Environmental Setting of the Morgan Creek Basin, Maryland, 2002-04

By Tracy Connell Hancock and Michael J. Brayton

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Conversion Factors and Vertical Datum

Multiply	By	To obtain
	Length	
centimeter (cm)	0.3937	inch (in.)
millimeter (mm)	0.03937	inch (in.)
meter (m)	3.281	foot (ft)
kilometer (km)	0.6214	mile (mi)
meter (m)	1.094	yard (yd)
	Area	
square meter (m^2)	0.0002471	acre
square kilometer (km^2)	247.1	acre
hectare (ha)	0.003861	square mile (mi^2)
square kilometer (km^2)	0.3861	square mile (mi^2)
	Volume	
liter (L)	0.2642	gallon (gal)
cubic meter (m^3)	264.2	gallon (gal)
cubic meter (m^3)	0.0002642	million gallons (Mgal)
liter (L)	61.02	cubic inch (in^3)
cubic meter (m^3)	35.31	cubic foot (ft^3)
	Flow rate	
cubic meter per second (m^3/s)	35.31	cubic foot per second (ft^3/s)
cubic meter per second (m^3/s)	22.83	million gallons per day (Mgal/d)
	Mass	
milligram (mg)	35.27	ounce, avoirdupois (oz)
gram (g)	0.03527	ounce, avoirdupois (oz)
kilogram (kg)	2.205	pound avoirdupois (lb)

Temperature in degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) as follows:

$$°F=(1.8\times°C)+32$$

Vertical datum: In this report, vertical coordinate information is referenced to the National Geodetic Vertical Datum of 1929 (NGVD 29) and (where noted) to the North American Datum of 1983 (NAD 83).

Concentrations of chemical constituents in water are given either in milligrams per liter (mg/L) or micrograms per liter (µg/L).

Water year is the 12-month period between October 1 through September 30. The water year is designated by the calendar year in which it ends and which includes 9 of the 12 months. Thus, the year ending September 30, 2003, is called the "2003 water year."

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Abstract

The Morgan Creek Basin is a 31-square-kilometer watershed in Kent County, Maryland on the Delmarva Peninsula. The Delmarva Peninsula covers about 15,500 square kilometers and includes most of the State of Delaware and parts of Maryland and Virginia east of the Chesapeake Bay. The Morgan Creek Basin is one of five sites selected for the study of sources, transport, and fate by the U.S. Geological Survey (USGS) National Water-Quality Assessment (NAWQA) Program's: Agricultural Chemicals: Sources, Transport and Fate study team (Agricultural Chemicals Team, ACT). A key component of the study is identifying the natural factors and human influences affecting water quality in the Morgan Creek Basin.

The Morgan Creek Basin is in the Coastal Plain Physiographic Province, which is a nearly level seaward-sloping lowland with areas of moderate topographic relief. The study area lies within a well-drained upland region with permeable and porous soils and aquifer sediments. The soils are well suited to most field crops.

Agriculture is the principal land use in the Morgan Creek Basin, as well as throughout the entire Delmarva Peninsula. Most agricultural land is used for row crops such as corn, soybeans, and small grains, and slightly less land is used for pasture and hay production involving alfalfa, clover, and various perennial grasses. There are several animal operations in the study area. Farm management practices include fertilizer and herbicide applications, different tillage practices, addition of lime, forested riparian buffers, grassed waterways, and sediment retention ponds. Irrigation in the study area is minimal.

The climate of the Morgan Creek Basin is humid and subtropical, with an average annual precipitation of 1.12 meters. Overall annual precipitation is evenly distributed throughout the year, from 76 to 101 millimeters per month; however, the spring and summer (March – September) tend to be slightly wetter than the autumn and winter (October – February). Anomalously high precipitation can occur in summer/early autumn due to occasional hurricanes and tropical storms. Thunderstorms can also produce relatively high localized precipitation over the Morgan Creek Basin during the summer months.

Mean daily streamflows for Morgan Creek are highly variable, and somewhat flashy due to the relatively small area of the basin. The long-term median base flow for Morgan Creek is 59 percent of total flow, indicating that total streamflow is most often dominated by a sustained ground-water contribution. Surface runoff accounts for the other 41 percent of the water in total streamflow and dominates during and just after precipitation events.

The surficial aquifer in the study area consists of permeable quartz-rich sand and gravel and is underlain by less permeable marine sand, silt, and clay. The depth to water table ranges from less than 0.4 meters below land surface in the floodplain to 12 meters below land surface in upland areas. Ground water generally flows from uplands toward the Morgan Creek floodplain at a variety of depths and time scales. Because the soils and sediments are permeable and porous, some fraction of chemicals applied to the land surface tend to move downward to the water table where they are transported to discharge areas near Morgan Creek.

Introduction

The Morgan Creek Basin is located in Kent County, Maryland on the Delmarva Peninsula (fig. 1), which covers about 15,500 km^2 (square kilometers) and includes most of the State of Delaware and parts of Maryland and Virginia east of the Chesapeake Bay. The Morgan Creek Basin is one of five sites selected for the study of sources, transport, and fate by the U.S. Geological Survey (USGS) National Water-Quality Assessment (NAWQA) Program's: Agricultural Chemicals: Sources, Transport and Fate study team (Agricultural Chemicals Team, ACT). The primary goal of the ACT study is to identify the natural and human factors affecting the transport and fate of agricultural chemicals in different environmental settings nationwide.

The other agricultural basins in the ACT study included Mustang Creek Basin and the lower Merced River Basin in central California, Leary Weber Ditch Basin and Sugar Creek Basin in central Indiana within White River Basin, DR2 Drain Basin and the Granger Drain Basin in south-central Washington within the Yakima River Basin, and Maple Creek Basin in Nebraska. Additionally, two more studies began in 2005 in Iowa and Mississippi. As the studies progress, additional basins will likely be added. The basins in the studies represent a range of agricultural settings—with varying crop types and agricultural practices related to tillage, irrigation, artificial drainage, and chemical use—as well as a range of landscapes with different geology, soils, topography, climate, and hydrology. Consistent methodology and analysis allow comparisons among the different basins. This study design leads to an improved understanding of the many factors that can affect the movement of water and chemicals in different agricultural settings. There was an attempt to keep the local study designs as consistent as possible, but only the study components that were locally pertinent were included.

Purpose and Scope

To understand the sources, transport, and fate of agricultural chemicals on a basin level, intensive chemical sampling was conducted in the Morgan Creek Basin from 2002 through 2004. Samples were collected from each environmental "compartment" within the basin and specifically from a single agricultural field along the creek. Environmental compartments sampled included precipitation, unsaturated zone water, surface water, ground water, and riparian zone seepage water. The report provides a description of major natural (physiography, geology, soils, climate, and hydrology) and human components (land and water use, population, and modifications to the natural hydrology) of the environmental setting.

Previous Studies

Several previous investigations characterized the surface- and ground-water quality of the Delmarva Peninsula. In 1986, the USGS NAWQA Program began pilot studies to assess the quality of the Nation's surface- and ground-water resources. A regional ground-water quality assessment of the Delmarva Peninsula was one of the pilot studies conducted for the NAWQA Program (Shedlock and others, 1993). The study focused on the surficial aquifer and used both existing data and newer data collected from 1988 to 1991 (Hamilton and others, 1991; Hamilton and others, 1993; Shedlock and others, 1999; Koterba and others, 1993) to characterize ground-water quality on the Delmarva Peninsula.

Later studies of the Morgan Creek Basin established an understanding of the effects of hydrogeology on surface-water quality and the interaction between surface and ground water on water quality. Böhlke and Denver (1995) evaluated the history and fate of nitrate contamination of ground water using age dating, chemical, and isotopic analyses. They documented the occurrence of denitrification in shallow subsurface geologic formations, and assessed the effect of denitrified discharge water on the chemical composition of stream base flow. The U.S. Environmental Protection Agency developed analytical and numerical models of ground-water flow and nitrate transport, and assessed the basin capacity for nitrogen reduction (Hantush and Cruz, 1999; Hantush and Marino, 2001). Bachman and others (2002) described the hydrogeology, ground-water geochemistry, and assessment of nitrogen yield from base flow in Morgan Creek.

Ator and others (2000; 2003) related previously collected shallow ground-water-quality data in the Mid-Atlantic Coastal Plain and newly collected stream-water-quality data in the study area to surficial hydrogeology. Ator and others (2005) delineated different hydrogeologic settings for the Mid-Atlantic Coastal Plain on the basis of geomorphology, and the thickness and texture of surficial sediments and underlying confining beds.

The NAWQA Program conducted a follow-up assessment of water quality, Cycle II, in ground water and streams on the Delmarva Peninsula from 1999 to 2001 (Denver and others, 2004). In a similar manner to the pilot study from 1988 to 1991, water quality was assessed at many scales–from local ground-water flow paths to regional ground-water networks, and in surface water. In this Cycle II NAWQA study, trends in water quality were evaluated with respect to changes in chemical sources, land use, and chemical transport and fate.

Water discharge data have been continuously collected by the USGS at one fixed streamflow-gaging station in the Morgan Creek Basin since 1951: USGS Station 01493500, Morgan Creek near Kennedyville, Maryland. The streamflow-gaging station on Morgan Creek is in Hydrologic Unit 02060002. This site consists of a telemetered water-stage recorder, which provides near real-time data via the Internet (http://waterdata.usgs.gov/md/nwis/uv?01493500). A concrete control weir forms a small pool, and a few hundred yards below this pool, the stream becomes tidal. During unusually strong storms, when southwesterly winds are sustained, water can mound on the eastern side of the Chesapeake Bay and be forced into tributaries. The result is a higher-than-normal high tide that affects the gage pool with backwater, raising the stage so as to inaccurately reflect the actual discharge. During these infrequent and short-duration tidal events, stream records can be estimated by removing tidal effects using downstream tide-gage data.

Surface-water quality data have been collected in several previous studies at both the Morgan Creek streamflow-gaging station (located in the southwest portion of the Morgan Creek Basin), and other upstream locations (Böhlke and Denver, 1995; Bachman and others, 2002; Ator and others, 2003). As part of the NAWQA National Trends Monitoring Program, a continuous in-stream monitor was operated in Morgan Creek

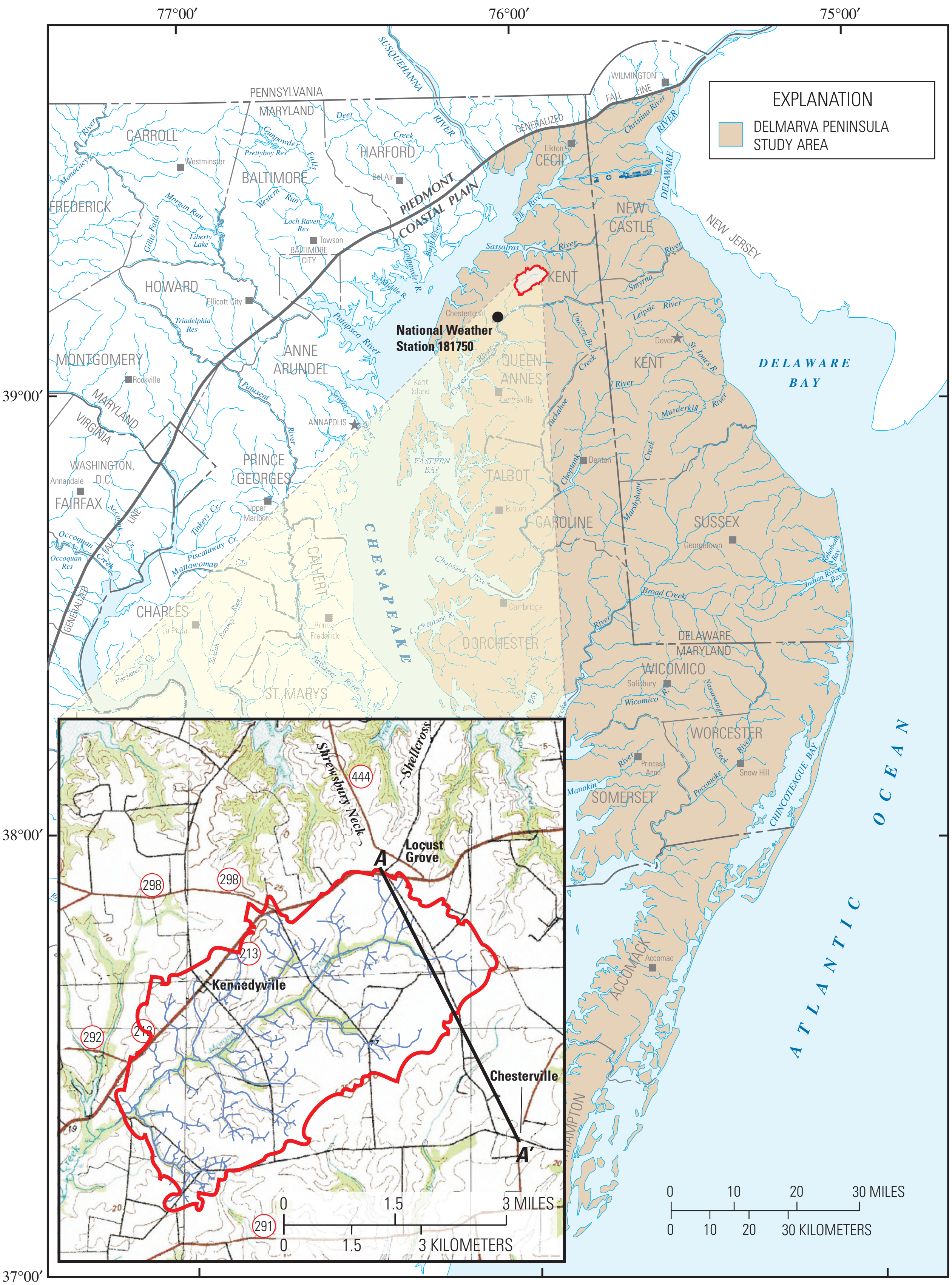

Figure 1. The Delmarva Peninsula and Morgan Creek Basin, Maryland.

at the streamflow-gaging station from April 2002 to October 2004, to measure temperature, specific conductance, dissolved oxygen, and pH.

