III. EARTH RESOURCES

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A. Geology

Geologic Overview: Age and History

The upper portions (headwaters) of the Darby Creek Watershed are comprised primarily of older rock from the Precambrian Era (older than 570 million years) and Lower Paleozoic Era (430 to 570 million years old). The lower portion of the Watershed consists of "younger" rock from the Tertiary and Quaternary Periods (up to 67 million years in age). Weathering and erosion of these various rock types (Figure III-1) has produced the rolling topography of the upper Watershed and the gently undulating and relatively even landscape of the lower Watershed.

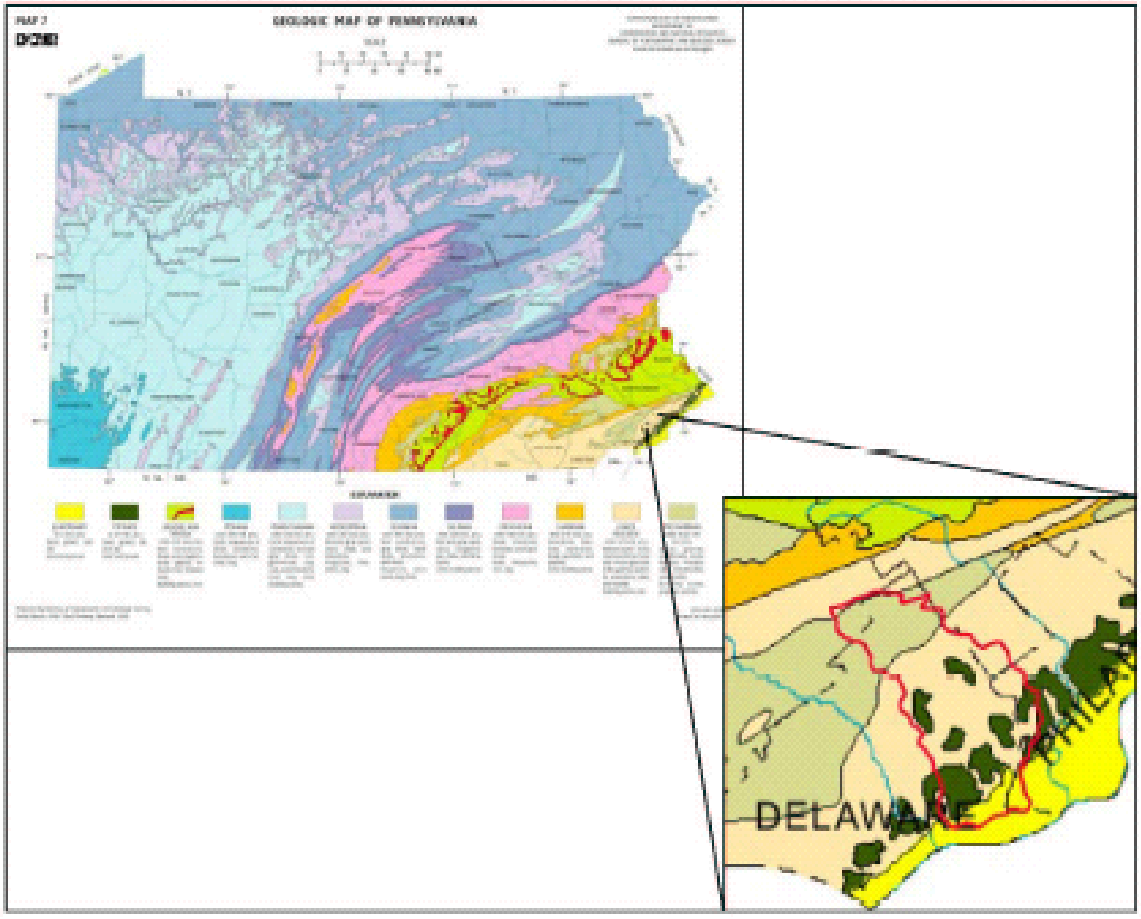

Figure III-1 Geologic map of Pennsylvania showing the Darby Creek Watershed, (DCNR)

During much of the Paleozoic Era (570 to 245 million years ago), the Earth's tectonic plate movements forced land masses together several times. One of the most significant "collisions" of these plates occurred 300 million years ago as the eastern margin of North America collided with South America and Africa. The impact lifted the land and produced the Appalachian Mountain range with elevations well over 15,000 feet, rivaling today's Alps and Himalayan ranges. Pangaea, the supercontinent created from the impact, subsequently began to break up and rift during the Triassic Period (245 to 208 million years ago) to create the modern day Atlantic Ocean. To put this historic activity into perspective for the Watershed, the Darby basin is the eroded remnant of what once was a massive mountain range. Watershed residents are currently residing on the weathered and eroded geologic material of this historic mountain range – the Appalachian range.

Remnants of this historical rifting activity appear in areas where younger rock was downfaulted into the older rock, creating Triassic basins (Figure III-2). Triassic basins are modern day remnants of a geologic transition period. Through the subsequent millions of years of intense geologic activity, the Appalachian range underwent vigorous erosion by wind and water, as well as cycles of uplifting and rifting, to create the present geology and landform within the Darby Creek Watershed region.

