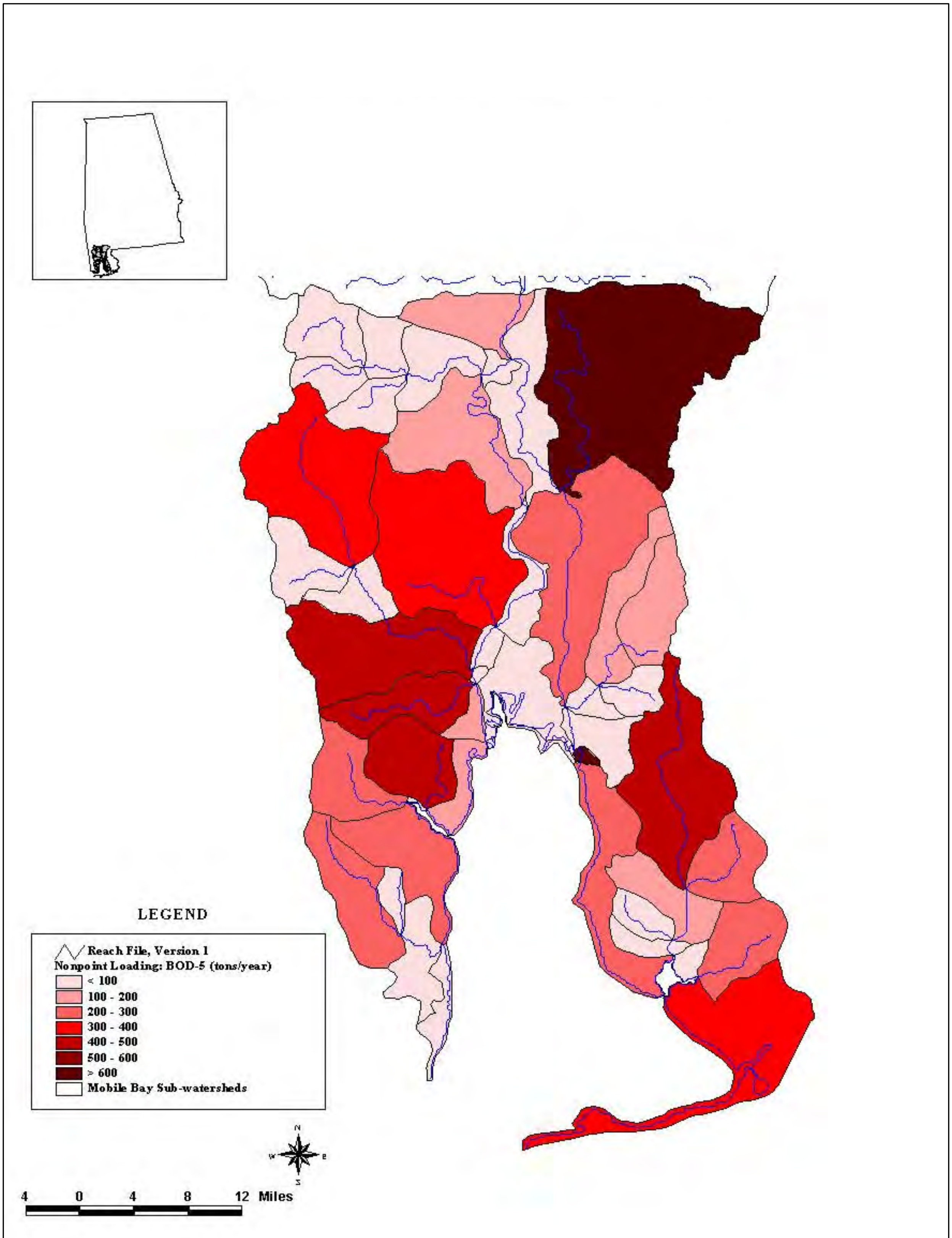

Figure J-1. Nonpoint source loading of BOD_5 in the Lower Mobile River basin

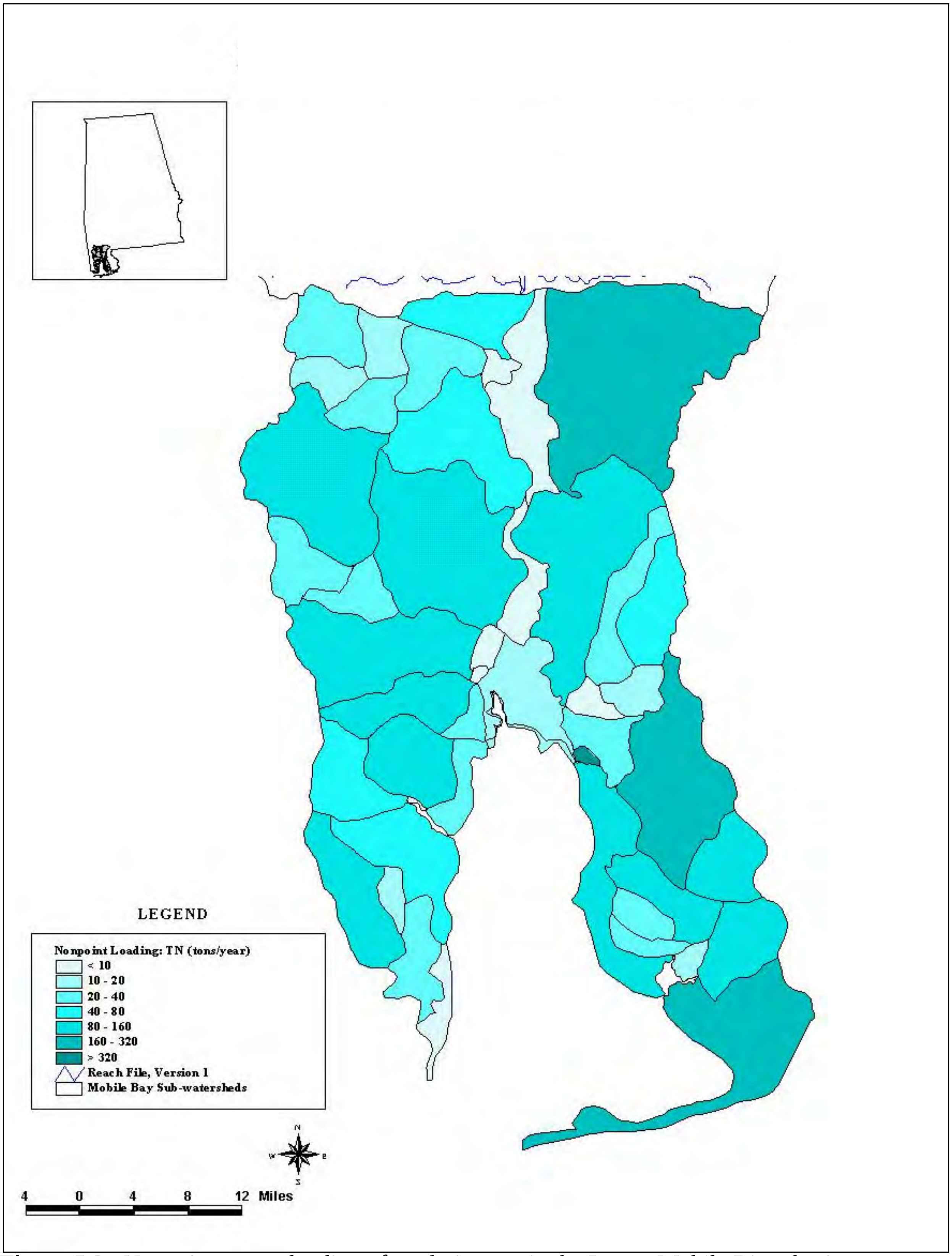

Figure J-2. Nonpoint source loading of total nitrogen in the Lower Mobile River basin

