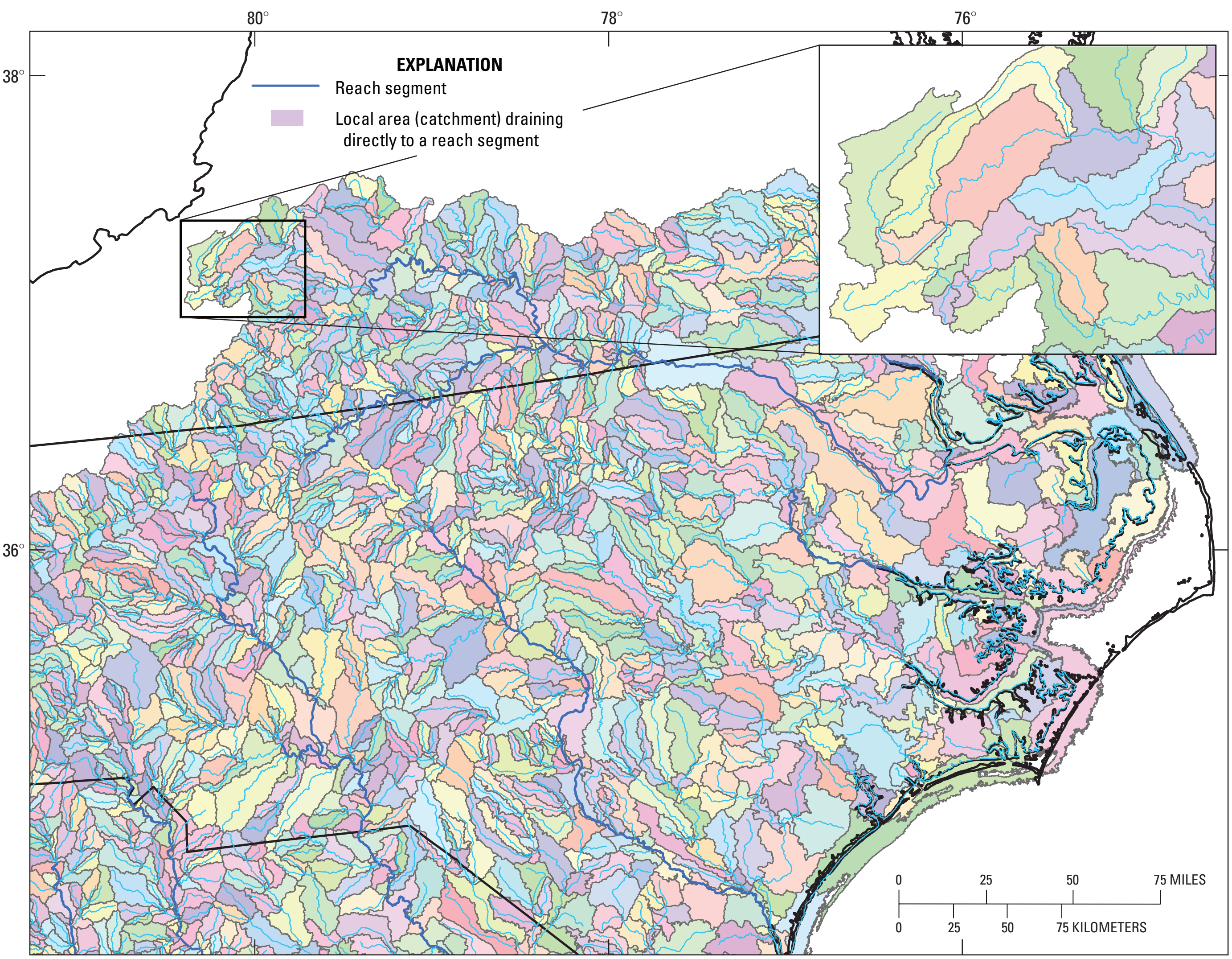
Hydrologic Network of Reaches and Associated Catchments

The SPARROW modeling framework is a hydrologic network of stream- or reservoir-reach segments and associated catchments. The network is used to determine flow pathways between the sources of the modeled constituents and the locations of water-quality monitoring sites; the downstream end of each reach corresponds to a model computation node.