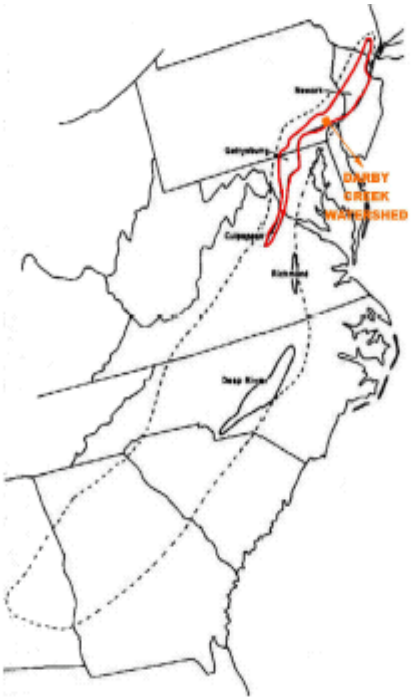

Figure III-2 Triassic Basin Deposits in Delaware County Region, (Godfrey 1997)

Physiography

The Darby Creek Watershed straddles two physiographic provinces: the Piedmont Uplands Province in the north and the Atlantic Coastal Plain Province in the south (see Figure III-3). A physiographic province is the expression of bedrock at the surface of the land. All the land in the Piedmont and the Coastal Plain provinces have undergone geological processes in the past, which have produced a characteristic topography. The northern portion of the Darby Creek Watershed, situated in the Piedmont Uplands, is characterized by generally very old and hard upland rocks, resulting from the erosion of the Appalachian Mountains. The Piedmont, meaning "foot of the mountains," is a region of gently rolling hills, fertile valleys, and well-drained soils. Weathering and erosion over the years has produced the rolling topography, often more deeply cut by streams with deeply incised stream valleys traversing the landscape.

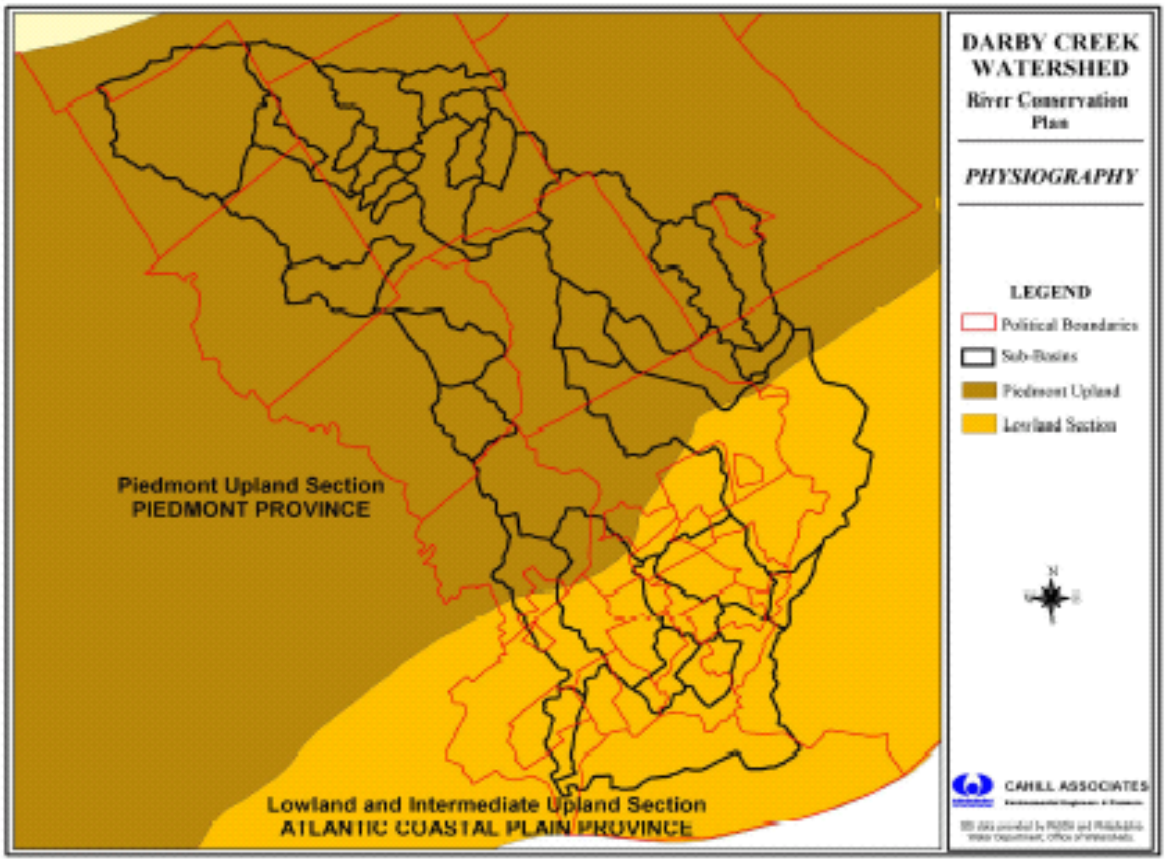

Figure III-3 Physiographic Provinces within the Darby Creek Watershed

The Coastal Plain portion of the Watershed in the south contains soft, unconsolidated sediments that were deposited by water and glacial erosion relatively recently (1.6 million years ago). This Coastal Plain land is generally low, gently rolling to flat and poorly drained, consisting of

