3.0 WATERSHED CHARACTERIZATION

3.1 Watershed Location

The watershed of the Schuylkill River is located in southeastern Pennsylvania, and includes large parts of Schuylkill, Berks, Montgomery, Chester, and Philadelphia Counties (see the map: **Watershed Orientation**). Smaller areas of Carbon, Lehigh, Lebanon, Lancaster, Bucks and Delaware Counties also lie within the watershed. The Schuylkill River watershed is about 80 miles long and 25 miles wide, and encompasses an area of approximately 1,916 square miles (4,962 sq. km). The Schuylkill River travels approximately 130 miles from its headwaters at Tuscarora Springs in Schuylkill County, to its mouth at the Delaware River in Philadelphia. The principal towns and cities along the mainstem of the river are Pottsville, Reading, Pottstown, Phoenixville, Norristown, Conshohocken, and Philadelphia. See the map: **Cities, Townships & Boroughs**.

For the purposes of this Conservation Plan, the Schuylkill River watershed was subdivided into 37 subwatersheds as shown in the map: **Subwatersheds & Municipalities**. The Schuylkill subwatersheds were designated to facilitate the water quality, landscape sustainability and institutional analyses, and for ease of reference. Subwatersheds were defined at a scale small enough to allow meaningful comparisons, while not exceeding the resolution of the data. The approximate size of each subwatershed is 125 square kilometers or 12,500 hectares (about 31,000 acres). Attempts also were made to delineate subwatersheds so that areas with existing (or in-progress) river conservation plans remained intact. This was done to facilitate the incorporation of issues and recommendations from other plans into the broader Schuylkill Watershed Conservation Plans.

3.2 History, Demographics and Land Use

3.2.1 Early History and Settlement

The first settlers of the Schuylkill River valley were Lenape Indians, mostly of the Unami tribe. Approximately 2,000 Lenapes lived along the Schuylkill, mostly settled in the lower reaches, although villages may have existed in the stretch of river above Phoenixville as well.

It was the Dutchman Arendt Corssen, sailing under the flag of the Dutch East Indies Company in the early 1600's, who gave the river its name: *Skokikl* or hidden creek. It is said that at that time, the mouth of the Schuylkill River was partially obscured by tall bulrushes. However, prior to this time the Lenapes had called the river *Ganshowahanna* or falling waters. It also was known to the Lenapes as *Manayunk*, meaning where we drink.

Four nations, at one time or another, have laid claim to ownership of the Schuylkill River. The Dutch and Swedes were the first settlers in Pennsylvania, but little remains other than the names from these settlements. It was the English under William Penn that formally acquired the lands from the Native American tribes. The United States took possession of these lands after the Revolutionary War.

3.2.2 Demographics and Population Growth

The Dutch and Swedes arrived in the Philadelphia region in the early 1600s. By 1680, a half-century after the landing of the *Mayflower*, Pennsylvania held no more than 700 people of European origin. Delayed by conflicting territorial claims and a perception that the interior was more or less impenetrable, effective

settlement came later in Pennsylvania than in any of the colonies except Georgia (Simkins 1995). This trend began to change after 1680, when William Penn obtained his land charter from King Charles II of England. From the 1680s through the 18th Century, Pennsylvania's population grew faster than the rest of the nation. This population growth resulted from natural increase, and more importantly from immigration, first by English Quakers and German Pietists, then by Scottish, Welsh, and Irish immigrants. **Table 3.1** summarizes population growth trends since the 1700s for Pennsylvania, as compared to the national population growth.

Table 3.1 Population Growth Trends Since the 1700's

Year	PA Population		US Population		PA as a % of US Population
	In Thousands	% increase over previous period	In Thousands	% increase over previous period	
1700	18	-	251	-	7%
1800	602	3,240	1,171	366	51%
1850	2,312	284	23,192	1880	10%
1900	6,302	173	76,212	229	8%
1950	10,498	67	151,326	98	7%
1990	11,882	13	248,710	64	5%
2000	12,281	3	281,422	13	4%

After 1800, the Commonwealth's population growth declined below the national average, as out-migration began to new states in the west. A second wave of mostly Eastern European immigration between 1890 and 1920 added more than a million people each decade to Pennsylvania's population. Pennsylvania was also part of the post World War II baby-boom, but at a lower rate of growth than the rest of the nation. Population growth through natural increase or immigration has stopped almost completely since the 1970s. Pennsylvania now has only about 4% of the nation's population, as compared to 200 years ago when it had more than 50%.

Pennsylvania's present county boundaries did not become fixed until 1878, which has made it difficult to follow regional population patterns. However, from the earliest colonial days, southeast Pennsylvania has been a major center of population growth. The Schuylkill River watershed was settled in the Philadelphia area by the 1700s, in Berks County by the 1720's, and in Schuylkill County by the 1740-1760s. In 1790, when the first Census was taken, nearly 75% of Pennsylvania's 450,000 population lived southeast of the Blue Mountains. In the early 1800s, the population began dispersing into more remote areas, only to retract again in the 1880's as timber harvests declined and agriculture practices became less labor-intensive. A temporary reversal of that trend occurred during the Depression, when urban workers left closed factories and returned to their rural homelands. Since the 1940s, the southeast has consistently been the area of most rapid growth in the Commonwealth.

Within the Philadelphia region, however, there has been significant redistribution of people. Between 1800 and 1940, Philadelphia gained population more rapidly than the surrounding counties. In 1900, Chester, Montgomery, Bucks and Delaware held only 6% (380,000) of the state's population, and Philadelphia 20% (1.26 million). In the 1940s the pattern was about the same, with 28% of the state's population (2.7 million) living in the five-county Philadelphia region of Philadelphia, Chester, Montgomery, Bucks and Delaware Counties. Philadelphia reached its largest population in the 1950s. By 1990, decentralization and suburbanization were in full swing, with only 13% (1.5 million) of the state's population in Philadelphia while 18% (2.2 million) resided in the surrounding four counties.

Population projections through 2010 indicate this trend will continue for the foreseeable future in the Schuylkill River watershed. Berks County and other central parts of the Schuylkill River watershed will see the greatest population growth (between 30-50% increases) under the influence of continued decentralization to the suburbs, and economically induced out-migration from Schuylkill County. See the map: **Estimated Population Change**, which displays projected population growth in the Schuylkill River watershed (Carson 1999). See **Section 6.6** in *Chapter 6.0 Promoting a Sustainable Landscape* for further discussion of this topic.

3.2.3 Historic Land Uses

Primary land uses within the Schuylkill River watershed have changed over the years. Early settlers relied on agriculture and used the Schuylkill River network to transport crops to larger markets downstream. However, the vast natural resources in the watershed, including iron ore, hardwood, and river power, soon created a thriving iron industry. Numerous mills and forges were built along the Schuylkill to support this industry. These contributed to Philadelphia's growth, making it the most populous city in the country during the Revolutionary War.

