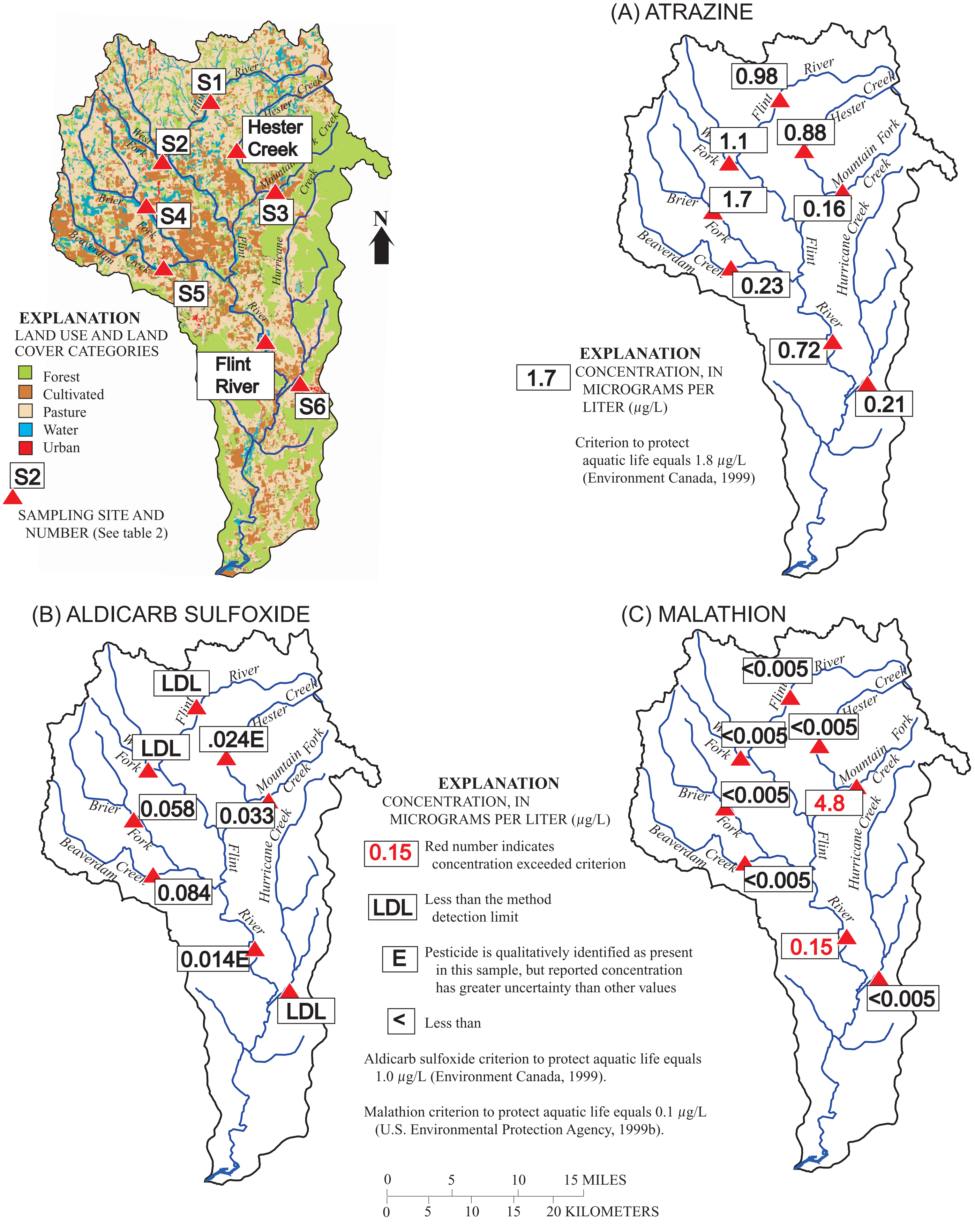

Figure 10. Land use and land cover, and spatial variation of concentrations of (A) atrazine, (B) aldicarb sulfoxide, and (C) malathion in the Flint River Basin during base flow, May 1999.