unconsolidated and poorly consolidated layers of Quaternary-age sand, gravel, and clay dipping gently to the east. The areas of the Darby Creek Watershed located in the Coastal Plain have primarily been developed for industrial and residential uses. The John Heinz National Wildlife Refuge at Tinicum is the exception and is one of the few remaining natural Coastal Plan habitats in Pennsylvania.

The boundary between the Piedmont and the Coastal Plain Provinces is marked by what is known as the "Fall Line". The Fall Line is a conceptual geologic break marked by waterfalls and rapids that form where the hard rock of the upland Piedmont region meets the softer rock of the Coastal Plain. Falls and rapids develop as erosion by streams wears away some of the softer rock, creating a ledge over which the water flows. In the Darby Creek Watershed, the falls and rapids historically provided sufficient energy for the development of numerous mills located adjacent to the Creek. Remnants of several of these mills can still be seen today and provide reminders of this important phase in the Watershed's historical development.

Digitally, this physiographic transition is represented through the manipulation of digital elevation models ("DEM") using a geographic information system ("GIS"). A DEM is transformed into a "hillshade" image in order to show the change in elevations at the land surface. When the hillshade is overlaid with the existing stream network (Figure III-4), it becomes easier to see how the current land surface was shaped by historic geologic activity.

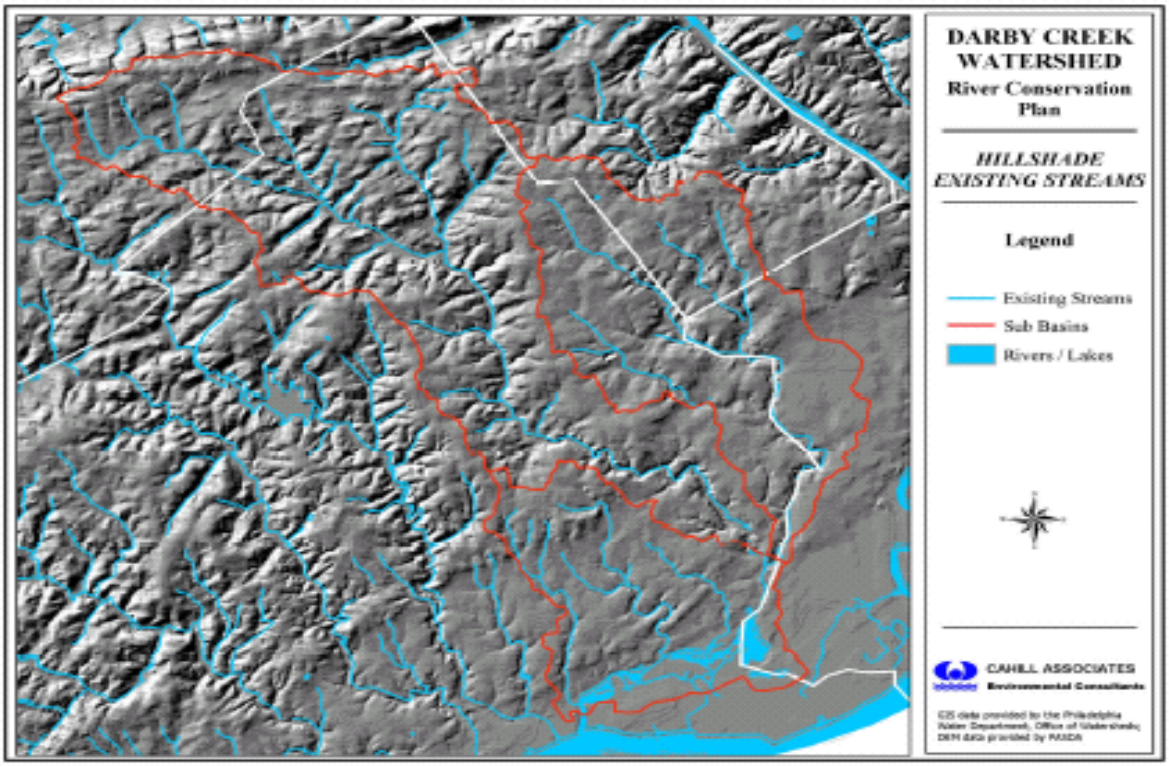

Figure III-4 Hillshade Showing the Fall Line between the Piedmont and Coastal Plain

Topography and Land Form

The topography of the Watershed was shaped by the great tectonic forces of the earth's shifting crustal plates, combined with hundreds of millions of years of erosion by wind and water. As described above, the contemporary topography is based on the physiographic region in which the Watershed lies. In the rolling hills of the Piedmont portion of the Watershed, elevations generally range from 200 to 100 feet above sea level. The range of elevations in the gently rolling and relatively flat Coastal Plain portion of the Watershed is 100 to 0 feet above sea level.

