III. HYDROLOGIC CHARACTERISTICS

The hydrologic setting of a watershed incorporates aspects of geology, hydrogeology, topography, and other factors. These are addressed below in separate sections.

A. Geology

The Deer Creek Watershed is located within the Piedmont physiographic province and is underlain by a complex sequence of Precambrian to lower Paleozoic crystalline rocks (Stose, 1939; Maryland Geological Survey, 1969; Otton, 1964; Kuchinski, 1977; VanOlden, 1977; Pennsylvania Geological Survey, 2006). A geologic map of the Deer Creek Watershed and surrounding area is presented on Figure 4. The rock sequence consists of intensely deformed metamorphic and igneous rocks (Table 1), including the Metagraywacke, Pelitic Schist, Metaconglomerate, and Boulder Gneiss members of the Wissahickon Formation; the Baltimore Gabbro Complex; the James River Gneiss; the Port Deposit Gneiss; muscovite quartz monzonite gneiss; gabbro/quartz diorite gneiss; metagabbro/amphibolite; and ultramafic and gabbroic rocks. The portion of the Deer Creek Watershed that is located in York County, Pennsylvania, is underlain by the Octoraro Formation, which is equivalent to the albite-chlorite schist facies of Wissahickon Formation (Low et al., 2002).

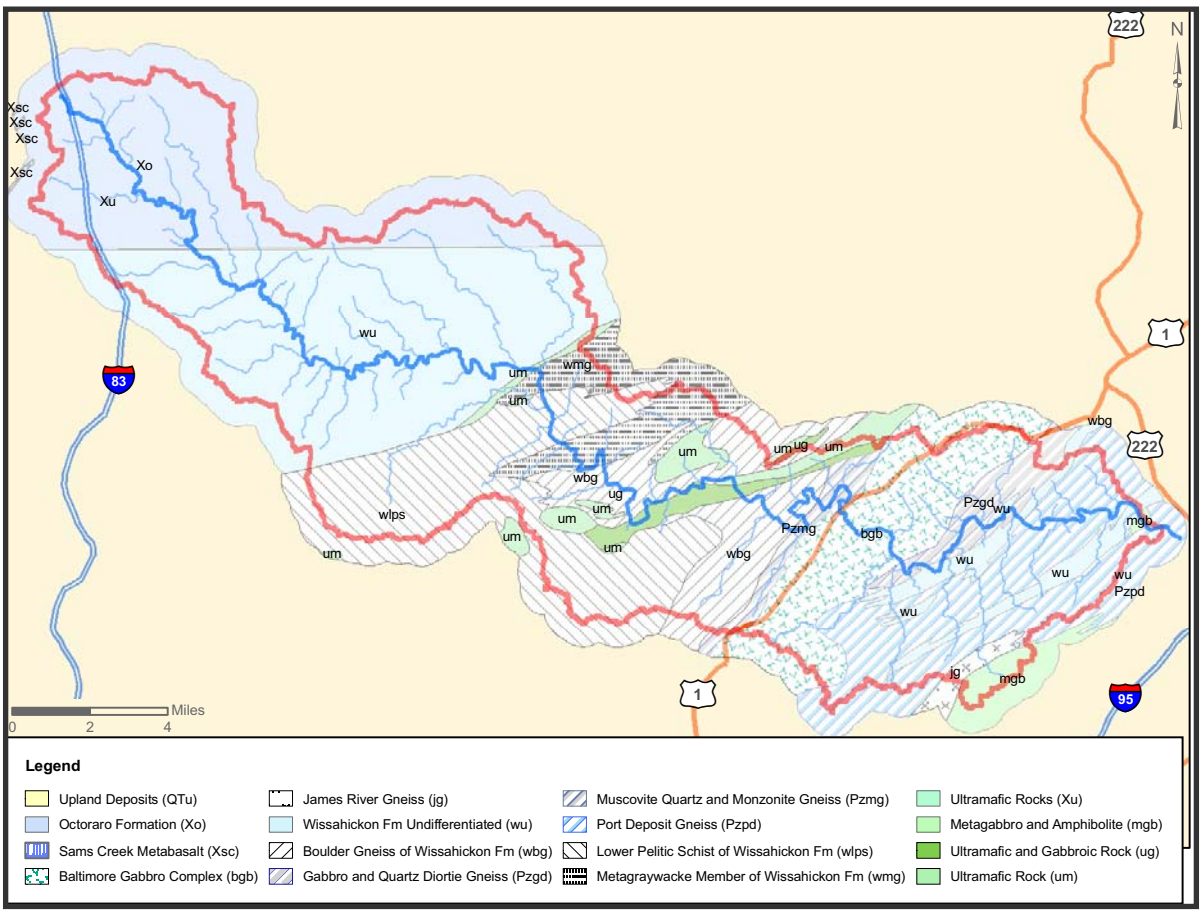

Figure 4. Geologic Map

Table 1. Description of Geologic Units

Geologic Unit	Description
Baltimore Gabbro Complex	Hypersthene gabbro with subordinate amounts of olivine gabbro, norite, anorthositic gabbro, and pyroxenite; igneous minerals and textures well preserved in some rocks, other rocks exhibit varying degrees of alteration and recrystallization, and still others are completely recrystallized with a new metamorphic mineral assemblage.
James Run Gneiss	Well-layered gneiss with a nearly continuous range of compositions between amphibolite and biotite-poor quartz-oligoclase gneiss. Quartz-amphibolite gneiss and biotite-quartz-plagioclase gneiss predominate
Metagabbro and Amphibolite	Weakly to strongly lineated metagabbro and epidote amphibolite.
Muscovite Quartz Monzonite Gneiss	Well foliated to nearly massive quartz monzonite gneiss, generally medium-grained and even textured but locally porphyritic and pegmatitic.
Octoraro Formation	Albite-chlorite schist, phyllite, and hornblende gneiss