Figure 11. The Flint River, designated as a canoe trail by the Madison County Commission in Alabama, is a popular water recreation resource used for canoeing and tubing. (Photograph by Susan F. Weber, Flint River Conservation Association.)

three samples (Flint River) or four samples (Hester Creek) collected over a 30-day period.

Variation of Concentrations with Streamflow and Turbidity

Concentrations of *E. coli* in the Flint River and Hester Creek are significantly different ($p < 0.001$, Wilcoxon rank-sum test) between base flow and storm flow (fig. 12). Concentrations of *E. coli* in the 11 base-flow samples from the Flint River, in the reach used for recreational boating, generally did not exceed the single-sample criterion, whereas *E. coli* concentrations in 12 out of the 13 storm samples exceeded the single-sample criterion. The median value for all base-flow samples from the Flint River was 50 col./100 mL, less than both the single-sample and geometric-mean criteria. However, the median value for samples collected 3 to 6 days after a storm was higher, almost equal to the geometric mean criterion, suggesting that the bacteriological risk remains elevated at least 6 days after a storm. Concentrations of *E. coli* were higher in Hester Creek when compared with the Flint River concentrations; concentrations in 3 of 14 base-flow samples from Hester Creek exceeded the single-sample criterion, and *E. coli* concentrations in 14 of 16 storm samples, and concentrations in 7 of 9 samples collected 3 to 6 days after a storm, exceeded the single-sample criterion (fig. 12).

Concentrations of *E. coli* did not vary as greatly with season ($p > 0.40$; Wilcoxon rank sum test) as with streamflow. Mass loading of *E. coli* was much greater in winter, however, because of more frequent occurrences of storms. Based on instream load calculations, 84 percent of the estimated annual instream load of *E. coli* in the Flint River was calculated for the 3-month period of December through February, whereas only 2 percent was calculated for the 3-month period of June through August; for Hester Creek, 54 percent of the estimated annual load was calculated for the period of December through February, and 2 percent for the period of June through August.

Concentrations of *E. coli* were strongly correlated with turbidity for the Flint River throughout the range of concentration values ($r > 0.9$, $p < 0.001$ for log-transformed data); correlation was not as strong for Hester Creek, especially for *E. coli* concentrations less than 1,000 col./100 mL (fig. 13). Turbidity, therefore, may be useful as a surrogate for estimating concentrations of *E. coli* in the Flint River. For example, a turbidity value of 22 nephelometric turbidity units (NTU) was estimated from a linear regression of the data (fig. 13) for the Flint River to be the value at which the *E. coli* concentration would be expected to exceed the single-sample criterion (406 col./100 mL).