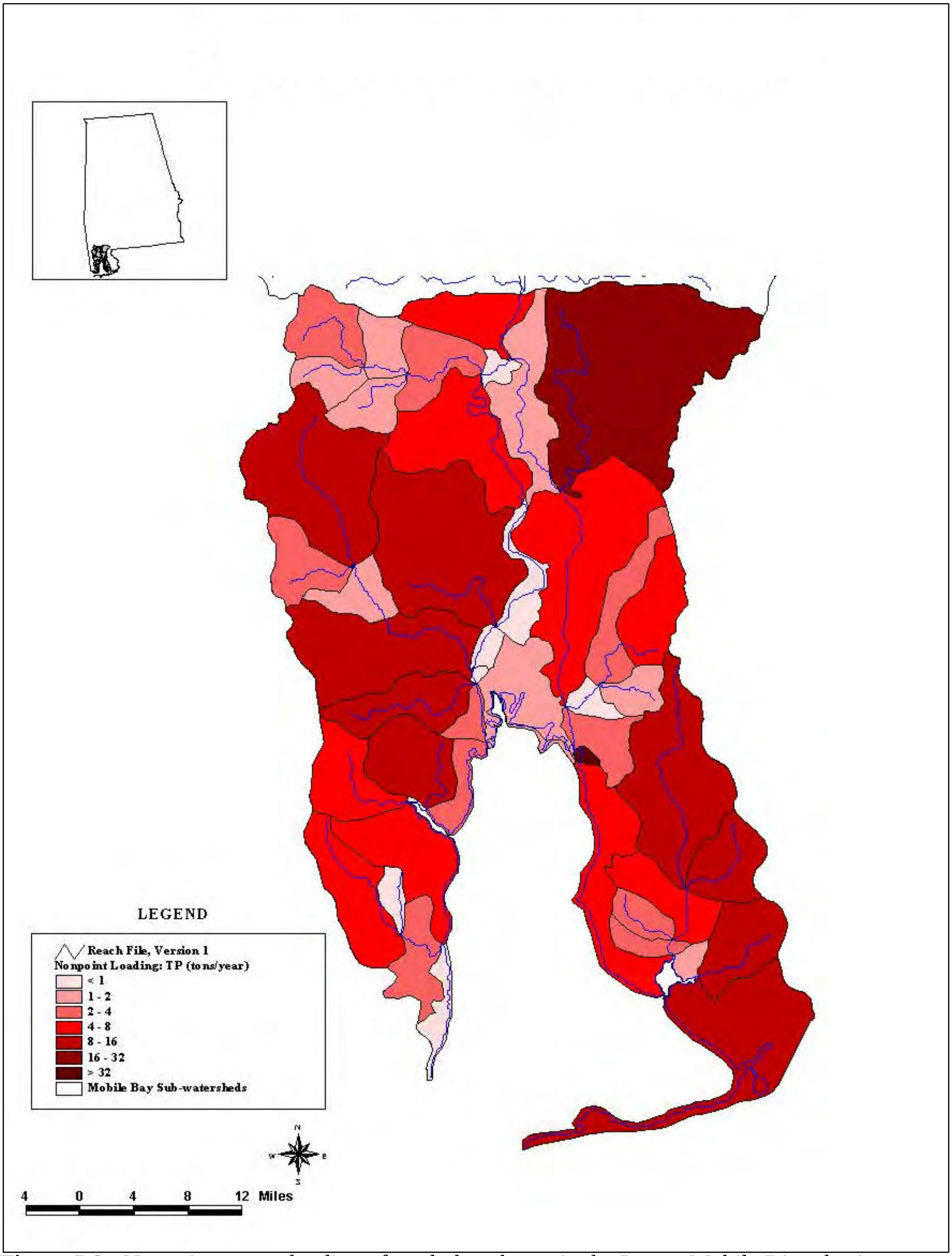

Figure J-3. Nonpoint source loading of total phosphorus in the Lower Mobile River basin