Port Deposit Gneiss	Moderately to strongly deformed intrusive complex composed of gneissic biotite quartz diorite, hornblende-biotite quartz diorite, and biotite granodiorite; all rocks foliated and some strongly sheared.
Quartz Gabbro and Quartz Diorite Gneiss	Mixed rock zone of greenish-black, uralitized, quartz-bearing gabbro to dark gray, weakly gneissic, pyroxene-hornblende-biotite quartz diorite.
Sams Creek Metabasalt	Grayish-green, massive to schistose, amygdaloidal metabasalt.
Ultramafic and Gabbroic Rocks	Mixed metagabbro, serpentinite, metapyroxenite, and actinolite-, chlorite-, and epidote-bearing schists.
Ultramafic Rocks	Chiefly serpentine with partly to completely altered dunite, peridotite, pyroxenite; and massive to schistose soapstone; talc-carbonate rock and altered gabbro are common in some bodies.
Wissahickon Formation– Lower Pelitic Schist	Medium to coarse-grained biotite-oligoclase-muscovite-quartz schist with garnet, staurolite, and kyanite; fine- to medium-grained semipelitic schist; and fine-grained granular to weakly schistose psammitic granulite (formerly mapped as oligoclase facies of Wissahickon Formation).
Wissahickon Formation – Boulder Gneiss	Thick-bedded to massive pebble and boulder-bearing arenaceous to pelitic metamorphic rock, typically a medium-grained garnet-oligoclase-mica-quartz gneiss (formerly mapped as Sykesville and Laurel Formations). Locally intensely foliated gneiss or schist.
Wissahickon Formation (undivided)	Muscovite-chlorite-albite schist, muscovite-chlorite schist, chloritoid schist, and quartzite, intensely folded and cleaved.
Wissahickon Formation-Metaconglomerate	Well-foliated micaceous quartz-pebble metaconglomerate and quartzite. Thickness about 1,200 feet at Deer Creek, Harford County
Wissahickon Formation-Metagraywacke	Interbedded chlorite-muscovite metagraywacke and fine-grained chlorite-muscovite schist (formerly mapped as Peters Creek Formation). Graded bedding preserved locally.
Wissahickon Formation– Upper Pelitic Schist	Albite-chlorite-muscovite-quartz schist with thin beds of laminated micaceous quartzite (formerly mapped as albite facies of the Wissahickon Formation). Coarsens from west to east, primary sedimentary structures include normal bedding, graded bedding and soft-sediment deformational structures.