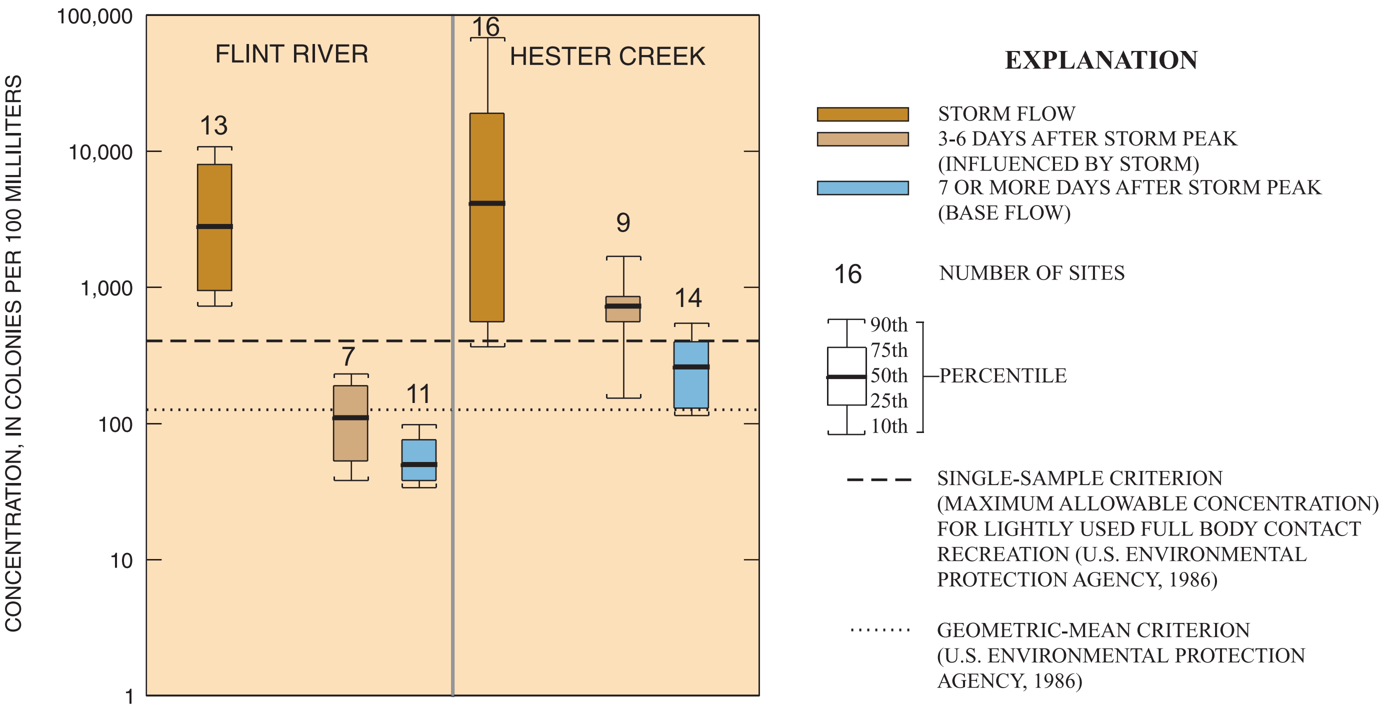

Figure 12. Concentrations of *E. coli* in the Flint River and Hester Creek during storm flows frequently exceed U.S. Environmental Protection Agency criteria for recreation. *E. coli* concentrations remain elevated at least 6 days after storm peaks in streamflow.

Spatial Variation of Concentrations During Base Flow

E. coli-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). Concentrations exceeded the single-sample criterion for recreation (406 col./100 mL) at two sites: Hester Creek and West Fork Flint River, site S2. The spatial pattern of *E. coli* concentrations was compared to the pattern for various watershed characteristics including percentage of pastureland and percentage of cultivated land, density of livestock population, and failing septic systems (table 2). The reader should note that input from livestock is not necessarily represented by density of population; stream access may also be an important factor, but one that was not considered in this analysis. Correlation was significant ($r > 0.9$, $p < 0.006$) between *E. coli* concentration during May 1999 and density of livestock population (highest for Hester Creek). A weaker correlation ($r = 0.7$, $p = 0.10$) was observed between *E. coli* concentrations during September 1999 and density of failing septic systems (highest for West Fork Flint River, site S2). These correlations suggest that, of the four variables considered, livestock populations were the most likely source of fecal material to streams during base flow in May 1999; whereas failing septic systems were the most likely source during base flow in September 1999, when sampling followed a prolonged 40-day dry period. Correlations should be interpreted with caution, however, because of the small number of observations ($n = 8$).

The *E. coli*-concentration data from the spatial network can be used to identify which tributaries in the Flint River Basin contribute the largest amount of fecal material to the Flint River during base flow. During May 1999, Hester Creek contributed the largest amount (41 percent) of the tributary load to the Flint River, and Beaverdam Creek (site S5) contributed the second largest amount (26 percent). Bacterial loading differed during September 1999 after a prolonged dry period, when West Fork Flint River (site S2) contributed the largest amount (56 percent).

