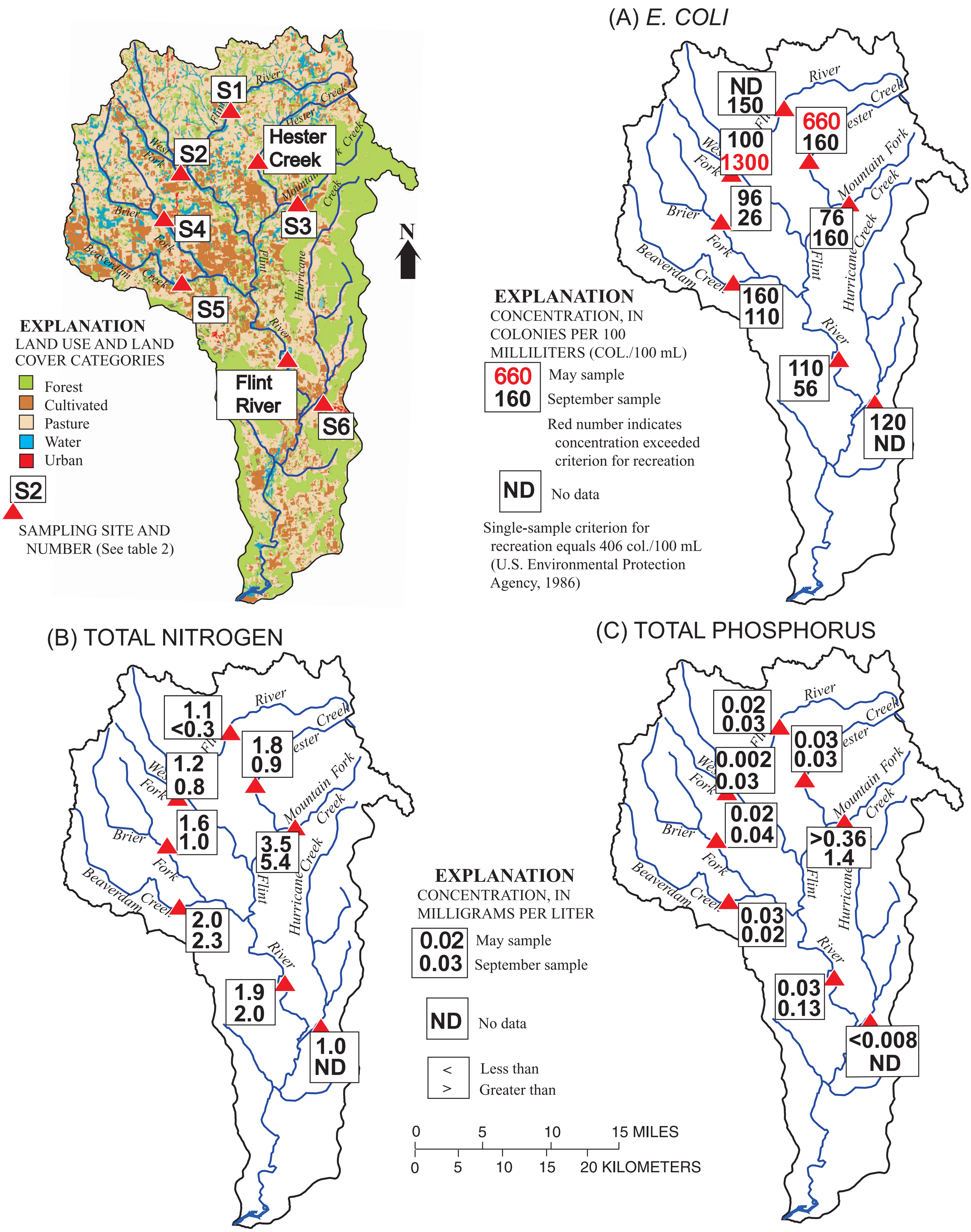

Figure 14. Land use and land cover, and spatial variation of concentrations of (A) *E. coli*, (B) total nitrogen, and (C) total phosphorus in the Flint River Basin during base flow, 1999.