The hydrologic network used for the SPARROW model of the SAGT river basins (fig. 2) is based on USEPA's 1:500,000-scale Reach File 1 (RF1), a national dataset of more than 60,000 stream segments (about 8,000 within the SAGT area) that describes surface-water flow paths using from-node and to-node topology (Dewald and others, 1985; U.S. Environmental Protection Agency, 1996). USEPA's RF1 has been enhanced (Alexander and others, 1999; Nolan and others, 2002) to support national- and regional-scale water-quality modeling. Each stream segment (also referred to as a reach) in the Enhanced River Reach File 2.0 (ERF1_2) includes additional attributes such as estimates of mean time of travel in river reaches and reservoirs and catchment drainage area derived from 1-kilometer elevation data.

The ERF1_2 reach set was further enhanced for the SAGT nutrient SPARROW model by inserting 433 segment boundaries, which was accomplished by splitting 433 reaches into two segments each. The locations of the added boundaries, and thus of the added model computation nodes, correspond with the locations of sites where mean annual nutrient load could be estimated from monitoring data. Methods similar to those used by Brakebill and others (2001) for the Chesapeake Bay SPARROW model were used to create the additional reach segments: (1) load estimation sites were



Digital segmented network based on 1:500,000-scale Reach File 1

Figure 2. Illustration of the network of stream segments and catchments used as model framework for the SAGT SPARROW model.

identified on the ERF1_2 stream network; (2) for sites located in the middle of a stream reach, the reach was split at that location; and (3) a unique node and reach were added to the upstream portion of the split reach. The values assigned for the unique reach identifier (variable name wshed) for the segments added to the ERF1_2 through this procedure were selected from the unassigned series (65,747 through 79,000) of values in ERF1_2, to maintain the unique identifier in the data model.

The geospatial dataset defining the SAGT ERF1_2 digital segmented network is available as a compressed ArcInfo shapefile (*erf1_spar.zip*, 5.1 megabytes, MB); with metadata descriptions (*erf1_spar.html*, 213 kilobytes, KB). Reach identification and connectivity information also are available in the data file *SAGT_ERF1_input.xls.zip* (2.1 MB).

The drainage boundary for the catchment associated with each of the 8,421 reach segments in the SAGT ERF1_2 set was delineated to create an area or zone for summarizing attribute data that could be associated to individual reaches. In this report, the terms catchment and incremental area are used interchangeably to refer to the local area that drains directly to a reach. The source for the drainage area delineation was a 100-meter resolution elevation dataset resampled from the 30-meter National Elevation Dataset (NED) (Falcone, 2003). The elevation data were forced to conform to the ERF1_2 reach segments with the insertion of a raster representation of the streams into the elevation data. The process, also referred to as "stream burning" (Saunders, 2000) uses a tool developed by Hellweger and Maidment (1997) to create an artificially low stream channel to ensure that the elevation surface would flow towards the stream segments. Depressions and sinks were removed from the elevation dataset and the streams were incorporated, then individual watersheds (catchments) were created around every uniquely identified stream reach. The geospatial dataset defining the SAGT ERF1_2 segmented catchments is available as a compressed Arc Info shapefile (*shed_cov.zip*, 13 MB) with metadata descriptions (*shed_cov.html*, 122 KB). The drainage area for the catchment associated with each SAGT ERF1_2 reach is included, as variable name sqkm, in the file *SAGT_ERF1_input.xls.zip* (2.1 MB).

Watershed Attributes

The SPARROW model uses a regression equation to describe the relation between watershed attributes (predictors) and measured instream load (response). The regression equation is structured to model two different types of effects of watershed predictors on instream load: source and transport. Watershed attributes that are considered to describe input conditions, such as atmospheric deposition of nitrogen, fertilizer application rates, and land cover, are included as source variables in the regression equation. Watershed attributes that are considered to affect rates of transport from land to water, such as characteristics of soil, landform, and climate, are included as land-to-water transport variables in the equation. In this report, the terms land-to-water transport variable and delivery variable are used interchangeably to refer to the watershed attributes that quantify the rate at which nutrient inputs to the land surface are delivered, by both overland and subsurface transport, to the adjacent stream reach.