In response to this growth, Philadelphia damned the Schuylkill River in 1819 and created the Fairmount Water Works. The industrial growth, however, continued to pollute the Schuylkill River, which was the primary drinking water source for the city. In an effort to protect its water supply, the city purchased a large estate (over 5,000 acres) near the water works that became Fairmount Park.

Later, with the discovery of vast coal sources in the northern headwaters, the Schuylkill River became a primary mode of transportation due to the Schuylkill Navigation System: a system of 32 dams and 103 locks. As Philadelphia became the workshop to the world, other factory towns such as Manayunk, Conshohocken, Norristown, and Phoenixville boomed as well. By the early 20th Century, competition from railroads led to the demise of the navigation system. However, numerous dams and canal features remained and many are still in existence today. The dams, while drastically improving navigation, also created obstacles to migratory fish such as shad and Atlantic salmon, and adversely affected these fish populations.

The coal industry peaked in the 1910s. By the 1930s, most of the coal lands had fallen into the hands of county governments, due to failure of paying taxes. Although mines were no longer in operation, leaking acid mine drainage (AMD) and sedimentation continued to affect water quality in the Schuylkill River watershed. Initial steps towards river renewal began 50 years ago when the U.S. Army Corps of Engineers (US ACE) began to dredge the accumulated sediment from the river, which has continued periodically since then. More recently, environmental legislation, spearheaded by the federal Clean Water Act, has resulted in laws governing the discharge of industrial and municipal sewage from point sources and is now focusing on reducing pollution from nonpoint sources.

The outcome of these efforts, along with the river's natural abilities to cleanse itself over time, is a river network on the rebound. This was exemplified by Pennsylvania's designation of the Schuylkill as the state's first scenic river in 1978, River of the Year in 1999, and culminating in its designation as a National Heritage Area in 2000.

3.3 Physical Setting (Physiography)

The geologic formations of the Schuylkill River watershed are part of the Appalachian Highlands, a belt of deformed rocks that stretches from Newfoundland to Alabama (US ACE 1981; Biesecker 1968). The region is

geologically complex due to major episodes of crustal deformation that produced mountain ranges. Because of this complexity, it is useful to discuss the geology of this region by physiographic province and section (see the map: **Geologic Provinces**). Physiographic provinces and sections (sub-divisions of physiographic provinces) are areas within the watershed with similarities in geology, topography, and soils. These characteristics have an important influence on the occurrence and chemical characteristics of surface water and groundwater within the watershed.

The headwaters of the Schuylkill River rise in the Blue Mountain Section of the Ridge and Valley physiographic province. The Blue Mountain Section consists of long, narrow mountain ridges separated by narrow to wide valleys. Very tough sandstones occur at the crests of the ridges, and relatively soft shales, siltstones, and in places limestone and dolomite occur in the lowlands. Soils in this section are characteristically well-drained or moderately well-drained shaly-loam or silt-loam, and have a low to medium erosion potential. Moving in a downstream direction, the Schuylkill River then enters the Great Valley Section of the Ridge and Valley Province. The Great Valley Section consists of gently undulating hills eroded and reformed into shales and siltstones on the north side of the valley, and a lower elevation, flatter landscape developed on limestones and dolomites on the south side. The soils of this section generally are well-drained silt loams with a low to medium erosion potential.

As the Schuylkill River approaches the city of Reading, it crosses into the Reading Prong Section of the New England Province. This Section consists of circular to linear, rounded low hills or ridges that contrast with surrounding lowlands. The hills and ridges are made up of granitic gneiss, granodiorite, and quartzite. The streams eroding into the hills and ridges of this section are short and steep.

Southeast of Reading, the Schuylkill River enters an area of rolling low hills and valleys developed on red sedimentary rock known as the Gettysburg-Newark Lowland Section of the Piedmont Physiographic Province. The soil associations in this section of the Piedmont are characteristically well to somewhat poorly drained silt loams, with a high to medium potential for erosion. Southeast of the Gettysburg-Newark Lowland Section and northwest of the city of Philadelphia, the Schuylkill River crosses into section known as the Piedmont Lowland Section of the Piedmont Physiographic Province. This section consists of broad valleys and low hills developed primarily on limestone and dolomite rock. The soil associations in this section of the Piedmont are generally silt loams, characteristically well to somewhat poorly drained with a high to medium potential for erosion. Northeast of Philadelphia, the Schuylkill River enters the Piedmont Uplands Section of the Piedmont Physiographic Province. This section consists of broad, gently rolling hills and valleys developed mainly on metamorphic rocks called schists. The soil associations in this section are well-drained silt loams with an erosion potential ranging from low to high.

At Philadelphia and near to its mouth, the Schuylkill River crosses into a region of low relief and tidal marshland known as the Atlantic Coastal Plain. The northwestern margin of the Section is marked by a change in slope known as the "fall line" where the relatively flat Coastal Plain joins the higher adjacent Piedmont Upland Section. Soil associations in this are generally well-drained loams with a medium to high erosion potential. The Schuylkill River is a tidal river from the Fairmount Dam south of Manayunk to its mouth.

3.4 Climate and Water Resources

This section provides an overview of climate and water resources within the Schuylkill River watershed. For additional information about climate, physiography, surface water, and groundwater in the Schuylkill River watershed, see Biesecker et al. (1968), and U.S. Army Corps of Engineers (1981).

3.4.1 Climate

The Schuylkill River watershed has a modified continental type climate. Warm and humid summers, moderately cold winters, and ample rainfall distributed throughout the year are characteristic of the region (US ACE 1981). The mean annual temperature for the watershed is 52°F (11°C) with summer and winter averages of 72°F (22°C) and 31°F (0°C), respectively (Biesecker et al. 1968). The rugged topography and higher elevations of the Appalachian Mountains causes greater temperature variations in these areas than in the Coastal Plain and Piedmont areas. Topography and elevation also have a major controlling effect on precipitation in the watershed. Average annual precipitation is highest in the mountainous headwaters region (45-50 in/yr or 114-127 cm/yr) and decrease eastward to the Coastal Plain (43 in/yr or 109 cm/yr). Precipitation is distributed fairly uniformly throughout the year, and is generally sufficient for crops and vegetation throughout the watershed.

3.4.2 Surface Water

Local precipitation is the source for water to rivers, streams, ponds and other aquatic environments within the Schuylkill River watershed. On average in Pennsylvania, about 50% of annual precipitation is evaporated or transpired by plants back to the atmosphere, about 20% runs off into rivers and streams as "stormflow" during rainfall and snowmelt events, and about 30% infiltrates the ground surface and runs off as "baseflow" during dry weather (Fleeger 1999; Biesecker et al. 1968). Rates of streamflow tend to be highest in late winter and early spring due to snowmelt and low evaporation/transpiration rates. The lowest streamflow rates generally occur in late summer and early fall primarily due to high rates of evaporation/transpiration from vegetation.