Steep slopes are rare in the Coastal Plain. Although elevations are not great in the areas of the Watershed in the Piedmont region, changes in elevation, and more steeply sloped areas, can be found in the more northern portions of the Watershed. Slopes can be especially steep in the sometimes deeply incised stream valleys that have been cut over the years. The geological history and variability is often revealed in the attractive, even dramatic rock outcroppings that are exposed in the Darby Creek's stream valleys.

Specific Geologic Description

The Darby Creek Watershed consists primarily of ancient crystalline bedrock, along with metamorphic and igneous rocks from the Precambrian Period (430 to 570 million years ago). Figure III-5 depicts the surficial geologic units of the Watershed and surrounding region, though only geologic units found within the Watershed boundaries will be discussed here. Each rock formation has important properties that influence the local hydrology, topography, vegetative composition and structure, and landform of the Darby Creek Watershed. Geology tends to be related to Watershed soils as well.

The Wissahickon Formation, a mica schist derived from sandstones and mudstones, is predominant in the Watershed as well throughout the Piedmont Plateau region of the Delaware Valley (see Figure III-5). The Wissahickon Formation is a consolidated rock aquifer and is the highest yielding crystalline aquifer in Delaware County (Balmer and Davis, 1996). Felsic gneiss and mafic gneiss are metamorphic rock units, located in the northern portion of the Darby Creek Watershed. These formations yield smaller quantities of water due to the smallness of the cracks, joints, and other openings within the rock. The Bryn Mawr Formation and the Bridgeton Formation are unconsolidated deposits that overlay the tighter and denser crystalline bedrock. These geologic formations are important in that they provide additional hydrologic recharge and groundwater volume for the crystalline rocks beneath them.

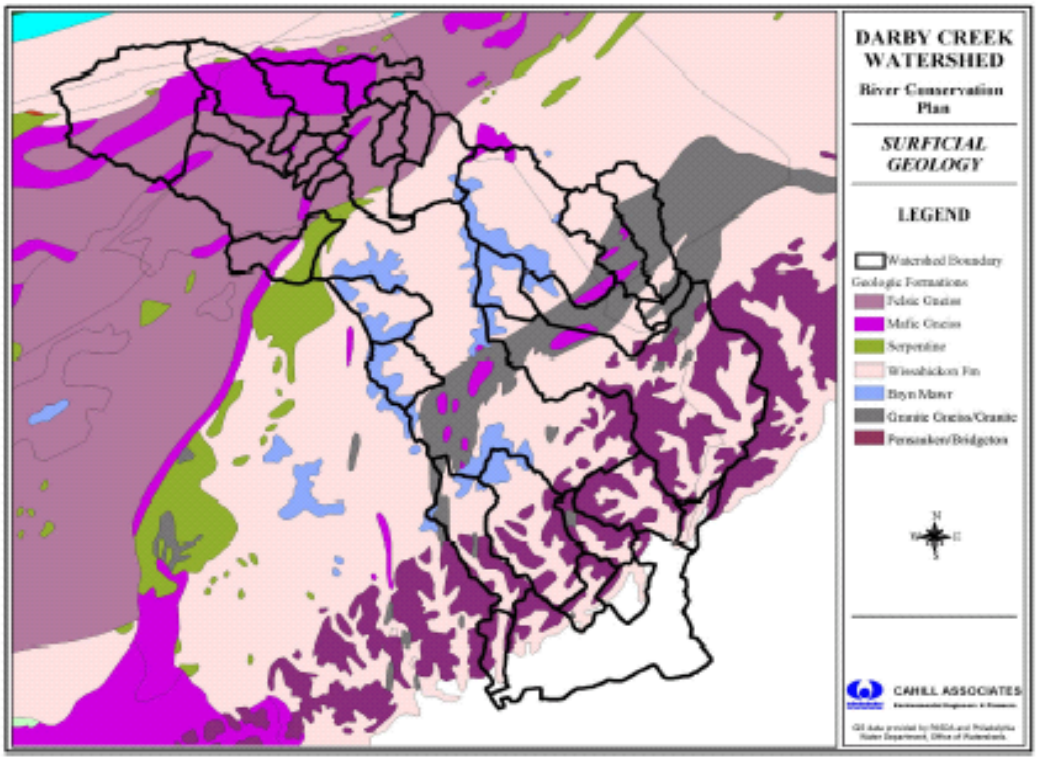

Figure III-5 USGS Geologic Composition of Darby Creek Watershed

Within the Watershed, small areas of serpentine rock appear in southern Radnor and Newtown Townships. Early in the 19th Century, the Watershed and surrounding region was famous for its serpentine rock quarries. Serpentine stone was easily extracted from the earth and provided building material for many local structures and homes in earlier periods. Serpentine and the minerals associated with this formation produce a sterile and toxic growing environment for crops and plants, and as such were often referred to as "serpentine barrens." Serpentine barrens are rare on the East Coast but where they exist they provide a habitat for many rare, threatened, and endangered species. These areas, however, have been impaired human behavior. Historical mining and quarrying destroyed many of these barrens. Continued development and suburban sprawl has led to the continued conversion and consumption of much of the remaining barrens habitat.