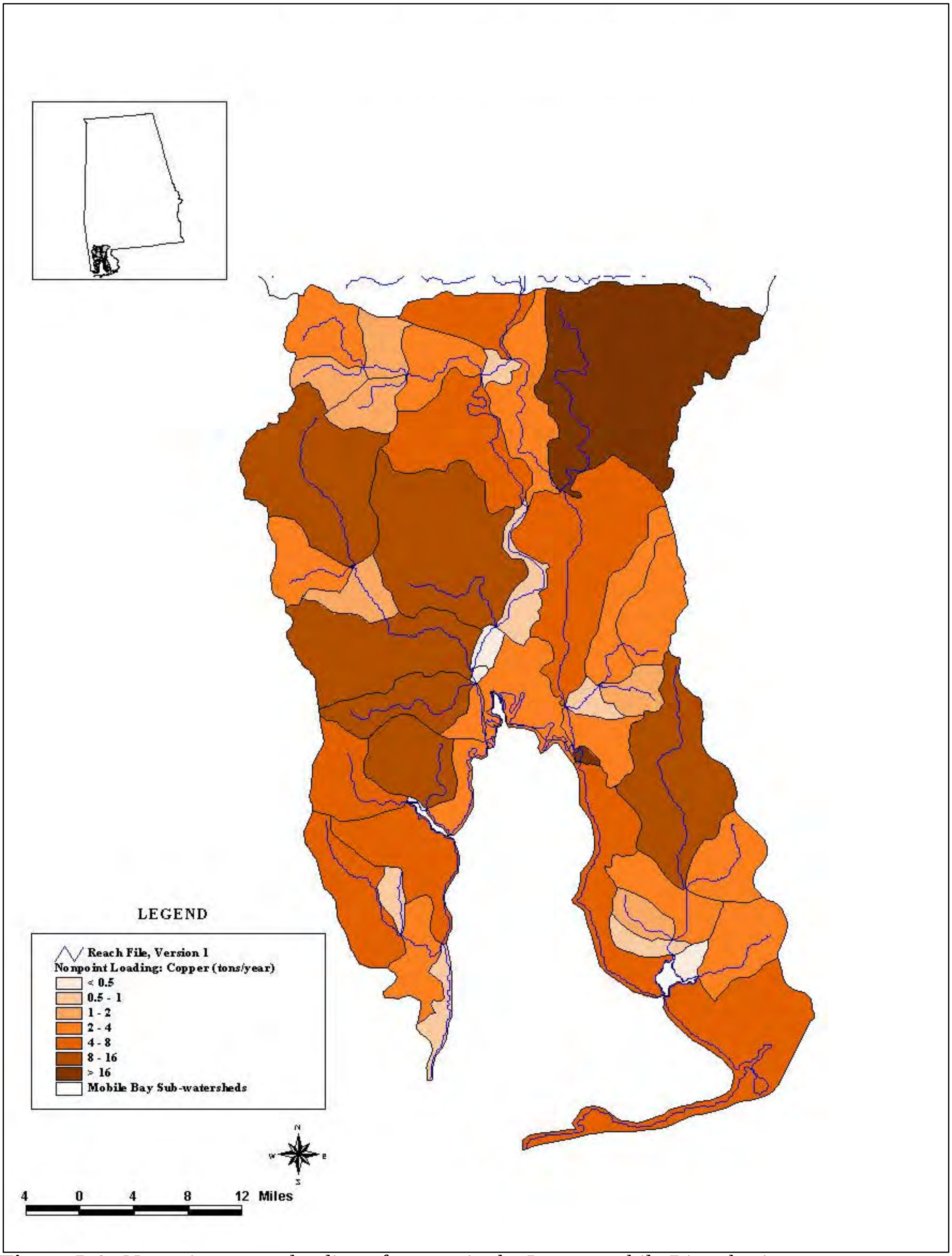

Figure J-4. Nonpoint source loading of copper in the Lower mobile River basin

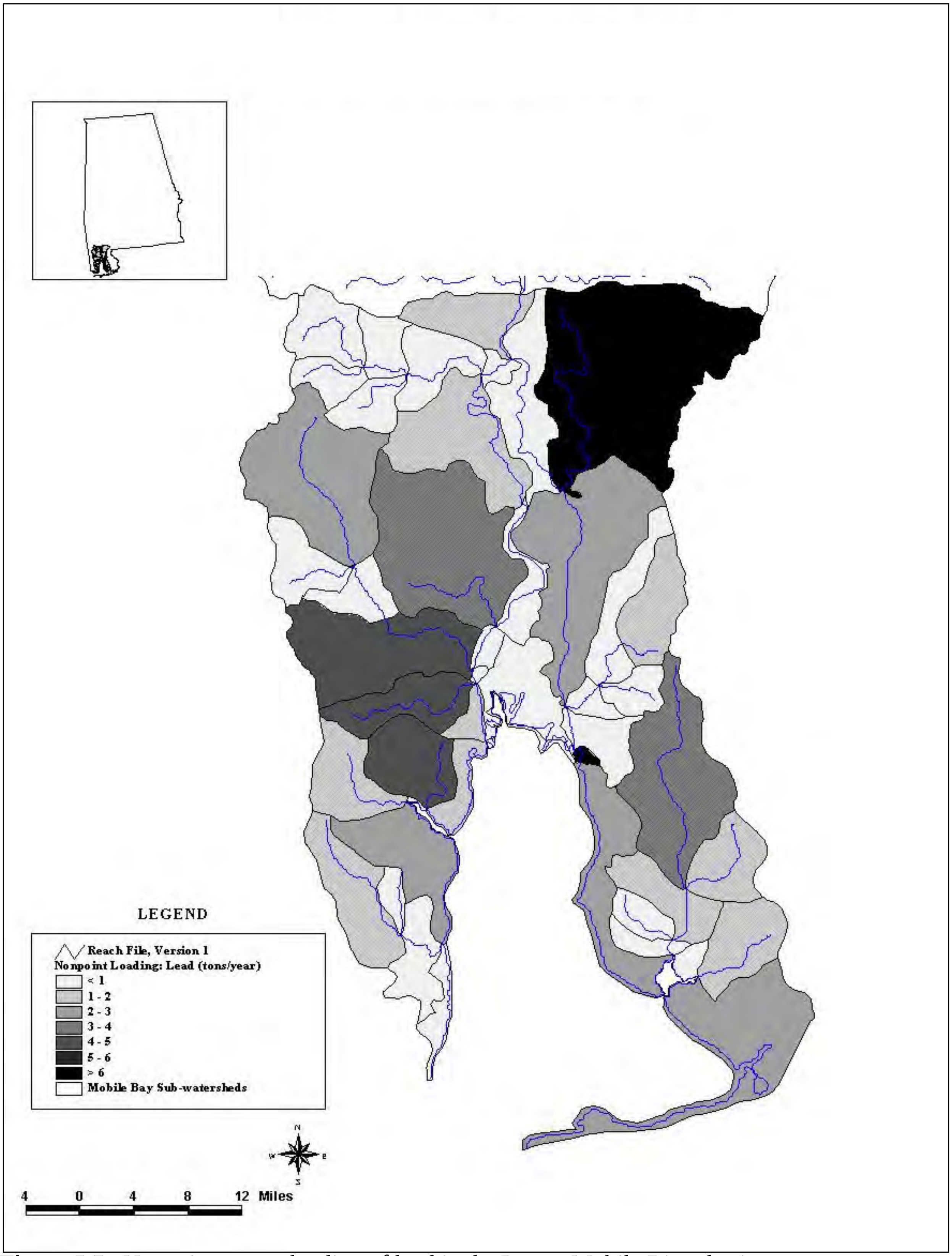

Figure J-5. Nonpoint source loading of lead in the Lower Mobile River basin

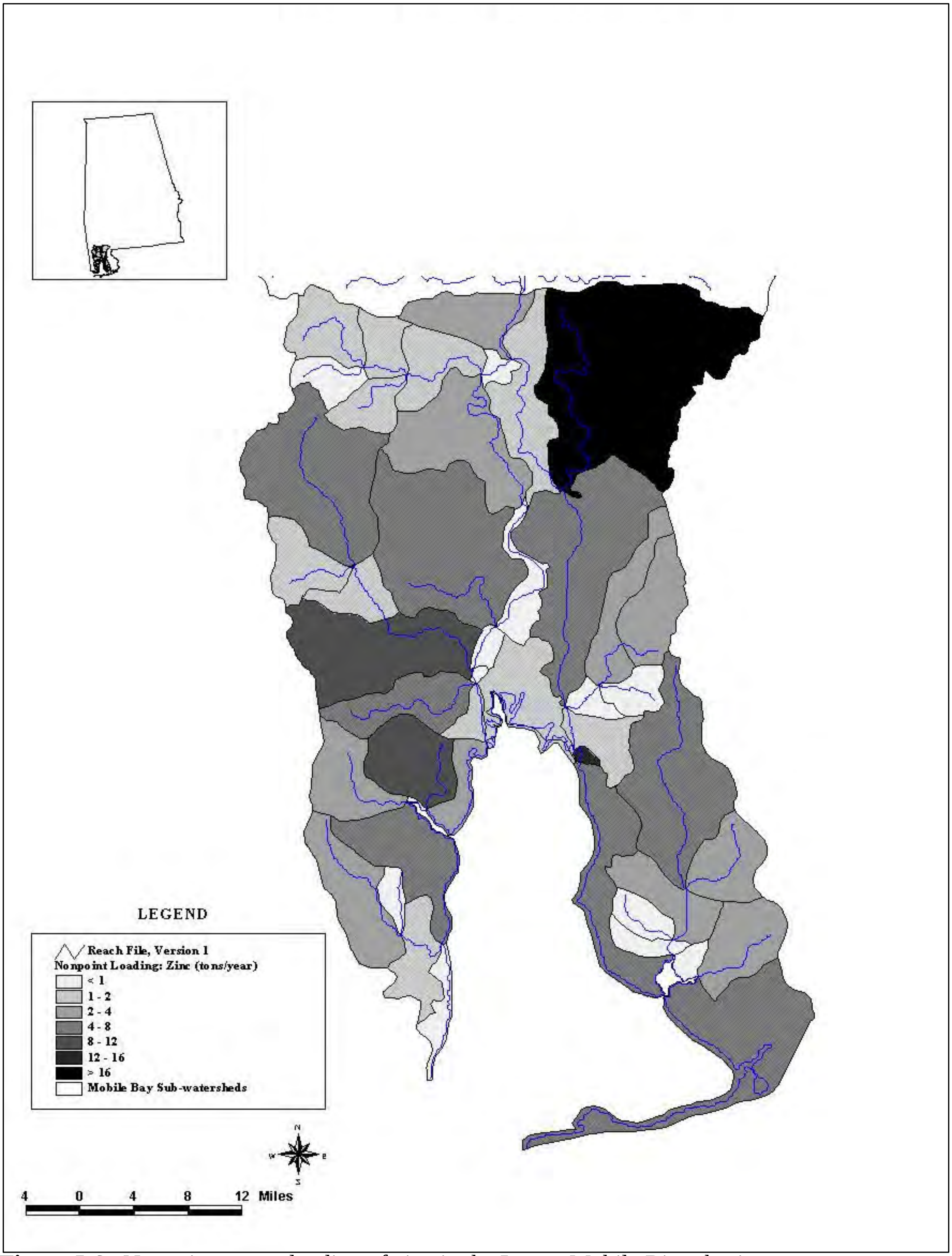

Figure J-6. Nonpoint source loading of zinc in the Lower Mobile River basin

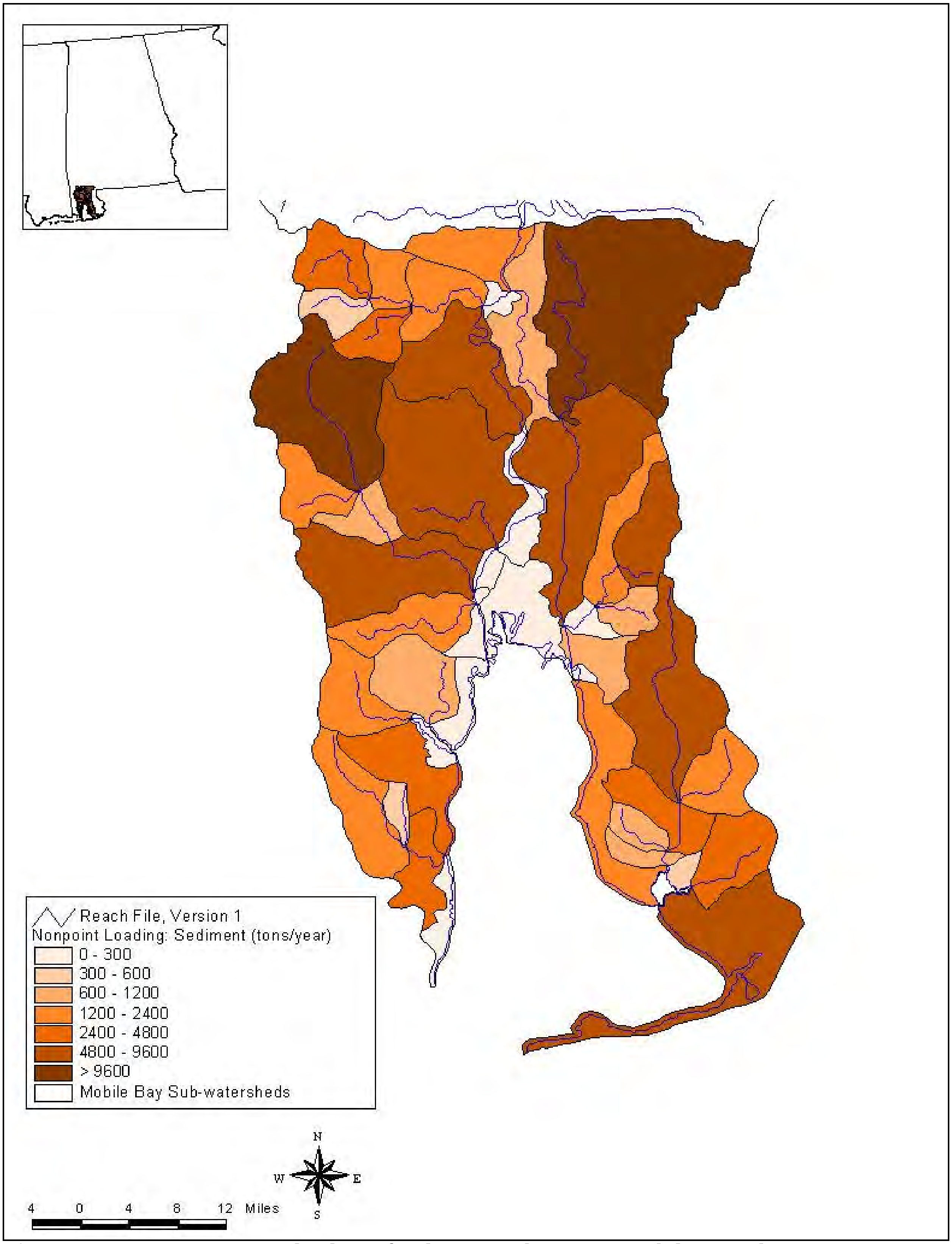

