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Does land use affect our streams?

A watershed example from Gwinnett County, Georgia, 1998–2001

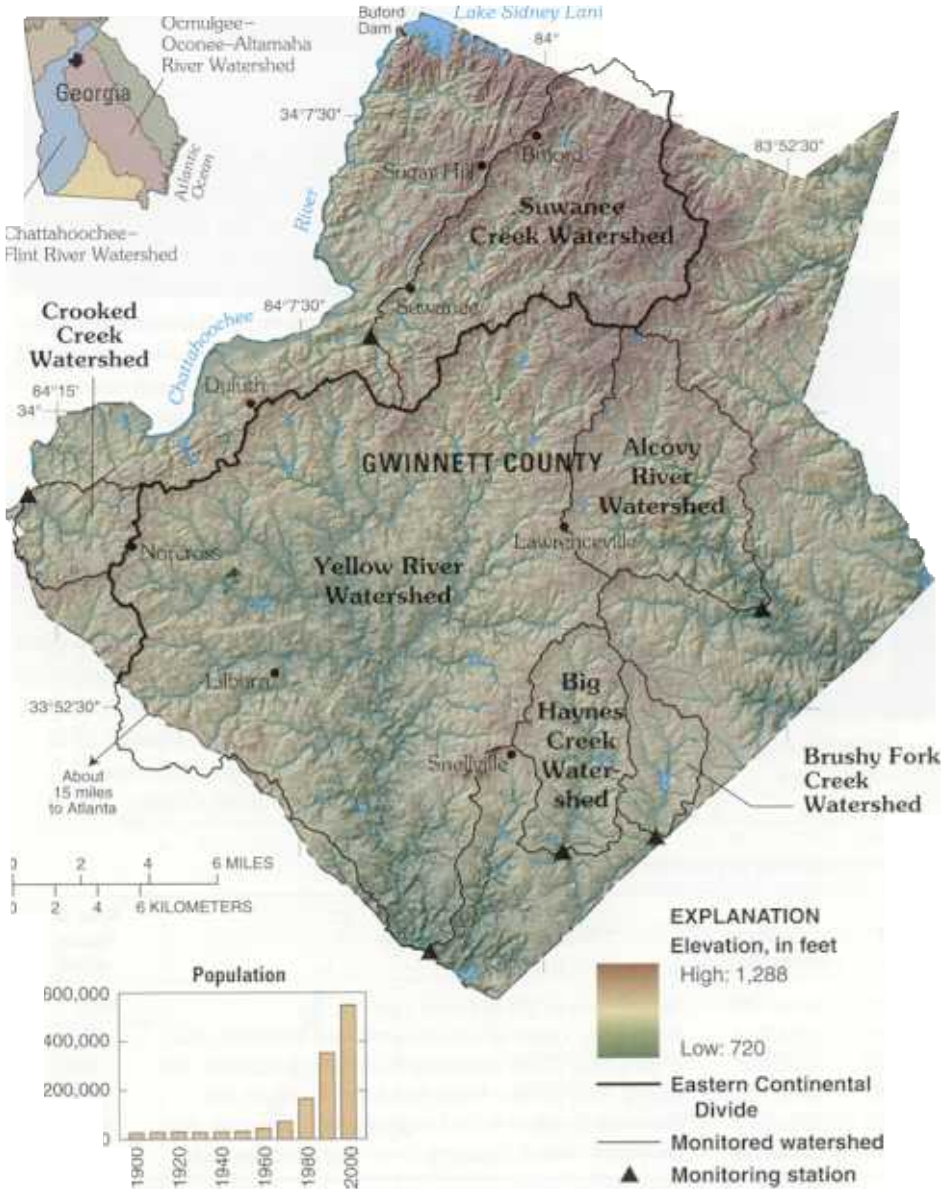
Stream quality is a barometer of urban land-use pressures on a watershed. Managing land use in a watershed is vital to protecting drinking-water supplies, recreational opportunities, and stream ecosystem health. However, the effect of land use and management practices on streams is difficult to assess and often unmeasured. Pollution due to land use, or nonpoint-source pollution, is complex in its origin, transport, impacts, and response to management practices. How does urbanization affect sediment or nutrient loads in streams? How effective is a detention pond or a stream-buffer requirement? In six watersheds of Gwinnett County, Georgia, monitoring results of an ongoing study show the effects of land use on streamflow and on loads of suspended solids, metals, and nutrients.