Water drains from the watershed through a series of successively larger streams known as a drainage network. The concept of a drainage network is well described by Leopold (1997):

> "Water drains from the land through streams that increase in size from small hillside rills to majestic rivers that discharge into the oceans. Each rill, brook, creek, or river receives water from an area or tract of land surface that slopes down toward the channel. Channels, therefore, occupy the lowest part of the landscape. The ridges of the land surface, that is, the rims separating the land that drains into one stream from the land that drains into another, are the watershed divides. The area enclosed by the divide is the drainage area or watershed."

The major tributaries of the Schuylkill drainage network, in downstream order, are Mill Creek, the West Branch of the Schuylkill, the Little Schuylkill, Maiden Creek, Tulpehocken Creek, Manatawny Creek, French Creek, Perkiomen Creek, and Wissahickon Creek (see the map: **Major Streams & Tributaries**). A number of lakes and ponds also occur within the watershed, mostly as reservoirs or small impoundments.

The relative size and location of a stream within a watershed drainage network can be expressed as a numerical value known as the *stream order* (see **Figure 3.1**). The smallest streams that have no tributaries are called first order streams. Where two first order streams flow together, the stream becomes second order. Second order streams only have first-order streams as tributaries. A third order stream is formed when two second order streams come together, and has only second and first order streams as tributaries. This basic pattern is repeated to the highest order stream in the drainage network. As the order of the stream increases, streamflow (flow volume) and flow velocity both increase, while channel gradient decreases. Channel dimensions (width and depth) also increase with stream order, as the channel accommodates the increased flow. At its mouth, the Schuylkill River is a seventh order stream.

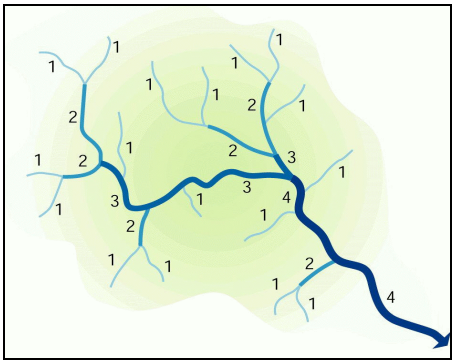

Figure 3.1 Stream Network with Stream Orders

Table 3.2 Summary of Stream Length by Stream Order in the Schuylkill River Watershed

Stream Order	*Kilometers*	*Percent of Streams*
1	2476.58	56.56%
2	863.56	19.72%
3	459.85	10.50%
4	298.68	6.82%
5	124.74	2.85%
6	103.89	2.37%
7	51.34	1.17%

A summary of the total length and percent of streams of each order in the Schuylkill River watershed is shown in **Table 3.2**. It is important to note that small first and second order streams represent a large proportion of the total stream length of the Schuylkill River. Small streams process foods, provide invaluable habitat for aquatic biota, and connect the Schuylkill River to its watershed in profound ways. The health of small streams is therefore of critical importance to the health of aquatic ecosystems throughout the watershed. Regrettably, smaller streams also tend to be the most impacted by human activities. To emphasize the importance of small streams to the health of the larger watershed, an analogy can be made between the tributaries and mainstem of the Schuylkill River and the network of trunk, branches and leaves that make up a tree system (**Figure 3.2**). The mainstem of the river is represented by the trunk of the tree, and the tributaries by successively smaller branches and leaves. Without healthy leaves and small branches to move important nutrients to the trunk and throughout the tree, a tree could not survive. Similarly, without healthy small streams, the Schuylkill River may become ecologically degraded.

Figure 3.2 Comparison of a River System to Tree System

3.4.3 Groundwater

In Pennsylvania, about 30% of annual precipitation on average infiltrates the ground surface to recharge groundwater aquifers (Fleeger 1999). An aquifer is a soil or rock formation that contains and transmits water within soil pores, fractures, joints, and other small cavities. All aquifers are bounded at some depth by an impermeable rock layer that is water tight due to cementation processes and high pressure. Water seeping down from the ground surface will thus collect above the impermeable layer. The top of this saturated zone of the soil is referred to as the water table (Leopold 1997). The water table will fluctuate seasonally and in response to wet or dry years, but in undisturbed watersheds the long-term average water table elevation will remain approximately constant.

Groundwater drains to springs and streams wherever the water table intersects the ground surface. During low flow or drought conditions, groundwater provides nearly all streamflow (Biesecker et al. 1968). Groundwater therefore has a significant influence on streamflow quantity and quality, and is important to maintaining the health of stream ecosystems. In areas where groundwater is used for water supply, it is important that withdrawals do not exceed rates of aquifer recharge to avoid groundwater depletion. Excessive pumping of groundwater from wells can lower water tables, reduce groundwater discharge to springs and streams, and in certain cases entirely de-water small streams that formerly flowed year round (Biesecker et al. 1968). Groundwater depletion is of particular concern in the Piedmont area around Montgomery and Chester Counties. Groundwater resources in the Schuylkill River watershed are discussed in **Section 5.4.1.2** of *Chapter 5.0 Water Quality*.

In the Schuylkill River watershed there are four principal groups of aquifers: unconsolidated deposits, crystalline rocks, carbonate rocks, and clastic rocks. Except for unconsolidated deposits on the Coastal Plain, most aquifers within the Schuylkill River watershed are composed of consolidated rocks (Biesecker et al.

1968). The median water bearing capacities for aquifers in most of the Schuylkill River watershed range from about 20 to 200 gallons per minute (Biesecker et al. 1968). Median water bearing capacities of greater than 200 gallons per minute occur in the carbonate rocks of the Great Valley, and in the unconsolidated deposits of the Atlantic Coastal Plain. Median water bearing capacities of less than 20 gallons per minute occur in parts of the Piedmont in northern Chester and Montgomery Counties (Biesecker et al. 1968).

3.5 Vegetation and Wildlife Issues

Pennsylvania has more than 20,000 species of plants and animals, which may be divided into eight classes, as depicted in the following diagram of Pennsylvania Species Richness (**Figure 3.3**). These classes include Protists, Vascular Plants, Bryophytes and Lichens, Birds, Fish, Mammals, Amphibians and Reptiles, and Invertebrates. Protists and Invertebrates have the greatest number of species.