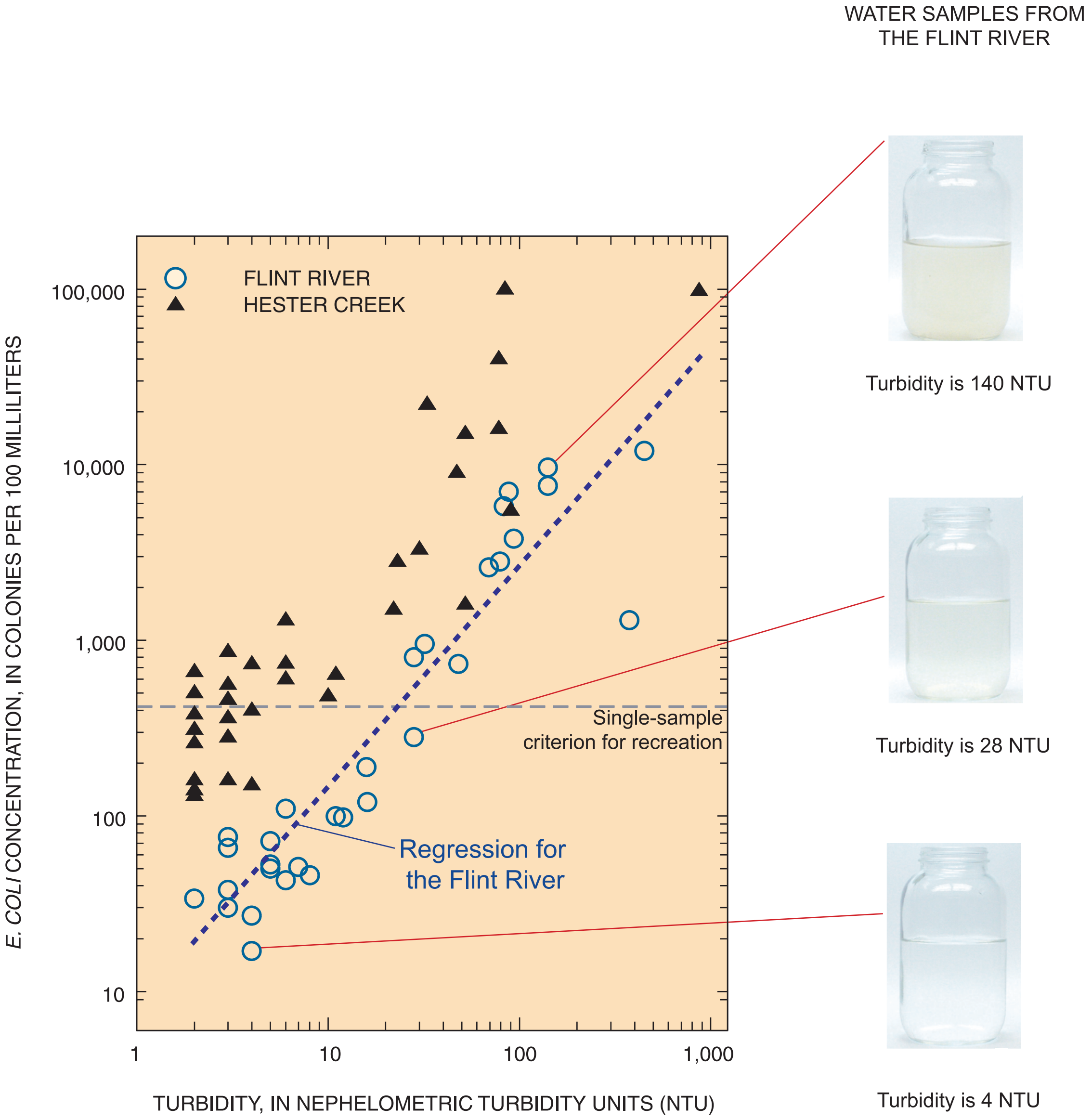

Figure 13. *E. coli* concentration and turbidity for the Flint River and Hester Creek. The strong correlation between *E. coli* concentration and turbidity for the Flint River and Hester Creek suggests that turbidity might be useful as a surrogate for estimating concentrations of *E. coli*. The photographs of water samples from the Flint River demonstrate the physical appearance of water with turbidity values below, near, and above 22 NTU, the value with expected *E. coli* concentration equal to the single-sample criterion for recreation.