SEDIMENT

Sediment can be defined as the particles of soil, surficial material, and rock that become detached as a result of the hydrologic *(fluvial)* processes of sheet, rilling, and gully erosion; and through the mass wasting action of the wind *(eolian)*. Fluvial processes are predominant in the Piedmont Basin. Thus, the remaining discussion will concentrate on this form of erosion.

Characteristics

Soil erosion from upland areas is an ongoing natural process, and a certain amount of sediment bed-load transport is necessary to maintain stream stability. However, through human influence on the landscape, this process can be accelerated by orders of magnitude. As a result, the natural balance is upset, often leading to serious environmental degradation. According to the EPA's *1992 National Water Quality Inventory Report*, siltation is the most prevalent cause of impairment in assessed rivers and streams and is one of the five leading causes of lake impairment.

The characterization of sediment is, of course, closely linked to the geology, climate, and soils of a particular watershed. The ratio of silt, sand, and clay in an individual soil series determines its cohesiveness and thus its capability to withstand erosive forces. Soils composed mostly of silt and sand will erode more easily, with heavier sands tending to settle out in the stream system, and lighter sands and silts being deposited in ponds, lakes, and tidal outfalls. Eroded clays often stay in suspension, causing turbidity problems. However, if detained long enough for flocculation to occur, they can also be deposited in receiving waters. In general, the soils found in the Piedmont geological province contain all three textural classes and contain a higher percentage of fine soils than those found in the Atlantic Coastal Plain. (For a more detailed discussion, please see the Soils section in this document.)

In addition to soil texture, vegetative cover and land slope are other major factors used in assessing potential soil erosiveness. In the watersheds of the Piedmont Basin, as in most watersheds, the more erosion-prone, steeper slopes tend to be adjacent to streams and tributaries. This can be seen on Map 20, which shows the soil slope classifications for the individual mapped soils within the basin. (Under this classification system, slope tends to increase as the factor progresses from "A" to "E." The slope factor does not indicate the same slope range between soil series, but rather is a relative measure of slope within the soil series. However, it is a good indication of whether a particular mapped soil is at the flatter or steeper range at which it can be found.) In general, Map 20 indicates that as the distance to a stream channel decreases, the soil slope factors tends to be steeper.

Where appropriate, soils were also mapped as being "moderately eroded" or as "severely eroded" in their natural state during the course of the soil survey. As expected, and as shown on Map 21, the "severely eroded" soils were generally located on the steeper slopes adjacent to the tributaries. Map 21 also indicates that, except for the tidal reaches lower in the basin, many of the remaining soils were mapped as being "moderately eroded." The implication is, of course, that the eroded material became sediment in the receiving waters.

As a physical pollutant, excessive accumulation of sedimentary material can fill streams and lakes to the point where they are no longer navigable. The acceleration of the erosion process started with the colonization of North America, as the native forest cover was converted to agricultural land uses. Such is evident in the Piedmont Basin, where many colonial ship landings such as the town of Christiana are no longer accessible by larger watercraft. A more contemporary impact is the loss of water carrying capacity in the streams of the Piedmont Basin and their associated bridges, culverts, etc. This can lead to flooding problems and disrupt the transportation infrastructure. Keeping these streams and structures sediment-free requires constant maintenance in many instances, and this, of course, translates into public expenditures. Sediments that are not deposited in the streams themselves tend to settle out in the ponds and lakes fed by those streams. For water-supply reservoirs, this results in a loss of capacity as well as increased treatment costs due to turbidity problems. For recreational ponds and lakes, surface area is often lost as the upper reaches silt in.

In some cases, it may be necessary to dredge accumulated sediments to restore recreational capabilities. The records of the Division of Soil and Water Conservation's Dredging Program indicate that the following dredging projects have been completed in the Piedmont Basin:

Follies Pond (Christina River)	28,000 yd^3 removed in 1979
Carousel Pond (White Clay Creek)	30,000 yd^3 removed in 1986
Smalley's Pond (Christina River)	50,000 yd^3 removed in 1989
Bellevue State Park (Shellpot Creek)	20,000 yd^3 removed in 1990
Lewis Pond (Christina River)	3,600 yd^3 removed in 1992
Four Seasons Pond (Christina River)	8,500 yd^3 removed in 1993

Besides human impacts, sediment has serious physical impacts on aquatic ecosystems. It can cover the stream

bottom, smothering fish eggs and bottom-dwelling organisms that rely on the "nooks and crannies" provided by the natural bottom substrate. Sediment particles can abrade and accumulate on the gills of fish and other aquatic creatures, causing stress and even death in some cases. Similar impacts can be observed in lake systems as well. It is generally accepted that deposition of sedimentary material and associated nutrients is the major mechanism leading to accelerated eutrophication of ponds and lakes. Submerged aquatic vegetation is particularly susceptible to problems associated with excessive sedimentation. The act of removing accumulated sediments can itself have negative impacts, as wetlands and other aquatic ecosystems are disturbed in the process.

