Nutrient and Triazine-Herbicide Concentrations in Streams of the Chickies Creek Basin, South-Central Pennsylvania, During Low-Flow Conditions

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Why Study Chickies Creek?

Excessive nutrients and herbicides in surface and ground water can affect human health and the aquatic life in Chickies Creek. Potential sources of these contaminants are all around us—direct application of nutrients and herbicides on land, discharge from wastewater-treatment and septic systems, and even deposition from the atmosphere. However, by far the largest source in the Chickies Creek Basin is the application of nutrients and herbicides for agricultural purposes. Because the land use in Chickies Creek Basin is predominantly agricultural (83 percent), the potential for surface- and ground-water contamination is great. In fact, the Pennsylvania Department of Environmental Protection (PaDEP) has listed the Chickies Creek Basin as 1 of 50 watersheds most susceptible to surface- and ground-water contamination in Pennsylvania (out of 478 surveyed).

The U.S. Geological Survey (USGS), with additional funding provided by PaDEP, conducted this study to determine the spatial distribution of nutrient and triazine-herbicide concentrations in streams during low-flow conditions in Chickies Creek Basin. Characterization of these contaminants could be used by land and water managers to target areas for implementation of agricultural management practices and to direct future surface- and ground-water monitoring efforts. Because the streamflow during low-flow conditions is largely sustained by ground water, samples collected for this study provide an indication of the ground-water quality in Chickies Creek Basin.

What are Nutrients and Triazine Herbicides?

Nutrients are some of the many elements or compounds required to sustain life. In this report, "nutrients" refers to nitrate and phosphorus, forms of two important nutrients essential for healthy plant growth. Although necessary in small amounts, elevated concentrations of nitrate and phosphorus have been associated with undesirable environmental conditions and human-health problems. For example, 0.3 mg/L (milligram per liter) of nitrate as nitrogen (N) is a critical concentration that, when exceeded, can stimulate excessive growth of algae in streams (McKee and Wolf, 1963), while the U.S. Environmental Protection Agency (USEPA) (1986) recommends total phosphorus should not exceed 0.05 mg/L as phosphorus (P) if nuisance growths in free-flowing streams are to be prevented. To protect human health, the USEPA has established a maximum contaminant level (MCL) of 10 mg/L as N for nitrate concentration in public drinking-water supplies.

Herbicides are chemicals used to control unwanted plant growth. They are widely used in both agricultural and urban areas. Triazine herbicides are a major class of these herbicides used extensively for weed control on agricultural lands in Pennsylvania. The most widely used of the triazine compounds is atrazine. The USEPA has established an MCL of 3 µg/L (micrograms per liter) for atrazine in public drinking-water supplies. Atrazine also has been listed as a "toxic of concern" for the Chesapeake Bay ecosystem.

How Was the Study Conducted?

During June 28-30, 1995, the USGS collected water-quality samples at 48 stream sites and 1 municipal wastewater-treatment outfall (site 15) during low-flow conditions in the Chickies Creek Basin (fig. 1). Samples were collected when streamflow was representative of normal summer base flow. During base-flow conditions, most of the streamflow is sustained by