Each watershed-attribute dataset has been georeferenced and allocated to the SAGT ERF1_2 catchment dataset. Unless otherwise noted, the ZONALMEAN function from the Arc/Info GRID module (Environmental Systems Research Institute, 2008) was used to allocate average values of the attributes to every catchment in the network. The catchment areas are the zones within which values are averaged. For every zone (catchment), the cells of the attribute variable that overlap the zone are summed then divided by the number of cells within the zone; this provides a zonal mean of the attribute for every catchment, which can be interpreted as the average value for the catchment.

Nutrient-Source Attributes

Most sources of nutrients are related to human activities: therefore, inputs from these sources are expected to change over time. Because temporal variation introduces noise to spatial comparisons of watershed attributes and instream load, nutrient-source data prepared for the SAGT nutrient SPARROW models describe conditions for years corresponding as closely as possible to a single time period. The year 2002 was selected because of the availability of datasets describing land cover and agricultural activities.

The watershed attributes considered as nutrient-source predictors for the SAGT SPARROW models, and the spatial datasets that were used to represent their distribution, are described in the following paragraphs. Nutrient sources are characterized by both mass-based attributes, such as total annual nutrient mass associated with atmospheric deposition, and area-based attributes, such as areas of urban or agricultural land. The catchment-level estimates of nutrient-source attributes are included in the file *SAGT_ERF1_input.xls* (4.5 MB).

Variability across the SAGT area in catchment-level estimates for each attribute is described in table 1 and figures 3 and 4. The estimates of mass-based attributes (except point-source discharge) and area-based attributes are normalized by the total area of the catchment so that the percentiles of distribution (table 1) and the mapped distribution (figs. 3 and 4) illustrate variation in intensity only and are not affected by variation in catchment size. Most of the attributes considered as nutrient-source predictors vary greatly across the individual catchments in the SAGT area; that is, ratio of 90 percentile of the distribution to 10 percentile of the distribution is greater than 10 (last column, table 1). Wet deposition of inorganic nitrogen and area in forested land are the exceptions, varying only by factors of about 2 and 5, respectively.

Table 1. Variation across the SAGT SPARROW model area in attributes representing nutrient source inputs and factors controlling land-to-water nutrient transport rates.

[For certain attributes, the measurement unit used for summarizing distribution differs from the unit of the estimates presented in the dataset "SAGT_modelinput.csv" (for example, expressed as mass per unit area of catchment rather than mass per catchment) to provide for comparisons of intensity of the input or factor; kg/yr, kilogram per year; kg/ha/yr, kilogram per hectare per year; —, not calculated; km^2, square kilometer; %, percent; CA, catchment area; in/h, inch per hour; in/yr, inch per year; in., inch; mm/yr, millimeter per year; HSG, hydrologic soil group; C, Celsius]