During the fall of 1993, DNREC's Watershed Assessment Section conducted an assessment of the habitat quality of 38 Piedmont streams. Several of the parameters, or "metrics," associated with that study were directly related to stream channel stability and sediment deposition. These included bank stability, velocity/depth ratio, sediment deposition, and embeddedness. This study suggested that an estimated 90% of the nontidal streams in the region had degraded (i.e., "Fair" or "Poor") physical habitat. The study also indicated a strong relationship between the amount of impervious area in a watershed and the degree of habitat degradation.

Ambient water-quality data historically have been collected by DNREC for the EPA's Storage and Retrieval of U.S. Waterways Parametric Data Base. The sampling sites located in the Piedmont Basin are depicted in Map 9. The sampling protocol is based on random sampling and does not distinguish between "dry flow" and "wet flow" conditions. A measure of total suspended solids is often used to characterize soil particles in the water column itself. Although this protocol does not include total suspended solids, it does include a measure of the total non-filterable residue, which can be used as an indicator for total suspended solids. Based on an analysis of the data from selected stations in the Piedmont Basin from 1991 through 1993, the mean total non-filterable residue concentrations for the various watersheds were as follows:

Christina River	12.69 mg/l (14 stations, N = 54)
White Clay Creek	6.00 mg/l (7 stations, N = 48)
Red Clay Creek	17.79 mg/l (5 stations, N = 48)
Brandywine Creek	4.29 mg/l (5 stations, N = 42)
Shellpot Creek	10.50 mg/l (3 stations, N = 10)
Naamans Creek	6.00 mg/l (3 stations, N = 9)

Based on data generated for the EPA's Water Body System, Becks Pond (Christina River watershed), was classified as only *partially supporting* primary contact recreation and recreational fishing. Siltation and suspended solids were indicated as having high likelihood as a cause of this non-attainment of the designated use. (Non-attainment of the designated use was indicated to have a high likelihood of being caused by siltation and suspended solids.) It was also indicated that this was linked with land development, highway construction and maintenance, drainage and filling operations, and removal of riparian vegetation. In this same data base, a 1.8-mile segment of Little Mill Creek (Christina River watershed) was classified as *threatened* for recreational fishing. Siltation was also shown to be a moderate cause for this non-attainment, with a positive link to land development.

Some of the more serious environmental impacts associated with sediment are of a chemical nature. Individual sediment particles have a large surface area, and many molecules easily adsorb or attach to them. As a result, sediments can act as chemical sinks by adsorbing metals, nutrients, hydrocarbons, pesticides, and other potentially toxic materials. Indicator bacteria are also associated with runoff-borne soil and organic matter. Thus, areas of high sediment deposition sometimes have high concentrations of nutrients and persistent (i.e., long-lived) chemicals and contaminants, which can be later released. Sediments that contain concentrations of constituents greater than those found in nature are classified as "enriched," while those with concentrations of constituents that are not normally found in natural sediments are classified as "contaminated."

According to the *1994 Delaware Watershed Assessment Report* (also known as the *305[b] Report*), bacteria are the most widespread contaminants in Delaware's surface waters, but nutrients and toxics pose the most serious threats to aquatic life and human health. Many bottom-dwelling organisms are filter feeders. As contaminated sediments pass through their bodies, some of the contaminants can be absorbed into body tissues. Since these organisms are often on the bottom tier of the "food web," the contaminants can move through the entire web, eventually reaching vertebrates such as fish. If higher vertebrates, such as birds and mammals (including humans), consume these fish in large enough quantities, there can be serious health consequences. This scenario has been well documented in the case of polychlorinated biphenyls (PCBs). Based on studies done within and outside DNREC, elevated concentrations of the following constituents have been identified either directly in the sediments or in fish tissue in these respective watersheds:

Christina River	PCBs, polynuclear aromatic hydrocarbons, zinc, other miscellaneous metals
White Clay Creek	PCBs, zinc, other miscellaneous metals
Red Clay Creek	PCBs, zinc, dioxin, chlorinated pesticides, other miscellaneous metals
Brandywine Creek	PCBs

Trends

The only historic sediment trend analysis that was found while researching this topic was completed by the U.S. Geological Survey for one of its gauge stations on the Brandywine Creek at Wilmington (Station 01481500). An analysis of the cumulative daily suspended sediment data indicated there was no significant change in annual loadings for the period of record from 1948 to 1979.