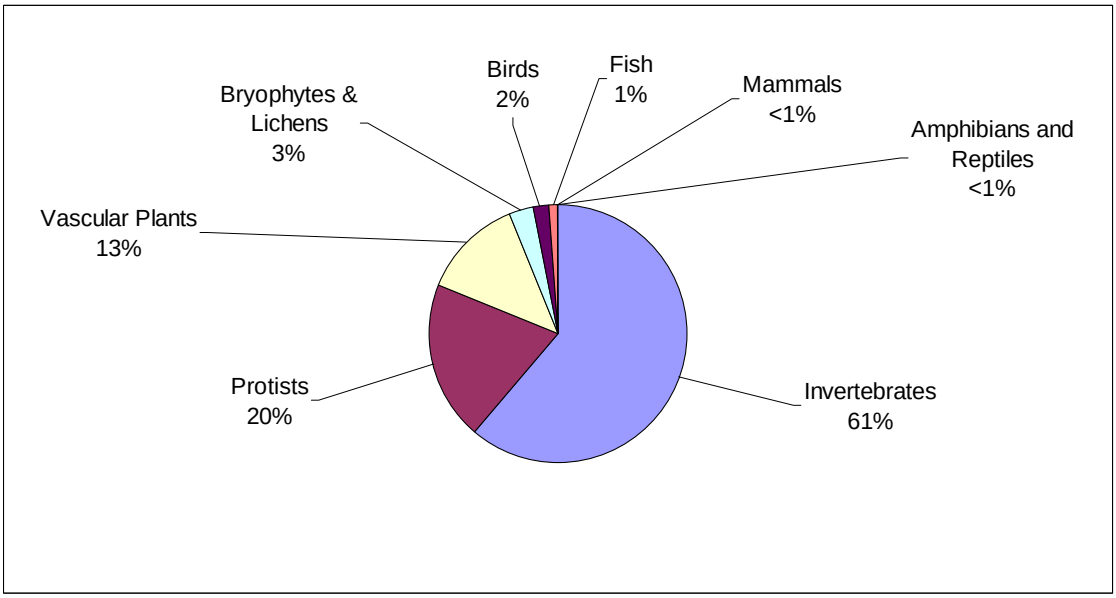

Figure 3.3 Pennsylvania Species Richness (adapted from PA Fish & Boat Commission 1995)

A more thorough accounting of species numbers by class, rarity as well as a discussion of threats to species diversity, is given in *A Heritage for the 21st Century: Conserving Pennsylvania's Native Biological Diversity* (PA Fish & Boat Commission 1995).

Ecologists divide the earth's vegetation types into communities, or recognizable associations of plants. This kind of stable association of plants depends on a certain environment or habitat, and the composition of vegetation changes based on landform, soil, water and climate. Ecologists have divided the earth's living surface into major communities, called biomes, which are complex associations of plants and animals in a region. The composition of animal species in a given region is determined by a number of factors, including vegetation, basic physical resources, inter-species dynamics, and historic patterns of distribution.

Biomes can be subdivided in turn into smaller communities called ecoregions, similar to the way that geology and topography can be described by physiographic provinces. The Nature Conservancy and the Pennsylvania

Department of Conservation and Natural Resources (PA DCNR) Bureau of Forestry have adopted Bailey's ecoregional maps as their standard system of vegetation classification.

The Schuylkill River watershed falls mainly in the Lower New England/Northern Piedmont (LNE/NP) ecoregion, also known as the Piedmont Province. The southern edge of the Great Valley marks the boundary with the Central Appalachians ecoregion to the northwest, which coincides with the Ridge and Valley Province. The city of Philadelphia is built on the dividing line in the southeast with the North Atlantic Coast ecoregion, or the Inner Coastal Plain Province.

Most of the Schuylkill River watershed that is in the LNE/NP ecoregion is in the Oak-Hickory-Tuliptree forest region of the Eastern Deciduous Forest biome. In contrast, the Central Appalachian boundary marks a gradual change in forest type to the White Oak-Hemlock-Hardwood transitional forest zone. Tuliptree is more prevalent in the southeast portions of the watershed, while hemlock and white pines are more prevalent in the Central Appalachian ecoregion. A new and detailed list of *Terrestrial and Palustrine Plant Communities of Pennsylvania* was produced by Fike (1999), documenting 11 types of forest and woodland types in Pennsylvania. However, associated mapping at the regional scale has not yet been carried out to define exactly where these forest types actually occur. In general, the following forest associations characterize the watershed (as defined by Delta Group et al. 1999).

- On dry upper elevations: chestnut oak, sweet birch, scarlet oak, red oak American beech, pignut hickory, black oak, white pine and black gum dominate the forest canopy.
- On cool north-facing slopes: hemlock, white pine, sweet birch, black cherry and red oak.
- In ravines with steep slopes: tuliptree, white oak, black cherry, American beech, red maple, shagbark hickory, ironwood, redbud, and dogwood.
- Along streams and floodplains: American sycamore, red maple, American basswood, river birch, white ash, ironwood, witch hazel, spicebush, elderberry and red-stem dogwood.
- On abandoned, cleared land: succesional native plants such as red cedar, box elder, sumac, black locust, black walnut, blackhaw viburnum, red stem dogwood, goldenrod, asters and many other herbaceous perennials.

Forests are the dominant form of vegetation in Pennsylvania. It is estimated that before colonial settlement around 97-98% of Pennsylvania was forested land cover (Schein and Miller 1995). Forest cover in the Schuylkill subwatersheds in the early 1990s ranged from over 70% forest cover in Schuylkill County and a few other isolated areas, to less than 33% in agricultural and developed sections. For more information, see **Section 5.5.1** in *Chapter 5.0 Water Quality* and the online **Reference Table 5G: Land Cover within Each Subwatershed**.

Apart from large-scale deforestation and loss of virgin and old growth forests, several other changes have occurred in the watershed flora since colonial times. American chestnuts and elms, once dominant elements in the region, have been virtually eliminated in the 20th Century due to imported pathogens. Many hemlocks are currently under attack from the woolly adelgid, another introduced pathogen, while a variety of other diseases are taking a toll on other native canopy trees in the watershed – e.g., ash yellows, anthracnose (dogwood and sycamore), beech blight, etc.

In addition, a wave of non-native (exotic) and/or invasive vegetation is sweeping the region. Invasive or non-native species are those species not naturally occurring in an area, which are quick to establish, may be adapted to highly disturbed or edge environments, and/or lack natural predators and competitors. These plant species

have the ability to invade an area and reduce natural diversity due to their competitive advantages. Eventually, the number of native species may be reduced, while the invasive species may dominate and become the only species surviving in an area. While some parts of the Schuylkill River watershed are probably remote enough that they have seen little impact, it seems likely that the more built-up area around Philadelphia is being affected due to high levels of land cover disturbance. The spreading patterns of these introduced species means that it is just a matter of time until the effects are seen watershed-wide. Some of the worst invasive species in the region are listed in **Table 3.3**.

Table 3.3 Key Invasive Species in the Mid-Atlantic Region

Vines	***Shrubs***	***Trees***	***Herbaceous***
Mile-a-minute	Autumn olive	Norway maple	Japanese knotweed
Japanese hops	Multiflora rose	Tree of heaven	Purple loosestrife
Asiatic bittersweet	*Berberis*	*Mimosa*	Japanese stilt grass
Akebia	Winged *Euonymous*	*Paulownia*	Lesser celendine
Japanese honeysuckle	Privet		Garlic mustard
Porcelainberry	Shrub honeysuckles		*Miscanthus* grasses
Buckthorn			*Pennisetum* grasses

Ecological management plans can be developed to address invasive exotic plant issues. These plans can be particularly effective if run as community-based programs, which leverage human resources to achieve the desired management outcome, while helping to educate the public about the environmental issues in the watershed. State and federal agencies are beginning to acknowledge invasive exotic plant problems in Pennsylvania. Purple loosestrife was recently listed as one of a handful of "Noxious Weeds" by Pennsylvania's USDA office, which listed only agricultural weeds until the past few years. Additional literature is being disseminated to educate the public about the invasive plant issue (PA DCNR 2000), and a web search on "invasive" reveals numerous web sites to search for further information. A good summary can be found at http://www.nps.gov/plants/alien.