Attribute	Units for attribute (as presented in the dataset "SAGT_model input.csv")	Description	Units used for summary statistics	Distribution of attribute across all SAGT ERF1_2 catchments										
				Number of catchments with observations	Mean value for SAGT area	Standard deviation	Minimum	10-percentile	25-percentile	Median	75-percentile	90-percentile	Maximum	Range, calculated as ratio of 90- to 10-percentile
Nutrient source attributes														
nadp_kg	kg/yr	Wet deposition of inorganic nitrogen (ammonia and nitrate)	kg/ha/yr	8,311	4.2	0.65	2.8	3.2	3.6	4.3	4.8	4.9	7.3	1.5
lc2_sqkm	km^2	Area in urban land	% of CA	8,311	8.9	12	0.00	1.9	3.4	5.2	8.6	19	100	9.8
lc8_sqkm	km^2	Area in agricultural land	% of CA	8,311	18	15	0.00	1.5	6.1	15	27	40	95	27
lc4_sqkm	km^2	Area in forested land	% of CA	8,311	47	22	0.00	16	31	48	63	75	111	4.8
impsurf_sqkm	km^2	Area in impervious surface	% of CA	8,311	2	4	0.00	0.1	0.3	0.6	1.3	3.9	51	36
wffert_n_2002	kg/yr	Nitrogen mass in fertilizer applied to farmland	kg/ha/yr	8,309	7.8	9.0	0.00	0.39	1.7	5.1	11	20	109	51
wffert_p_2002	kg/yr	Phosphorus mass in fertilizer applied to farmland	kg/ha/yr	8,309	1.9	2.3	0.00	0.08	0.35	1.1	2.5	4.7	33	57
wlvtotal_n_2002	kg/yr	Nitrogen mass in manure from livestock production	kg/ha/yr	8,309	10	15	0.00	0.38	1.8	5.2	12	25	196	64
wlvtotal_p_2002	kg/yr	Phosphorus mass in manure from livestock production	kg/ha/yr	8,309	3.1	5.1	0.00	0.11	0.52	1.5	3.6	7.5	83	69
kgn_02	kg/yr	Nitrogen mass in permitted wastewater discharge	kg/yr	8,321	6,118	45,000	0.00	0.00	0.00	0.00	0.00	3,009	2,052,772	—
kgp_02	kg/yr	Phosphorus mass in permitted wastewater discharge	kg/yr	8,321	1,674	45,076	0.00	0.00	0.00	0.00	0.00	516	3,903,606	—
Nutrient transport attributes														
hsg1	km^2	Area underlain by soils of HSG A[a]	% of CA	8,309	0.06	0.18	0.00	0.00	0.00	0.00	0.00	0.24	1.00	—
hsg2	km^2	Area underlain by soils of HSG B[a]	% of CA	8,309	51	40	0.00	0.00	5.2	55	95	100	100	—
hsg3	km^2	Area underlain by soils of HSG C[a]	% of CA	8,309	19	29	0.00	0.00	0.00	0.04	30	69	100	—
hsg4	km^2	Area underlain by soils of HSG D (and others)[a]	% of CA	8,309	21	32	0.00	0.00	0.00	0.00	32	82	100	—
hsg5	km^2	Area underlain by soils of HSG W (Water)[a]	% of CA	8,309	2.5	10.0	0.00	0.00	0.00	0.00	0.00	3.5	100	—
perml	in/h	Soil permeability, low value for the range in permeability rate across soil layer or horizon	in/h	8,307	1.5	1.2	0.00	0.6	0.7	1.0	1.8	3	11	5.1
awch	in./in.	Available water-holding capacity of soil, high value for the range across soil layer or horizon	in./in.	8,307	0.15	0.03	0.00	0.12	0.14	0.15	0.16	0.17	0.41	1.5
clayl	%	Clay content, low value for the range across soil layer and horizon	%	8,307	17	7	0	8	12	17	23	26	47	3.3
rockdepl	in.	Depth to bedrock, low value for the range across the map unit	in.	8,307	53	10.2	0	37	48	58	60	60	60	1.6
kfact	dimensionless	Soil erodibility factor (not adjusted for rock fragments)	dimensionless	8,307	0.24	0.06	0.00	0.16	0.21	0.25	0.28	0.29	0.43	1.9
slope_mean	%	Land-surface slope	%	8,311	4.9	5.5	0.0	0.56	1.7	3.5	5.5	10	44	19
p_flat	fraction of CA	Fraction of catchment with slope less than 1%	fraction of CA	8,311	0.26	0.31	0.00	0.02	0.04	0.11	0.40	0.82	1.0	55
precip_mm	mm/yr	Annual precipitation, 1971–2000 mean	mm/yr	8,311	1,358	157	966	1,188	1,220	1,334	1,463	1,572	2,163	1.3
pmpe_inches	in/yr	Precipitation minus evapotranspiration, 1961–90 mean	in/yr	8,296	17	6.3	3.1	10	12	17	22	24	44	2.4
meantemp_c	degrees C	Air temperature, 1971–2000 mean of daily mean	degrees C	8,311	17	2.3	8.7	14	15	17	18	19	23	1.4

[a] Definitions of hydrologic soil group are from U.S. Department of Agriculture, 2002: HSG A, high infiltration rate when thoroughly wetted; HSG B, moderate infiltration rate when thoroughly wetted; HSG C, slow infiltration rate when thoroughly wetted; HSG D, very slow infiltration rate when thoroughly wetted, includes certain wet soils that can be adequately drained; HSG W, water body.