Denver and others (2004) found that on the Delmarva Peninsula in 2001, nitrogen concentrations were greater than 3 mg/L (milligrams per liter) in about half of the headwater streams sampled during base-flow conditions in the spring. At the same time, in the surficial aquifer, the median nitrate concentration in 48 ground-water wells was 5.8 mg/L as N (nitrogen). In well-oxygenated areas of the surficial aquifer, this concentration increased by an average of 2 mg/L between 1988 and 2001. Concentrations of nitrate were above 10 mg/L as N, the Federal standard for drinking water (U.S. Environmental Protection Agency, 2002), in about one-third samples from 29 wells in the part of the aquifer used for domestic water supply.

Denver and others (2004) also found that phosphorus was transported to streams and rivers on the peninsula, primarily with overland runoff during storms. Concentrations of total phosphorus were typically less than 0.1 mg/L at base flow in well-drained areas. Phosphorus strongly attaches to soil particles in well-drained agricultural soils and, as a result, concentrations of dissolved phosphorus in ground water in the surficial aquifer rarely exceed 0.1 mg/L in spite of relatively large phosphorus applications.

Atrazine was one of the most frequently detected herbicides in streams and surficial ground water throughout the Delmarva Peninsula (Denver and others, 2004; Ator and others, 2004) and the Nation (Kolpin and Kalkoff, 1993). Denver and others (2004) frequently observed metolachlor and simazine in surficial ground water and streams throughout the Delmarva Peninsula.

Environmental Setting: Physical and Cultural Features, Climate, and Hydrology

The Morgan Creek study area is in central Kent County, Maryland in the northwest region of the Delmarva Peninsula (fig. 1). It is situated between the tidal Chester and Sassafras Rivers, about 15 km (kilometers) northeast of Chestertown, Maryland. Morgan Creek is a small stream which drains a 31-km^2 basin and flows directly into the tidal part of the Chester River. It is surrounded by rural farmland and flows past the village of Kennedyville. Forested riparian zones border most areas of the creek and many of its tributaries. Morgan Creek flows 9.8 km toward the southwest from its source in the upper northeast portion of the basin to the streamflow-gaging station (USGS Station 01493500), and a total of 18.8 km from its source to the confluence with the Chester River (fig. 1).

Physical Features

The Delmarva Peninsula covers about 15,500 km^2 and includes most of the State of Delaware and parts of Maryland and Virginia east of the Chesapeake Bay. The entire peninsula lies within the Coastal Plain Physiographic Province, which is locally a broad central upland with flat to gently rolling topography, flanked by low plains that slope toward surrounding water bodies (Denver and others, 2004). The highest elevation on the Delmarva Peninsula is 151 m (meters) above sea level, in the northern part (National Elevation Dataset, 1999).

The peninsula is underlain by a series of unconsolidated deposits of sand, silt, clay, gravel, and seashells. This wedge of unconsolidated sediments underlying the peninsula thickens to the south and east. The thickness ranges from virtually zero in the northern part of the peninsula to more than 2,400 m along the Atlantic Coast of Maryland. Cushing and others (1973) divided these deposits into a complex aquifer system consisting of a series of confined aquifers of coarse sediments (sands and gravels) and associated confining units of finer sediments (silts and clay).

Several different hydrogeologic settings have been delineated within the Delmarva Peninsula (fig. 2) at several different scales by different methods (Shedlock and others, 1993; Bachman and others, 2002; Ator and others, 2000; Ator and others, 2005). Each hydrogeologic setting has a unique set of geologic, geomorphology, drainage patterns, soils, and land-use patterns.

Physiography

The Morgan Creek Basin is characterized by flat and gently rolling topography (fig. 3) (White, 1982). The majority of the study area is from 18 to 25 m above sea level and consists of nearly level or undulating land that is dissected in places by ravines. The study area lies within a well-drained upland region (fig. 2), which includes permeable soils and aquifer sediments that are deeply incised by stream valleys (Hamilton and others, 1991; Shedlock and others 1993). The valleys are sometimes inundated by water during periods of heavy rainfall or high tides.

The drainage network for Morgan Creek (fig. 3) includes a series of tributaries that originate in the central upland regions of the basin. In general, surface drainage in the study area is good. Ponds are fairly common in the basin and most of them were constructed for sediment retention from farm runoff. Grassed waterways are prevalent and serve to route water off fields and control eroding sediment during rain storms (Natural Resources Conservation Service, 2005). Most of these grassed waterways lead to sediment retention ponds that are often not lined (Craig McSparron, University of Maryland, Cooperative Extension, oral commun., 2005).

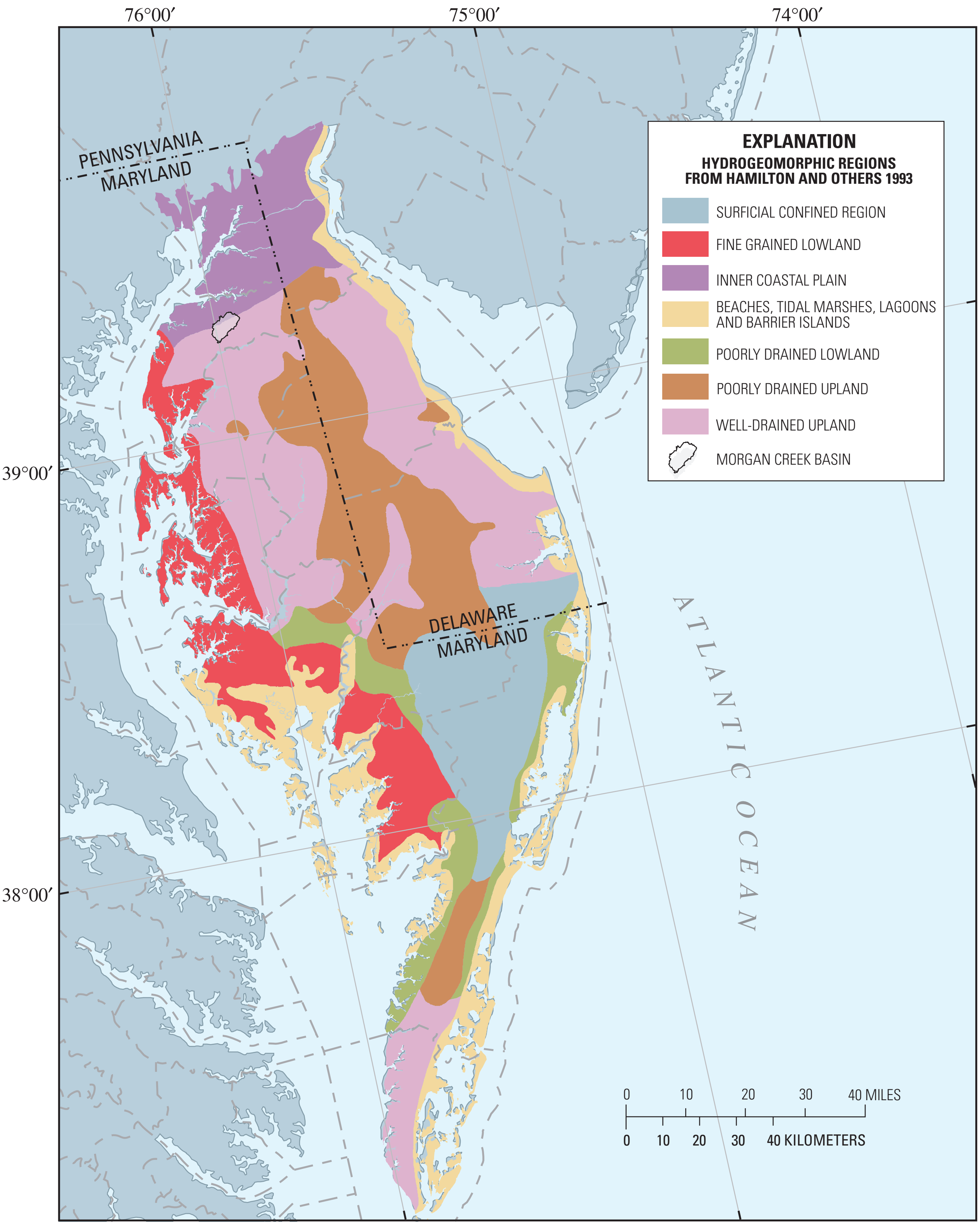

Figure 2. Hydrogeomorphic regions in the surficial aquifer on the Delmarva Peninsula (from Hamilton and others, 1993; modified from Shedlock and others, 1999).

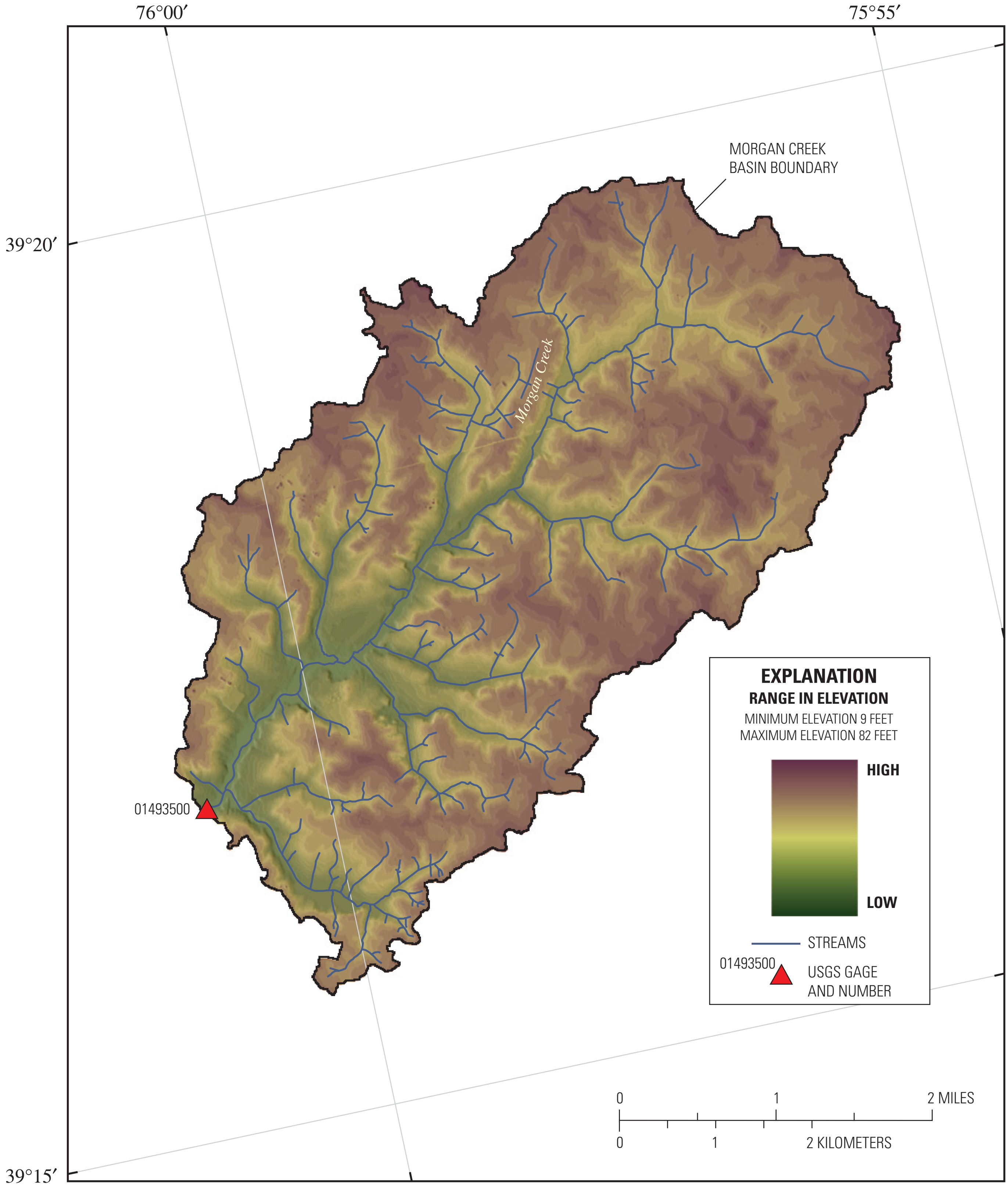

Figure 3. Topography and hydrography of the Morgan Creek Basin, Maryland.