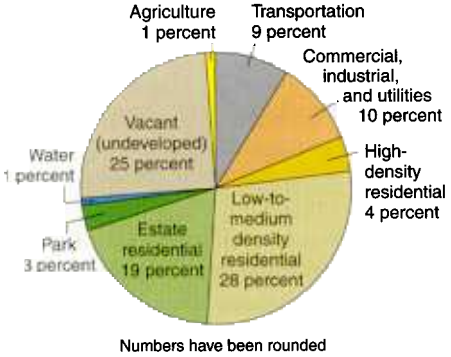
Gwinnett County background

Gwinnett County lies in northeastern Metropolitan Atlanta, Georgia, and is one of the most rapidly developing counties in the United States. The population of Gwinnett County grew by more than 250 percent from 1980 to 2000, and the 2001 population is estimated at 621,500 (U.S. Census Bureau, 2002).

Land use in the county is broadly mixed, with residential being the largest. Urban development is most dense in the southwestern portion of the county and along major transportation corridors. Agricultural land use, which now accounts for only about 1 percent of the county, peaked around 1920. However, stream channels and floodplains may still have large surpluses of sediment resulting from poor agricultural soil conservation practices of that period (Trimble, 1969).

The major hydrologic feature of Gwinnett County is the Eastern Continental Divide. Streams southeast of the divide flow to the Atlantic Ocean, draining 74 percent of the county. Streams northwest of the divide flow to the Gulf of Mexico, draining 26 percent of the county. The Chattahoochee River is the principal water supply for Metropolitan Atlanta and forms the 25-mile northwestern boundary of the county. Buford Dam impounds Lake Sidney Lanier at the extreme northern boundary of the county.





Gwinnett County land use in 1998
(Gwinnett County Department of Public Utilities, 2000).

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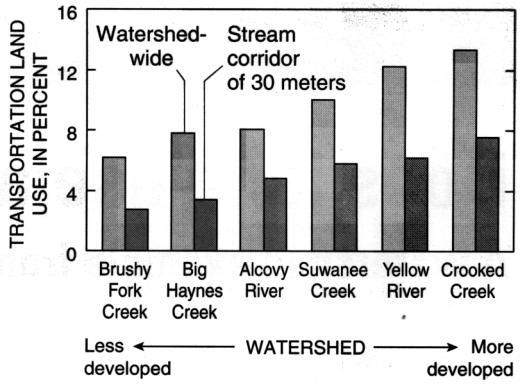
Stream-corridor land use

Streams are particularly sensitive to land use in and near their floodplains. When protected from development, these stream corridors may filter out and substantially reduce pollutants entering streams. The Gwinnett County Stormwater Design Manual (1999) provides incentives to preserve additional stream-buffer areas beyond the 25-foot requirement of Georgia law.

Stream-corridor land use is compared with watershedwide land use. A corridor width of 30 meters (98 feet) was chosen based on the limited resolution of available land-use data. Land is much less developed in the stream corridor than watershedwide. In the more developed watersheds, however, a greater percentage of the stream corridor is developed. The bar chart on the right illustrates this for transportation land use, which has a high impact on water quality.



Stream monitoring

Monitoring streams is critical to watershed assessment and informed management. Long-term monitoring using consistent methods is essential to compare conditions between watersheds and to identify trends. The watershed-monitoring network for Gwinnett County was designed and installed during 1996 as a cooperative investigation of the U.S. Geological Survey and the Gwinnett County Department of Public Utilities. Stream gages in six watersheds continuously monitor water level, streamflow, and precipitation, and periodically collect water-quality samples. At each stream gage, three storm-composite samples and three baseflow samples are collected every 6 months. In baseflow conditions, streamflow is from ground water that seeps through the channel bed and banks. Discharge measurements also are routinely made to define stage-discharge relations. Aquatic invertebrate sampling and habitat assessments were conducted in four watersheds. This report includes data collected through September 2001. During 2002, monitoring began at six additional watersheds in Gwinnett County.

Stream-monitoring station at Crooked Creek.