There are also imbalances in the watershed's fauna. Most notable is the overabundance of white-tailed deer in the southern portion of the watershed. Before colonial times, it is estimated that the natural deer density was between 8-15 deer per square mile (Natural Resource Consultants, Inc. 1996). Now it is typical for deer populations around suburban Philadelphia to be as high as 25-50 per square mile. Such high deer densities cause unsustainable conditions to develop, particularly in forested natural areas, as native vegetation seedlings are browsed so much that new plants cannot replace the older plants. This high pressure of deer browsing changes the nature of the forest vegetation layers. Since most of the browsing is focused on the herbaceous and shrub layers, a more open zone develops than would normally exist in the forest structure. This in turn reduces the food and cover opportunities for many other animals such as birds, amphibians, reptiles and small mammal species.

Other ecological imbalances are being determined, such as the Asian longhorn beetle and Asiatic earthworm and their impacts on forest soils and ecosystems (Dunmore 2000). The effects of the gypsy moth, another introduced animal, on forest resources in the region are well documented, and management programs have been put in place.

Much more is known about the Commonwealth's terrestrial resources than its aquatic resources, but there are indications that the aquatic resources are more threatened (PA Fish and Boat Commission 1995). At the same time, the U.S. has some of the most diverse aquatic resources in the world, many of which are now known or

assumed to be under threat of extinction. “Inhabitants of freshwater ecosystems have, as a whole, suffered far more than plants and animals dependent on upland habitats such as forests and prairies” (The Nature Conservancy 1998). One of the major issues with aquatic resources is the need to conduct a thorough biological inventory to assess species presence, absence and population trends.

Many of these imbalances in fauna and flora, both terrestrial and aquatic, need to be better documented and addressed in the watershed if we are to achieve a sustainable landscape. Ecological Land Management Plans can be developed to address some of the invasive exotic and species imbalance issues. For further discussion about such plans and how they can be developed and implemented in the Schuylkill River watershed, please see **Section 6.8**, Recommendations **R6.14 and R6.15** in *Chapter 6.0 Promoting a Sustainable Landscape*.

3.6 Watershed Conservation Projects

A brief synopsis of a selection of conservation projects in the Schuylkill River watershed that the planning team is currently aware of is provided below for the convenience of the user. These lists also serve to provide general background and reference for this Plan. Summaries of other conservation plans are provided below by category:

- River Conservation Plans
- Other Current Watershed Plans
- Environmental Education Projects

Please note that acquiring and maintaining these project descriptions in a completely up-to-date status is virtually impossible within the context of this report due to the size of the watershed. The PA DCNR Rivers website (http://www.dcnr.state.pa.us/rivers) houses updated information regarding status of the Rivers Conservation Plans and should be checked regularly for current information. However, there is no single existing repository that houses information on all the other numerous conservation and education projects underway in the watershed.

Clearly, the burden of maintaining this list in a complete and updated format serves to illustrate the need to coordinate conservation and planning activities in the Schuylkill River watershed. The magnitude of this task will require on-going dedicated resources and is one of the key activities that should be undertaken in the future as part of a watershed-wide clearinghouse (see Recommendation **R7.11** in **Section 7.5** of *Chapter 7.0 Institutional Assessment*).

3.6.1 River Conservation Plans

River Conservation Plans (RCPs) aim to develop comprehensive plans for managing watershed resources. These RCPs typically identify significant natural, recreational and cultural resources, as well as issues, concerns and threats to river resources. These plans also may develop recommendations on how to conserve, enhance and restore Pennsylvania’s many streams and rivers. A full outline of a typical RCP and many other details about the program can be found at PA DCNR’s Rivers website (http://www.dcnr.state.pa.us/rivers/newrconhome.htm). This website also includes maps and a brief synopsis of the plans approved for PA DCNR funding that are either underway or have been completed in the Commonwealth. The website is one of the best places to obtain up-to-date information on the status of watershed planning projects in the Commonwealth and within the Schuylkill River watershed.

Of the plans completed to date, most address watershed characteristics, at least on a basic level, as well as biological, water, land and cultural resources. RCPs also document issues of concern in the watershed as evidenced through public meetings and/or literature reviews. However, it should be noted that these plans often have different areas of focus by geography and/or by subject matter. Some, such as the French and Pickering Creeks Plan, focus almost exclusively on surface water resources, while others, such as the Wissahickon Plan, focus more on ecological land management and restoration. Depending on the scale of the plan's assessment, components typically receiving less attention include reviews of zoning and ordinances, land ownership and other site-specific information such as the precise location, size, condition and/or value of land parcels of interest or concern – such as landfills, quarries, etc. This is particularly true where an RCP covers multiple municipalities in the study area, due to the fact that each municipality likely has different zoning and ordinances and because site-specific data is generally unavailable at the municipal level, and only occasionally available in geographic information systems (GIS) format at the County level.

Once a plan has been completed and approved for listing on the Rivers Registry, river support groups and municipalities within these watersheds can apply for future grant funding from PA DCNR and other agencies (e.g., PA Department of Environmental Protection or PA DEP) to conduct implementation and development projects based on the recommendations of the RCP. The registry is used to promote river conservation and to recognize rivers or river segments in communities who have completed RCPs. The Registry is also an avenue to endorse local initiatives by binding them together in a statewide recognition program. In order for a river to be placed on the Registry, it must have an approved plan and local municipal support.

As of January 2001, three of the nineteen rivers listed on the Registry were located in the Schuylkill River watershed.

- Tulpehocken and Cacoosing Creek corridors
- French and Pickering Creeks watersheds
- Wissahickon Creek watershed

Ten other plans in the Schuylkill River watershed were underway as of January 2001, including this plan, for the following subwatersheds.

- Manatawny Creek
- Pigeon Creek and Stony Run
- Sandy Run
- Tulpehocken Creek Watershed
- Maiden Creek
- Chester Countywide Plan
- Upper and Lower Perkiomen Watersheds
- Hay Creek
- Unami Creek
- Schuylkill River watershed

A brief overview of each of these RCPs is provided below, together with additional plan information known about the subwatershed. The PA DCNR website provides a project summary and the name of each project grantee and their contact information for additional information.