Geology

The geology of the Morgan Creek Basin, like that of the peninsula, includes a series of coarse and finer sediments in unconfined aquifers and confining units. The regional confining layer is a low-permeability clay bed in the Severn Formation (fig. 4). This unit lies more than 50 m below land surface throughout most of the study area (Bachman and others, 2002). Above this confining layer, there are two lithologically similar, coarsening upward sequences of marine glauconitic sands with varying amounts of silts and clays, which dip and thicken to the southeast. Specifically, these consist of fine-to-medium quartz sands with abundant (30 to 50 percent) glauconite grains in a silt-clay matrix and are light olive-brown with dark reddish-brown flecks of glauconite. The lower of these units is the Paleocene Hornerstown Formation (Bachman and others, 2002), and above that is the upper Paleocene Aquia Formation (figs. 4 and 5).

Throughout the study area, the Hornerstown Formation is generally 16 m thick. The top of this formation ranges from 10 m above sea level in the northwest part of the study area to more than 20 m below sea level in the southeast part of the study area. The contact between the Aquia and the Hornerstown Formations is usually not a distinctive lithologic break and is commonly identified on gamma logs as the transition between the silt-clay-rich parts at the bottom of the Aquia and the sandy top part of the Hornerstown (fig. 4) (Bachman and others, 2002). The Aquia Formation subcrops within 3 to 5 m of land surface in a band that strikes southwest to northeast across the northern edge of the study area, but its exact location is poorly known (Bachman and others, 2002). This formation thickens from 5 to 25 m from northwest to southeast.

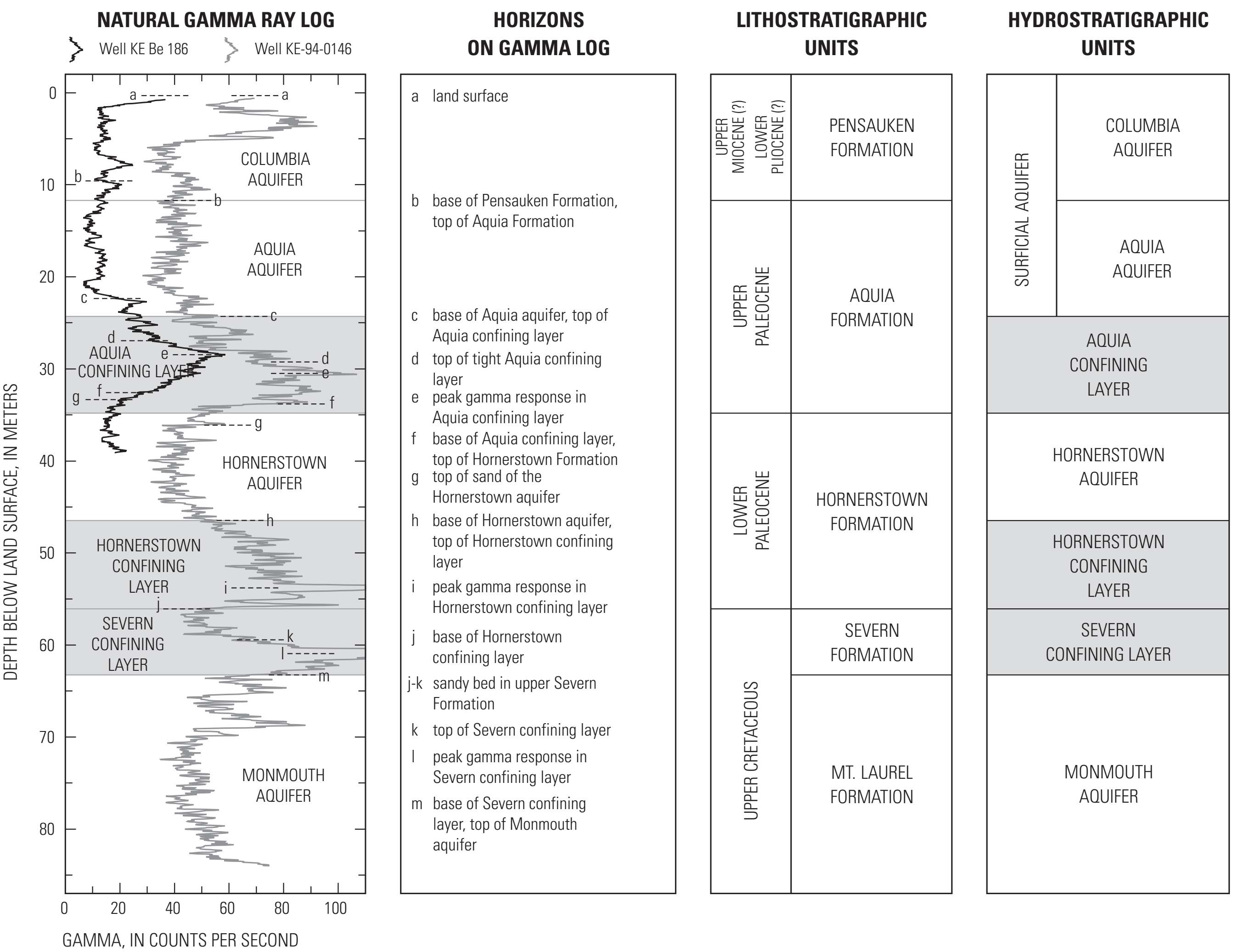

Figure 4. Composite hydrostratigraphic sequence of central Kent County, Maryland (modified from Shedlock and others, 1999; Bachman and others, 2002).

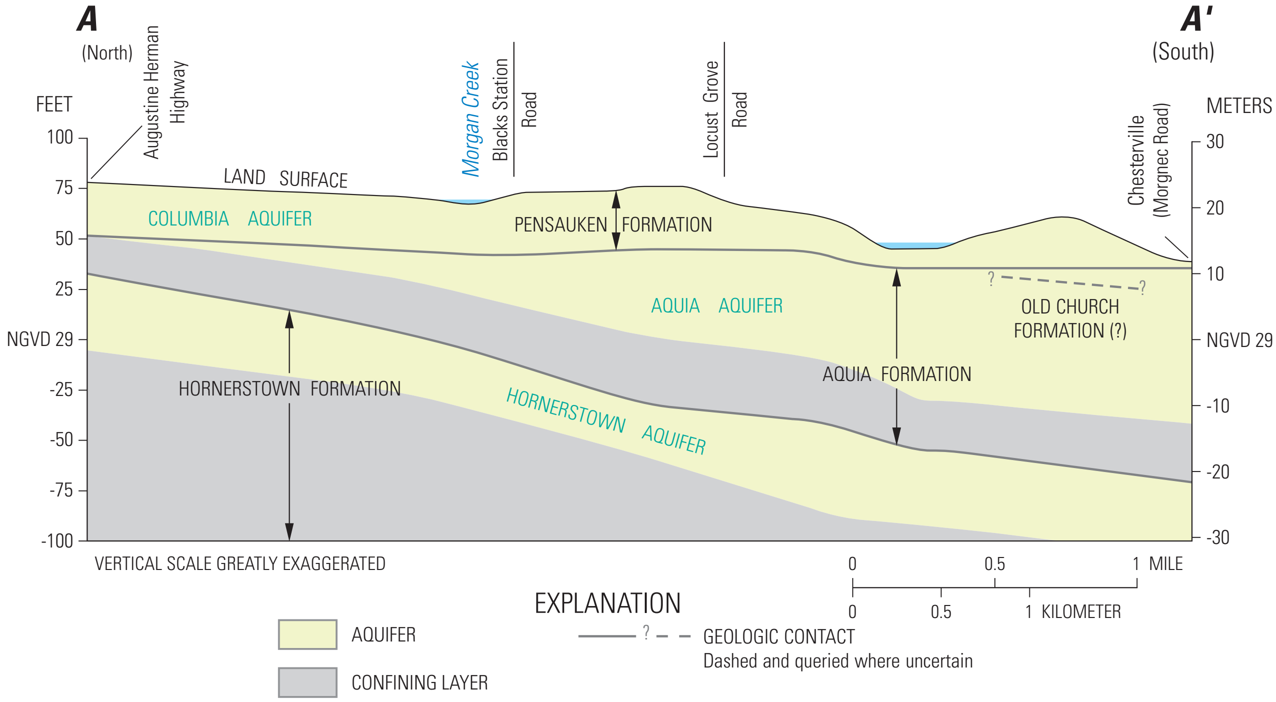

Figure 5. Cross section showing generalized hydrostratigraphy across central Kent County, Maryland (modified from Bachman and others, 2002; Ator and others, 2005). Location of *A-A'* shown in figure 1.

The upland regions of the Morgan Creek Basin are capped by a gravelly, coarse sand known as the Pensauken Formation (figs. 4 and 5), which is thought to be late Miocene to early Pliocene (Owens and Denny, 1979; Owens and Minard, 1979). The Pensauken Formation is lithologically similar to the Columbia Formation (Jordan, 1962, 1964) and some references use these interchangeably. The Pensauken Formation includes medium-to-coarse sands and gravels with common cobbles and less common boulders (Bachman and others, 2002). The sediments are poorly sorted and deeply weathered; the dominant colors are yellowish-orange, light to very light brown (tan), and light gray. These sediments were deposited in a braided-river system that covered most of the central peninsula. Fluvial erosion during the deposition truncated older sediments resulting in a regional angular unconformity at the base of the Pensauken (Bachman and others, 2002). The Pensauken is typically 6 to 15 m thick in the study area and the base is between 12 to 15 m above sea level, but is irregular because of channelization and scouring.

The youngest sediments in the Morgan Creek Basin are the incised valley fill. These Holocene alluvial sediments were derived from erosion of the adjacent upland and are dominantly coarse sands with gravels interbedded with some peat layers and trace amounts of glauconite (Bachman and others, 2002). Although the thickness of this alluvium is inferred because of limited core data, Bachman and others (2002) indicate there may be as much as 4 to 6 m in the stream axis of Morgan Creek. Silty overbank deposits form the modern floodplain and contain organic matter accumulated from the riparian forest (Bachman and others, 2002).

Soils

Soils in the Morgan Creek Basin are predominantly well- to moderately well-drained (fig. 6a) fine silt loams (fig. 6b) that have some clay (Maryland Department of State Planning, 1973; White, 1982; U.S. Department of Agriculture, 2005). These soils have formed in the upland regions and in sloped parts of the study area. Fine loam soils have formed along the wooded regions near the creek, tributaries, and other drainages, and in some upland regions in the southeast part of the study area. Coarse loam soils are typically found in and near the stream channels.

Soils in the uplands and side-sloped regions of the study area, including fine silt loams and fine loams (fig. 6b), are generally 1.5 to 1.9 m deep (including the substratum), fine-to-medium textured, well-drained (fig. 6a), and have moderate to low permeability (White, 1982). Available water capacity is moderate to high. In cultivated areas, the potential for runoff is medium and the hazard of erosion is mostly moderate, although in some soils it is slight. The soils are strongly to