Figure J-7. Nonpoint source loading of sediment in the Lower Mobile River basin

Appendix K

Comparison of Upper Basin Loads and Lower Basin Loads Contributing to Mobile Bay

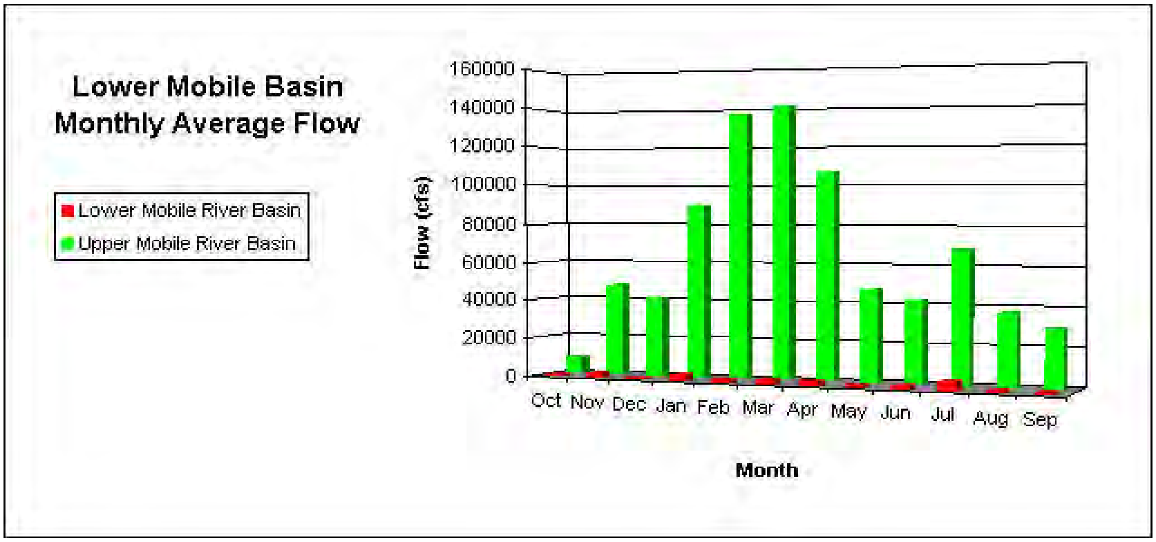

Figure K-1. Monthly average flow in the Upper and Lower Mobile River basin

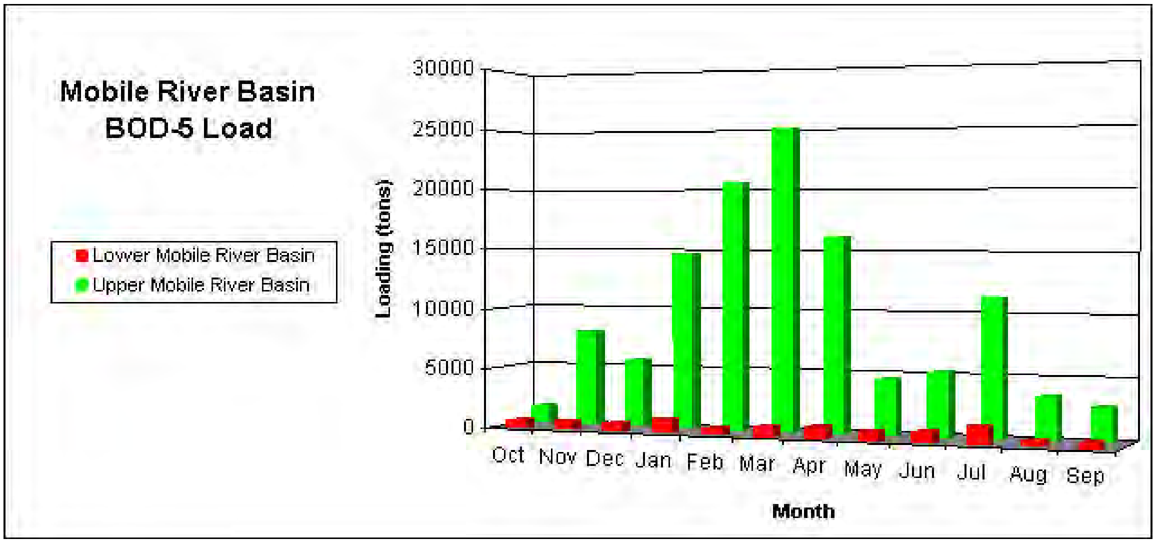

Figure K-2. BOD_5 loading in the Upper and Lower Mobile River basin

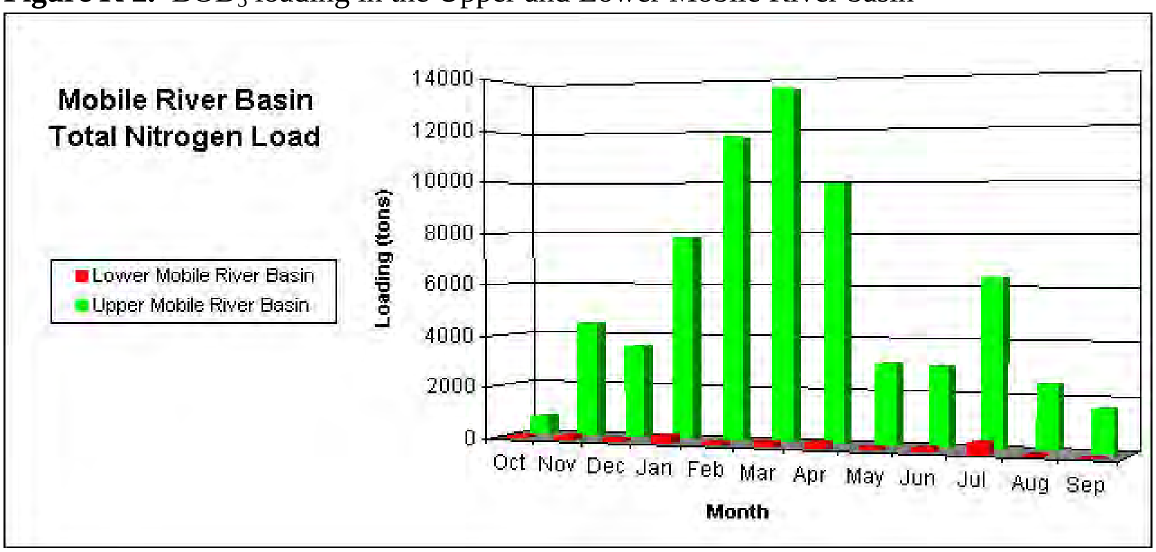