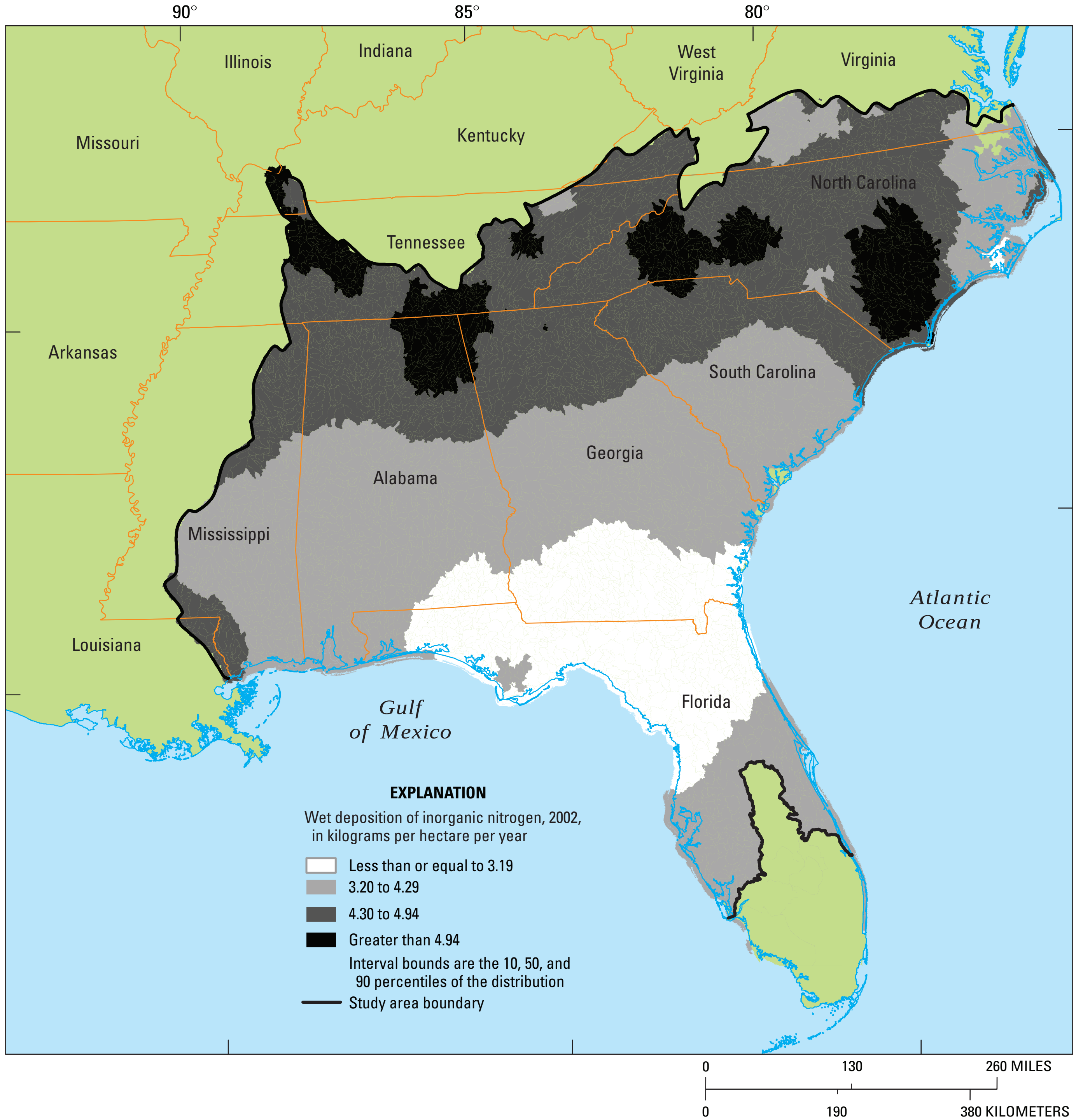


Figure 3A. Estimates of wet deposition of inorganic nitrogen for individual catchments in the SAGT SPARROW model area, 2002.