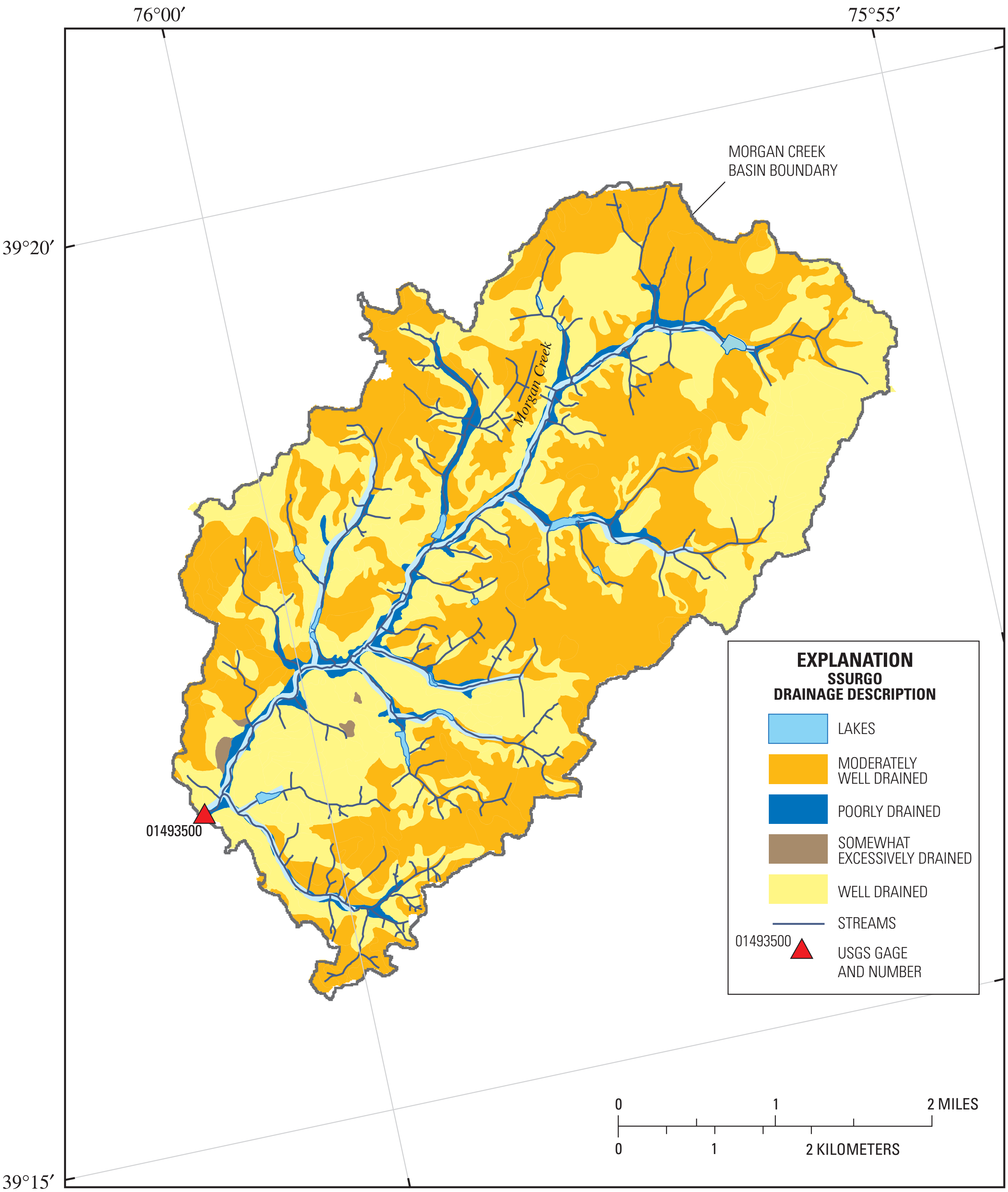

Figure 6a. Soil drainage descriptions in the Morgan Creek Basin, Maryland, based on the Soil Survey Geographic (SSURGO) Database for Kent County, Maryland (from U.S. Department of Agriculture, 2005).

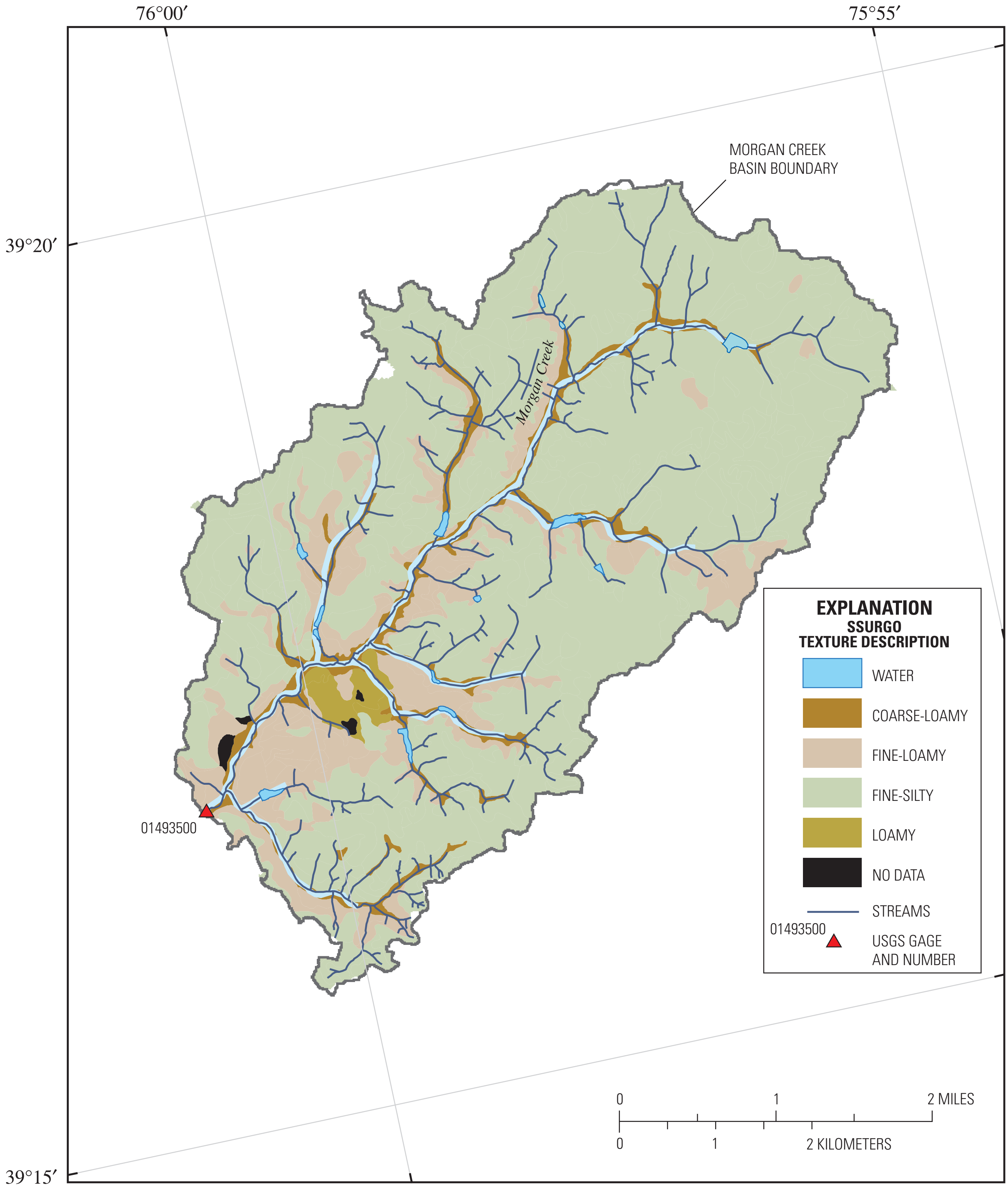

Figure 6b. Soil textures in the Morgan Creek Basin, Maryland, based on the Soil Survey Geographic (SSURGO) Database for Kent County, Maryland (from U.S. Department of Agriculture, 2005).

extremely acidic under natural conditions, although most areas with crop production have been repeatedly treated with lime. These soils are classified as prime farmland (White, 1982) and are well suited to most field crops; however, many of the soils are also well suited for woodland.

Soils in the floodplains are level to nearly level and are poorly drained (fig. 6a) coarse loams (fig. 6b) (White, 1982). These soils are generally 1.5 m deep (including substratum) and have moderate permeability. Available water capacity is high, and surface runoff is low. These soils are frequently flooded, especially in winter and early spring, and strongly acidic throughout the profile. Poor drainage, flooding, and the narrow shape of the areas makes them generally unsuitable for most field crops, and well suited to woodland and wetland habitat.

Cultural Features

The Delmarva Peninsula is mostly a rural setting with several small cities and towns. Agriculture is the main land use and most agricultural land is used for row crops such as corn, soybeans, and small grains. There are also poultry and dairy operations scattered throughout the peninsula.

Land Use

Because of the fertile, well-drained soils, agricultural crop production is the main activity in the Morgan Creek Basin (fig. 7; table 1). A few dairy operations and poultry houses are scattered throughout the study area. The only nonrural area within the study area is the village of Kennedyville (fig. 7) along the northwest edge of the Morgan Creek Basin. Woodlands and wetlands are predominantly located in steep valleys along Morgan Creek and its tributaries.

Farm management practices for the 2 years of study (water years 2003 and 2004) were documented by gathering information from local farmers, commercial applicators of farm chemicals, and the University of Maryland, Cooperative Extension, Kent County Office. This information included fertilizer and herbicide applications on production crops, applications of lime, animal operations, different tillage practices, irrigation, forested riparian buffers, grassed waterways, and sediment retention ponds. The information was subsequently used with public records (Alexander and Smith, 1990; Aspelin and Grube, 1999; Bandel and others, 1990; Cornell University, 2005a,b; E.I. du Pont de Nemours and Company, 2005; Gianessi and Puffer, 1991; Information Ventures, Inc., 1995a,b,c; Poole, 2004; Spectrum Laboratories,

Table 1. Summary of crops and animal operations in the Morgan Creek Basin, 2003-04.

[Information gathered from local farmers, commercial applicators, and the University of Maryland, Cooperative Extension, Kent County Office (Craig McSparron, University of Maryland, Cooperative Extension, oral commun., 2005; Michael Bandstra, Horizon Organic Dairy, oral commun., 2004). Bold values represent totals for particular categories (row crops or animal operations)]

Activity	Area (hectares)	Percent of agricultural land	Percent of total watershed area
Row Crops	**2249.5**	**80.1**	**59.1**
Corn	1079.0	38.4	28.3
Soybeans	1148.0	40.9	30.2
Small Grains	22.5	0.8	0.6
Pasture, Hay	**490.0**	**17.4**	**12.9**
Nursery, Orchard	**56.4**	**2.0**	**1.5**
Animal Operations	**13.3**	**0.5**	**0.3**
Dairy Operations	8.0	0.3	0.2
Chicken Houses	5.4	0.2	0.1

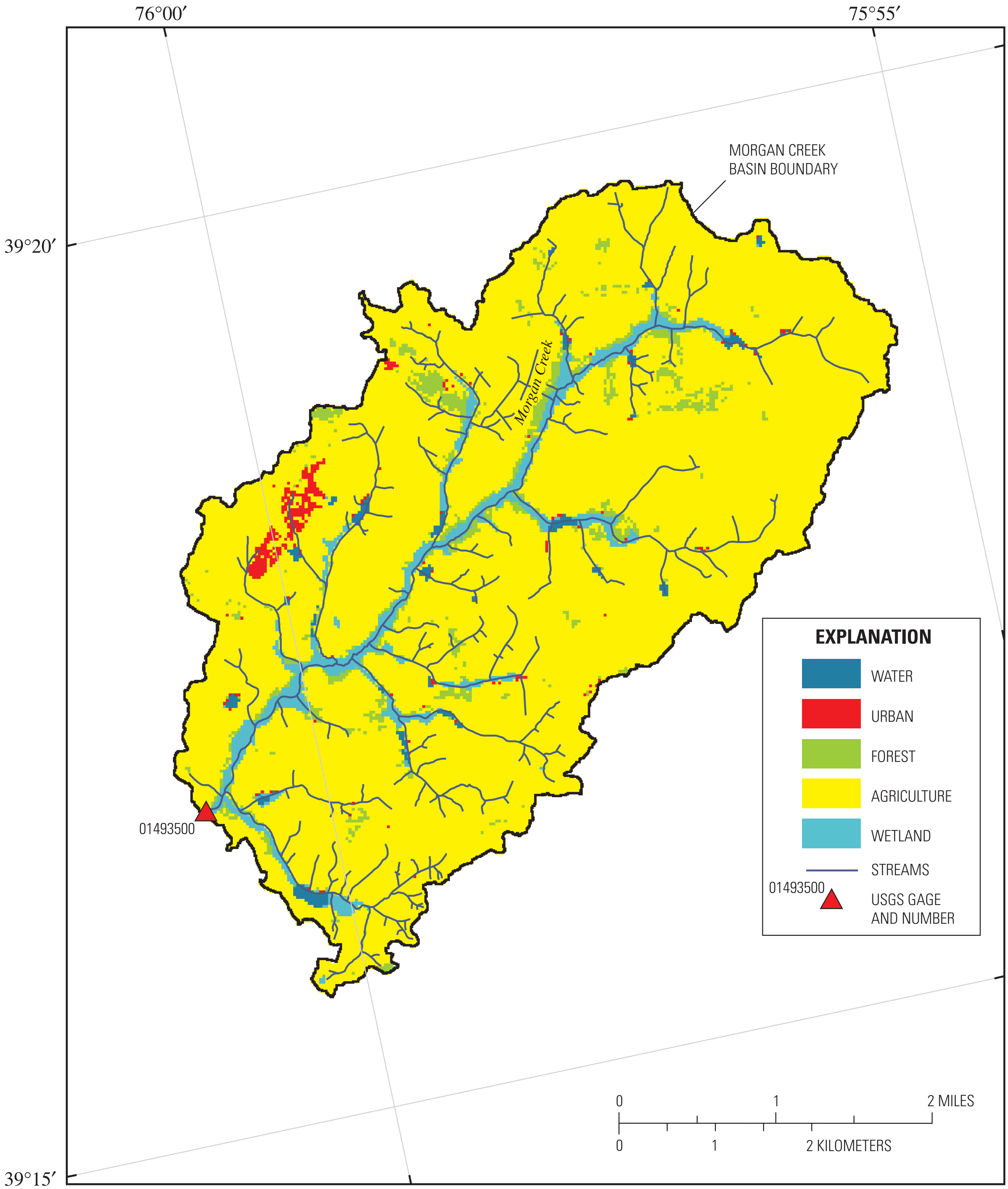

Figure 7. Land use and land cover in the Morgan Creek Basin, Maryland (modified from light detection and ranging (LIDAR) imaging and National Elevation Dataset, 1999).

2003; Toth and Stinner, 2005; U.S. Department of Agriculture, 2002; Vance Communication Corporation, 2004), area reconnaissance, and extrapolation to calculate amounts of herbicides and fertilizers applied to the basin for each field in the study area.