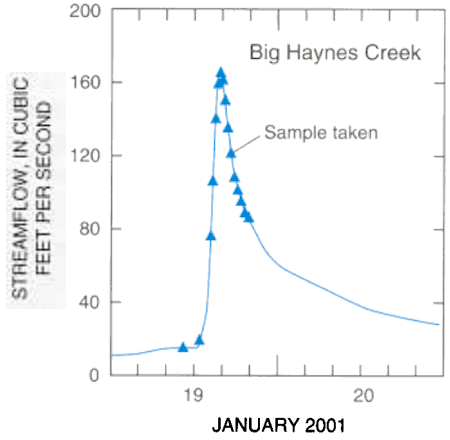
Monitoring stations for the six monitored watersheds

USGS station number	Gwinnett County site number	Monitoring-station name	Area, in square miles
02207120	GWLT-02	Yellow River at SR 124 near Lithonia, Ga.	162
02207385	GWLT-04	Big Haynes Creek at Lenora Road near Snellville, Ga.	17.3
02207400	GWLT-05	Brushy Fork Creek at Beaver Road near Loganville, Ga.	8.15
02208150	GWLT-07	Alcovy River at New Hope Road near Grayson, Ga.	30.8
02334885	GWLT-12	Suwanee Creek at Buford Highway near Suwanee, Ga.	47
02335350	GWLT-01	Crooked Creek at Spalding Drive near Norcross, Ga.	8.89

Crooked Creek during baseflow.

Crooked Creek during stormflow.

Baseflow samples are collected using depth and width integrating techniques. Quality-assurance/quality-control measures ensure that sampled data are not contaminated by outside sources and are representative of the entire stream cross section. All stormflow and baseflow water-quality samples are processed and analyzed at USGS laboratories.



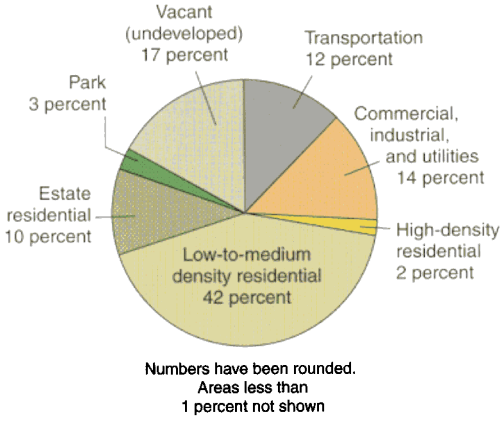
*Assessment of nonpoint-source pollution requires water-quality sampling **during** rainfall runoff. Stormwater samples are collected with automatic samplers to obtain a discharge-weighted composite sample of the storm runoff.*

Properties analyzed

During sample collection, standard field properties are measured including pH, specific conductance, water temperature, and dissolved oxygen. Water samples are analyzed for the following constituents: biological oxygen demand, chemical oxygen demand, total suspended solids, turbidity, total dissolved solids, total phosphorus, dissolved phosphorus, several nitrogen species, and hardness. Trace metals analyzed include cadmium, copper, lead, zinc, chromium, and magnesium.