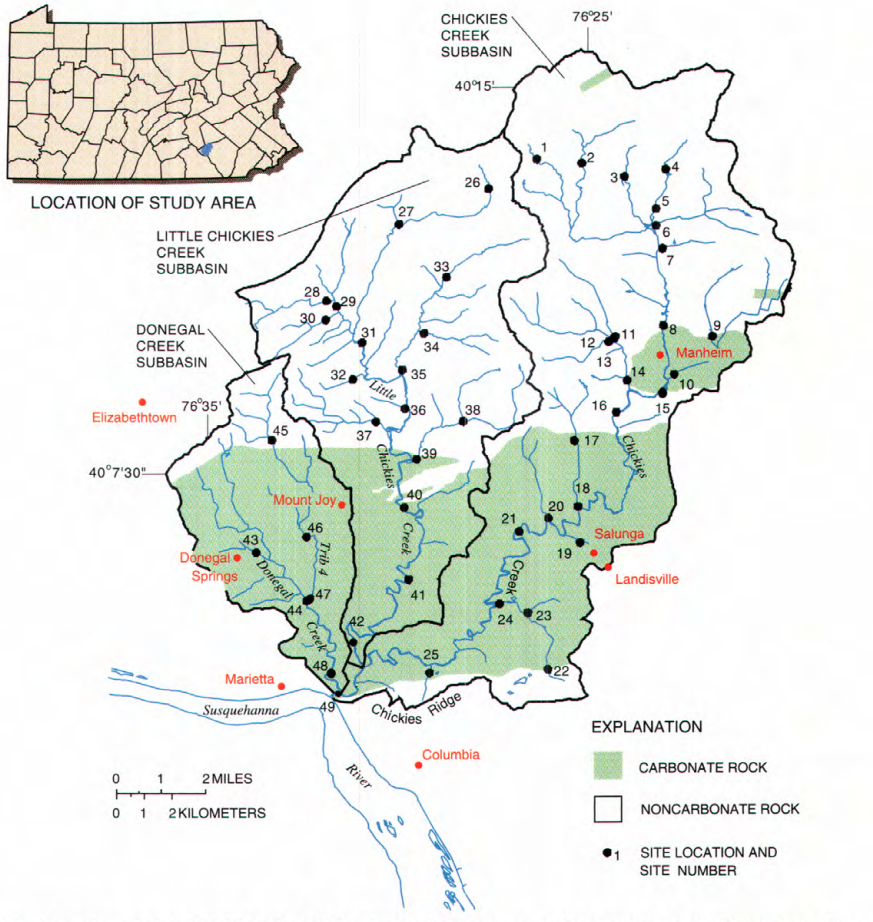

Figure 1. Location of the Chickies Creek Basin, major streams, urban areas, sampling sites, site numbers, and rock type.

Figure 2. Major land uses in the Chickies Creek Basin.

ground-water discharge; thus, concentrations of nutrients and herbicides in the stream should approximate concentrations in ground water. Stream sites were selected so that a spatial distribution of nutrients and triazine-herbicide concentrations could be determined and, where possible, concentrations could be related to a predominant land use or rock type.

Water-quality samples were analyzed by the USGS for dissolved nutrients and triazine herbicides. The sampling for dissolved nutrients included analyses for ammonia, nitrite, organic nitrogen, nitrate, phosphorus, and orthophosphorus. Only the predominant forms of these nutrients (nitrate and phosphorus) are discussed in this report. The herbicides were measured using an immunoassay procedure sensitive to the predominant triazine compounds used in the basin. Additionally, streamflow discharge was measured, and pH, water temperature, specific conductance, and alkalinity were recorded at the time of sample collection. Duplicate samples were collected from five sites and analyzed for all constituents to provide quality assurance.

Where is Chickies Creek Located?

The Chickies Creek Basin is located in the Piedmont Physiographic Province in south-central Pennsylvania. The basin occupies approximately 126 mi^2 (square miles)—7.6 mi^2 of southern Lebanon County and 118.4 mi^2 of western Lancaster County. Chickies Creek drains into the lower Susquehanna River between the towns of Marietta and Columbia (fig. 1).

Chickies Creek receives drainage from over 50 small tributaries. Near where it empties into the Susquehanna River, the main stem of Chickies Creek is joined by two large tributaries, Little Chickies Creek and Donegal Creek (fig. 1). For purposes of discussion in this report, the Chickies Creek Basin is divided into three subbasins, the 64.3 mi^2 that drain directly to Chickies Creek (Chickies Creek subbasin), the 44.5 mi^2 that drain to Little Chickies Creek (Little Chickies Creek subbasin), and the 17.2 mi^2 that drain to Donegal Creek (Donegal Creek subbasin).