Approximately 2,300 hectares of the Morgan Creek Basin are used for row crops such as corn, soybeans, and small grains, and approximately 500 hectares are used for pasture and hay production involving alfalfa, clover, and various perennial grasses (table 1) (U.S. Department of Agriculture, 2002). Small grains such as wheat, barley, and rye are often used as cover crops and for silage, grazing, and hay (Poole, 2004). One of the most common crop rotation practices in the basin involves planting corn in 1 year, then wheat (or other crops), followed by soybeans. In this area of Kent County, wheat, barley, or hay is planted in the fall, then soybeans are planted later in the spring or summer (Poole, 2004).

The majority of row-cropped fields in the Morgan Creek Basin undergo conservation no-tillage practices. This significantly reduces soil erosion and nutrient runoff, and often produces higher crop yields and more efficient utilization of plant nutrients (Craig McSparron, University of Maryland, Cooperative Extension, oral commun., 2005; Bandel and others, 1990). In no-tillage practices, cover crops are typically used in the late fall through winter and into early spring to reduce the growth of weeds and prevent soil erosion. Prior to planting in the spring, a pre-emergent application of herbicides is often used as a dessicant to "burn-down" the winter cover crop. Applications of fertilizer and lime also occur in the spring. The farm machinery that is often used to sow the spring crop seeds will disc or knife the soil, turning the winter cover crop debris into the near-surface soil, so the winter cover crop debris can be used as "green fertilizer" for the spring crop.

Nitrogen, phosphorus, and potassium are the most commonly applied fertilizers in the study area (table 2) and the source of these is commercial inorganic fertilizers and animal manures (Bandel and others, 1990; Alexander and Smith, 1990; Denver and others, 2004). Potash is commonly used as

Table 2. Summary of fertilizers used, crops treated, application method, area of application, and total elemental mass applied in the Morgan Creek Basin, 2003-04.

[Information gathered from local farmers, commercial applicators, and the University of Maryland, Cooperative Extension, Kent County Office and from specific sources (Craig McSparron, University of Maryland, Cooperative Extension, oral commun., 2005; Michael Bandstra, Horizon Organic Dairy, oral commun., 2004; Alexander and Smith, 1990; Bandel and others, 1990; Toth and Stinner, 2005; Poole, 2004; and U.S. Department of Agriculture, 2002)]

Fertilizers and other soil additives	Crops treated	Application method(s)	2003		2004	
			Area of application (hectares)	Total mass (kilograms)	Area of application (hectares)	Total mass (kilograms)
Nitrogen	mostly corn, little on soybeans, rarely on pasture/hay	pre- and post-emergent surface application	3,260	265,000	3,400	226,300
Phosphorus	mostly corn, little on soybeans, rarely on pasture/hay	pre- and post-emergent surface application	3,160	120,000	3,050	145,000
Potassium	mostly corn, little on soybeans, rarely on pasture/hay	pre- and post-emergent surface application	3,160	150,200	3,180	166,500
Sulfur	mostly corn, little on soybeans, rarely on pasture/hay	pre- and post-emergent surface application	2,980	57,300	2,730	52,500

Table 3. Summary of herbicide use in the Morgan Creek Basin, 2003-04.

[Information gathered from local farmers, commercial applicators, and the University of Maryland, Cooperative Extension, Kent County Office and from specific sources (Aspelin and Grube, 1999; Cornell University, 2005a,b; E.I. du Pont de Nemours and Company, 2005; Gianessi and Puffer, 1991; Information Ventures, Inc., 1995a,b,c; Spectrum Laboratories, 2003; Toth and Stinner, 2005; Poole, 2004; U.S. Department of Agriculture, 2002; Vance Communication Corporation, 2004)]

Herbicides	Crops treated	Application method(s)	2003		2004	
			Area of application (hectares)	Total mass (kilograms)	Area of application (hectares)	Total mass (kilograms)
atrazine	corn	pre- and post-emergent surface application	1,310	2,740	1,630	3,460
glyphosate	soybeans	post-emergent surface application	1,660	2,460	1,350	2,160
simazine	corn, small grains	pre- and post-emergent surface application for corn; pre-emergent surface application for small grains	1,160	1,340	1,860	2,160
paraquat	soybeans, corn	pre-emergent surface application	1,850	2,100	1,940	2,100
metolachlor	corn	pre-emergent surface application	1,270	1,780	1,470	2,000
2,4-D	soybeans, corn, pasture/hay	pre-emergent surface application	1,720	1,960	1,510	1,800
thifensulfuron methyl	corn, small grains	post-emergent surface application for break-through weeds in corn; pre-emergent surface application for small grains	700	6.8	620	5.7
rimsulfuron	corn, small grains	post-emergent surface application for break-through weeds in corn; pre-emergent surface application for small grains	430	7.5	530	9.3
dicamba	corn	post-emergent surface application for break-through weeds in corn	150	23	430	66
dimethenamid	corn	pre-emergent surface application	33	16.5	70	33
difluenzopyr	corn	post-emergent surface application for break-through weeds in corn	153	9	430	26
tribenuron methyl	small grains	pre-emergent surface application	390	2.4	220	1.6
chlorimuron ethyl	small grains	pre-emergent surface application	120	17.4	160	24
sulfentrazone	small grains	pre-emergent surface application	120	21	160	29
metsulfuron methyl	pasture	surface application	320	5.5	330	5.6

a fertilizer because it is a source of soluble potassium. Sulfur is also commonly applied with commercial inorganic nitrogen fertilizer mixtures in the form of ammonium sulfate.

Nitrogen fertilizers are applied to nearly all the corn in the study area. Little nitrogen or other fertilizers are applied for soybean production; however, depending on results of field-soil analysis, some fertilizers may be used. Nitrogen applications in the study area are commonly in the form of either an ammonium sulfate or a urea-ammonium nitrate (UAN) solution. These nitrogen forms are applied to field crops throughout the growing season such as the pre-emergent herbicide applications, during seeding of the crop, and as a post-emergent sidedressing to growing crop (Craig McSparron, University of Maryland, Cooperative Extension, oral commun., 2005). Most post-emergent sidedressed applications of nitrogen to corn occur as a 28-35 percent UAN solution (Bandel and others, 1990). Some dairy waste is applied to row crops and pasture/hay fields for fertilizer and disposal. Composted poultry litter is also used for fertilizer, albeit infrequently in this part of the Delmarva Peninsula (Craig McSparron, University of Maryland, Cooperative Extension, oral commun., 2005).

Numerous years of fertilizer applications on the Delmarva Peninsula have led to increased soil concentrations of phosphorus that often exceed crop uptake needs (Sprague and others, 2000). For this reason, phosphorus is not used as often, or in as high quantities, as nitrogen on the Delmarva Peninsula (Alexander and Smith, 1990; U.S. Department of Agriculture, 2002).

A herbicide is a type of pesticide used to kill plants. Herbicides are the most widely used pesticides in the Morgan Creek Basin and on the Delmarva Peninsula where they are used for weed control (Denver and others, 2004). Metolachlor and simazine are often used in combination with atrazine for corn production (table 3). Glyphosate and paraquat are the major herbicides applied to soybeans in the study area (table 3). Numerous other herbicides are used in the production of row crops, pasture, hay, and nursery stock (table 3). There is no record of fungicide and insecticide use in the study area for the water years 2003 and 2004.

There are a few dairy operations scattered throughout the Morgan Creek Basin and fewer poultry houses. The dairy operations cover a total of 8 hectares of land in the study area and the poultry houses cover a total of 5.4 hectares (table 1). Most dairy operations implement agricultural management practices such as stream fencing to keep cattle out of the creek, open grazing in pastures, and spraying of liquid lagoon waste and disposal of solid waste on fields for fertilization of forage and silage crops. There is at least one location on Morgan Creek where cattle cross the stream. Most dairy operations have approximately 100 adult females and varying numbers of calves. Only half of the waste lagoons in the study are lined and most are emptied twice a year (Craig McSparron, University of Maryland, Cooperative Extension, oral commun., 2005).

There is a large commercial organic dairy operation in the Morgan Creek Basin, which consists of a primary farm of 72 hectares located along the southwest edge of the basin. As of 2002, the primary farm had over 600 adult female cows, several waste lagoons, and 49 hectares in various rotations of corn, perennial rye grass, clover, and alfalfa. The organic dairy operation also uses another property in the basin. Of the 89 hectares on this second property, 65 hectares are used for alfalfa and 18.2 hectares are used for pasture. As of 2002, approximately 75-100 calves were raised on this smaller property (Michael Bandstra, Horizon Organic Dairy, oral commun., 2004).

The organic dairy employs the practice of no-tillage, unless weed problems are encountered, in which case conventional tillage is used. There is some spraying of liquid waste on the primary farm fields. During periods of heavy precipitation, lagoons on the main farm may overflow and run overland into Morgan Creek. Solid waste is disposed of on the smaller organic dairy property and at a local nursery. At the nursery, the solid waste is combined with unsold trees to create compost, which is used in the production of nursery stock (Michael Bandstra, Horizon Organic Dairy, oral commun., 2004).

Less than 2 percent of the Morgan Creek Basin contains nursery crops (table 1); however, 30 percent of an adjacent basin is used for cultivation of plant nursery stock (Bachman and others, 2002). This nursery, located in the northern part of the Morgan Creek Basin and adjacent basin, most commonly grows a variety of ornamentals including premium Root Pruned Holly, Juniper, Arborvitae, Taxus, and Flower Carpet Roses (James Kohl, Angelica Nursery, oral commun., 2004).

Population

In 2000, about 1.1 million people lived on the Delmarva Peninsula; the population is increasing in the urban area around Wilmington, Delaware and near vacation resorts along the Atlantic coastline (fig. 1) (U.S. Bureau of Census, 2004). In general, there are at least 327 people per km^2 throughout the study area, except in the village of Kennedyville, where there are over 327 people per km^2 (fig. 8). The population in Kent County, Maryland, increased approximately 10 percent from 1990-2004 to 19,600 (U.S. Bureau of Census, 2004).

Climate

The climate of the Morgan Creek Basin is humid and subtropical, with an average annual precipitation of 1.12 m. The mean temperature in January, the coldest month, is 0.6 °C (degrees Celsius), and mean temperature in July, the warmest month, is 25.2 °C (National Weather Service, 2004).

Monthly mean high and low temperatures were generally lower than the long-term average for the first 6 months of 2003, and similar or greater than the long-term

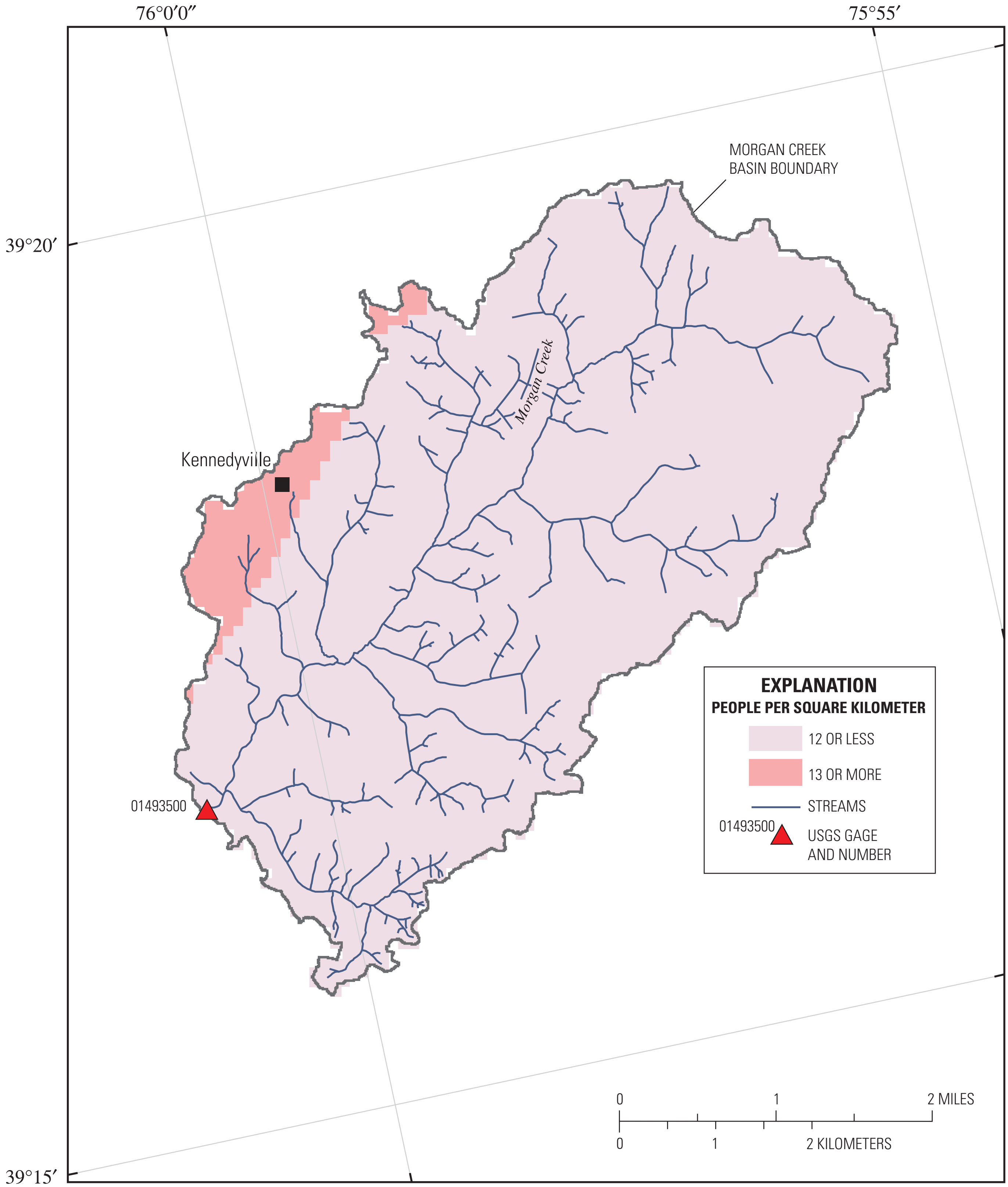

Figure 8. Population density for the Morgan Creek Basin, Maryland (based on the U.S. Bureau of Census, 2004).