- **Maiden Creek (Upper and Lower Maiden Creek, Ontelaunee/Kistler and Sacony Creek)**

A RCP grant was awarded to Berks County Conservancy for work on the Maiden Creek in 1997. Work is still in progress. Pennsylvania State University (PSU) worked with Berks County Conservancy on this project as a Student Technical Experience in Problem-Solving (STEPS) agreement. The project report, *Maiden Creek*

Watershed: Keystone Project 1990-2000, compiles data about the watershed characteristics, land resources, water and biological resources, and concludes with a discussion of issues and strategies for management.

In addition, several other reports have focused on Maiden Creek, including a *Watershed Assessment* report that was prepared in 1998 for EPA and PA DEP by The Cadmus Group, which focused on water quality issues and made recommendations to address them.

A diagnostic *Feasibility Study of Lake Ontelaunee* also was also completed by F.X. Browne, Inc. in April 1992, which looked at the entire watershed as part of the analysis. The report was prepared for the City of Reading Bureau of Water and focuses on water quality, as Lake Ontelaunee is a primary drinking water supply for the City of Reading.

- **Sustainable Watershed Management Program for the French and Pickering Creeks, Pigeon Creek and Stony Run (Schuylkill River 3)**

The preliminary sustainable watershed management plans for these subwatersheds were issued in January 1997 for the French and Pickering Creeks, and August 1998 for Pigeon Creek, Stony Run, and a portion of the Schuylkill River. The *Vision Program for Sustainable Watershed Management*, which covers all these subwatersheds, was issued in the spring of 2000 by the Green Valleys Association with assistance by Cahill Associates and Brandywine Conservancy. A companion Technical Report has been published and distributed.

The *Sustainable Watershed Management Program* was developed for the communities of northern Chester County but the goals are sufficiently broad to be applicable and appropriate for all sub-basins within the Schuylkill River Watershed and beyond. The goals of the program are to sustain the quality and quantity of ground and surface waters, maintain natural stream conditions, and prevent groundwater and surface water contamination.

The vision report notes that the natural water system is sustained where: the flow regimes of the stream have not been significantly altered; worsened flooding has not been created; drying up of streams during drought has not occurred; the water table is maintained to support wells, natural springs, and wetlands; water quality is preserved to support aquatic communities and fisheries; and, where drinking water sources are protected for downstream communities.

This program is being implemented by townships through the adoption of a model stormwater ordinance, the updating of zoning ordinances and the updating of comprehensive plans. In the near future, multi-municipal Integrated Resource Plans for these subwatersheds will be presented to the Delaware River Basin Commission in anticipation that these plans will be incorporated into the Commission's Compact.

- **Wissahickon Creek**

A final report the *Wissahickon Creek River Conservation Plan* was released in December 1999. It was prepared for the Fairmount Park Commission, City of Philadelphia, and Montgomery County Planning Commission by the Delta Group and others. Major plan components include: analyses of natural and cultural factors; restoration goals and strategies; a listing of organizations involved in restoration and best management practices; an inventory of restoration implementation tools; subwatershed planning, projects, and costs; and watershed-wide management alternatives.

The 64 square mile watershed was broken down into 28 subwatersheds. However, specific recommendations were developed for only three of these: the headwaters, Trewellyn Creek, and Cresheim Creek. Watershed-wide management alternatives also were presented including planning, coordination tasks and policy

implementation recommendations.

- **Sandy Run Creek**

The *Preliminary Findings Report for the Sandy Run Creek Watershed Conservation Plan* was prepared by Gaadt Perspectives for the Montgomery County Planning Commission in November 1999. The findings report includes detailed management strategies and actions including greenways, open space outside greenways, pedestrian and bicycle paths and corridors, water resources management, public information and outreach, and funding and administration.

- **Chester County Water Resources Management Plan**

This plan is being created through a partnership of the Chester County Water Resources Authority, Camp, Dresser & McKee, and Gaadt Perspectives. The plan will complement Chester County's Landscapes Plan. The first component of the *Water Resources Management Plan* is essentially a River Conservation Plan for the Chester County. The second component is an RCP for the Brandywine Creek. The plan is in draft format and is being reviewed for completeness. It is expected that the plan will be finalized by spring of 2001.

- **Upper Perkiomen Creek**

The *Preliminary Findings Report for the Upper Perkiomen Creek Conservation Plan* was prepared by Natural Lands Trust and the Pennsylvania Environmental Council for the Upper Perkiomen Watershed Coalition in February 2000. The report addresses six primary subjects: water quality; water quantity; land stewardship; environmental education; public parks, trails, and recreation; and institutional issues.

The report notes that the water quality of the Upper Perkiomen Creek and its tributaries is reasonably good, although there may be some agricultural impacts. The intent of the plan is not so much to restore these creeks as to ensure that they are not degraded. The draft conservation plan is scheduled for completion in fall of 2001.

- **Lower Perkiomen Creek**

A grant to prepare the *Lower Perkiomen Creek River Conservation Plan* was received by the Perkiomen Watershed Conservancy in April 2000. Work is underway.

- **Hay Creek**

A grant to prepare the *Hay Creek River Conservation Plan* was received by Berks County Conservancy in April 2000. Work is underway.

- **Unami Creek**

A *Preliminary Landscape Conservation Plan* is being prepared for part of the Unami Creek watershed by Natural Lands Trust. The project is funded by The William Penn Foundation and is due for completion in 2001. It will focus on assessing the biological resources in the Malborough/Salford Township area of the lower watershed. A second phase of this project, funded by a PA DCNR planning grant, is due for completion in 2002. In addition, Milford Township is in receipt of a PA DEP Growing Greener grant as of summer 2000, to develop a watershed protection plan for the creek, with work underway by F.X. Browne, Inc. Note that the Unami Creek also is within the Upper Perkiomen watershed.

- **Tulpehocken Creek**

A PA DCNR-funded River Conservation Plan is currently being developed for the Tulpehocken Creek and is expected to be completed by spring of 2001. In addition, the following reports have been completed within the

watershed with funding from various government agencies.

- *Forest Resources Report*, USDA Forest Service, November 1996
- *Fish & Wildlife Resources*, USFWS, April 1997
- *Final Watershed Protection Plan and Environmental Assessment*, USDA NRCS & Forest Service, November 1997
- *Tulphehocken Creek Scenic River Study*, Berks County Conservancy (undated)
- *A Qualitative Analysis of Tulpehocken Creek and its Tributaries*, Berks County Conservancy, August 1996

- **Manatawny Creek**

This RCP focuses on integration of growth management concerns with the preservation of agricultural, natural and historic resources, requiring cooperation between two County governments (Berks and Montgomery) as well as sixteen municipalities. The grant was awarded in April 1997 to Berks County Conservancy, and the plan is due for completion and draft review shortly.

3.6.2 Other Current Watershed Projects

Numerous other land use studies and projects are underway in the watershed. The following is not intended to be a complete listing of all projects, but rather an indication of the types of projects that are being undertaken.

- *Schuylkill River Source Water Assessment*. The 1996 Safe Drinking Water Act reauthorization requires states to conduct source water assessments (SWAs) for every community water supply. These assessments will identify significant potential sources of pollution and look at raw water quality at each facility intake. They are not assessments of final water compliance by the water supplier, but instead are meant to provide suppliers and consumers with information about the sources of their drinking water supply.