Chickies Creek originates in a heavily wooded area in the northernmost part of the basin, flows south through agricultural land, flows adjacent to the Borough of Manheim, and finally flows through more agricultural land before emptying into the Susquehanna River. Little Chickies Creek also originates in the heavily wooded northernmost areas of the basin, flows south through agricultural land, and joins Chickies Creek about 1 mi (mile) upstream from the Susquehanna River. Donegal Creek originates in agricultural land near Donegal Springs, about 3 mi southwest of Mount Joy, flows south through agricultural land, and enters Chickies Creek about 0.3 mi upstream from the Susquehanna River.

What is the Land Use in the Chickies Creek Watershed?

Agriculture, forest, and urban are the three major land-use groups used to characterize the Chickies Creek Basin (fig. 2). Agriculture accounts for 83 percent of the land use in the basin and varies in intensity within each subbasin. The Chickies Creek subbasin is the least agricultural (78 percent), whereas in the Donegal Creek subbasin, nearly 91 percent of the land is used for agricultural purposes (table 1).

Table 1. Total area and percentage for each of three major land-use classifications in three subbasins and the entire Chickies Creek Basin

[mi^2, square miles]

Land-use classification	Chickies Creek subbasin		Little Chickies Creek subbasin		Donegal Creek subbasin		Entire Chickies Creek Basin	
	mi^2	percent	mi^2	percent	mi^2	percent	mi^2	percent
Agriculture	50.5	78	38.3	86	15.6	91	104	83
Forest	10.7	17	2.8	6	0	0	13.5	11
Woodlots	1.2	2	1.4	3	.2	1	2.8	2
Urban	1.9	3	2.0	5	1.4	8	5.3	4
Total	64.3	100	44.5	100	17.2	100	126	100

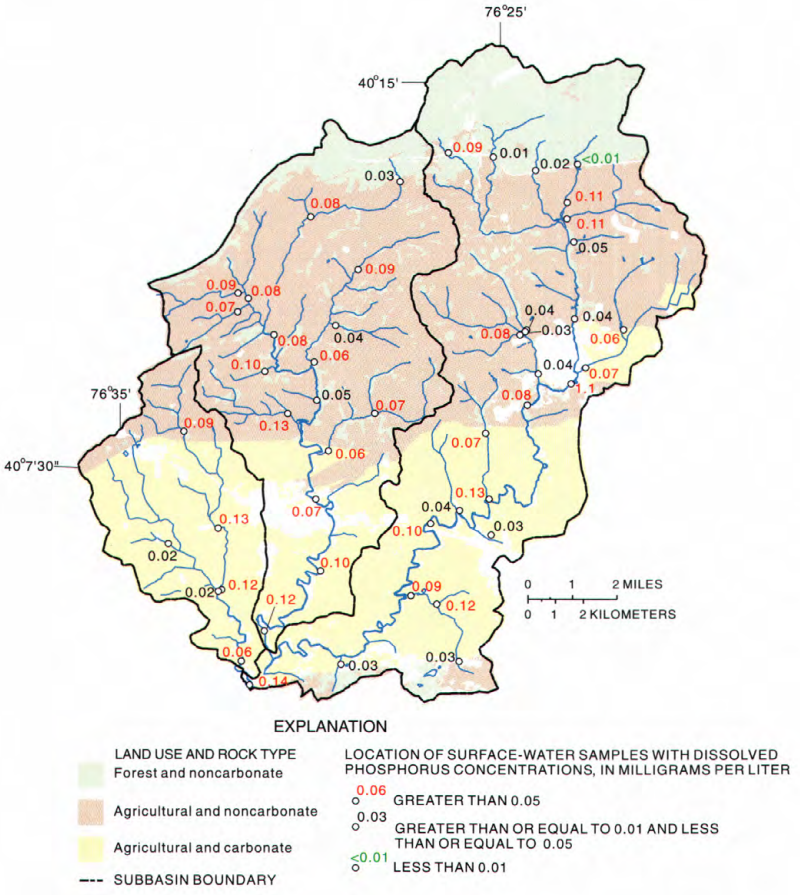

Figure 4. Distribution of dissolved phosphorus concentrations in the Chickies Creek Basin.

What is the Spatial Distribution of Nutrient Concentrations?