Figure K-3. Total nitrogen loading in the Upper and Lower Mobile River basin

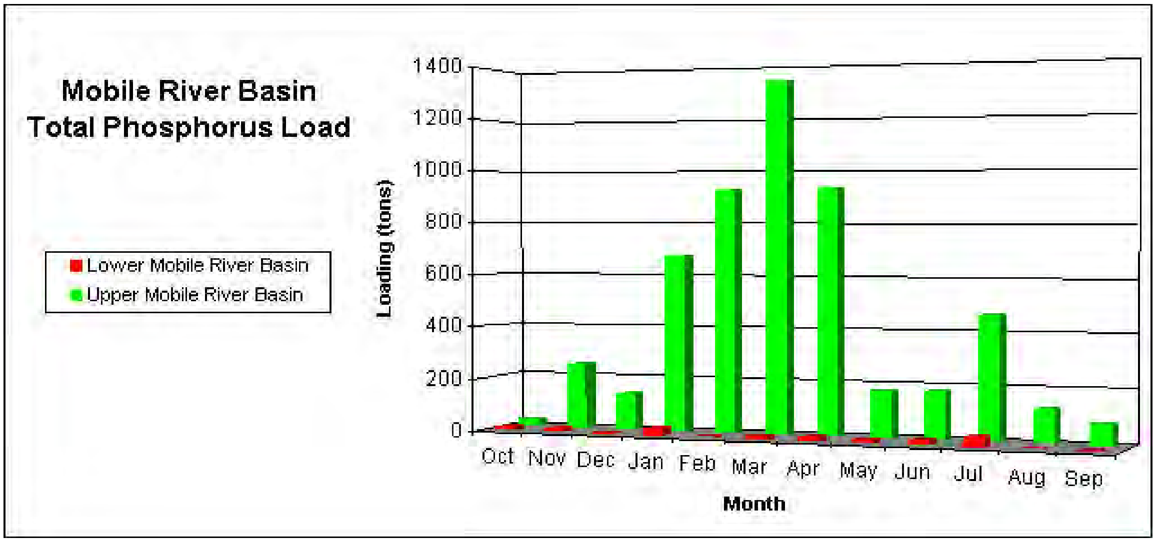

Figure K-4. Total phosphorus loading in the Upper and Lower Mobile River basin

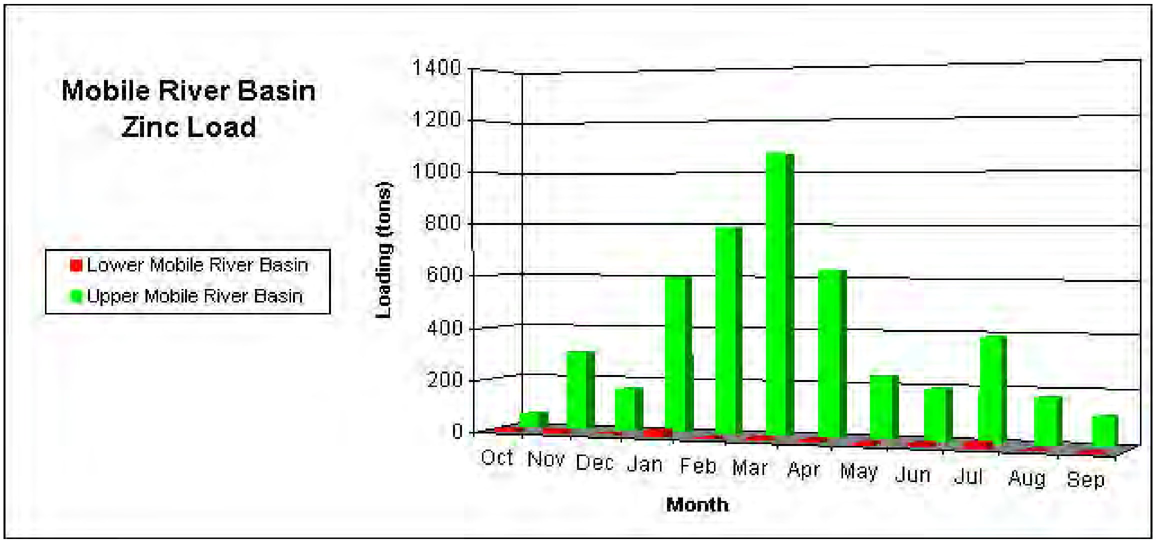

Figure K-5. Zinc loading in the Upper and Lower Mobile River basin

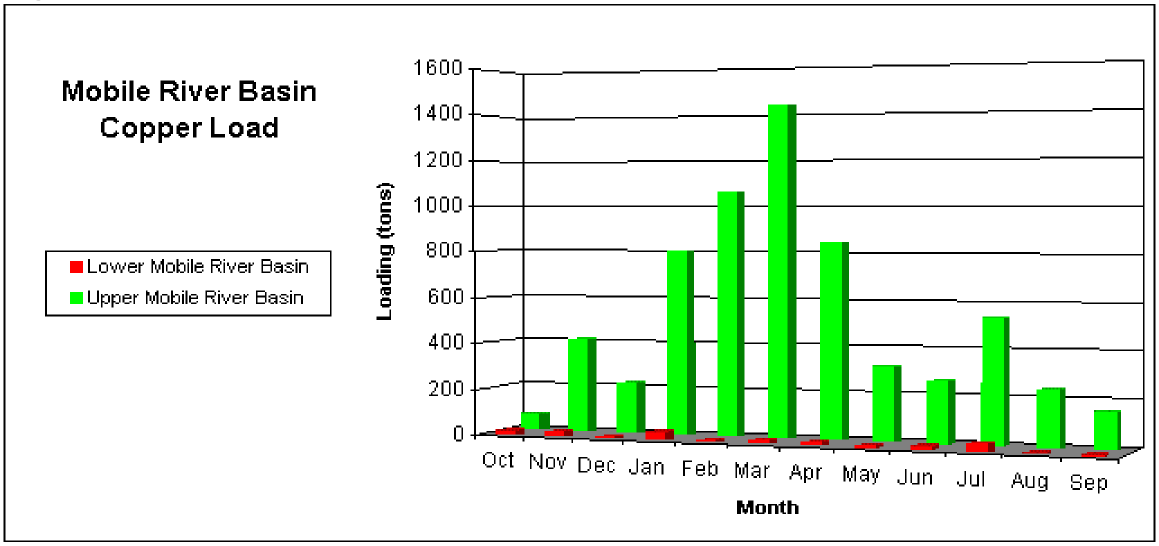

Figure K-6. Copper loading in the Upper and Lower Mobile River basin