Nutrients

Nutrient overenrichment of streams can promote excess growth of aquatic plants, resulting in recreational impairment and adverse effects on aquatic life. In the Flint River Basin, Hester Creek and its tributaries and the upper part of the Flint River (from the Alabama/Tennessee State line to headwaters) and its tributaries were assessed as impaired by nutrients in 1998 (fig. 2) (Tennessee Department of Environment and Conservation, 2000).

Variation of Concentrations with Season and Streamflow

Concentrations of the nutrients nitrogen and phosphorus in samples from the Flint River generally exceeded thresholds indicating eutrophic potential, whereas concentrations in samples from Hester Creek generally were below the thresholds (fig. 15). The threshold indicating eutrophic potential should be compared with conditions during the summer period of aquatic-plant growth (Dodds and others, 1998). The median total nitrogen concentrations for the Flint River and Hester Creek during the summer growth period were 2.0 and 1.2 milligrams per liter (mg/L), respectively, compared with a threshold value of 1.5 mg/L for temperate streams. The median total phosphorus concentrations for the Flint River and Hester Creek during the summer growth period were 0.12 and 0.05 mg/L, compared with a threshold value of 0.075 mg/L for temperate streams.

Comparisons of the thresholds indicating eutrophic potential with the Flint River Basin data during 1999 should be made with caution for the following reasons.

1. Nutrient concentrations above the threshold do not necessarily cause eutrophication because other factors, such as turbidity and stream shading, influence the relation between nutrient concentrations and aquatic-plant productivity.
2. Conversely, eutrophication may occur even where observed nutrient concentrations are well below the threshold.
3. Comparison of nutrient concentrations in 1999 with thresholds may be of limited use for evaluating long-term conditions in the Flint River Basin because of the below-normal rainfall and streamflow during the sampling period.

The seasonal pattern of nitrogen (specifically nitrate) and phosphorus concentrations differed between the Flint River and Hester Creek sites. Base-flow concentrations of nitrate (fig. 15) and dissolved phosphorus in Hester Creek were significantly lower ($p < 0.05$, Wilcoxon rank sum test) during the period August through November 1999 when compared with the rest of the study period; this pattern partly is attributed to nutrient uptake by aquatic plants. In contrast, base-flow concentrations of these constituents in the Flint River during the summer equaled or exceeded base-flow concentrations during other seasons. The higher base-flow concentrations of nitrate and phosphorus during the summer accounted for the higher median concentration in the Flint River when compared with concentrations in Hester Creek and also when compared with threshold values indicating eutrophic potential. Base-flow concentrations of nitrogen and phosphorus also were elevated in the tributary Mountain Fork Creek during May and September (discussed in the following section).

Estimates of unit-area inputs of nitrogen and phosphorus to the watersheds for the Hester Creek and Flint River sites are similar, except for inputs from livestock waste, which are higher (almost double) for Hester Creek when compared with the Flint River (Appendix C). In contrast to unit-area inputs, annual instream yields for nitrogen and phosphorus were higher for the Flint River when compared with Hester Creek: 3.0 and 2.1 tons per square mile per year [(tons/mi^2)/yr], respectively, for total nitrogen, and 0.34 and 0.20 (tons/mi^2)/yr, respectively, for total phosphorus (Appendix C). Consequently, the ratios of unit-area export (instream yield) to unit-area input for nitrogen and phosphorus are about three times greater for the Flint River when compared with Hester Creek (Appendix C). This disparity in the ratio may be due to differences in the processes by which the inputs from the two watersheds are transported from the land surface to the stream channel, or to inaccurate or inappropriate estimates of input, or to other important sources of nutrients not quantified in this analysis.