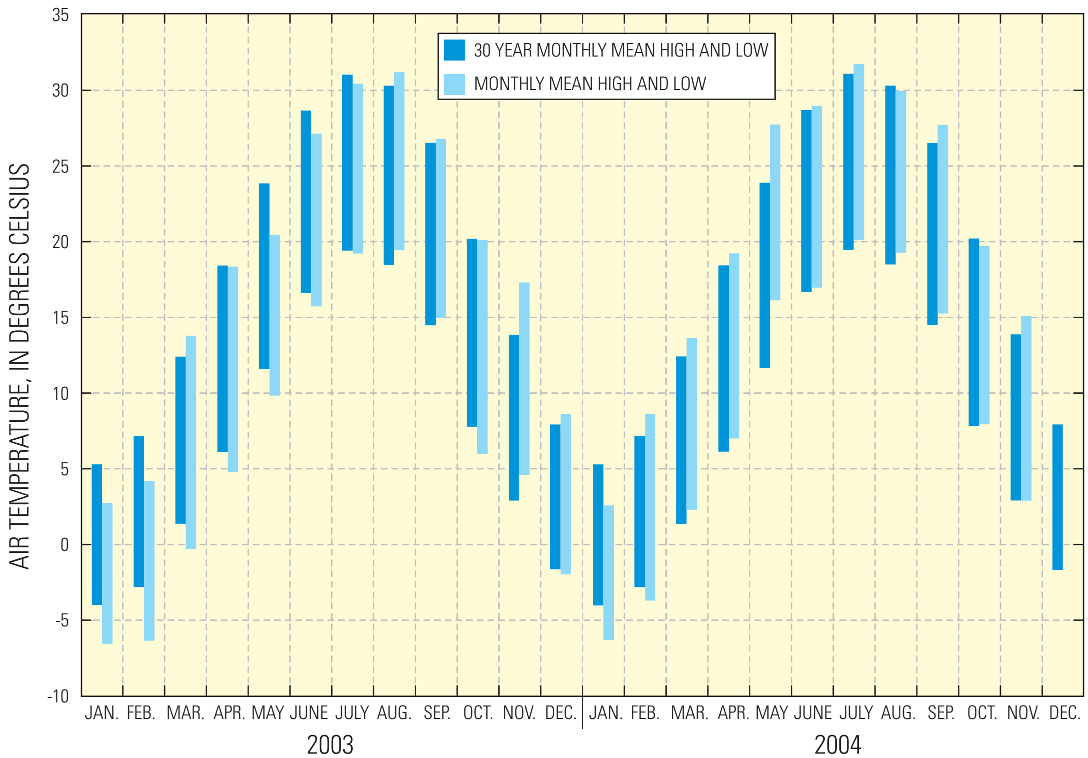

Figure 9. Average daily high and low temperatures for 2003 and 2004 at National Weather Service, Station 181750, Chestertown, Maryland (from National Weather Service, 2004). Location of station is shown in figure 1.

average for the second half of 2003 and all of 2004 (fig. 9). The only exception was in January 2004, when temperatures were much colder than the long-term average. Extreme temperatures for the study period were marked by a high of 36.7 °C on July 5, 2004, and a low of minus 15 ˚C on January 10, 2004.

At the National Weather Service monitoring station at Chestertown, Maryland, located 8.3 km from the Morgan Creek streamflow-gage, mean annual precipitation was 112 cm (centimeters) for the period 1975-2004. Precipitation during 2003, 162 cm, was much greater than the long-term average, and precipitation during 2004, 100 cm, was slightly less than the long-term average (fig. 10). On average, annual precipitation is evenly distributed throughout the year, from 7.3 to 11.1 cm per month (fig. 11); however, the spring and summer period (March – September) tends to be slightly wetter than the autumn and winter period (October – February). Anomalously high precipitation can occur in late summer/early autumn due to occasional hurricanes and tropical storms. Thunderstorms can also produce relatively high localized precipitation during the summer months.

Monthly precipitation during 2003, a relatively wet year, was above normal for all months except January and April. February, June, and September had nearly twice the normal precipitation (fig.11). In 2004, which was drier than normal, precipitation for most months was near or below normal, except for April and November (fig.11). In water year 2003, there were more frequent storms than in water year 2004.

Hydrology

The hydrology of the Morgan Creek Basin can be described by partitioning the annual mean precipitation of 112 cm into a basic water budget.

$$PPT = SW + GW + ET,$$

where

PPT	is	annual precipitation, 112 cm
SW	is	streamflow loss = 28 percent, 31.4 cm
GW	is	ground-water loss to adjacent basins = 2 percent, 2.2 cm
ET	is	evapotranspiration loss = 70 percent, 78.4 cm

Evapotranspiration is predominant during the growing season from April through September, whereas simple evaporation is more likely to occur from October through March.

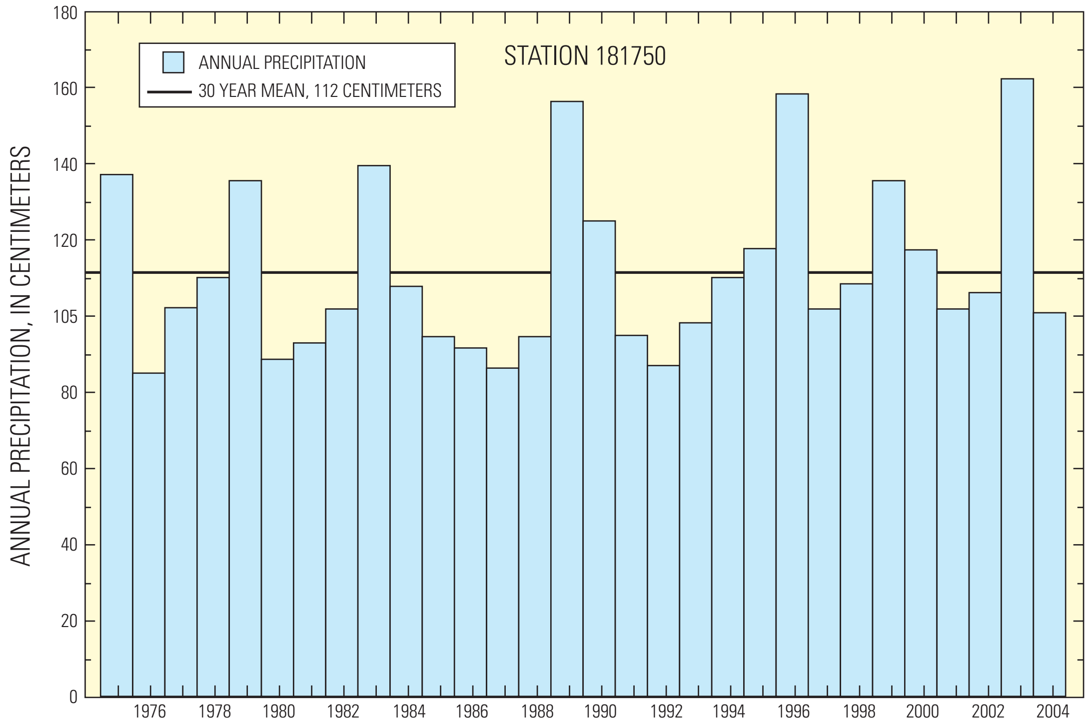

Figure 10. Annual precipitation over time at National Weather Service, Station 181750, Chestertown, Maryland (from National Weather Service, 2004).

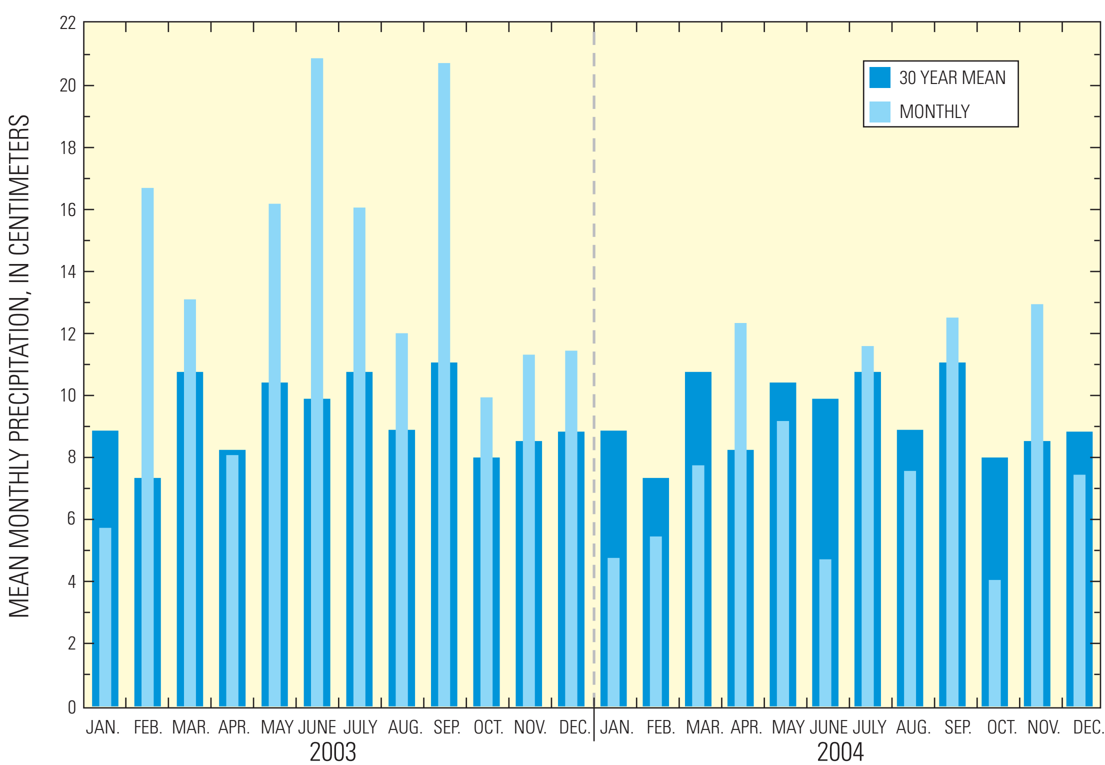

Figure 11. Mean monthly precipitation for 2003 and 2004 at National Weather Service, Station 181750, Chestertown, Maryland (from National Weather Service, 2004).