After Dingman et al. (1956), Nutter and Otton (1969), and Pennsylvania Geological Survey (2006).

As can be seen on Figure 4, the northwestern half of the watershed is underlain by low-grade schist of the Wissahickon and Octoraro Formations. In contrast, the southeastern portion

of the watershed is primarily underlain by gneisses and gabbro, with subordinate schist. Ultramafic and gabbroic rocks occur within relatively restricted bands in the center and southeast portion of the watershed. In the center of the watershed, these units are expressed as distinctive topographic ridges that form the characteristic landforms at Rocks State Park (Figures 1 and 2). The course of Deer Creek clearly follows the northern edge of the gabbroic rocks between Routes 24 and 543 in Harford County.

The bedrock is mantled with saprolite (a layer of weathered, decomposed bedrock with pores and fracture features), typical of the Piedmont region of the Mid-Atlantic states. The lithology, texture, and structure of the parent rock govern the characteristics of the saprolite, as many features of the parent rock are preserved in the saprolite. There is a general tendency for the gneiss and quartzose schist to weather to a sandy, fairly permeable saprolite, whereas the gabbro, metabasalt, and ultramafic rocks weather to saprolite with a higher clay content and lower permeability (Nutter and Otton, 1969).

The thickness of the saprolite at any location depends on the parent rock type, the topography, and the degree of fracturing (Table 2). Saprolite thickness can be approximated by the depth of the casing installed in water supply wells. In Harford County, the saprolite thickness is reported to range from 0 to 100 feet, with an average thickness of 42 feet (Nutter, 1969). Saprolite thickness is generally highest in upland areas and along hilltops, and lower or absent in stream valleys where it has been eroded. The degree of fracturing in the parent rock contributes to the development of saprolite, as more highly fractured parent rocks tend to produce a thicker, better developed saprolite mantle.

Table 2. Saprolite Thickness and Parent Rock in Harford County

Parent Rock	Average Saprolite Thickness (feet)
Gabbro	50
Lower Pelitic Schist (Wissahickon)	48
Metagraywacks (Wissahickon)	49
Baltimore Gneiss	38
Upper Pelitic Schist (Wissahickon)	33

Post-settlement sediment deposits are frequently present within the valleys of Deer Creek and its tributaries. These fine-grained materials document the increase in sediment erosion and transport associated with deforestation and agricultural development in the eighteenth to early twentieth centuries (Jacobson and Coleman, 1986). Under current conditions, the streams tend to be incised into these sediment units. The bed of Deer Creek and its tributaries varies from exposed bedrock to sandy and gravelly depending upon local conditions (Figure 5).

Figure 5. Photographs of Deer Creek
A) Deer Creek and USGS Gage in Rocks State Park; B) Deer Creek, South of Stewartstown, Pennsylvania.; C) Deer Creek near Aberdeen Proving Ground Churchville Site; D) Deer Creek above Ebaugh's Creek

B. Hydrogeology

Within the Deer Creek Watershed, groundwater occurs under unconfined water table conditions in the crystalline rock aquifer of the Piedmont province. Groundwater generally moves downward and laterally away from upland areas to topographically lower areas of groundwater discharge (Figure 6). Groundwater occurs in fractures in the unweathered crystalline rock and in pores and relict fractures in the weathered, decomposed bedrock (saprolite). Porosity in the saprolite is orders of magnitude higher than in the fractured bedrock. As a result, the relative amount of extractable water is much higher in the saprolite than in the unweathered bedrock. The thickness, porosity, and permeability of the saprolite are key characteristics for understanding the occurrence and availability of groundwater in the region (Nutter and Otton, 1969; Richardson, 1982).