Despite differences between the two sites in seasonal- and streamflow-related patterns of concentrations and differences in median concentrations and instream yield, estimates of flow-weighted mean concentrations of nutrients compare closely (Appendix C; flow-weighted mean concentration is calculated as the ratio of annual instream load to annual mean streamflow). The flow-weighted mean concentrations for water year 1999 for both sites were 1.8 and 0.2 mg/L for total nitrogen and total phosphorus, respectively.

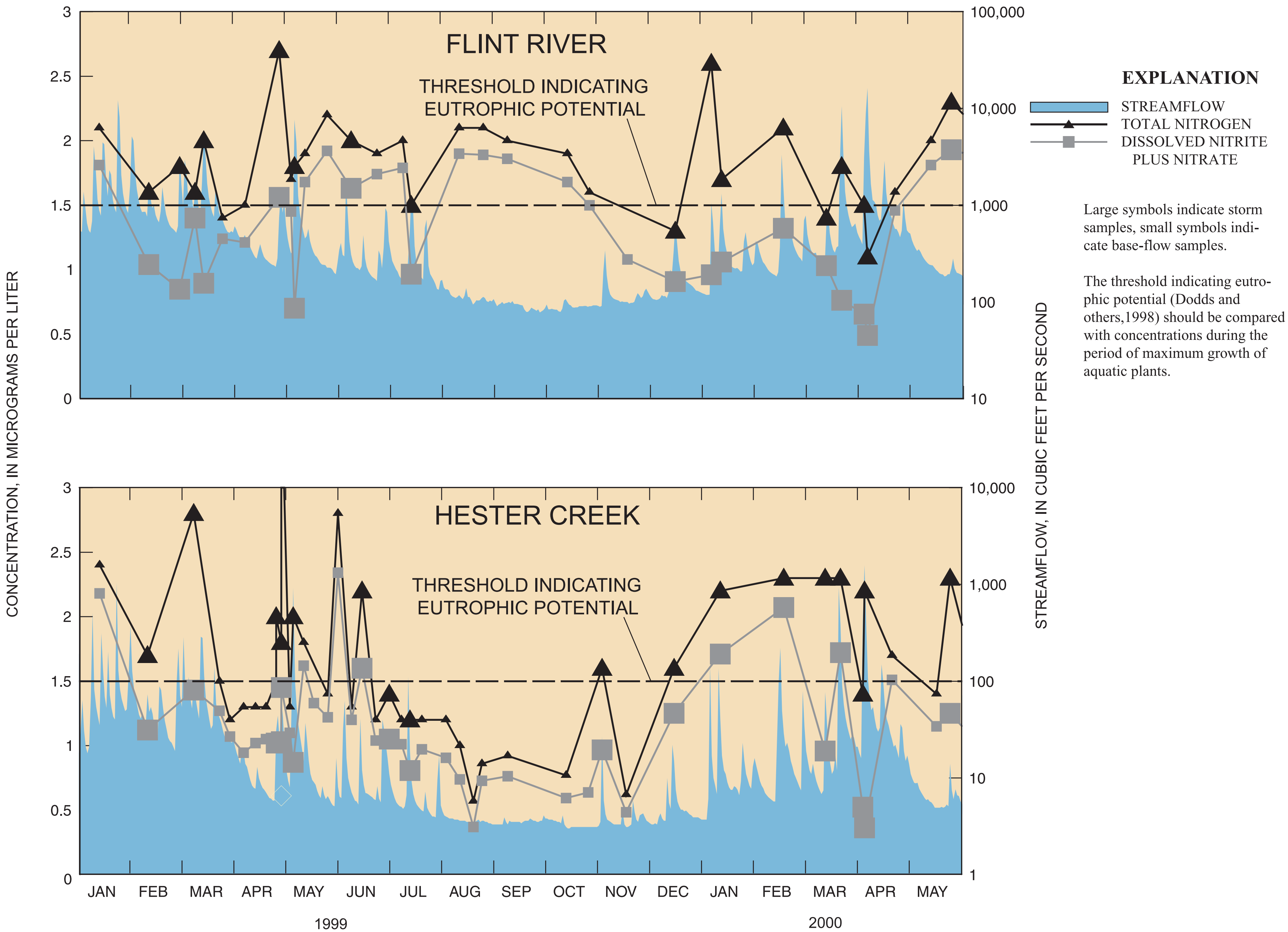

Figure 15. Streamflow and concentration of total nitrogen and dissolved nitrite plus nitrate for the Flint River and Hester Creek, 1999-2000.