In terms of hydrogeology, groundwater is present in and moves in different degrees through cracks, fractures, and voids within the bedrock material in virtually all of these rock formations in the Watershed. Because these cracks, fissures, and voids have been created and modified by weathering over the millennia and are therefore most common closer to the surface, most groundwater is present relatively close to the earth's surface as well, typically less than 500 feet in depth (as depth increases, weathering and water "opportunities" generally decrease). Although small wells have been developed over the years, none of the geologic formations in the Darby Creek Watershed yields enough water consistently for large industrial or public supplies

because of the inherently low storage capacity of the rocks, both consolidated and unconsolidated (Balmer and Davis, 1996). This topic is discussed in more detail in Section IV "Water Resources".

Streams in Delaware County generally act as "drains" for the groundwater aquifers, as they are called, with the groundwater continuously discharging by gravity to the surface streams through systems of springs, seeps, wetlands, and other points of discharge (more discussion in Section IV). The Darby Creek is one of five creeks (Darby, Crum, Ridley, Chester and Brandywine) that flow northwest to southeast (see Figure III-6 below) across Delaware County, all discharging into the Delaware River. These five creeks all flow in remarkably parallel routes through the hard rock and deeply cut Piedmont valleys and the subdued hills of the Coastal Plain.

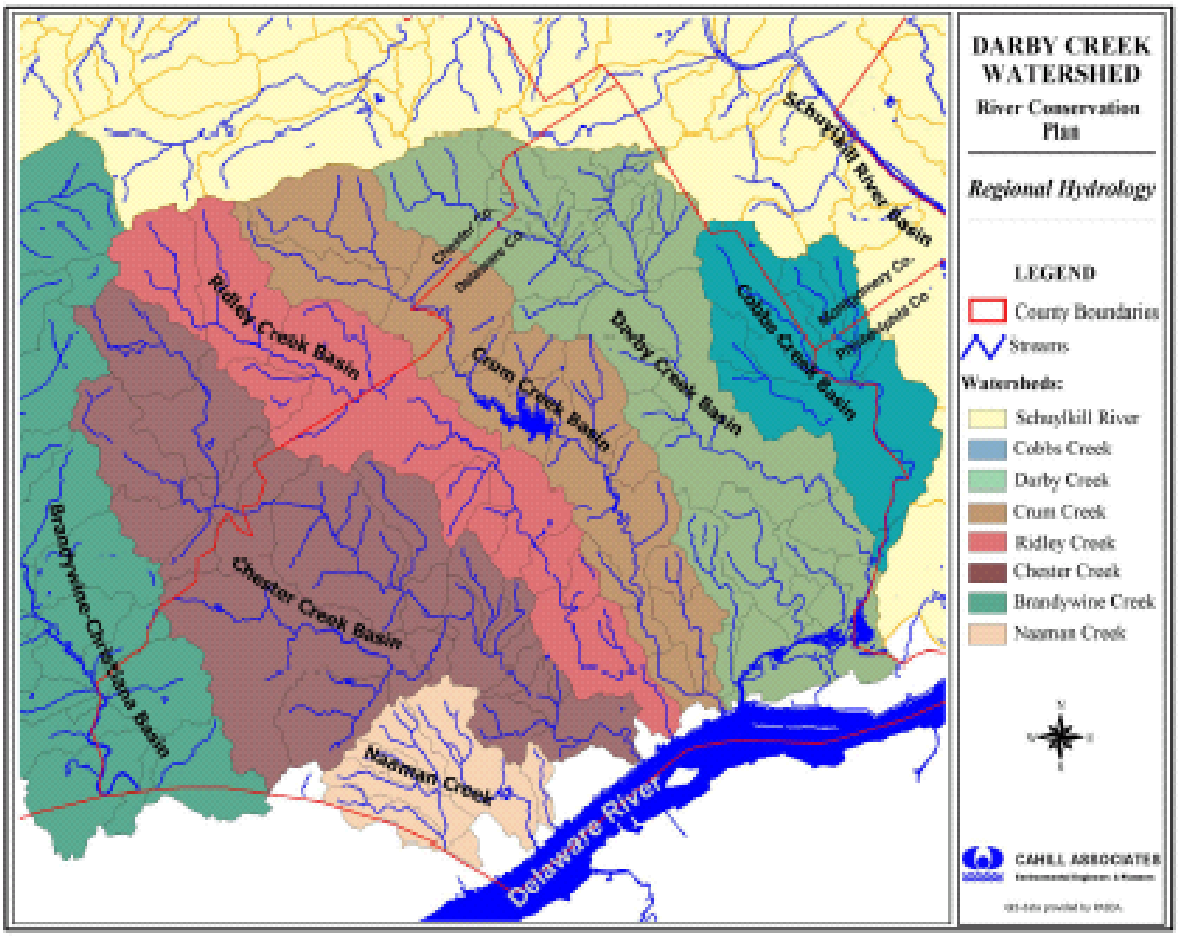

Figure III-6 Parallel Stream Networks Flowing to the Delaware River

B. Soil Characteristics

Major Soil Series & Characteristics

The soils in the Watershed (Figure III-7) reflect the weathering process of the parent bedrock geology. In the Piedmont Region schist, gneiss, and crystalline rock are the predominant bedrock material. These upland areas of the Darby Creek Watershed consist of well-drained silt loam soils including Glenelg, Manor, and Wheaton. Both Glenelg and Manor formed in materials weathered from micaceous schist, and support native oak and red maple vegetation. The Wheaton soil series is the product of human alteration of the land (including Glenelg and Chester soils) and is predominately used for human dwellings. Wehadkee, Chewacla, and Congaree series are floodplain soils that are moderately to poorly drained, and occur in low-lying areas around headwaters of streams. Urban soil predominates in the southern Coastal Plain and Philadelphia portion of the Watershed, reflecting the extensive land cover of this area. Found scattered throughout the southern Coastal Plain portion of the Watershed are Butlertown, Chewacla, and Woodstown, all fine-loamy soils that were deposited from sandy marine and alluvial sediments along streams that drain from the Piedmont (USDA, 1959).