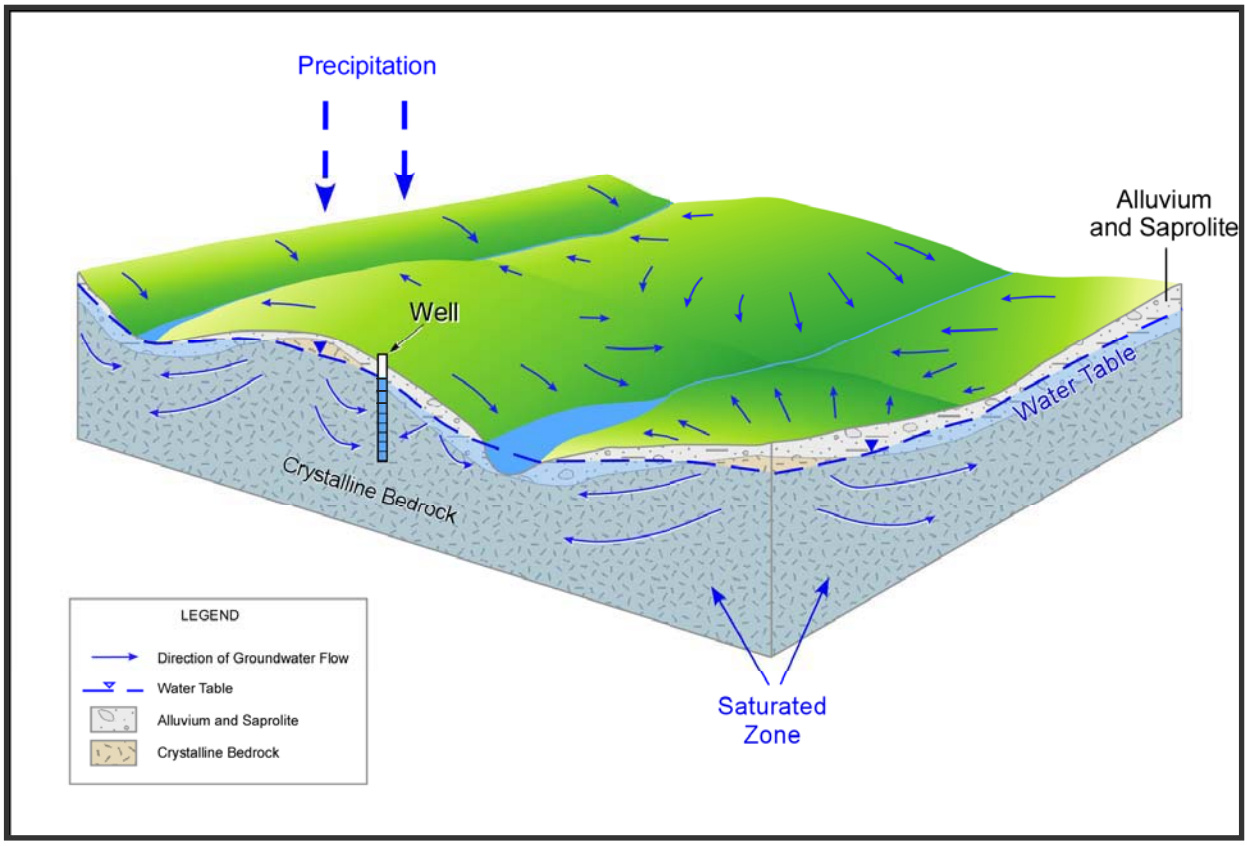

Figure 6. Schematic Hydrogeologic Conditions

Dingman and others (1956) found the porosity of saprolite developed from crystalline rocks of Harford County, Maryland, to range from 34 to 56 percent. The average porosity of saprolite developed from rocks of the Wissahickon Formation was about 48 percent, with measured porosity values ranging from 45.7 to 51.9 percent. The effective porosity, or that porosity which contributes to transmission of groundwater, will, however, be somewhat lower than these values. Estimates of the specific yield of saturated regolith in parts in the Piedmont of Pennsylvania ranged from about 8 percent to 10 percent (Low et al., 2002). Regolith is the mantle or blanket of unconsolidated or loose rock material that overlies the intact bedrock and nearly everywhere forms the land surface.