These values can be placed in a regional context by comparing with the statistical distribution of estimated values of annual flow-weighted mean concentrations from two different USGS nutrient data sets from the southeastern region of the United States. The first data set is from 16 streams draining undeveloped basins, monitored during 1990-95 (Clark and others, 2000). The second data set is from 24 streams draining mainly agricultural basins (agricultural land use in the watershed exceeds 50 percent) that were monitored during 1993-97 (J. Stoner, U.S. Geological Survey, written commun., 2000). The values for total nitrogen and total phosphorus at Flint River and Hester Creek are well above the 90th percentile values of their respective distributions for undeveloped basins in the southeastern region of the United States (fig. 16), indicating that these sites are nutrient enriched compared with background levels. When compared with concentrations from the set of 24 agricultural basins in the southeastern region, the concentrations from the Flint River and Hester Creek were slightly above the regional median.

Spatial Variation of Concentrations During Base Flow

Nutrient-concentration data were collected from the network of eight stream sites in the Flint River Basin during base flow in May and September 1999 (fig. 14). The spatial pattern of nutrient concentrations was compared with the pattern for various watershed characteristics including percentage of pastureland and percentage of cultivated land; acreage of cotton, corn, and soybeans; and density of livestock and failing septic systems (table 2). Base-flow nitrogen concentrations did not correlate with any of these watershed characteristics; concentrations were highest for Mountain Fork Creek (site S3), but watershed characteristics that would indicate high nutrient input were not in the high ends of their respective ranges for the Mountain Fork Creek watershed (table 2). When this site was removed from the data set ($n = 7$ for the trimmed set), correlation was significant ($p = 0.01$) between percent of watershed in cultivated land and total nitrogen concentration, and was stronger for total nitrogen concentration during September ($r = 0.9$) when compared with the concentration during May ($r = 0.7$). Correlation also was significant ($r = 0.8$, $p = 0.02$) between cotton acreage and total phosphorus concentration (May only). Correlations were not significant between density of livestock or failing septic systems and base-flow nutrient concentrations; however, this analysis may not accurately evaluate the contribution from livestock, as stream access by livestock was not considered.

The elevated concentrations of nitrogen and phosphorus at Mountain Fork Creek (site S3) may be caused by input from a nutrient source not included in this analysis. During a separate base-flow sampling project of the Mountain Fork Creek watershed on May 15, 2000, concentrations of dissolved nitrate were elevated (greater than 2 mg/L) in samples from three sites near the downstream end of Mountain Fork Creek, but concentrations were at trace levels (0.1 mg/L) in samples from two upstream sites (U.S. Geological Survey, unpub. data, 2001). The Mountain Fork Creek tributary made the largest contribution of nutrients to the Flint River during base flow; 42 and 74 percent of the summed tributary load of total nitrogen during May and September 1999 sampling, respectively, and 85 and 98 percent of the summed tributary load of total phosphorus during May and September 1999 sampling, respectively. The elevated concentrations of nitrogen and phosphorus in Mountain Fork Creek may have contributed to the elevated base-flow concentrations of nitrate and phosphorus observed in the Flint River as compared to Hester Creek (discussed in the previous section).