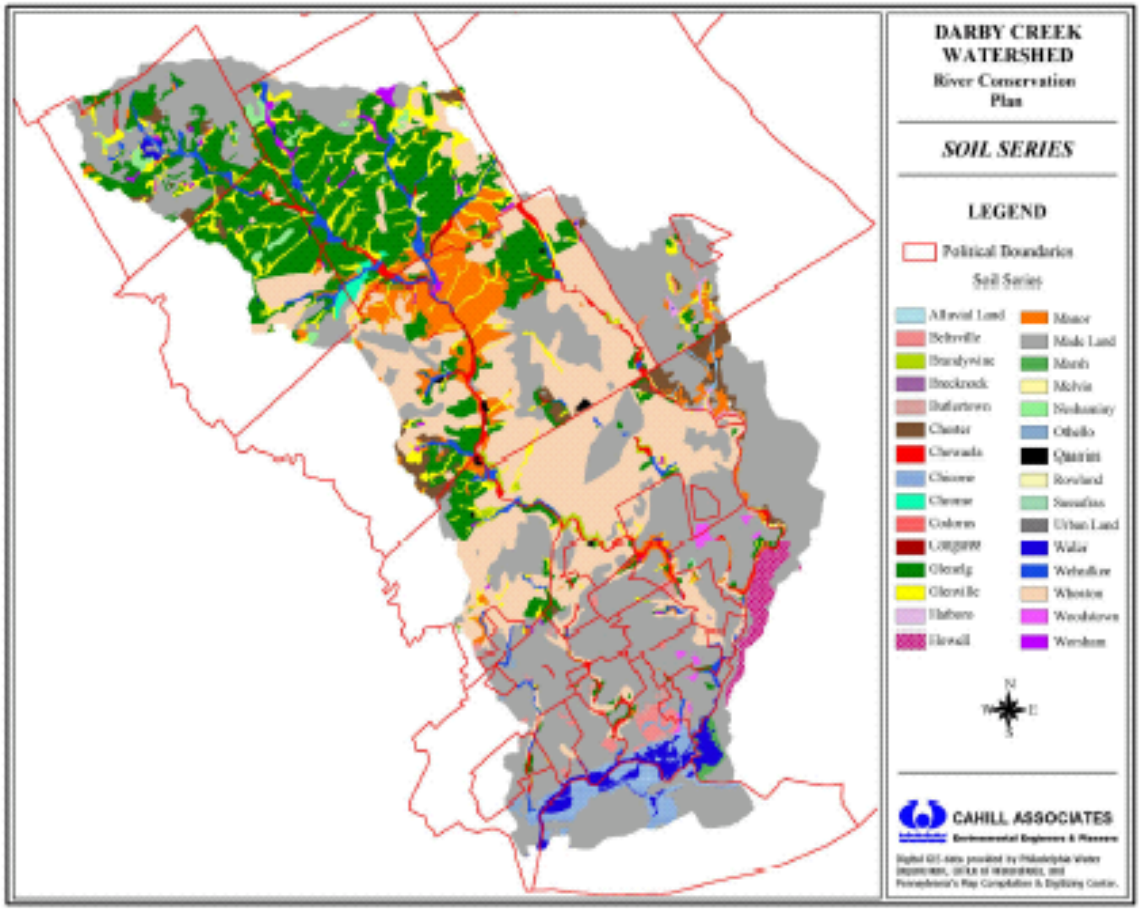

Figure III-7 Soil Composition within the Darby Creek Watershed

Hydrologic Soil Groups

The relationship between water resources and land development impacts can be expressed by the Hydrologic Soil Group (HSG) classification of the soil series (USDA, 1979; Figure III-8). HSG is given a rating, A through D. These HSG ratings describe the physical drainage properties of each soil series, including texture and permeability, as well as certain physiographic properties, such as depth to bedrock and water table. HSG Group A is well drained and highly permeable, in contrast to HSG Group D which is poorly drained and which produces much greater runoff. The HSG classification is of importance in determining the feasibility of using infiltration or recharge-oriented Best Management Practices ("BMPs") for stormwater management, as well as for determining feasibility of land-based wastewater treatment technologies that recycle wastewater effluent. The Watershed within the Piedmont region contains mostly B soils. Watershed lowlands