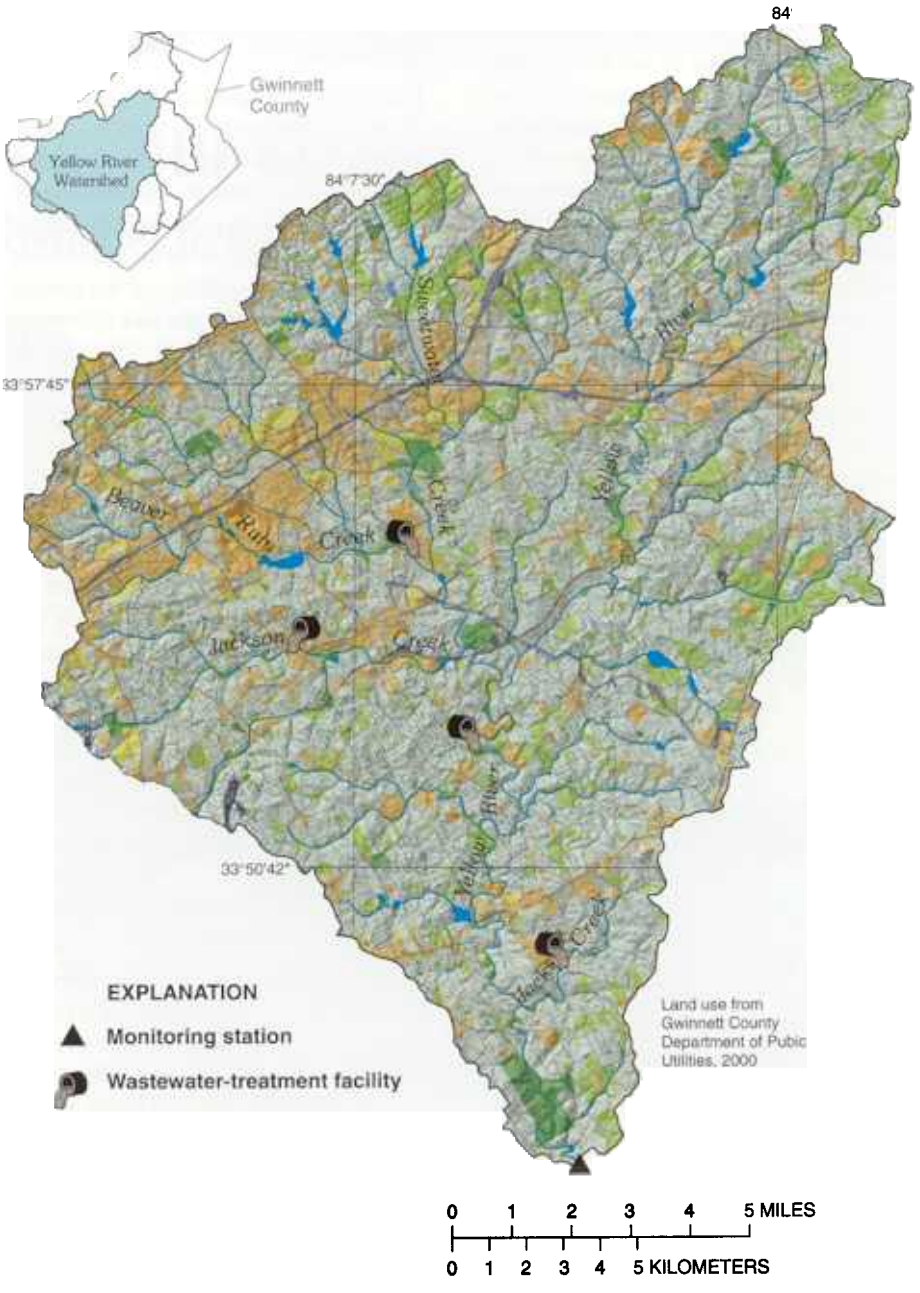
A closer look at land use and hydrology, Yellow River watershed

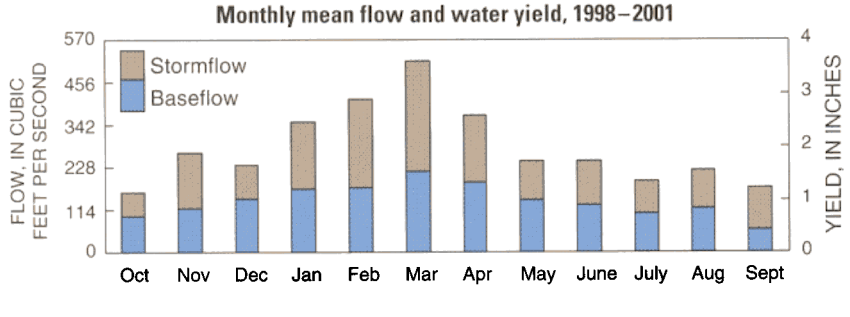
The Yellow River watershed is the largest (162 square miles) in the county and lies in the Ocmulgee River watershed. It is situated in the more densely developed, southwestern part of the county. Land use (in 1998) is shown for the portion (97 percent) of the watershed located within Gwinnett County. The predominate land use (42 percent) is low-to-medium density residential. Commercial and industrial development are concentrated along the major transportation corridors. Four wastewater-treatment facilities discharge into the watershed upstream from the monitoring station.