RELATION OF STORM TRANSPORT OF SELECTED PESTICIDES IN THE FLINT RIVER BASIN TO CONCENTRATIONS IN THE SOURCE FOR DRINKING WATER FOR THE CITY OF HUNTSVILLE, ALABAMA

About 40 percent of the public water supply for the City of Huntsville, Ala., is withdrawn from the right bank of the Tennessee River at mile 334 (South Parkway Water Treatment Plant), about 5 mi. downstream of the confluence with the Flint River (also on the right bank, at river mile 339). The watershed and presumed source area for the Tennessee River at the Huntsville intake encompasses a 25,000-mi^2 area that is predominantly (about 60 percent) forested land. Numerous impoundments along the Tennessee River upstream from the Huntsville intake regulate streamflow and dampen short-term fluctuations in streamflow and water quality caused by runoff. During storms, however, the quality of water at the intake is greatly affected by the smaller (570 mi^2),

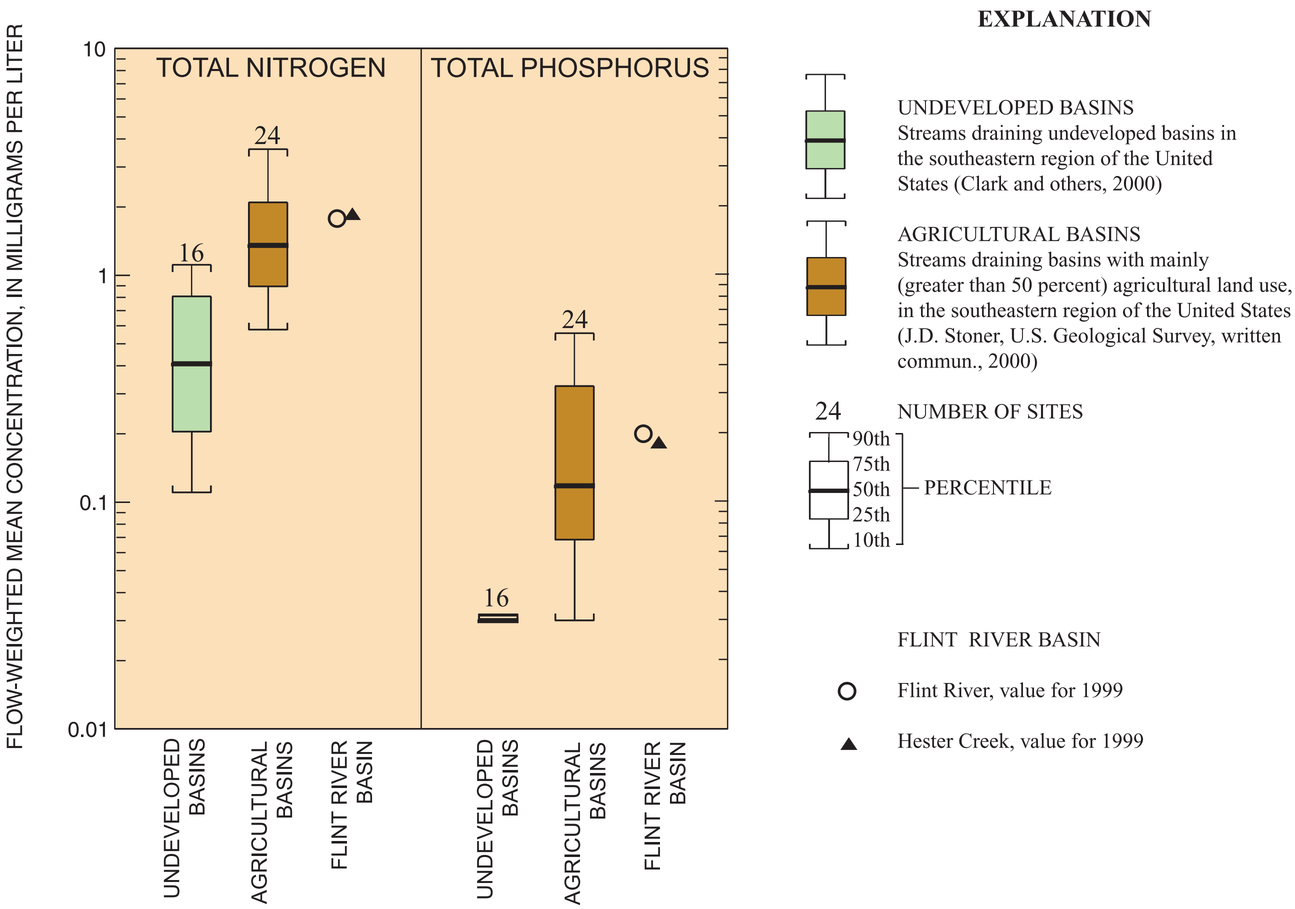

Figure 16. Flow-weighted mean concentrations of total nitrogen and total phosphorus for the Flint River and Hester Creek, 1999, as compared to undeveloped and agricultural basins in the southeastern region of the United States.

predominantly agricultural Flint River Basin as a result of two factors: larger percentages of flow from the Flint River to the regulated Tennessee River during storms (as high as 30 percent, compared with the drainage-area ratio of 2 percent), and incomplete mixing at the confluence of the Flint and Tennessee Rivers. Comparison of turbidity measured in samples from the Huntsville intake water with runoff events in the Flint River (fig. 17) demonstrates the influence of inputs of streamflow from the Flint River on suspended material in the Tennessee River and at the intake.

One of the objectives of this study was to determine whether the observed incomplete mixing in the Tennessee River also affects transport of dissolved constituents; that is, constituents that may not be removed during treatment (filtration) of the intake water supply. Other studies have shown that several pesticides commonly transported in the dissolved phase (for example, atrazine, cyanazine, and metolachlor, which were detected frequently at sites throughout the Flint River Basin) are not completely removed during conventional water treatment (Miltner and others, 1989). A special storm sampling project was conducted April 2-5, 2000, with the assistance of staff of the South Parkway Water Treatment Plant, in order to test the hypothesis that during high flow events in the Flint River Basin, the quality of water (both suspended and dissolved material) withdrawn from the right bank of the Tennessee River at the South Parkway intake is more similar to water quality of the Flint River than to water quality of the main channel of the Tennessee River. Rainfall amounts during April 2-5 were greater in the Flint River Basin (about 5 in.) than in the rest of the Tennessee Valley (about 1 in.); consequently, the Flint River contributed almost 15 percent of the total streamflow in the Tennessee River at mile 334 (TRM 334) during this