Concentrations of dissolved nitrate in the streams of the Chickies Creek Basin sampled June 28-30 ranged from 0.26 to 22 mg/L as N. The lowest concentrations (0.26 to 1.6 mg/L as N) were measured in samples collected from streams that drain the forested areas along the northern edge of the basin (fig. 3). Samples from streams that drain agricultural areas throughout the remainder of the basin had significantly higher concentrations of dissolved nitrate than samples from streams in the forested areas. Nitrate concentrations in streams that drain the noncarbonate rocks in agricultural areas (brown-shaded area in fig. 3) ranged from 1.2 mg/L as N in an unnamed tributary that drains a small noncarbonate basin with minimal agricultural activity north of Mount Joy (site 32) to about 14 mg/L in a tributary northeast of Manheim (site 9). About 42 percent of the nitrate concentrations ranged from 6 to 8 mg/L as N.

Nitrate concentrations in the streams that drain intensively farmed areas underlain by carbonate rocks (yellow-shaded areas in fig. 3) ranged from 5.6 to 22 mg/L as N. About 44 percent of the nitrate concentrations were greater than 10 mg/L. Although the range and median concentration of dissolved nitrate were greater in the agricultural areas underlain by carbonate rock than the agricultural areas underlain by noncarbonate rock, these differences were not statistically significant.

The median concentration of nitrate in the Donegal Creek subbasin (15 mg/L) was significantly higher than the median concentrations in Chickies Creek subbasin (6.8 mg/L) and the Little Chickies Creek subbasin (7.9 mg/L). The nitrate concentrations are higher in Donegal Creek subbasin, in part, because it contains the greatest percentage of intensively farmed areas underlain by carbonate rocks of the three subbasins. The nitrate concentration measured in Donegal Creek just downstream from Donegal Springs (site 43) was 20 mg/L as N, one of the highest concentrations in the Chickies Creek Basin (fig. 3). The concentration of nitrate in Donegal Creek just upstream from the confluence with tributary 4 (site 44) was 19 mg/L. Nitrate concentrations in the upper and middle reaches of tributary 4 to Donegal Creek averaged 7.5 mg/L and increased to 14 mg/L as N in the lower reach just upstream from the confluence with Donegal Creek (site 47). The nitrate concentrations at the mouth of Donegal Creek (site 48) remained elevated (17 mg/L as N) compared to the mouths of Chickies Creek (site 49, 7.6 mg/L as N) and Little Chickies Creek (site 42, 8.6 mg/L as N). Additionally, the nitrate concentration in a tributary draining a mostly urban area at Salunga (site 19) was 5.6 mg/L, and the nitrate concentration in a stream underlain by the noncarbonate Chickies Formation (site 25) along the extreme southern edge of the basin was 2.5 mg/L (fig. 3).

Dissolved phosphorus concentrations were not nearly as variable as nitrate concentrations, ranging from less than 0.01 to 0.14 mg/L (fig. 4). Similar to nitrate concentrations, dissolved phosphorus concentrations were lowest (less than 0.01 to 0.09 mg/L as P) in the forested areas underlain by noncarbonate rock along the northern edge of the basin (green-shaded areas in fig. 4) and were greatest (0.03 to 0.14 mg/L as P) in the agricultural areas underlain by carbonate rock in the southern one-third of the basin (yellow-shaded areas in fig. 4).

What is the Spatial Distribution of the Triazine-Herbicide Concentrations?

Triazine-herbicide concentrations were lowest in the forested areas of the Chickies Creek and Little Chickies Creek subbasins. All but one sample in the forested areas were below the detection limit of 0.1 µg/L. Similar to nitrate concentrations, triazine concentrations showed a gradual increase from the headwaters to the mouth of each subbasin (fig. 5). This increase coincided with the change in land use and rock type. The median concentration of triazine herbicides (0.70 µg/L) in Donegal Creek subbasin was greater than in either of the other two subbasins. Triazine-herbicide concentrations reached the maximum value of 2.0 µg/L at the mouth of Chickies Creek near the Susquehanna River. The concentrations probably were low throughout the basin due to the sampling occurring in mid-summer. Most of the triazine herbicide is applied when crops are planted (usually in April) as pre-emergent weed control. Over time, triazine concentrations slowly decline in the soil and surface and ground waters.