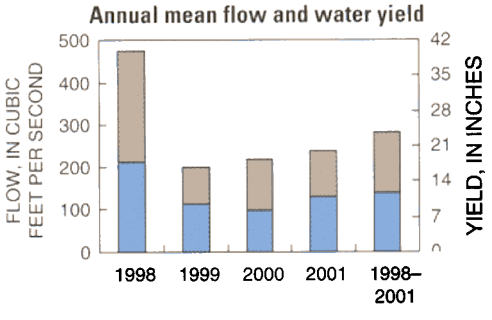


Yellow River watershed land use in 1998.

Continuously monitored streamflow can be divided into components of stormflow and baseflow using hydrograph separation techniques (Sloto and Crouse, 1996). Stormflow is the rainfall runoff that enters the drainage network from overland flow. As a percent of total flow, stormflow is greatest during wet months and years. Baseflow enters the drainage network through the streambed and banks and is more stable.







The seasonal nature of streamflow is evident in the monthly mean water yield. Water yield is the total volume of streamflow during a month or year divided by watershed area. The average yield for the wettest month (March) is more than three times greater than that of the driest month (October). Annual variability is evident in the annual mean flow and yield. The 1998 average flow was at least twice the flow of the drought years 1999–2001. For the period 1998–2001 in the Yellow River watershed, the average total water yield was 23.7 inches, which is 52 percent of the average precipitation.

Streamflow concentrations and watershed loads and yields, Yellow River watershed

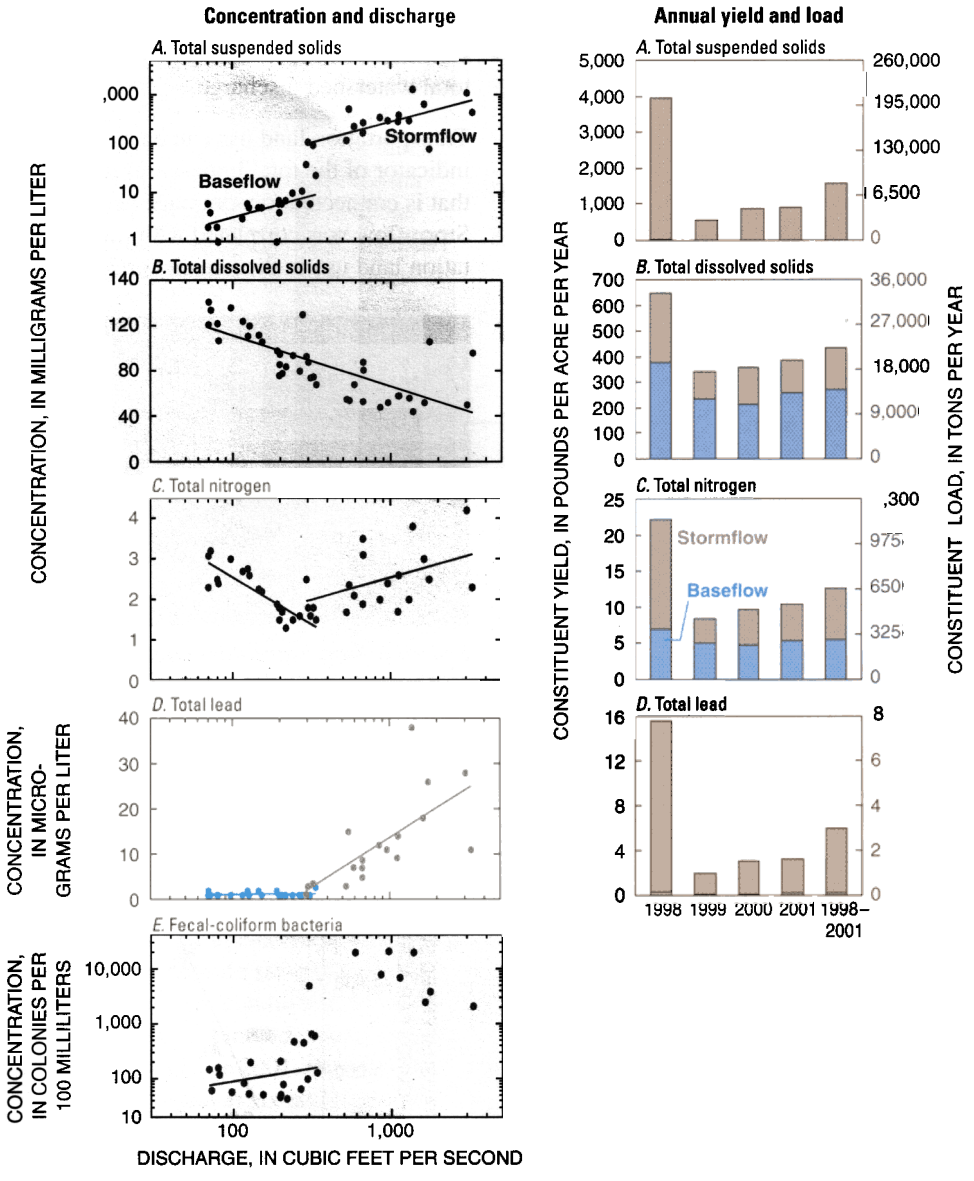
Streamflow samples are analyzed to determine constituent concentrations. These data define whether the stream quality is adequate for uses such as recreation, for drinking-water supply, for fishing, and as a habitat for aquatic organisms. However, one must know more than the condition of a stream in order to mitigate pollution and manage the resource. Is the pollution from point sources or nonpoint sources? When and how are constituents transported? An intensive monitoring program, such as the one for Gwinnett County, can address these questions.