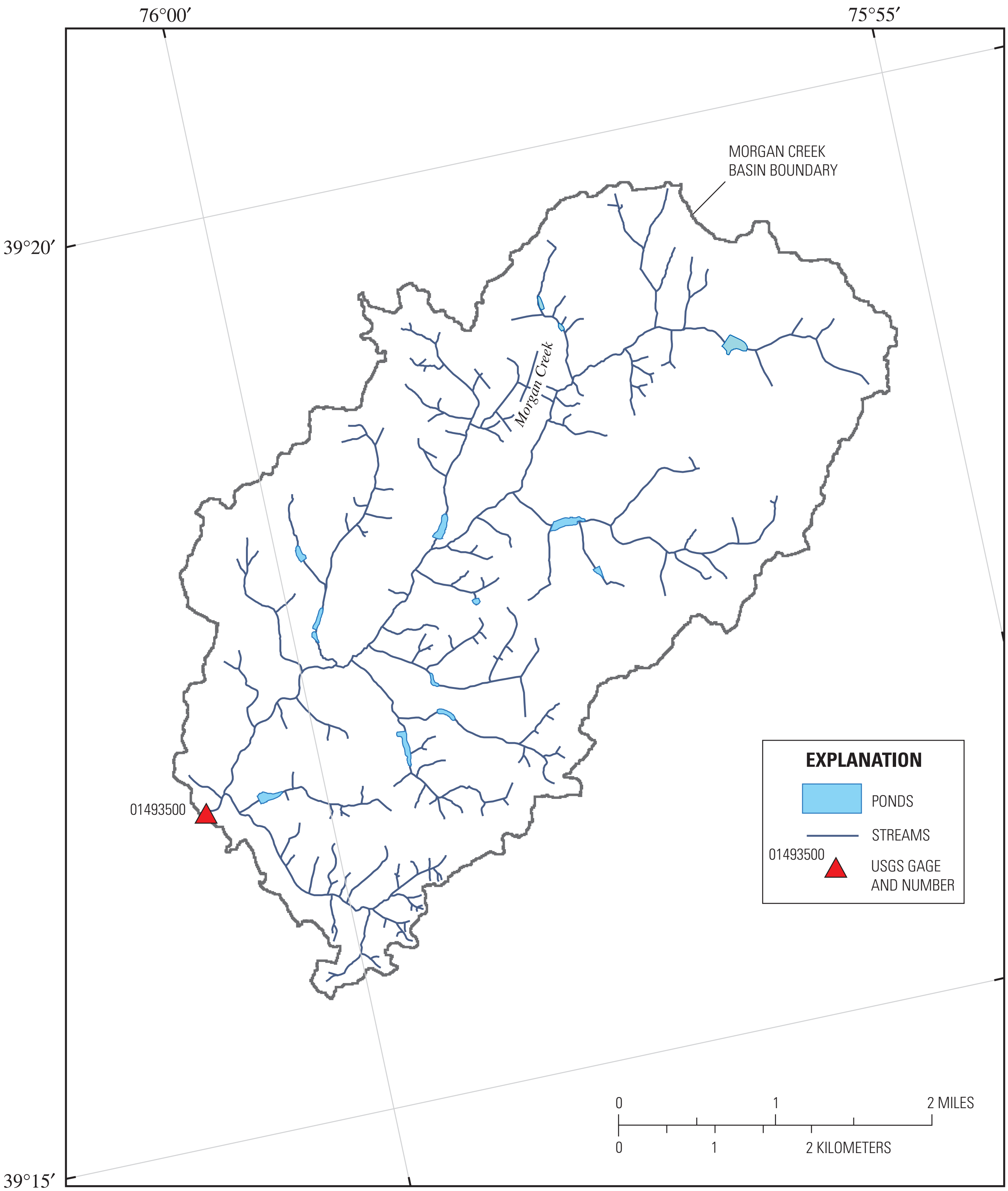

Figure 12. Location of Morgan Creek and tributaries in relation to the streamflow-gaging station.

An estimate for recharge to ground water is 18 cm; while runoff contribution to streamflow is 15.5 cm.

Natural hydrologic processes dominate water movement in the basin; however, there are some non-natural modifications that affect streamflow conditions and water quality. These features include grassed waterways that direct overland runoff, and small (less than 0.04 hectares) sediment retention ponds, which are common on many farms. There are limited ground-water withdrawals for both agricultural and municipal uses, as well as some permitted surface discharges to Morgan Creek.

Surface Water

Water discharge data were continuously collected by the USGS at one fixed streamflow-gaging station in the Morgan Creek Basin: USGS Station 01493500, Morgan Creek near Kennedyville, Maryland (fig. 12). The streamflow-gaging station on Morgan Creek is in Hydrologic Unit 02060002.

Mean annual discharges for water years 2003 (0.52 m^3/s [cubic meter per second]) and 2004 (0.45 m^3/s) were both greater than 0.31 m^3/s, the long-term mean annual discharge for Morgan Creek (fig. 13). Interannual variation in discharge is fairly common. Mean annual discharge for water year 2003, for example, was almost three times greater than for water year 2002 (0.19 m^3/s), which was a drought year. Seven of the last 10 water years have been near or greater than the long-term mean annual discharge, indicating a relatively wet period of time.

Mean monthly discharges for water year 2003 were greater than the long-term mean monthly discharges for all months except October and January (fig 14). In water year 2004, mean monthly discharges were again equal to or greater than normal for all months, except January, March, and August (fig 14).

Mean daily discharges (logarithmic scale), plotted with mean monthly discharges, show the relative frequency and duration of storm events, and the general pattern of other flow variations within each month. Mean daily discharge for Morgan Creek can be highly variable, and somewhat flashy due to the relatively small area of the basin. A successive sequence of storms (rainfall events) is capable of sustaining high mean daily discharges. In water year 2003, there were more frequent storms than in water year 2004; however, some of the storms in water year 2004 were much larger (more intense and(or) with greater total rainfall amounts) than those in water year 2003. Frequent rainfall events tend to maintain saturated conditions in near-surface soils, resulting in sustained greater than average streamflow.

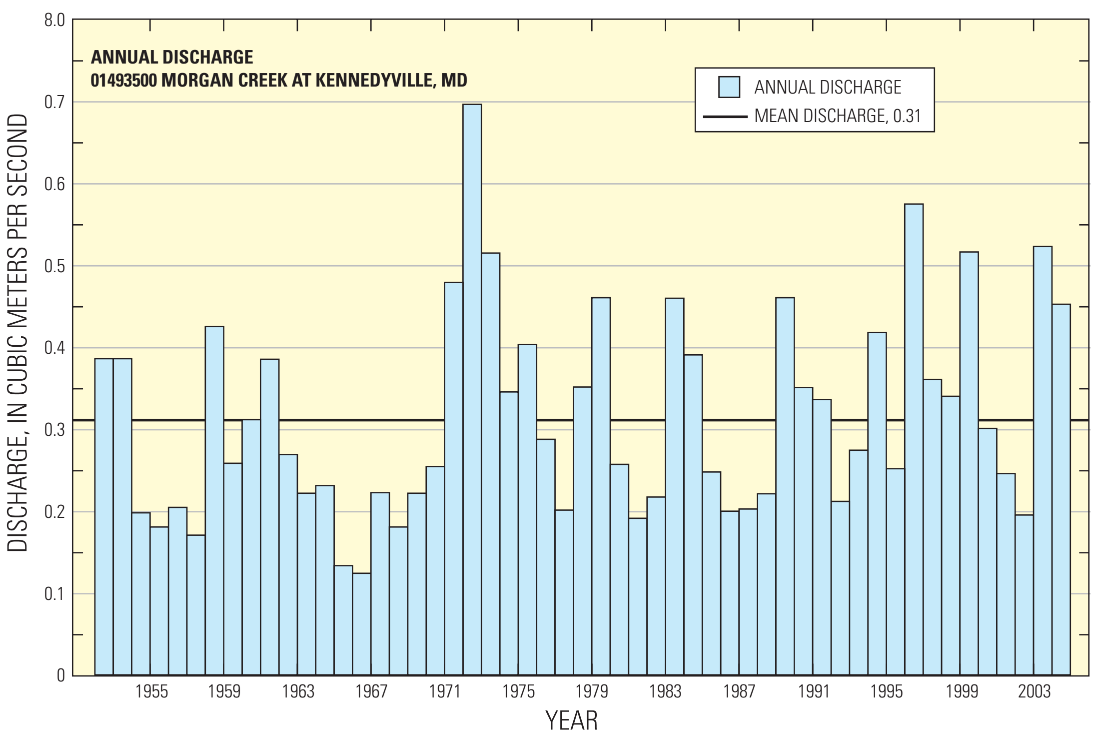

Figure 13. Long-term annual discharge at the Morgan Creek streamflow-gaging station, water years 1952-2004 (from U.S. Geological Survey, 1952-2004).

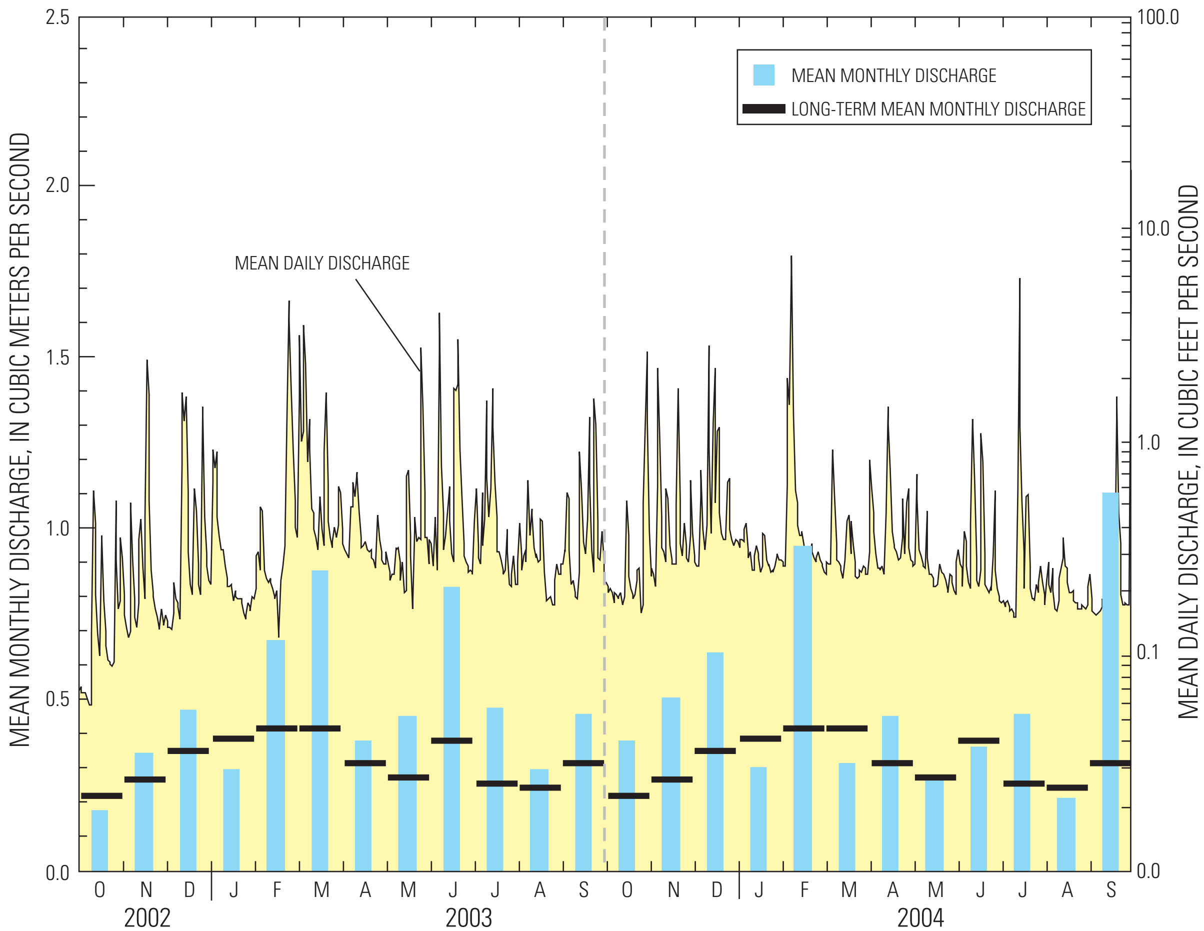

Figure 14. Mean daily discharge and mean monthly discharge at the Morgan Creek streamflow-gaging station, water years 2003 and 2004.

Daily mean streamflow characteristics for the Morgan Creek Basin are summarized for water years 1952-2004 (fig. 15). Flow duration computations show the relative percent of time that the daily mean streamflow exceeded the discharge value shown. Low flows are discharges less than 0.09 m^3/s (90-percent exceedance), and high flows are discharges greater than 0.85 m^3/s (5-percent exceedance).

Using steamflow-component separation techniques (HYSEP, local minimum method, Sloto and Crouse, 1996) for water years 1952-2004, the long-term median base flow for Morgan Creek was calculated to be 59 percent of total flow. This indicates that total streamflow is most often dominated by sustained ground-water contribution. Surface runoff accounts for the other 41 percent of total streamflow and dominates during and just after precipitation events. Streamflow separation calculations support the estimates of runoff and recharge in the total water budget.

Wetlands constitute less than 5 percent of the Morgan Creek Basin and occupy low-lying and relatively flat areas, mostly the floodplain and main channel of Morgan Creek and its tributaries (fig. 7). Many wetland areas are also forested and the combined forest and wetland land use is close to 9 percent of the total study area. Because soils in the wetlands are frequently flooded, especially in winter and early spring, and poorly drained, these areas are generally unsuitable for most field crops. The high organic content of these soils creates favorable conditions for denitrification; however, other forms of microbial and chemical degradation of agricultural chemicals may occur as surface water flows through the forested wetlands during and after rainfall, and as ground water discharges in and near these areas (Böhlke and Denver, 1995; Bachman and others, 2002).