Are There Relations Between Concentrations, Land Use, and Geology?

Previous studies (Lietman and others, 1983; Ott and others, 1991; Langland and Fishel, 1993; Langland and others, 1995) have shown that in Pennsylvania, land use within a basin has a direct effect on water quality. Results from this investigation in the Chickies Creek

Figure 5. Distribution of triazine-herbicide concentrations in the Chickies Creek Basin.

Basin support these previous studies. Agricultural activity, together with basin hydrogeology, is believed to have the greatest effect on nutrient and triazine-herbicide discharges in surface and ground water in the Lower Susquehanna River Basin. Applications of manure, commercial fertilizers, and herbicides provide large sources of these contaminants available for transport either by direct surface runoff or infiltration to the ground water. Hydrogeologic factors such as bedrock structure, bedrock chemistry, and soil type affect nutrient pathways and transport rates.

To evaluate the effect of land use and rock type on concentrations of nitrate, phosphorus, and triazine herbicides in the Chickies Creek Basin, samples were grouped into three categories—(1) forested land underlain by noncarbonate rock, (2) agricultural land underlain by noncarbonate rock, and (3) agricultural land underlain by carbonate rock (see figs. 3-5). The distribution of nitrate, phosphorus, and triazine-herbicide concentrations in each group were compared in figure 6 and apparent differences were tested for statistical differences. The highest concentration of nitrate (22 mg/L as N) and the greatest median concentrations of nitrate (8.3 mg/L), phosphorus (0.09 mg/L), and triazine herbicide (0.60 µg/L) were in areas of agricultural land underlain by carbonate rock (fig. 6). These areas are located in the southern one-third of the basin where agricultural activity is most intense and highly productive (yellow-shaded areas in figs. 3-5). The lowest median concentrations of nitrate (1.08 mg/L), phosphorus (0.03 mg/L), and triazine herbicide (0.10 µg/L) occurred in forested areas underlain by noncarbonate rock (fig. 6) located in the headwaters where agricultural activity is less intense and less productive (green-shaded areas in figs. 3-5). Differences in concentrations of dissolved nitrate, dissolved phosphorus, and triazine herbicides were statistically significant between samples from forested sites and the other two groups (fig. 6). However, there was no significant difference between agricultural land underlain by carbonate rock and the agricultural land underlain by noncarbonate rock for any constituent sampled. The highest median concentrations of dissolved nitrate, dissolved phosphorus, and triazine herbicides in any subbasin occurred in the Donegal Creek subbasin. Concentrations of nitrate and triazine herbicides from samples collected in the Donegal Creek subbasin were also significantly higher than the concentrations in samples collected from either the Chickies Creek subbasin or the Little Chickies Creek subbasin.

Nutrients and Triazine Herbicides—Is There a Concern?

Results of this sampling during low-flow conditions indicate that 47 of the 48 samples had nitrate concentrations in excess of 0.3 mg/L as N, which is the approximate level at which excessive growth of algae is promoted in lakes and slow-moving stream waters. Nitrate concentrations at 13 sites (27 percent) exceeded 10 mg/L, the MCL set by the USEPA for public drinking-water supplies. The nitrate concentration in the main stem of Donegal Creek exceeded the drinking-water standard for all samples collected along the entire length of the creek. Samples at 30 of the 48 sites (62 percent) contained concentrations of dissolved phosphorus in excess of 0.05 mg/L. Dissolved phosphorus at this level can promote nuisance growths of algae. The concentrations of triazine herbicide did not exceed the MCL of 3.0 µg/L established for atrazine in public drinking-water supplies (U.S. Environmental Protection Agency, 1991) in any of the 48 water-quality samples.