Because most wells in the Deer Creek area tend to be screened across the saprolite/bedrock interface, it is difficult to find independent estimates of the transmissivity of bedrock and saprolite. Undoubtedly, the transmissivity of the bedrock is highly variable, depending upon lithology and degree of fracturing, as well as fracture orientation. The transmissivity results of aquifer tests from wells in crystalline rock aquifers of the Maryland Piedmont vary from 4 to 4,700 square feet per day (ft^2/day), with the majority of the values between 270 and 900 ft^2/day (Nutter and Otton, 1969). Estimates of transmissivity from Baltimore and Harford County (Dingman et al., 1956), and the albite-chlorite facies of the Wissahickon (Octoraro) Formation (Low et al., 2002) are found in Table 3.

Table 3. Transmissivities and Well Yields in the Maryland and Pennsylvania Piedmont

	Baltimore and Harford Counties (Dingman et al., 1956)		Piedmont Province of Pa. (Low et al., 2002)		Transmissivity from Aquifer Tests in Pa. and Md.
Unit	**Range of Well Yield (gpm)**	**Average Well Yield (gpm)**	**Range of Well Yield (gpm)**	**Median Well Yield (gpm)**	**(ft^2/day)**
Schist (Wissahickon)	0 to 200	10.5	0 to 300	10	80 *(median for albite chlorite facies, Low et al., 2002)* 400 to 1,300 * *(Dingman et al., 1956)*
Gneiss and granitic rocks	0.5 to 55	10.8	0 to 650	15	300 to 700 (Baltimore Gneiss)
Gabbro and serpentine	0.5 to 80	10.3	2.0 to 80	12	

* The coefficient of storage for the Wissahickon wells ranged from 0.002 to 0.01.
ft^2/day – square feet per day

Well yield for supply wells in the Piedmont varies significantly, depending on the degree of weathering, topography, type of parent rock, well depth, and degree of fracturing and jointing encountered by the well. In Maryland, well yields overall range from 0 to 200 gallons per minute (gpm); however, greater than 70 percent of the wells have a yield of 10 gpm or less, and only 2 percent have a yield of 50 gpm or greater (Dingman et al., 1956). In Pennsylvania, wells from the albite-chlorite schist are reported to have a median yield of 10 gpm, and a seventy-fifth percentile yield of 25 gpm. Wells installed in areas with thicker saprolite development generally have a higher well yield. Dingman et al. (1956) found that for wells in Baltimore and Harford Counties, wells located at ridge tops generally have a reduced yield compared to wells installed in draws and valleys primarily due to the configuration of the water table. Data in Nutter (1975) confirm that the highest yields and specific capacities occur in wells that have the shortest surface casings or are the shallowest.

The type of parent rock influences the development of secondary porosity in the aquifer, in particular the presence of joints, solution features, and fractures. Since the primary porosity of the crystalline rocks is very low, groundwater is transmitted through fractures, joints, and other openings in the rock formation, and wells installed in formations that are more highly fractured will have more water available. Because the presence of open fractures tends to decrease at depth, well yield tends to decrease at depths greater than about 200 feet. About 25 percent of the wells greater than 350 feet deep in the crystalline rock aquifer of Baltimore and Harford County yielded less than a gallon a minute (Dingman et al., 1956). A summary of well yield according to rock type in the Maryland Piedmont is provided in Table 3.