along stream valleys typically consist of HSG Groups C and D soils, reflecting an almost constant saturation/poor drainage condition. The lower portion of the Watershed is almost entirely C soils, while the Tinicum Marsh area is poorly drained with D soils.

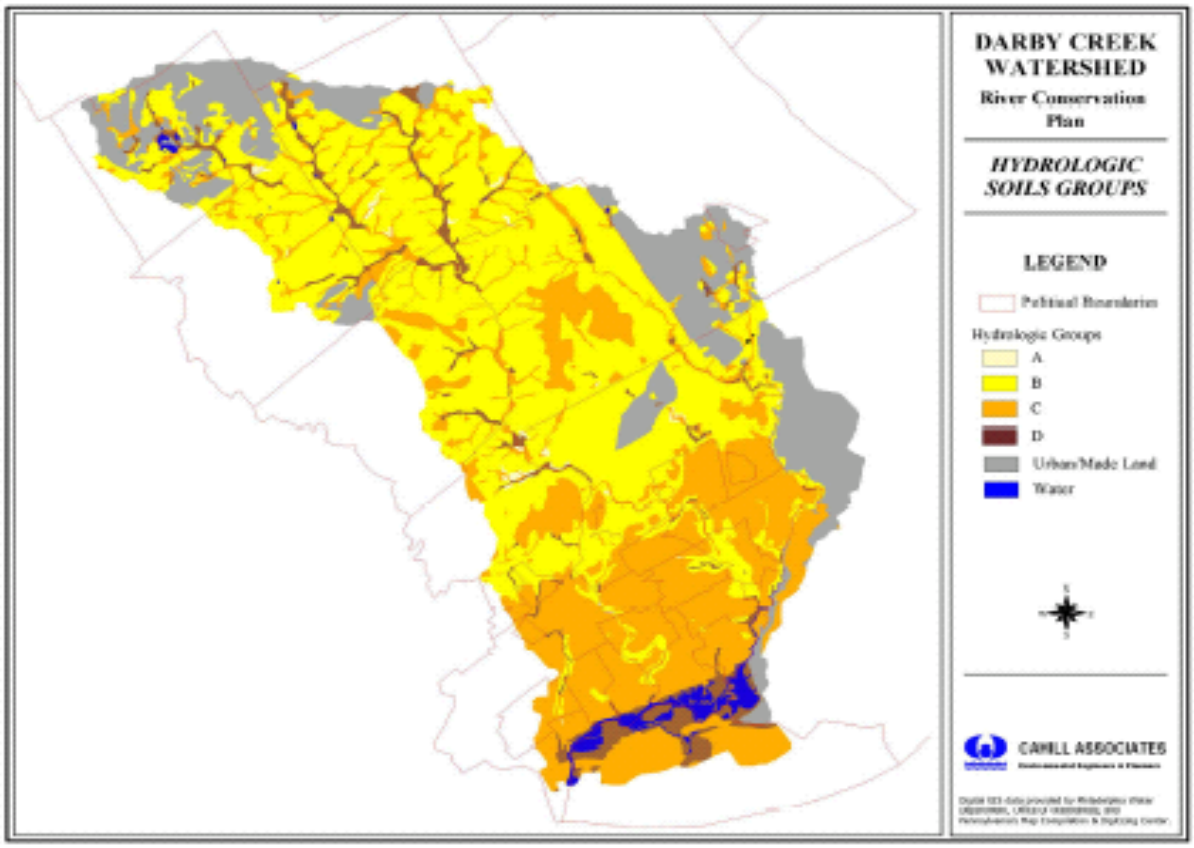

Figure III-8 Hydrologic Soil Groups within the Darby Creek Watershed

Soils that have been altered or disrupted during construction and development tend to be limited in their drainage capabilities. These soils are classified as "Urban Land" or " Made Land" and require site-specific investigations in order to determine whether they might be suitable for recharge or infiltration BMPs, and therefore, have no HSG rating. Much of the land in the Darby Creek Watershed has been developed, redeveloped, or altered from its original state. According to data provided by the Pennsylvania USDA – Natural Resources Conservation Service's Map Compilation & Digitizing Center (http://mcdc.cas.psu.edu/), thirteen percent (13%) of the watershed area is made up of Urban or Made Land.