Collecting a stream sample at baseflow.

Constituent load, shown to the right in units of tons per year, is the product of concentration and discharge. Constituent yield, shown in units of pounds per acre per year, is the load divided by the watershed area. Loads are computed using a relatively simple rating-curve model (Crawford, 1996). The model is calibrated and run using a stormflow load-to-discharge curve, and a baseflow load-to-discharge curve, and applied to the daily time-step hydrograph for the Yellow River. The results, summarized in the graphs to the right, illustrate several important points.

- Water quality typically is **worse during stormflow than during baseflow**.
- **Concentration-to-discharge curves are dissimilar** for stormflow and baseflow for suspended solids and for constituents having an affinity for solid phase particulates (such as metals); whereas the curves are similar for total dissolved solids.
- The absence (lead) or presence (total nitrogen) of **constituents from point sources is evident** in the baseflow concentration-to-discharge curves. Concentrations of constituents from point sources are diluted and decrease with increasing baseflow.
- **Nonpoint-source constituent concentrations increase** with increasing streamflow because larger storms typically wash off more constituent mass from a larger area of the watershed.
- In constituent loads and yields, the effect of dissimilar baseflow and stormflow concentration characteristics is multiplied. **Stormflow loads of nonpoint-source constituents vary exponentially with stream discharge** because concentration increases with discharge, and the load is a product of concentration and discharge.
- **Seasonal and annual loads vary** with precipitation and total streamflow. **Baseflow loads are relatively constant** from year to year.

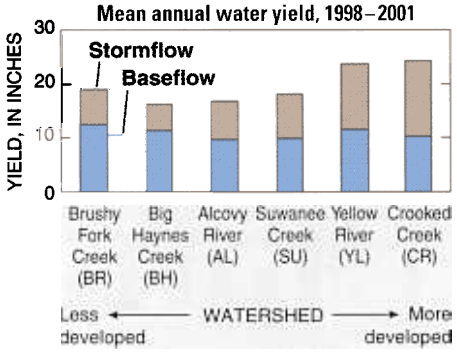
These findings are relevant to analyses of total maximum daily load, watershed assessments, and watershed protection strategies.



***A.** Excessive total suspended solids are a major cause of habitat degradation in north Georgia streams. Stormflow and baseflow have dissimilar total-suspended-solid characteristics; 99 percent of the annual load is carried by stormflow. **B.** Total dissolved solids are naturally higher in baseflow, which has filtered through the ground. The total dissolved solids-to-discharge curve is similar for baseflow and stormflow. **C.** The dilution of point-source nitrogen is evident in baseflow. Nonpoint-source nitrogen increases with discharge. These nitrogen levels **do not** indicate an impaired status for the Yellow River. **D.** Lead concentrations are typically below detection limits during baseflow, indicating no lead point sources. Stormflow carries 97 percent of the annual lead load. **E.** Fecal-coliform bacteria serve as an indicator for possible pathogenic bacteria in streams. Fecal-coliform data are highly variable, but stormflow concentrations typically are much greater than baseflow concentrations.*