Nutter (1977) compiled well data for Harford County. Based upon specific capacity data for wells screened in different formations, he subdivided the rocks of Harford County into five hydrogeologic units, three of which (Units 3, 4 and 5) occur within the Deer Creek Watershed. The specific capacities of Unit 3 were reported to be higher than those for Unit 4, and Unit 4 higher than those in Unit 5. These units are represented on Figure 7.

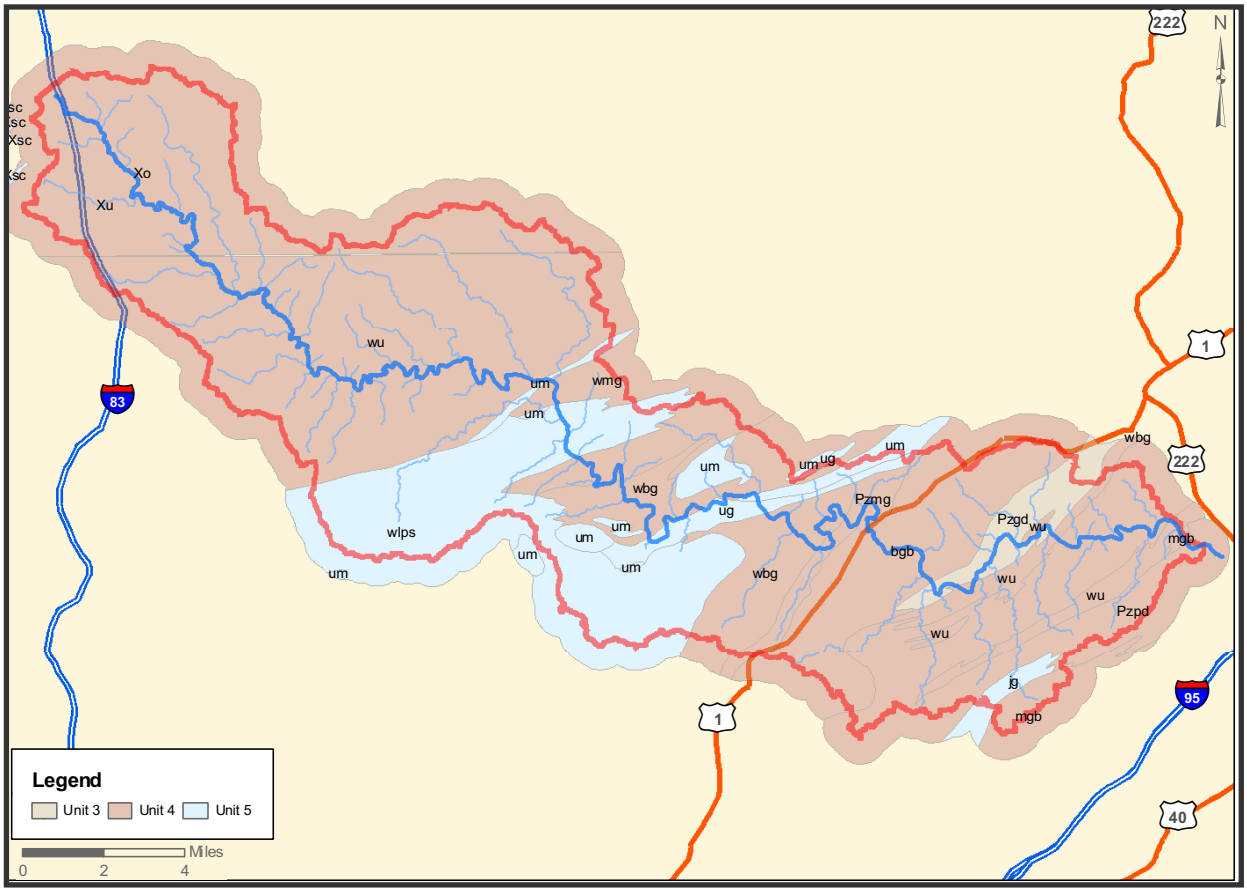

Figure 7. Hydrogeologic Units