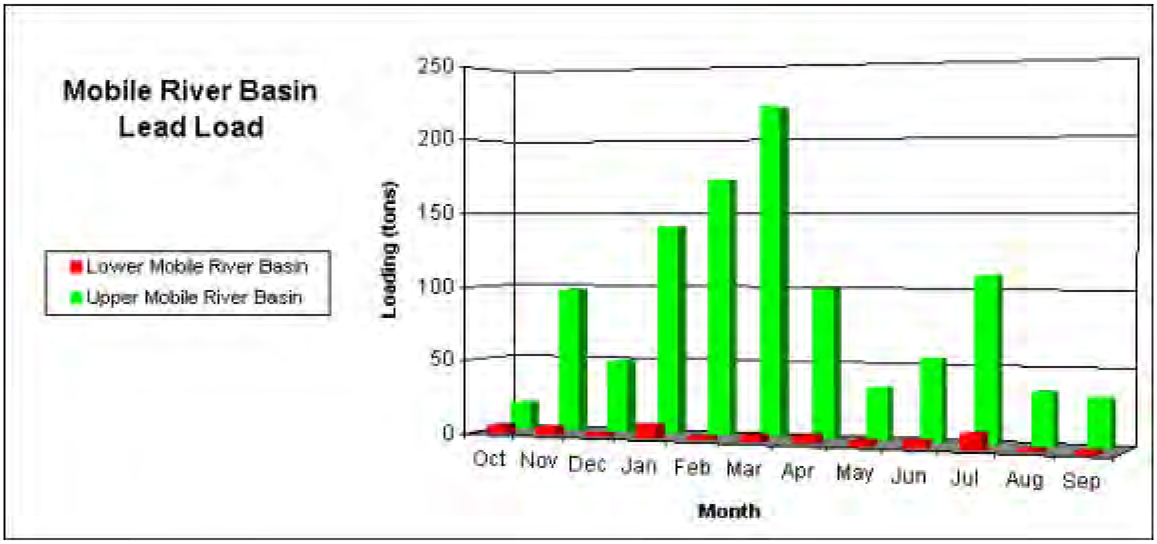

Figure K-7. Lead loading in the Upper and Lower Mobile River basin

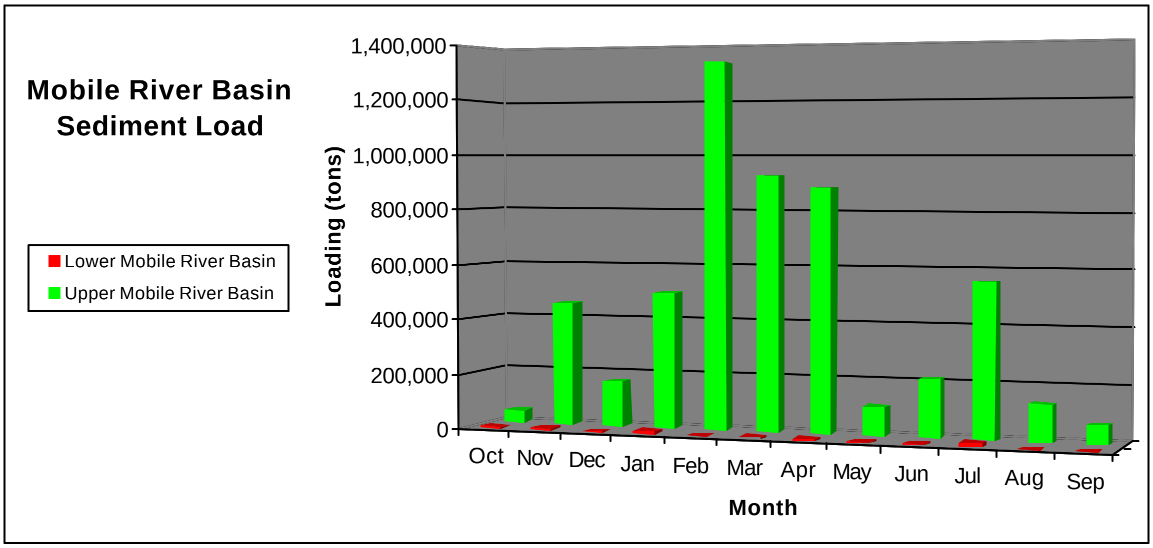

Figure K-8. Sediment loading in the Upper and Lower Mobile River basin

Appendix L

Comparison of Nonpoint and Point Source Loadings in the Lower Basin

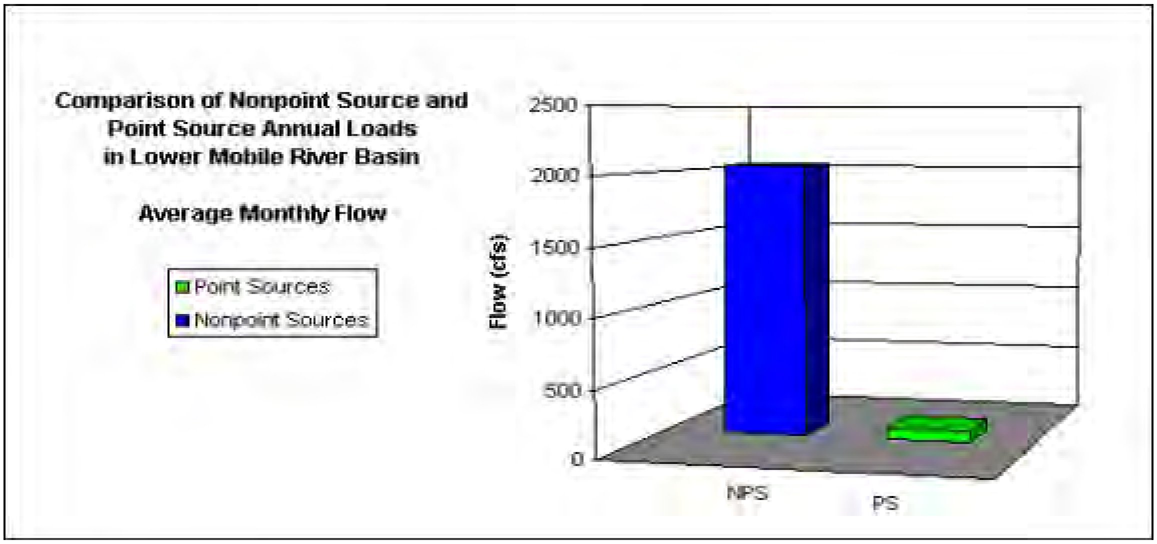

Figure L-1. Flow from point and nonpoint sources in the Lower Mobile River basin