C. Outstanding or Unique Features

In this Watershed, the transition between the Piedmont Plateau and Coastal Plain physiographic regions is a unique attribute of watershed location. Outstanding characteristics in the upper and middle portion of the Watershed include the deeply incised stream valleys, the steeply sloping ridgeline, the softly undulating hills. In the lower portion, the tributaries that drain directly to the main stem of Darby Creek flow through a more subtle and delicate, yet sturdy and determined, landscape. Unique earth resource features are also included in the discussion of the Pennsylvania Natural Diversity Inventory in the Biotic Resources section of this RCP (Section V).

D. Issues, Threats, Opportunities

The Darby Creek Watershed is blessed with a relative lack of geological and soil-related constraints. The extensive development which has proliferated throughout the Watershed is testifies to its general developability -- that is, the good rock foundations and the good soil have provided a landscape well suited for development. With a few exceptions, even the less desirable soils in the southern Watershed portions tolerated extensive building, provided that certain accommodations were made.

At this point, vacant land is not easily found anywhere in the Watershed, though scattered parcels with added building constraints, such as wet soils, steep slopes and floodplains, may still remain, especially in the northern portions of the Watershed. Unfortunately, as development pressures mount, the likelihood of developing these remaining sites also mounts. The scarcity of available land generally results in developers willing to pay higher prices. As a result, the owners of these properties are faced with greater financial incentive to sell these properties. Local officials faced with important decisions regarding the development of these sites are subject to highly motivated developers persistently seeking approvals and emphasizing the economic benefits to the municipality of permitting their particular development proposal. These pressures are very real. As a result, it is critical for all stakeholders in the Watershed to find ways to conserve and improve qualities important to the Watershed. In some cases, it may be possible for the county or a particular municipality to purchase the land and preserve it for future generations as a park. In other instances, the land may be developed for private use as a residential or commercial site, in which case it is important for Watershed stakeholders to ensure

that the layout of the site respects important Watershed features. It is important for Watershed stakeholders to realize that the ways to preserve important Watershed qualities are as varied as the threats facing the Watershed. While every parcel of land in the Watershed cannot be preserved as a park, any parcel of land in the Watershed can be developed in a manner that respects the Watershed's qualities.

More generally, it is also good news that the stream system itself provides a framework upon which to build a region-wide Watershed conservation strategy. The hillshade image (see Figure III-4) reveals an overall Watershed physiography (elevations and topography) that provides a clear pattern and overall structure and, as several of the following sections will document, a way to link the remaining natural and important human values characterizing the Darby Creek Watershed.

When that same hillshade image is overlaid with the Delaware County 1870's stream network (Figure III-9), the linkage between the landform and the water system is underscored. Historical streams, many of which are now "lost," very carefully conform to the existing system of ridges and valleys of the Watershed--the foundation upon which our conservation efforts should be focused. Though many of the natural functions have been sacrificed and compromised, these critical natural functions are still operating. The Darby's stream valleys, though encroached upon, still cut through a virtual sea of development and aging impervious surfaces with a surprising degree of "naturalness." After driving through miles of high-density development, they constitute a remarkable surprise. There is tremendous potential to create more green spaces and more recreational facilities (both active and passive) along these stream valley spines in order to achieve multiple benefits. In many ways, this natural greenway system is a significant amenity that can stimulate economies and neighborhood revitalization that is critically needed in many communities in the Watershed.

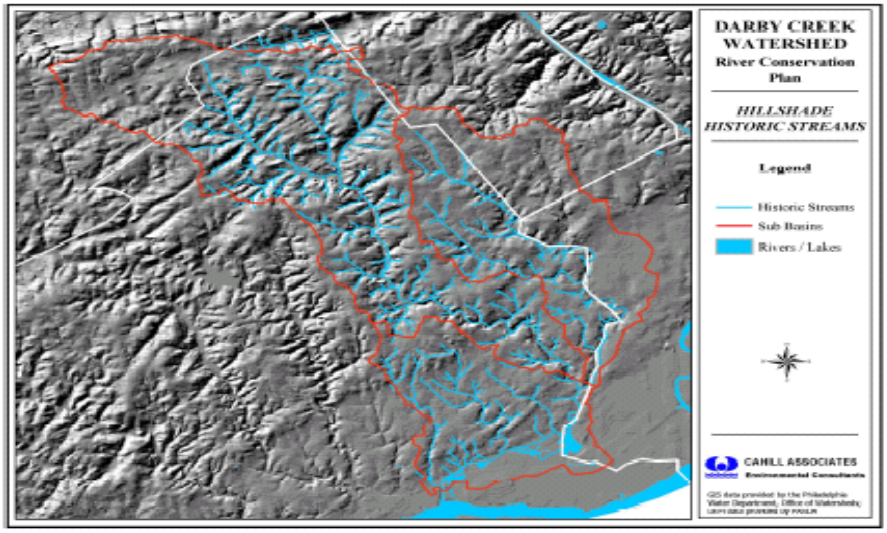

Figure III-9 Delaware County 1870 Stream Network for the Darby Creek Watershed overlaid on Hillshade