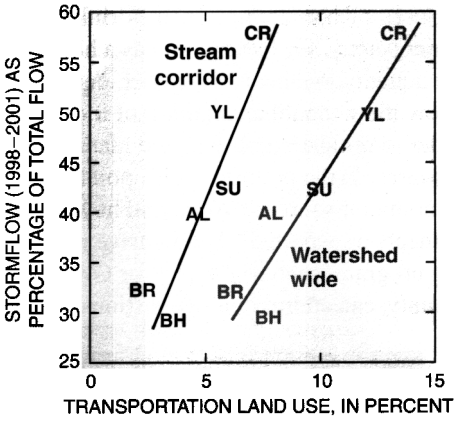
Effects of land use on stream hydrology

Bare or impervious areas and a more developed stormwater drainage system produce greater volumes of high-energy stormflow and reduce baseflow in a stream. A measure of this effect is the average stormflow of a watershed, taken as a percentage of total watershed flow. The bar chart below shows that with increasing watershed development, stormflow increases as a percentage of total watershed discharge.



Transportation land use can be an indicator of the total impervious area that is connected to a drainage network. Stormflow was correlated with transportation land use in the stream corridor and watershedwide. The correlation is slightly better for stream-corridor land use. Additional stream-corridor analyses are needed using higher resolution land-use data.

Sediment from stormflow into the Yellow River.



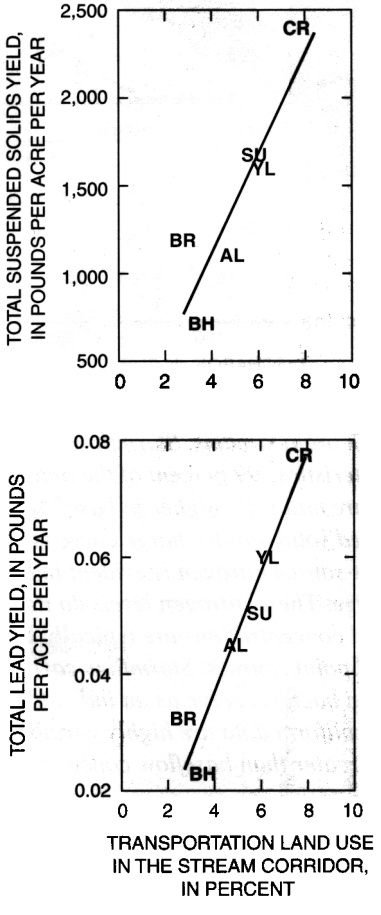
Stormflow, as a percent of total flow, increases with increasing transportation land use.

Effects of land use on stream loads and yields

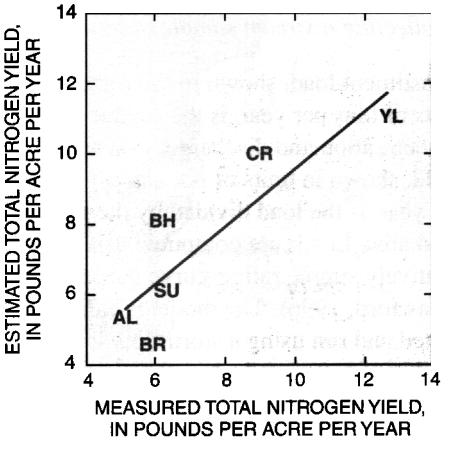
Increased stormwater runoff accelerates erosion of the land surface, particularly for areas under construction, and causes scouring of stream channels resulting in much higher stream-sediment loads. Total suspended solids are used as a measure of overall development impacts in the Gwinnett County Watershed Protection Plan (2000). The usefulness of that management strategy is illustrated here in the strong relation shown between total suspended solids and transportation land use in the stream corridor.

Lead levels in most streams have decreased since the early 1970s as a result of compliance with environmental laws. Lead yields in the six monitored watersheds are closely related to transportation land use in the stream corridor. This may be due to increased lead deposition in paved areas by transportation and related land uses; and because of the greater efficiency of wash off from these surfaces, accompanied by reduced filtration of runoff before it reaches the drainage network.

Nitrogen loads in the watershed have both nonpoint and point sources. Nonpoint sources include natural organic detritus and applied nitrogen, such as from fertilizer. Nitrogen yield was estimated based on an index of whether or not the watershed contains wastewater-treatment facilities, and based on land-use percentages in the following categories: low-to-medium density residential, high-density residential, commercial/utilities, and transportation.