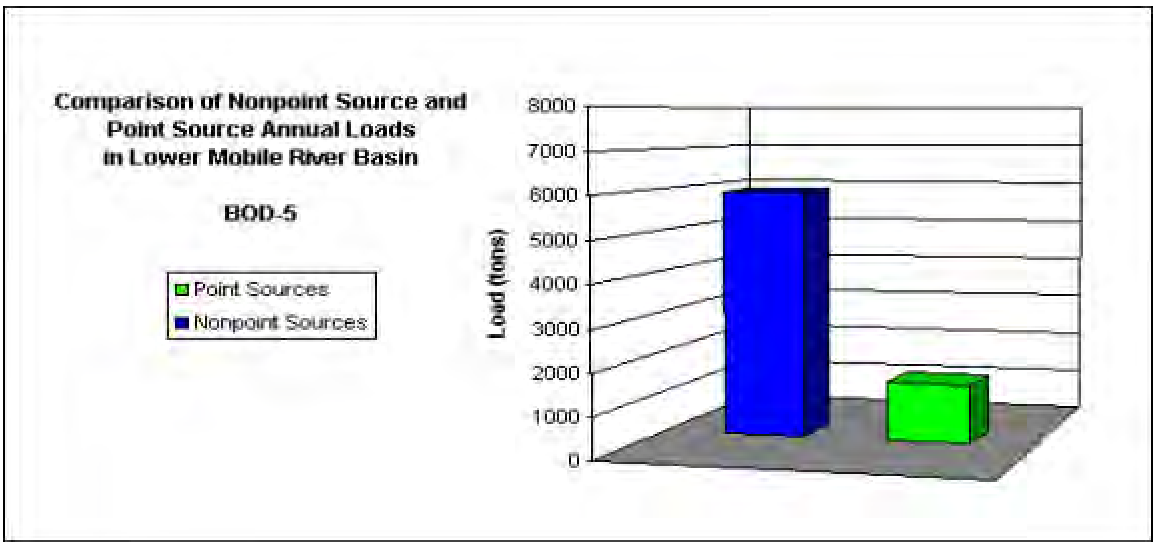

Figure L-2. BOD_5 from point and nonpoint sources in the Lower Mobile River basin

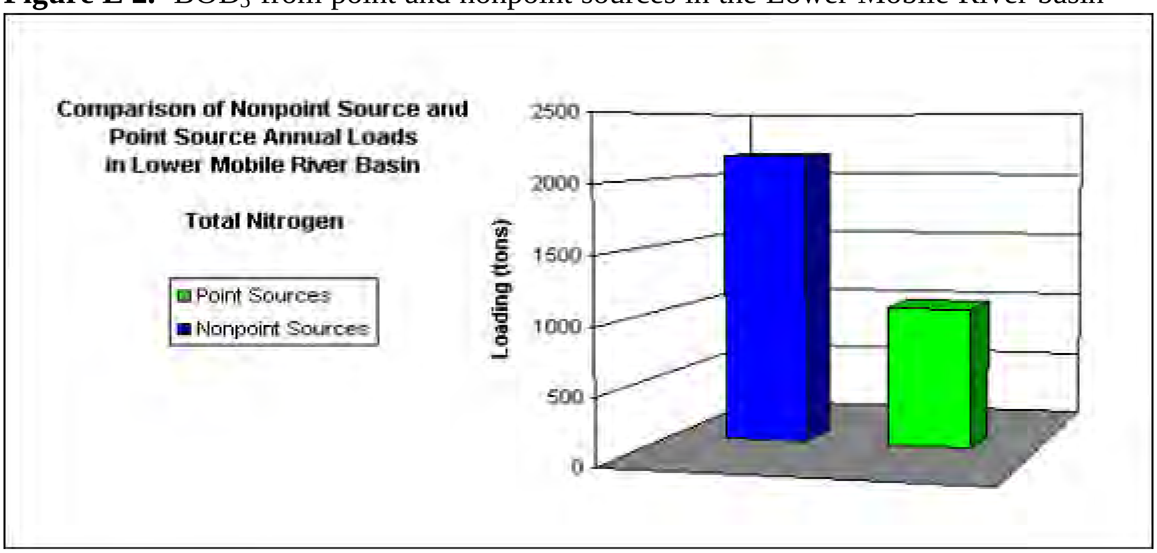

Figure L-3. Total nitrogen from point and nonpoint sources in the Lower Mobile River basin

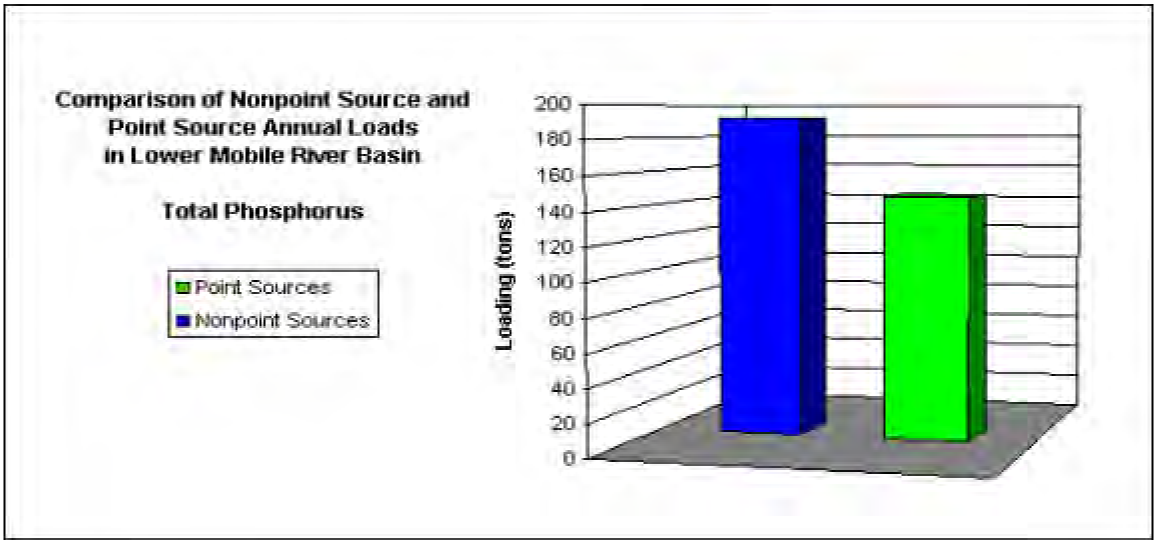

Figure L-4. Total phosphorus from point and nonpoint sources in the Lower Mobile River basin