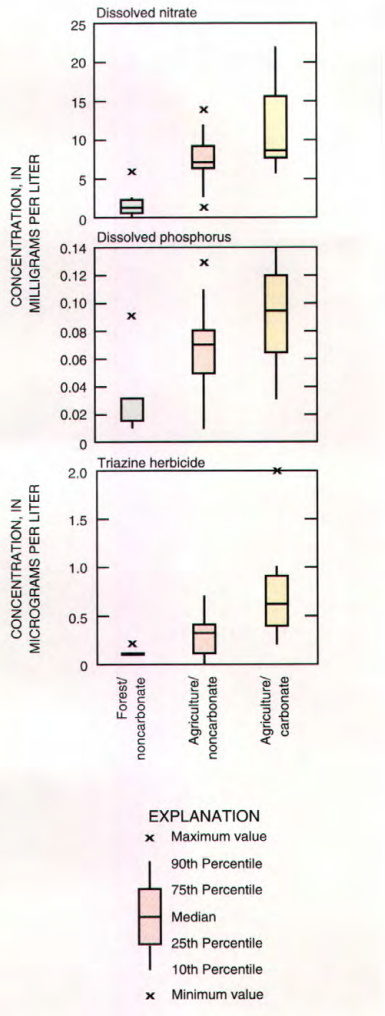

Figure 6. Concentration distribution for three land uses and rock-type combinations in the Chickies Creek Basin.

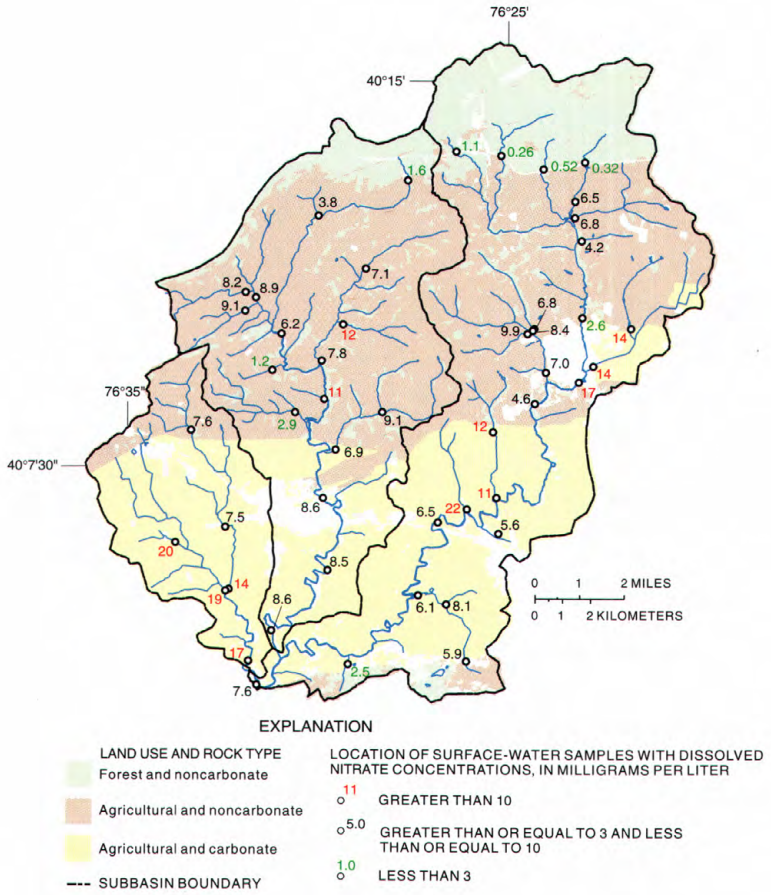

Figure 3. Distribution of dissolved nitrate concentrations in the Chickies Creek Basin.

The least intensive agricultural operations are located in the northern half of the Chickies Creek Basin. These farms typically produce corn, soybeans, and hay and have small herds of dairy cattle, about 40 or less. Most farms in the southern half of the basin have very animal-intensive operations with either large dairy herds or several operations with hogs or chickens. Most intensive farm operations grow corn on all available land. Collection of specific types of animal operations, animal numbers, and crop-production records is beyond the scope of this report, but this type of data is available from the Pennsylvania Department of Agriculture.