  Approximately 14,000 drinking water sources in Pennsylvania will be assessed. PA DEP is coordinating this effort statewide. In the Schuylkill River watershed, the Philadelphia Water Department (PWD), Philadelphia Suburban Water Company (PSWC) and Pennsylvania American Water Company have drinking water intakes that together serve more than 1.5 million people. These suppliers have teamed up to perform a joint SWA that will cover the entire Schuylkill River watershed. The plan is now underway, and the first public meeting was held on October 25, 2000.

- *Schuylkill River Valley National Heritage Area*. In September 1999, the Schuylkill River Valley National Heritage Area Act (S. 1584), was introduced in the U.S. Senate by Senator Rick Santorum. The bill was enacted in September 2000 and became Public Law 106-278 on October 6, 2000, designating the Schuylkill River Valley a National Heritage Area. This Act, which names the geographic boundaries as "those portions of Schuylkill, Berks, Chester, Montgomery and Philadelphia that are in the Schuylkill River Watershed," recognizes the national significance of the contribution of the Schuylkill River Valley to the nation's political, cultural and industrial development. The purpose of the Act is to enable local communities to conserve their heritage while continuing to pursue economic opportunities, and to conserve, interpret and develop the natural, historical, cultural and recreational resources related to the industrial and cultural heritage of the area. The Act provides for cooperative projects with other National Heritage Areas in the anthracite coal region and requires development of a Management Action Plan within three years of authorization. An update of the Schuylkill River Heritage Corridor plan is declared to be sufficient to meet this requirement. The act also authorizes the appropriation of up to $1 million per year, with a maximum of $10 million total. It names the Schuylkill River Greenway Association as the

management entity.

- *Schuylkill Watershed Indicators Report*. The Conservation Fund, in partnership with 25 key nonprofit organizations within the watershed, is developing the first Indicators Report for the Schuylkill River watershed. This indicators report will create an important baseline from which future reports can measure progress and trends, as well as draw attention to the environmental, historical, and educational resources within the watershed. In addition, it will foster coordination among the various groups working within the watershed and highlight the activities of participating nonprofit organizations. The report will address multiple watershed issues including water quality, water supply, biological health, greenway development, educational activities, and land use patterns, etc. Anticipated completion is July 2001.

- *Blue Marsh PL566 Implementation Project*. The Lebanon and Berks County Conservation Districts are currently performing the Blue Marsh PL566 Implementation Project. This project involves the dedication of a nutrient management technician to make contact with farmers for the installation of Best Management Practices (BMPs), in order to reduce sediment and nutrient loading in the watershed. Since 1998, $5.9 million in federal grants have been allocated to reduce nutrients and sediments over the next 10 years in the watershed.

- *Schuylkill Riparian Restoration* is being performed by the Schuylkill Riverkeeper in partnership with the Acedemy of Natural Sciences. This project identifies streamside lands in need of restoration, selects sites for BMP installation, designs restoration plans, and involves local citizens and municipalities in installing and maintaining riparian BMPs. 10 miles of degraded streambanks are being restored to reduce sedimentation and pollution in the Schuylkill River and its tributaries.

- The Delaware Estuary Program completed a management plan for the Delaware Estuary in 1996 titled *The Delaware Estuary - Discover its Secrets: A Management Plan for the Delaware Estuary*. This report covers the entire lower Delaware watershed, of which the Schuylkill River watershed is a significant part. Although focusing principally on the estuary, this report is an excellent source of watershed data, technical guidance, and public outreach. Specific actions to address problems in the Delaware Estuary (many of which apply to the Schuylkill River watershed) are presented, covering land management, water use management, habitat and living resources, toxics, education, monitoring, and regional information management.

- *Stoltzfus Farm Streambank Restoration & Sediment Reduction on Limekiln Creek*. Berks County Conservancy has received a Growing Greener Grant to create cattle crossings and access areas as well as to put up streambank fencing along a stretch of the Limekiln Creek.

- *Upper Schuylkill River Watershed Tributary Area Assessment*. The Eastern Pennsylvania Coalition for Abandoned Mine Reclamation currently is working on the Upper Schuylkill River Watershed Tributary Area Assessment in conjunction with the Schuylkill Headwaters Association, the Schuylkill Conservation District, and the Schuylkill Riverkeeper. This assessment, completed in October 2000, located and prioritized mine drainage sites for future remediation and restoration projects. Funding for this assessment was provided by 319 grant funds.

- The Delaware River Basin Commission (DRBC) published its report *Flowing Towards the Future - 21st Century Visions and Directions for the Delaware River and its Watershed* in September 1999. The report was based on input from public meetings held in April and May of 1999. This plan presented five visions for the watershed: an Ecological Vision (habitat and clean environment characterizations); a Water Supply Vision (ample, high quality, and controlled water supply); a Viable, Pleasing Places Vision (human quality

of life); a Vibrant Economy Vision (blending economic and environmental goals); and a Stewardship Vision (personal responsibilities). The report also proposed directions and recommendations for achieving these visions.

- *Upper Schuylkill River Watershed Protection Plan*. The Berks County Conservancy currently is assessing the Upper Schuylkill River watershed from Reading north to the Berks and Schuylkill County line in order to develop a protection and restoration plan.

- *Water Quality Assessment*. The Stroud Water Research Center is complementing the DEP program by conducting a five-year water quality study of aquatic macroinvertebrates at 19 sites throughout the Schuylkill River watershed.

- *Orphan Dam Removal – Manatawny Creek*. The greater Pottstown Watershed Alliance has received funding to remove an orphan dam from Manatawny Creek. The project is part of an initiative to restore the upstream riparian corridor and meet the larger Pennsylvania goal of resolving watershed problems and issues well beyond the life of the grant.

- *Montgomery County Greenway Stewardship Study* is being prepared by the Montgomery County Planning Department. This plan envisions the creation of a greenway along the Schuylkill for the entire county border along the river. A draft of the study was released for public comment and is expected to be adopted in 2001.

- *Schuylkill River Trail* being developed by the Schuylkill River Greenway Association (SRGA) will connect Philadelphia to the headwaters in Schuylkill County while also increasing public access along its route. The Borough of Phoenixville has received a Pennsylvania Heritage Grant for the design of the trail along the south bank of French Creek. Chester and Montgomery Counties have received funding for construction of 19.5 miles of the trail in their respective counties.

- SRGA, the Pennsylvania Fish and Boat Commission and others are developing a Schuylkill River Water Trail to complement other efforts to connect river communities and increase public access to river recreation.

- The *Botanic Trail*, a component of the Schuylkill River Trail, is being developed by the John Bartram Association. The trail will be placed along the west bank of the lower Schuylkill River.

- An abandoned coal-desilting basin is being converted into a *wetland for migratory birds* with a mile long interpretive trail around its perimeter. This is being developed by the Chester County Department of Parks and Recreation.