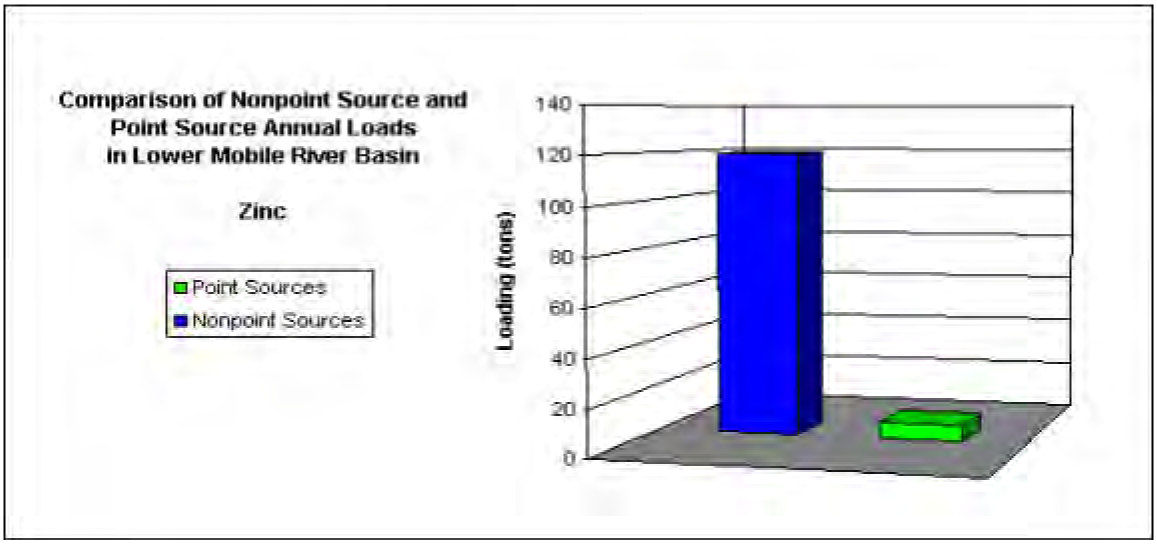

Figure L-5. Zinc from point and nonpoint sources in the Lower Mobile River basin

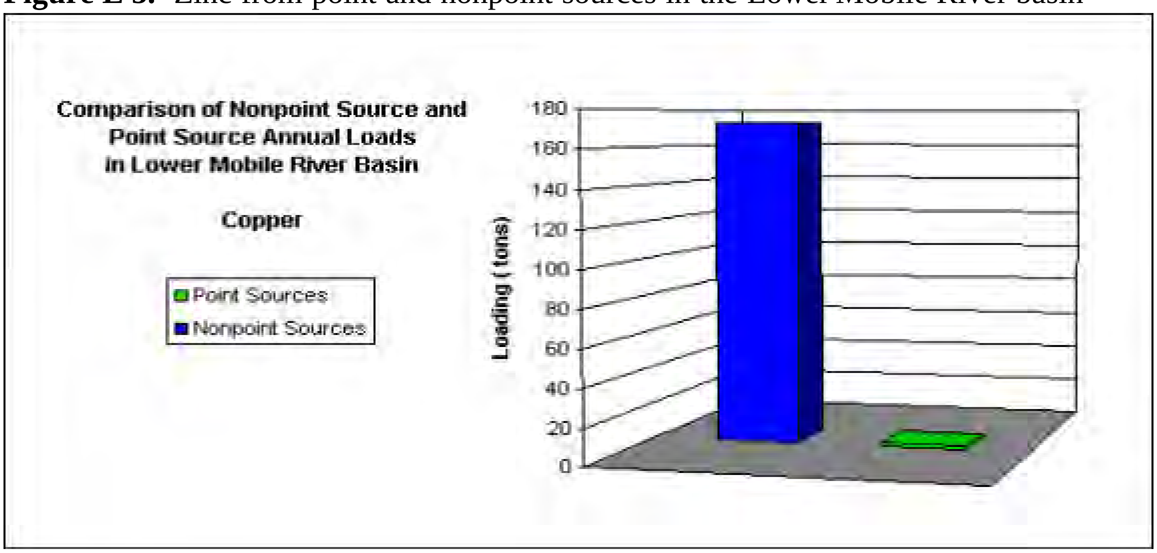

Figure L-6. Copper from point and nonpoint sources in the Lower Mobile River basin

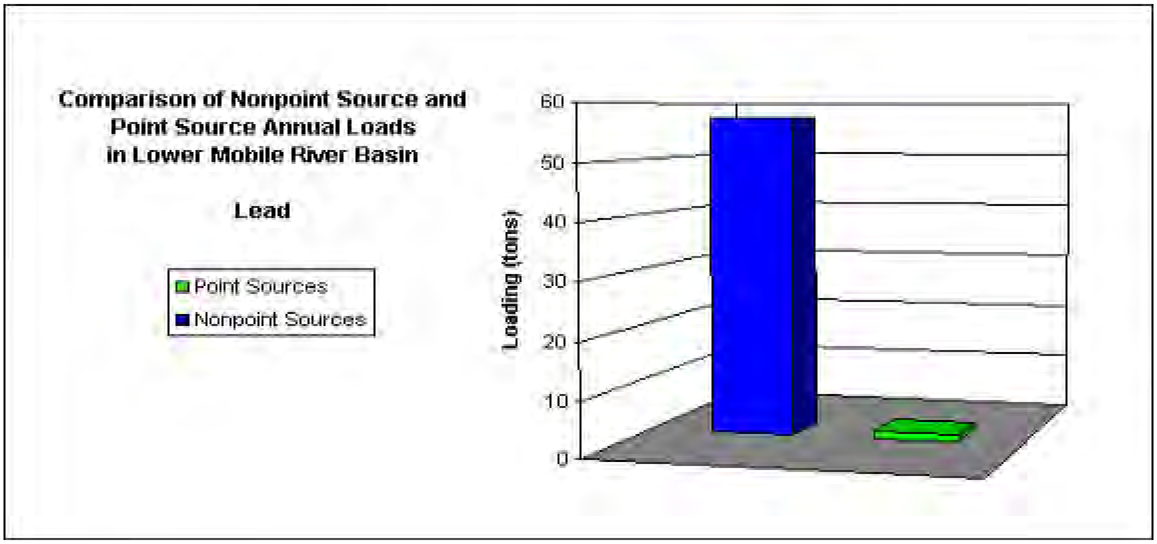

Figure L-7. Lead from point and nonpoint sources in the Lower Mobile River basin

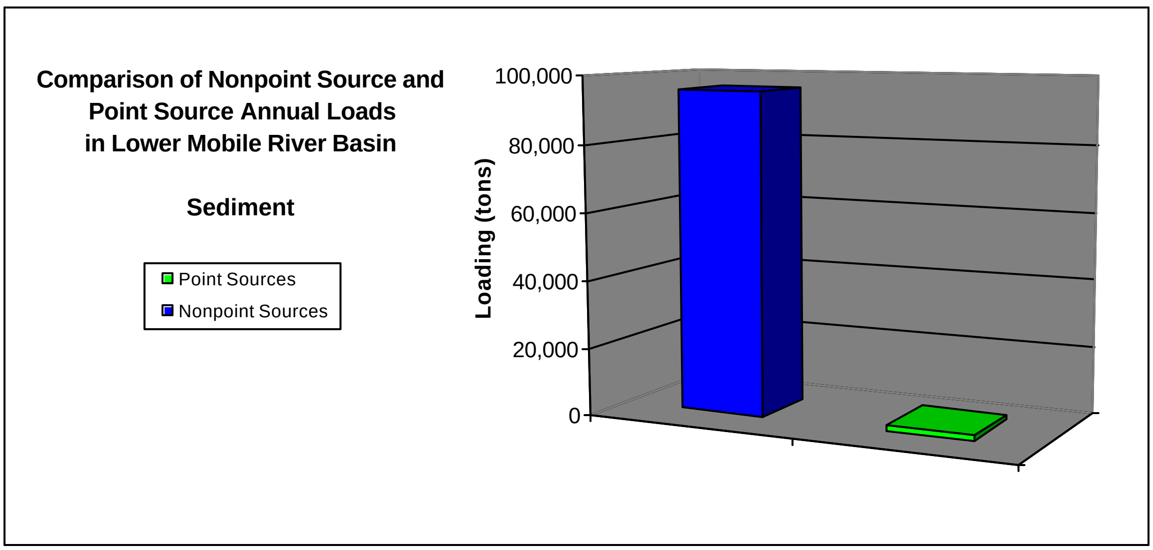

Figure L-8. Sediment from point and nonpoint sources in the Lower Mobile River basin