Monitoring data from six Gwinnett County watersheds show strong relations between transportation land use in the stream corridor and watershed yield of total suspended solids and lead.



Nitrogen yield can be estimated from watershed land use and point-source indices.

The annual yield of a constituent in streamflow is affected by an array of land uses, point sources, hydrologic factors, chemical processes, and other factors. Effective water-resource management is difficult because of these many factors. However, stream monitoring can provide information and tools that are valuable for watershed assessments, land-use planning, and informed water-resource management.

Effects of land use on stream ecosystems

Just as stream-water quality is affected by watershed land use, so are the aquatic organisms. Stream communities in Gwinnett County are composed of a relatively diverse group of organisms rarely seen by most people. These stream inhabitants spend all or parts of their life cycles in aquatic environments and include insects as well as crayfishes, snails, mussels, and aquatic worms. Since these organisms generally live in the same section of stream during their entire lives, the invertebrate community that develops is correlated with water-quality and habitat conditions of that stream section.

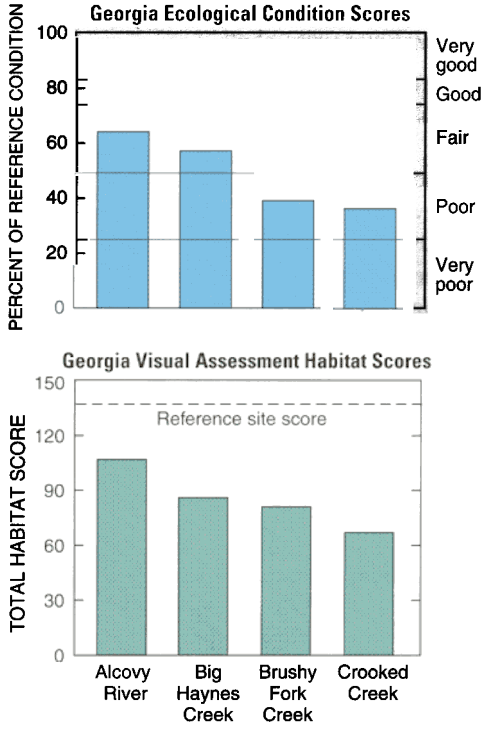
To determine the Georgia Ecological Condition Scores (Georgia Department of Natural Resources, 1997), invertebrates collected during site visits are identified and counted by a trained taxonomist. Similar species are grouped according to how tolerant they are to pollution or how they feed in the aquatic environment. Using these data, indices that have been shown to be related to environmental degradation are calculated.

Collecting an invertebrate sample from riffle habitat in a stream in Metropolitan Atlanta.

Part of the Georgia Ecological Condition Score is composed of a separate index known as the Georgia Visual Assessment Habitat Score (Georgia Department of Natural Resources, 1997). This index provides managers with an assessment of the physical condition of the stream habitats present at a site and allows comparison among streams included in the study as well as to regional reference sites. Habitat data allow more accurate interpretation of the biological data especially when viewed in conjunction with water-quality data.

Invertebrate samples were collected near the stream gages of four of the six monitored watersheds. A reference site, located on the Alcovy river in the upper Alcovy watershed, was selected and sampled to represent relatively unimpaired ecological conditions in Gwinnett County. Georgia Ecological Condition Scores are expressed as a percentage of the score of the reference site and rated from very good to very poor, in comparison with conditions across northern Georgia, including Gwinnett County.

The most densely urbanized watershed, Crooked Creek, has the lowest Ecological Condition Score. However, for the three other watersheds, the comparative ecological condition does not agree with the comparative land-use development. This may be largely due to the localized effects of past channelization on aquatic habitat in Big Haynes Creek and Brushy Fork Creek. The effects of channelization also are apparent in the habitat scores.



Georgia's Ecological Condition and Visual Assessment Habitat Scores for selected watersheds in Gwinnett County

Streams are strongly affected by watershed land use. Land-use effects are evident in the amount of streamflow during storms, in the amount of constituents in a stream, and in the stream ecosystem. Monitoring and understanding of these effects provide information for the wise management of land use and water resources.

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Base maps from Gwinnett County Board of Commissioners, Department of Support Services.

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