- *Wissahickon Creek* multi-purpose trail and riparian restoration project is being planned by the Morris Arboretum of the University of Pennsylvania.

- *Hawk Mountain Sanctuary biological inventory* is ongoing, in conjunction with a land management plan to preserve its view shed and open space on adjacent properties.

- *Spring Mountain wildlife habitat protection plan* is being performed by The Perkiomen Watershed Conservancy and other partners.

- *The Schuylkill River Park* is being developed by the Schuylkill River Development Council along the

lower Schuylkill River to promote recreation and draw people to Center City. Also, the *Tidal Schuylkill Master Plan* being undertaken by the Council with funding by PA DCNR will examine conservation planning and revitalization of the riverfront along the tidal portion of the Schuylkill River in Philadelphia.

- Fairmount Park Natural Lands Restoration and Environmental Education Program (NLREEP) is developing plans for *environmental education facilities and programs*, as well as natural area inventories and focused plans for ecological restoration projects throughout six parks in the Fairmount system, including Wissahickon and East and West Park. Final restoration plans are due in 2002.

- *Ryerss Farm Streambank Fencing and Restoration* project is being conducted by the Green Valleys Association. This project provides a riparian buffer and streambank fencing along a 300-foot stretch of Rock Run, a tributary of French Creek.

- *Brights Lane Detention Basin Retrofit Demonstration Project* is being performed by Lower Gwynedd Township. This project is reconstructing a historic detention basin, constructed before consideration was given to pollution removal, in order to better treat the first flush of stormwater.

- *French Creek Scenic Restoration Project* is being conducted by the Green Valleys Association in East Vincent Township, Chester County. This reclamation project involves the demolition of an abandoned slaughterhouse on the banks of French Creek and the replanting of the one-acre site with native plants.

- *Montgomery County Brownfields Project* focuses on redevelopment opportunities at brownfields and old industrial sites primarily along the Schuylkill River.

- *Manayunk Canal restoration* by the Manayunk Development Corporation is restoring the historic Manayunk Canal while promoting environmental stewardship and conserving open space on Venice Island.

- *Phoenixville Redevelopment* is being performed by the Phoenixville Area Economic Development Corporation. This project is renovating a historic, abandoned iron foundry with shops and environmental interpretation. It will also include a link to the Schuylkill River Trail.

- *The Schuylkill Canal restoration* at Mont Clare is being developed by the Schuylkill Canal Association.

- *Valley Creek restoration* activities are taking place through the Valley Forge National Historical Park.

- *The Fairmount Water Works* is being remodeled into an interpretive center by the Fund for the Fairmount Water Works and the Philadelphia Water Department (PWD). The Philadelphia Water Department has begun construction of the Fairmount Water Works Interpretive Center on the river level of this historic landmark. The Interpretive Center will be the environmental education forum for the Philadelphia Water Department on urban, regional, and national water resources and management issues. Programs and exhibits will use the history and technology of the site and the science resources of the Philadelphia Water Department and many area partners to promote the benefits of environmental stewardship to visitors.

3.6.3 Environmental Education Projects

Finally, there are also numerous education efforts ongoing in the Schuylkill River watershed, including the following programs and projects.

- *Schuylkill River Greenway Association* is developing marketing materials to promote the historic, cultural, recreational, and natural resources of the Schuylkill River watershed.

- *Perkiomen Watershed Conservancy* is conducting environmental education programs for all ages, along with public outreach to municipal officials, developers, and other business stakeholders.

- *Peopling of Philadelphia Collaborative, Inc.* is a collaboration of community, school, and business partners creating innovative school curricula to teach environmental science and local history unique to the watershed.

- *Riverbend Environmental Education Center* is restoring its original 1923 Sears Roebuck barn into a state of the art environmental education facility for its 7,000+ annual visitors.

- *Stroud Water Research Center* teaches cutting edge environmental science curricula to teachers and trains volunteer water quality monitors.

- *Schuylkill Center for Environmental Education* provides on-site environmental education to groups and individuals. It also conducts educational outreach off-site to groups in addition to monitoring water quality.

3.7 References

The Academy of Natural Sciences. 1995. My River is the Schuylkill: A Vision for the Schuylkill River Watershed Initiative. Unpublished report. The Academy of Natural Sciences, Philadelphia, PA.

Biesecker, J.E., J.B. Lescinsky, and C.R. Wood. 1968. Water Resources of the Schuylkill River Basin. Water Resources Bulletin No. 3. Pennsylvania Department of Forests and Waters, Harrisburg, PA.

Browne, F.X. April 1992. Feasibility Study of Lake Ontelaunee. Prepared for City of Reading Bureau of Water.

Carson, L. 1999. Land Use Change in the Schuylkill Watershed: An Analysis of Population Changes and Development 1990-2010. Final Project Report, Environmental Studies 499, University of Pennsylvania. Philadelphia, PA. 31pp.

Dunmore, R. Fall 2000. Disturbance and restoration in northern Piedmont forests. Ecological Restoration 18(3).

Delta Group et al. December 1999. Wissahickon Creek River Conservation Plan.

Fike, J. June 1999. Terrestrial & Palustrine Plant Communities of Pennsylvania. Pennsylvania Natural Diversity Inventory.

Fleeger, G.M. 1999. The Geology of Pennsylvania's Groundwater. Third edition. Pennsylvania Geological Survey, 4th series, Educational Series 3. 34 pp.

Leopold, L.B. 1997. Water, Rivers and Creeks. University Science Books. Sausalito, CA.

Natural Resource Consultants, Inc. August 1996. Development of Deer Management Recommendations for the Wissahickon Valley. Philadelphia, PA.

Pennsylvania Department of Conservation and Natural Resources. April 2000. Invasive Plants in Pennsylvania. Brochure #8100-PA-DCNR 3077 4/00. PA DCNR, Harrisburg, PA.

Pennsylvania Fish & Boat Commission. 1995. A Heritage for the 21st Century: Conserving Pennsylvania's Native Biological Diversity. Harrisburg, PA.

Robinson, G.R., M.E Yurlina, and S.N. Handel. 1994. A Century of Change in Staten Island: Ecological Correlates of Species Losses and Invasions. Rutgers University, NJ. *In* Bulletin of the Torrey Botanical Club.

Schein, R.D., and E W Miller. 1995. Forest Resources. *In* E.W. Miller, ed. A Geography of Pennsylvania. Penn State University Press, Philadelphia, PA.

Simkins, P.D. 1995. Growth and Characteristics of Pennsylvania's Population. *In* E.W. Miller, ed. A Geography of Pennsylvania. Penn State University Press, Philadelphia, PA.

The Nature Conservancy. 1998. Rivers of Life: Critical Watersheds for Protecting Freshwater Biodiversity.

U.S. Army Corps of Engineers. 1981. Feasibility Report of the Schuylkill River Review Study. US ACE, Philadelphia District, Philadelphia, PA.