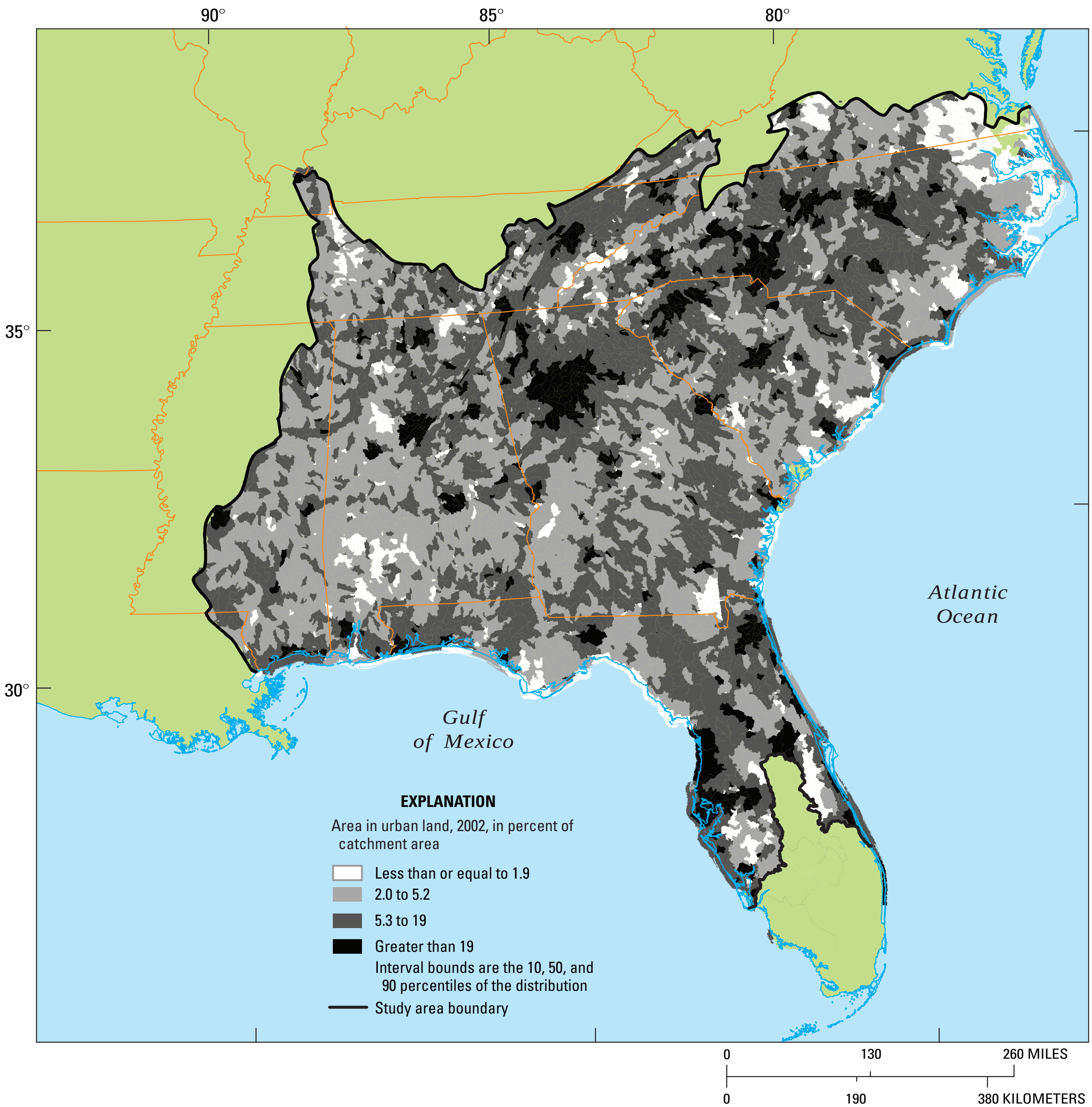


Figure 3B. Estimates of area in urban land for individual catchments in the SAGT SPARROW model area, 2002.