Ambient water-quality data, which have been collected in support of the EPA's Storage and Retrieval Program, were analyzed in 1996 by DNREC's Watershed Assessment Section. A trend analysis indicated that total suspended solids concentrations have generally declined for all the Piedmont stations analyzed. The period of record varied by station and no distinction was made for wet-flow and dry-flow conditions. However, this appears to complement findings of the U.S. Geological Survey.

No data were found on long-term sediment deposition. This prevents any kind of trend analysis for this important parameter. However, there is a very clear trend in land use in the Piedmont Basin, with a steady conversion of agricultural and forested lands to urban/suburban land uses. As discussed in the next section, this will likely continue to make sediment a significant environmental stressor throughout the basin.

No data were available to assess trends in contaminated sediments. Historic discharges from past unregulated industry may be responsible for much of the sediment contamination in the basin. However, it is likely that many of the nutrients, metals, toxics, and other contaminants currently identified in sediments are still being actively deposited. What is not well established at this point is the magnitude of current loadings.

Sources of Impact

Sediment has been identified by the EPA as one of the major nonpoint source pollutants due to its diffuse nature. Nationwide, agricultural activity has been identified as the leading source of sediment to receiving waters. This is probably also true for the state of Delaware as a whole. However, the Piedmont Basin encompasses the most urbanized area of the state. Based on 1992 land-use data, none of the sub-watersheds of the Piedmont Basin exceeded 27% in agricultural lands. Additionally, these areas are shrinking as they continue to be converted to urban and suburban land uses. Although construction activity is considered to be a temporary land use, up to 10 times more erosion than agricultural land uses and up to 2,000 times more erosion than forested land uses can occur over the same period of time. This conversion process is therefore expected to be the major contributor of sediment loading in surface runoff as build-out continues in the basin.

Recent studies performed in other parts of the country also indicate that a significant portion of the sediment load in receiving waters of urbanized watersheds is coming from the stream channel system itself. The natural stream channel gradients associated with the Piedmont Basin are the steepest in the state, which results in the highest flow velocities. As impervious surfaces are added, runoff volumes increase and bank-full storm flows occur at a greater frequency. Higher stream velocities, longer duration of flow, and more frequent high-flow conditions can cause the system to interfere and go out of equilibrium, resulting in accelerated stream channel erosion.

Potential contamination sources for sediments are typically associated with point sources. The location of known Superfund and Hazardous Waste Facilities in the Piedmont Basin is illustrated in Map 4. These should not be interpreted as known contamination sites, but as areas that could potentially act as sources for sediment contamination.

Map 4 also shows the location of all sites in the basin regulated under the federal National Pollutant Discharge Elimination System (NPDES). These sites are typically associated with industrial activities and wastewater treatment facilities with defined discharge points. They have the potential for discharging "clean sediments" as well as materials that could lead to contaminated sediments.

Positive Initiatives

The entire Christina River watershed is currently under study as part of DNREC's comprehensive five-year plan being initiated under the Nonpoint Source Pollutant Management Strategy for the Christina River basin using funds provided by Section 319 of the Clean Water Act.

DNREC's Nonpoint Source Program and Delaware Coastal Management Program provide grant funding for initiatives that strive to reduce the impacts of both agricultural and urban nonpoint source pollution.

The New Castle Conservation District prepares individual Conservation Plans for agricultural landowners in the watershed. These plans are intended to reduce nonpoint source pollution associated with agricultural activities.

Since the passage of the Delaware Sediment and Stormwater Law in 1991, all new construction activities that disturb over 5,000 square feet are required to have an approved sediment and stormwater plan unless specifically exempted. The program is delegated to various local agencies with oversight by DNREC's Sediment and Stormwater Program and uses a "best available technology" approach to control nonpoint source pollution associated with construction activities.

DNREC's National Pollutant Discharge Elimination System Program regulates stormwater discharges for

specific industries, as identified in the law. At the time this report was being prepared, it was not clear if Phase II of the program was to be implemented. If so, all major storm drainage outfalls in New Castle County would also fall under these regulations.

DNREC's Hazardous Waste Management Branch oversees existing facilities and performs routine investigations, which sometimes involve contaminated sediments. If contaminated sediments are found, rigorous control and /or cleanup procedures are implemented in conformance with appropriate regulations.

The federal Superfund Program was established to address the country's worst hazardous waste sites. These sites have been determined to pose a significant risk to public health or the environment and have the potential to be sources for some of the most toxic contaminants. DNREC's Site Investigation and Restoration Branch oversees the cleanup of those sites that will not be addressed by the federal government.