Forested areas account for about 13 percent of the basin's total land use. The most heavily forested subbasin is the Chickies Creek subbasin (17 percent), nearly all of which is located in the headwaters. Small "woodlots" (small areas of woods) are present in each subbasin (fig. 2) with a total area of 2.8 mi^2. The largest of the woodlots is about 30 acres, and most are along streams in the northern half of the basin.

Urban land occupies only about 4 percent of the basin, and is fairly evenly spread across the three subbasins (table 1). The largest urban areas include the towns of Manheim, Mount Joy, Salunga, and Landisville. Numerous housing developments are located within the basin along with development that parallels many of the roads in the basin.

What is the Geology of the Chickies Creek Watershed?

The rocks in the basin can be divided into two groups on the basis of their composition: carbonate and noncarbonate (fig.1). The carbonate rocks (limestone and dolomite) weather to produce deep, rich soils, which are some of the most fertile and agriculturally productive in the United States. Sinkholes, closed depressions, large springs, and karst topography are typical features of these areas underlain by carbonate rocks. The carbonate rocks generally underlie the central and southern areas of the basin and consist of the Stonehenge and Epler Formations of Ordovician age and several formations of Cambrian age, which include the Millbach, Snitz Creek, and Buffalo Springs Formations (Berg and others, 1980). About 42 percent of the basin is underlain by carbonate rocks (table 2), but that percentage varies among the subbasins. For example, about 83 percent of the Donegal Creek subbasin is underlain by carbonate rocks compared to 27 percent of the Little Chickies Creek subbasin.

The noncarbonate rocks include shale, sandstone, quartzite, conglomerates, and diabase. These rocks weather and usually produce thin, poorly drained, rocky soils—factors that are not conducive to productive agricultural activities. Because areas underlain by noncarbonate rocks are more resistant to weathering than carbonate rocks, these areas tend to have steep slopes; however, slopes in some noncarbonate areas can be flat. The noncarbonate rocks underlie about 58 percent of the basin and are located in the northern half and along the southern limit of the basin (fig. 1). The noncarbonate rocks consist of the Hammer Creek Formation and diabase dikes, both of Triassic age, which are generally forested, and the Triassic New Oxford Formation and Ordovician Cocalico Shale, which supports varying amounts of agriculture. The southern limit of the basin is along the top of Chickies Ridge, an area underlain by noncarbonate rocks of Cambrian age.

Table 2. Total area and percentage of carbonate and noncarbonate rocks in three subbasins and the entire Chickies Creek Basin
(mi^2, square miles)

Rock type	Chickies Creek subbasin		Little Chickies Creek subbasin		Donegal Creek subbasin		Entire Chickies Creek Basin	
	mi^2	percent of total	mi^2	percent of total	mi^2	percent of total	mi^2	percent of total
Carbonate rock	26.2	41	12	27.0	14.3	83	52.5	42
Noncarbonate rock	38.1	59	32.5	73	2.9	17	73.5	58
Total	64.3	100	44.5	100	17.2	100	126	100

Summary

Results from 48 samples collected at low flow in the Chickies Creek Basin indicate:

- the highest concentrations of dissolved nitrate, dissolved phosphorus, and triazine herbicides occurred in the agricultural areas;
- the lowest median concentrations of dissolved nitrate, dissolved phosphorus, and triazine herbicides occurred in the forested areas;
- statistically significant differences in concentrations of dissolved nitrate, dissolved phosphorus, and triazine herbicide exist between the forested areas underlain by noncarbonate rocks and agricultural areas regardless of underlying rock type;
- statistically significant differences in concentrations did not exist between agricultural land underlain by carbonate rock and agricultural land underlain by noncarbonate rock; and
- the Donegal Creek subbasin is the most impacted subbasin in terms of high nutrient and triazine-herbicide concentrations.

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Contacts for Further Information

Additional water-quality data collected during this study are published in the USGS Annual Data Report for water year 1995. Please contact the following:

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