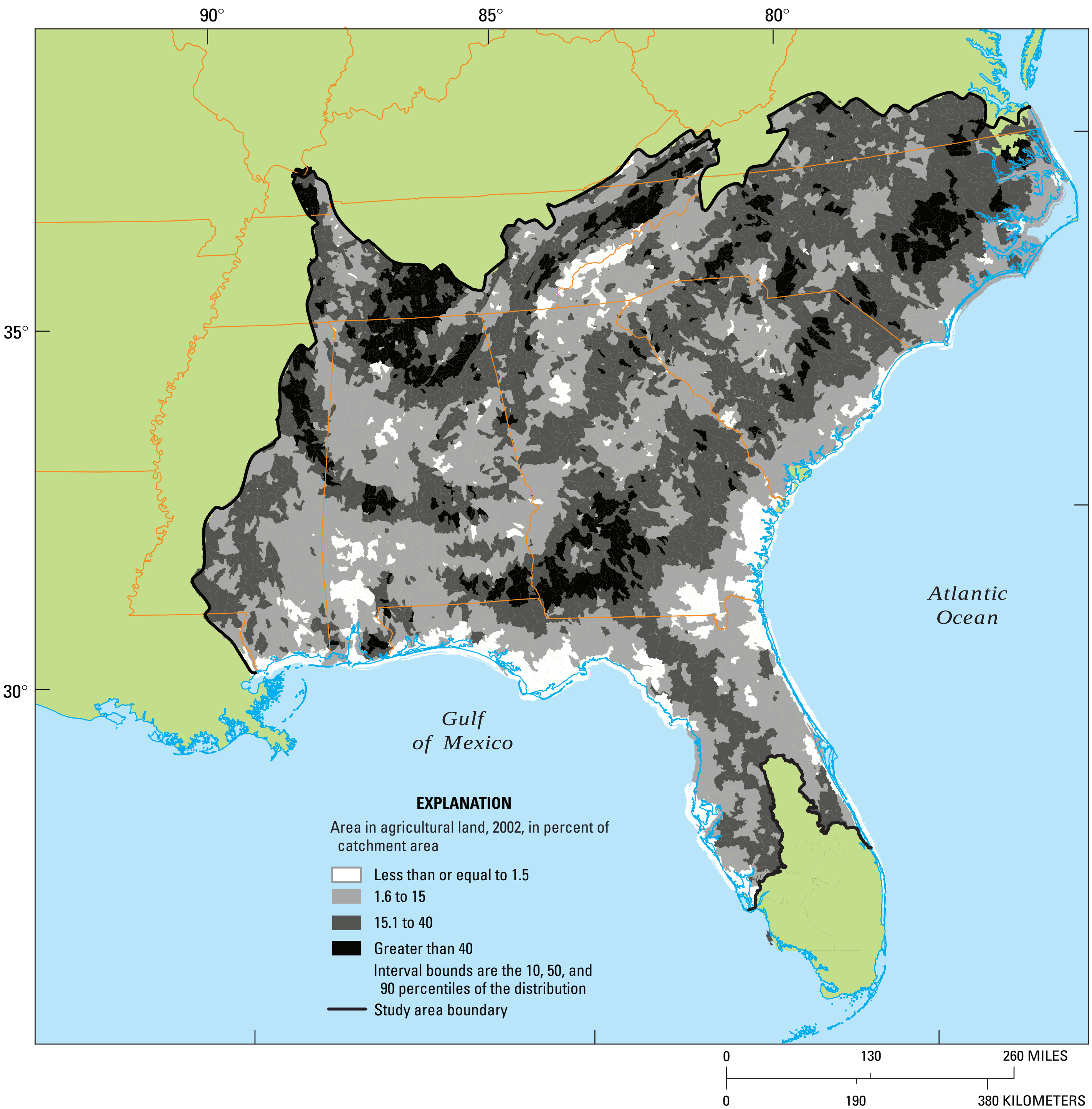


Figure 3C. Estimates of area in agricultural land for individual catchments in the SAGT SPARROW model area, 2002.