Ponds are fairly common in the Morgan Creek Basin and most were constructed for sediment retention on farm fields. Secondary use of these ponds is for hunting and recreation. As of 2002, there are 30 known retention ponds, ranging in size from 0.2 to 4.9 hectares. In sum, these ponds cover an estimated surface area of 36.8 hectares, or 1.1 percent of

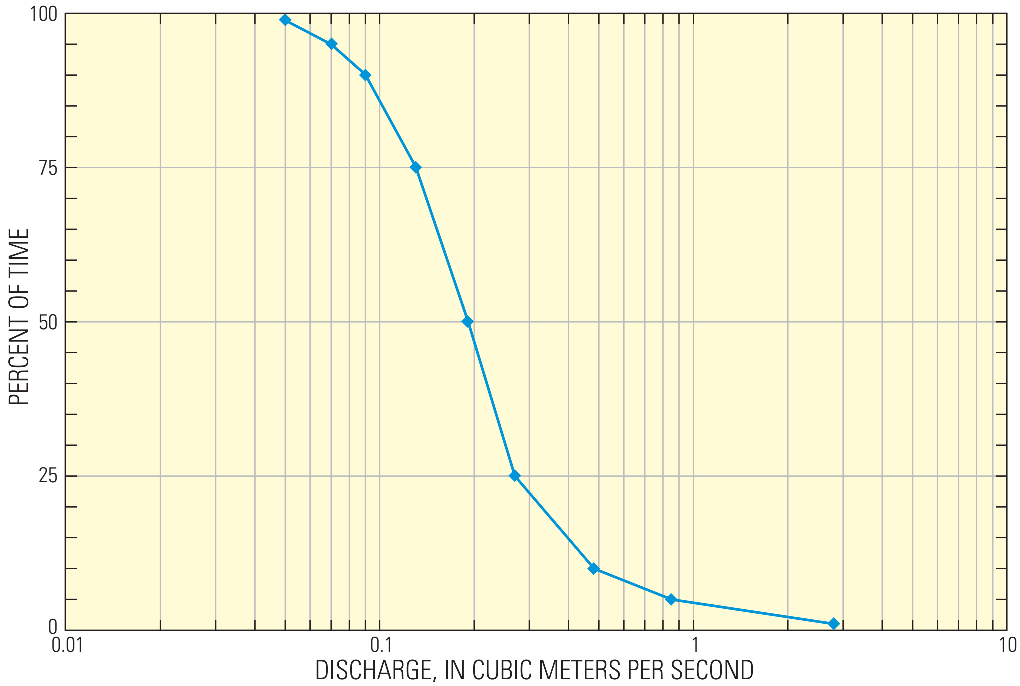

Figure 15. Summary of daily mean streamflow characteristics at Morgan Creek streamflow-gaging station, water years 1952-2004 showing percent of time that daily mean streamflow was greater than or equal to the discharge value shown, in cubic meters per second.

the total basin land area. Most ponds were constructed with design assistance from the Natural Resources Conservation Service (2005). Although the actual surface area of the ponds is relatively small, the total contributing areas to these ponds is considerable. These farm field ponds may increase potential evaporation, and can also serve as areas of focused recharge if unlined.

The formation of natural ponds in uplands is inhibited by the presence of well-drained soils; however, some transitory ponds form in the main stem of Morgan Creek and some tributaries. These ponds are created by the buildup of channel debris, or more likely, from beaver activity, and may persist for weeks or even years in extreme cases. Ponds formed in the mainstem channel affect streamflow by delaying the movement of water downstream. Aside from effective use in sediment retention, ponds tend to slow down the traveltime of water in the basin, which allows for settling of other particulate matter and greater time for nutrient uptake by vegetation.

Ground Water

In the Morgan Creek Basin, the surficial aquifer consists of permeable quartz sand and gravel of the Pensauken Formation and fine-to-medium quartz sands and glauconite in a silt-clay matrix of the upper part of the Aquia Formation (fig. 5). The depth of the surficial aquifer ranges from 15 m above sea level at the northern edge of the study area to near sea level at the southern edge (fig. 4) (Bachman and others, 2002). Depth to the water table ranges from less than 0.4 m below surface in the floodplain to 12 m below land surface in upland areas (Bachman and others, 2002). Ground water flows generally from uplands toward the Morgan Creek floodplain at a variety of depths and time scales (Bachman and others, 2002). In the upper reaches of the basin where the floodplain is narrow and floodplain sediments are thinner, direct discharge of ground water to the stream is possible. In the lower reaches of the basin, where the floodplain is wider, direct contribution of ground water to the stream is more limited, and perennial seeps along the fringes of the broad floodplain are a major source of ground-water discharge.

There is a wide range of ages and sources of ground water discharging to the Morgan Creek floodplain. Along the fringes of the floodplain, recently recharged water less than 5 years old is common. Toward the middle of the floodplain, closer to the stream channel, ground waters traveling along longer and deeper flow paths are encountered, ranging in age from 10 to more than 30 years old, based on recent age-date sampling (Bachman and others, 2002). For the entire Morgan Creek Basin, there is regional ground-water loss via the deepest flow paths in a southeasterly direction toward an adjacent basin, consistent with the overall dip and strike orientation of subsurface geologic units (Leon Kauffman, USGS, oral commun., 2005).

Floods and Droughts

Hydrologic conditions such as floods and droughts can be inferred, in part, from examining streamflow records. Morgan Creek has sustained flows typically ranging from 0.13 to 0.27 m^3/s. In the context of streamflow, a storm event for Morgan Creek is considered a discharge greater than 0.48 m^3/s (10-percent exceedance), and is typically generated by 15-25 mm (millimeters) of rainfall within a 24-hour period. On occasion, precipitation of great intensity and(or) long duration (large storm event) will create flooding conditions. Because Morgan Creek Basin is relatively small, large storm events can inflate the overall monthly, or even yearly mean discharges. This occurred during February 2004, when one storm event raised the overall mean monthly total to more than twice the long-term average (fig. 14).

High flows, greater than 0.85 m^3/s (5-percent exceedence), are almost always attributed to storms and will visibly transport sediment. Direct field observation of streamflows greater than 2.8 m^3/s (1-percent exceedance) showed inundation of parts of the floodplain. Flooding events, defined for Morgan Creek as discharges exceeding 2.8 m^3/s, were more common in water year 2003 (8 separate days), than in water year 2004 (3 separate days). The greatest instantaneous discharge ever measured at Morgan Creek was 317 m^3/s during Hurricane Floyd, on September 16, 1999 (gage height, 4.6 m). Most examples of extreme flooding are related to hurricanes passing near the area.

Low streamflows are considered to be discharges less than 0.07 m^3/s (95-percent exceedance). During the study period, low-flow conditions existed only during early October of water year 2003, a remnant of drought conditions during the summer of 2002. During the remainder of the study period, discharges never dropped below 0.14 m^3/s (fig. 13). The smallest instantaneous discharge ever recorded for the period of record at the streamflow-measurement gage was 0.017 m^3/s on August 28-29, 1966, during the drought of 1966. A drought is difficult to define solely based on low streamflow; however, as it also requires measurement of soil moisture, and measured lack of precipitation.

Water Use

Both surface- and ground-water uses are permitted in the Morgan Creek Basin by the Maryland Department of the Environment. Because of the relatively high yielding aquifers, water quantity is plentiful. Ground-water quality is dependent on specific location. Regionally, water quality is highly affected by past and present agricultural land use (Denver and others, 2004).

Within Kent County, permitted ground-water withdrawals range from 0.38 to 30 cubic meters per day (m^3/d) for small users and 30 to 2,700 m^3/d for large users (U.S. Geological Survey, 1985). Small-scale uses include livestock watering, seasonal pond filling, and irrigation of lawns, gardens, and recreation fields. There are also limited withdrawals for drinking water for small businesses and restaurants. Large-scale ground-water uses include farm irrigation, livestock watering and sanitation, and the Kent County Sanitary District at Kennedyville.

Surface-water withdrawals are limited, and primarily used for farm irrigation. Most agricultural operations in the study area rely on natural rainfall. There is center pivot irrigation in some areas of the study area where there are well-drained soils (University of Maryland, 2005). There are no known or permitted surface-water withdrawals that are used for drinking water.

The Kent County Sanitary District is permitted to discharge treated wastewater to Morgan Creek from its Kennedyville road facility. Most water withdrawn is either recharged back to ground water or is lost to evapotranspiration; very little water leaves the basin through interbasin transfer (Leon Kauffman, USGS, oral commun., 2005).

Summary

The Morgan Creek Basin is one of five sites selected for the study of sources, transport, and fate of agricultural chemicals by the Agricultural Chemicals Team as part of the U.S. Geological Survey's National Water-Quality Assessment Program. This basin is in Kent County, Maryland, in the northeast region of the Delmarva Peninsula. Morgan Creek is a small stream that drains a 31-square-kilometer basin and flows directly into the tidal portion of the Chester River. It is surrounded by farmland and bordered by wooded riparian zones. There are no large towns in the basin.

Morgan Creek Basin lies within the Coastal Plain Physiographic Province, which is a generally flat, seaward-sloping lowland with areas of moderate topographic relief. The basin lies within a well-drained upland region, which includes permeable soils and sediments that are incised by stream valleys. This region contains a mixed sequence of unconsolidated deposits of sand, silt, clay, gravel, and shells.

Soil types in the Morgan Creek Basin are predominantly silt loams that have some clay, but have a higher proportion of silts and sands. These are often found in the upland regions and in sloped areas away from drainages. Over half of the soils in the study area are classified as well drained and moderately well drained. Available water capacity is moderate to high. In cultivated areas, the potential for surface-water runoff is medium and the hazard for soil erosion is mostly moderate. The soil is strongly to extremely acidic in areas where limed is added. These soils are classified as prime farmland and are well suited to most crops, including row crops, pasture, hay, and specialty crops such as nursery stock.

Agriculture is the main land use in the study area. Most agricultural land is used for row crops such as corn, soybeans, and small grains, and, slightly less is used used for pasture and hay production involving alfalfa, clover, and various perennial grasses. Conservation no-tillage practices are commonly employed in the row cropping of corn and soybeans. The major growth enhancer used is nitrogen. The majority of nitrogen applied comes from inorganic ammonium sulfate and urea-ammonium nitrate applications; however, some liquid dairy and solid poultry waste is used on a few fields. Glyphosate and paraquat are the major chemical herbicides used in soybean production and atrazine and metolachlor are the major chemicals used in corn production. Insecticides are rarely used in the study area. Irrigation is minimal.

The Morgan Creek Basin exhibits moderate temperatures ranging from a mean of 25.2 degrees Celsius in July to a mean of 0.67 degrees Celsius in January. The mean annual precipitation is 1.12 meters. Generally, precipitation is evenly distributed throughout the year, with total amounts in spring and summer slightly exceeding that of fall and winter. Evapotranspiration plays a large role in the water budget. In the study area, an annual average of 78.4 centimeters of moisture moves into the atmosphere as a result of evaporation and transpiration, and this occurs predominantly during the growing season from April to September.

A streamflow-gaging station on Morgan Creek was used to measure discharge in the study area—Morgan Creek near Kennedyville, Maryland (Station number 01493500). Mean daily streamflows for Morgan Creek are highly variable, and somewhat flashy due to the relatively small area of the basin. Frequent storm events that maintain saturated conditions in the basin help to sustain greater than average streamflow. The long-term median base flow for Morgan Creek is 59 percent of total flow, indicating that total streamflow is most often dominated by sustained ground-water contribution. Surface runoff accounts for the other 41 percent of total streamflow and dominates during and just after precipitation events.

Ponds are fairly common in the Morgan Creek Basin, and most were constructed for sediment retention on farms. Some transitory ponds form in the main stem of Morgan Creek and some tributaries. These ponds are created by the buildup of channel debris, or more likely, from beaver activity, and may persist for weeks or even years in extreme cases. Aside from effective use in sediment retention, ponds tend to slow down the travel time of water in the basin, which allows for settling of other particulate matter and greater time for nutrient uptake by vegetation.

The surficial aquifer in the study area consists of permeable quartz sand and gravel and is underlain by less permeable silt and clay. Depth to the water table ranges from less than 0.4 meters below land surface in the floodplain to 12 meters below land surface in upland areas. Ground water generally flows from uplands toward the Morgan Creek floodplain at a variety of depths and time scales. In the upper reaches of the basin where the floodplain is narrow and floodplain sediments are thinner, direct discharge of ground water to the stream is possible. In the lower reaches of the basin, where the floodplain is wider, direct contribution of ground water to the stream is more limited, and a major source of ground-water discharge is perennial seeps along the fringes of the broad floodplain.

Flooding in the Morgan Creek Basin occurs occasionally when precipitation is of great intensity and(or) long duration. High flows are almost always attributed to storms and stormflows will infrequently inundate parts of the floodplain. The greatest instantaneous discharge ever measured at Morgan Creek was 317 cubic meters per second during Hurricane Floyd, on September 16, 1999. Most examples of extreme flooding are related to hurricanes passing near the area. During the study period, low-flow conditions existed only during early October of water year 2003, a remnant of drought conditions during the summer of 2002. The smallest discharge ever recorded for the gage period of record (1951 to 2004) was 0.017 cubic meters per second on August 28-29, 1966, during the drought of 1966.

Both surface- and ground-water use is permitted in the Morgan Creek Basin by the Maryland Department of the Environment. Within Kent County, permitted ground-water withdrawals range from 0.38 to 30 cubic meters per day for small users and 30 to 2,678 cubic meters per day for large users. Small-scale uses include livestock watering, seasonal pond filling, and irrigation of lawns, gardens, and ball fields. There are also limited withdrawals for drinking water for small businesses and restaurants. Large-scale ground-water uses include farm irrigation, livestock watering, and sanitation. Surface-water withdrawals are limited, and used for farm irrigation. There are no known or permitted surface-water withdrawals for use as drinking water.

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