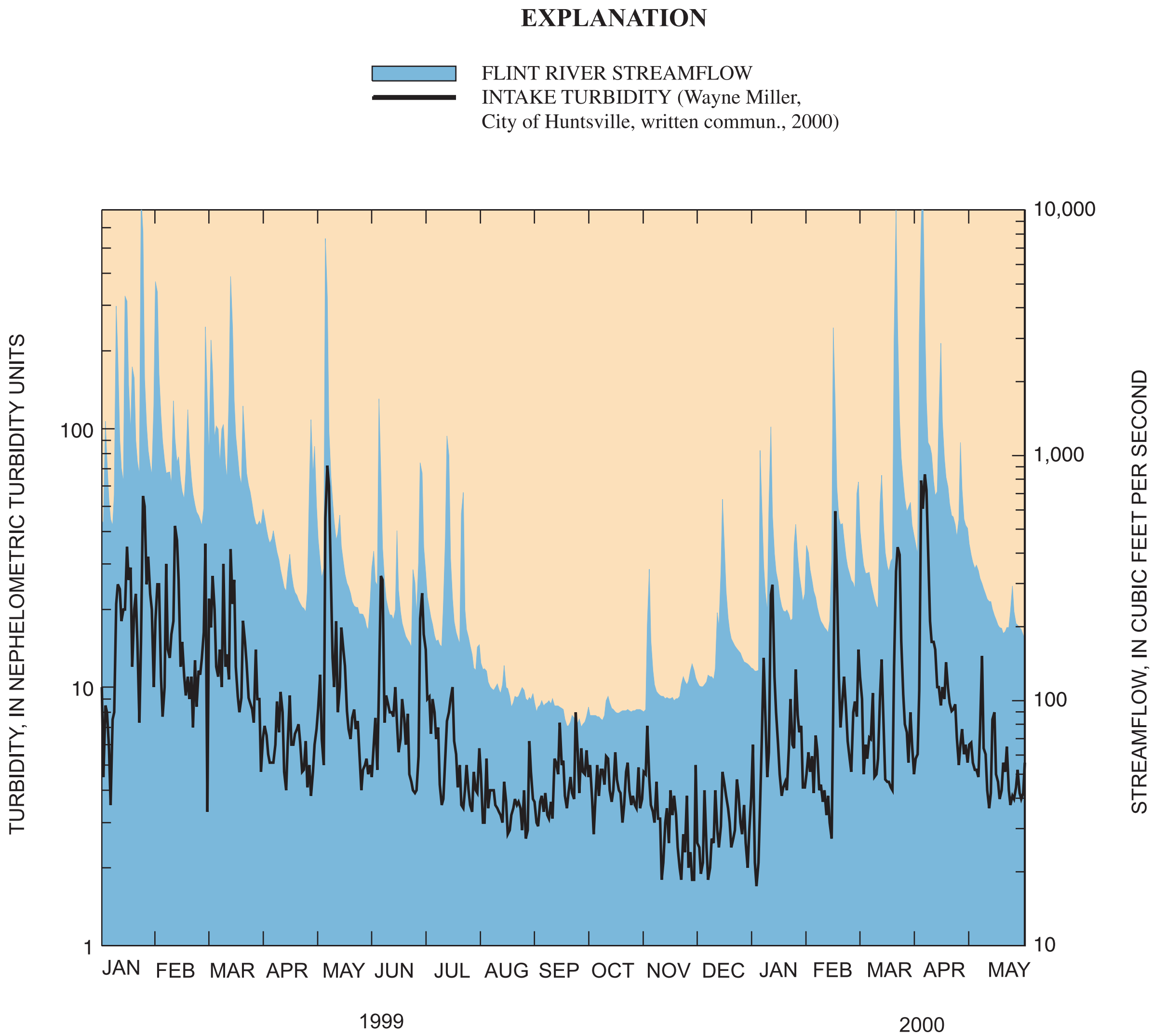

Figure 17. Relation between turbidity of intake water for the City of Huntsville water-treatment plant (South Parkway Plant) and streamflow in the Flint River near Brownsboro, Ala., 1999-2000.

period. The sampling sites for the Tennessee River are described in tables 1 and 2. Streamflow and atrazine concentrations in the Flint and Tennessee Rivers during the storm are shown in figure 18.

In water samples collected at the South Parkway intake, peak concentrations of all target pesticides for which drinking-water standards have been established were below those standards. Comparison of concentrations among the four sites supports the hypothesis that the chemical load from the Flint River (entering at TRM 339) strongly influenced water quality at TRM 334 near the intake during this storm. Concentrations of atrazine (fig. 18), acetochlor, carbofuran, diazinon, and metolachlor were at least a factor of five times greater in the intake water compared to the Tennessee River upstream from the Flint River. In addition, the higher concentrations in the intake and right channel of the Tennessee River main stem compared with the lower concentrations in the left channel of the main stem near Hobbs Island (all at TRM 334) indicate that the mass of dissolved chemicals contributed by the Flint River is not completely mixed with the Tennessee River between TRM 339 and TRM 334, influencing water quality more strongly than would be expected from mass balance considerations. For example, the expected peak concentration of atrazine in the intake water (based on mass balance calculations using data from the Flint River and TRM 340) is 0.62 µg/L, the