

Setting of the Upper Delaware Watershed

A Technical Report for the Upper Delaware
Watershed Management Project
November 2001



• Mountain Lake, Warren County



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The Settings Report is intended to provide an overview of the existing conditions in the Upper Delaware, both natural and human induced. It is not designed to be a highly technical examination of these existing conditions. This report shall serve as a starting point for the watershed characterization process, which in turn will be the foundation for the subsequent watershed planning effort.

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Setting of the Upper Delaware Watershed

Overview

Watershed planning is the most efficient and effective method to balance environmental quality with land-use choices. The reason for this is that a watershed is a naturally formed environment that is strongly interrelated; actions in one area impact another area downstream. As man's influence on the land extends, quality and quantity of natural resources can be compromised.

In order to strike this balance it is necessary to understand the resources in place that shape the character of a watershed. The Settings Report is the first step in this process. Geology, topography, soils, water, vegetation, land-use, recreation, population, transportation, and employment are examined to provide a sound basis for future watershed planning and management activities. The report summarizes natural and socio-economic resources that characterize the Upper Delaware Watershed and will serve as a foundation of basic understanding for the subsequent series of technical reports that will be developed to provide a fuller characterization and assessment of the watershed.

The Upper Delaware Watershed is located in the northwest portion of New Jersey. It is contained within the Valley and Ridge and Highlands physiographic provinces, with well-defined mountain ridges running in a southwest to northeast direction. It includes portions of Sussex, Morris, Hunterdon, and all of Warren Counties. Fifty-four municipalities make up the local governing bodies. Generally not densely populated, the region contains some significant towns, most notably Phillipsburg, Washington, Hackettstown, Hopatcong, and Newton.

The Upper Delaware Watershed is approximately 746 square miles in total area. At its extremes, the area is approximately 59 miles long and 30 miles wide. Many subwatersheds are contained within the region, most notably Shimers Brook, Clove Brook, Little and Big Flat Brook, Van Campens Brook, Dunnfield Creek, Trout Brook, Paulins Kill, Stony Brook, Delawanna Creek, Pequest River, Bear Creek, Beaver Brook, Pophandusing Brook, Buckhorn Creek, Lopatcong Creek, Pohatcong Creek, and the Musconetcong River.

The New Jersey Department of Environmental Protection: Watershed Management Areas

The New Jersey Department of Environmental Protection (NJDEP), Division of Watershed Management, has developed delineations of 20 major Watershed Management Areas (WMA) for New Jersey. These watersheds are organized under the umbrella of five Water Regions within the Division of Watershed Management. The Upper Delaware Watershed is designated as Watershed Management Area 1 or WMA-1. The purpose for NJDEP making these watershed designations is to recognize naturally formed regions that are of sufficient size to encompass major drainage basins, while being small enough to make unified planning and management activities feasible.

The watershed boundaries of WMA-1 (Figure 1) are the Delaware River to the west, Central Delaware (WMA 11) to the south, North Branch and South Branch of the Raritan (WMA 8) to the east, Upper Passaic-Whippany-Rockaway (WMA 6) to the northeast, and Walkkill (WMA 2) to the north.

The Delaware River

New Jersey's Upper Delaware Watershed is an important section of the entire Delaware River basin. This characterization and assessment effort will address only the lands and tributaries of the Upper Delaware region (WMA-1), not the Delaware River mainstem.

The Delaware River mainstem extends 330 miles from the confluence of its east and west branches at Hancock, NY, to the mouth of the Delaware Bay. Its drainage area encompasses 12,755 square miles in New York, Pennsylvania, New Jersey, and Delaware. The total New Jersey portion makes up 23.3% of the mainstem's total; the Upper Delaware Watershed (WMA-1) drainage area makes up about 6%.

The Delaware is a significant resource in many ways. Three stretches of the Delaware River, extending 178 miles from Hancock, NY to Washington Crossing, have been included in the National Park Service National Wild and Scenic Rivers System. Almost 10% of the nation's population relies on the Delaware River Basin for drinking and industrial use. Additionally, the river is less than a day's drive away for about 40% of the people living in the United States.

The Delaware is an unusually valuable resource because of its scenic value, wildlife habitat, water quality and the large population that makes use of these attributes. The Upper Delaware Watershed region is a crucial portion of the whole basin because the network of tributaries are among the most pristine in New Jersey. Maintaining the quality of water in this portion of the Delaware River basin will provide a large benefit to all life downstream.

Natural Resource Characteristics

Climate

The climate of this region is characterized as *continental* with minimal influence from the Atlantic Ocean, except when winds are from the east. Prevailing winds are from the southwest in summer and northwest in winter.

Located in the northernmost portion of the state with small mountains up to 1800 feet in elevation, the Upper Delaware region normally shows a colder temperature range than other climate regions of New Jersey. This difference is most dramatic in winter when average temperatures in the region can be more than 10 degrees cooler than in central Jersey. This difference is reflected clearly in snowfall averages. WMA-1 annual snowfall averages 40-50 inches compared to just 15-20 inches in southern New Jersey. Available climate records for stations within the watershed show:

Average highest temperature: 84.9° (Belvidere, 1951-1973 data)
Minimum temperature normal: 12.1° (High Point)
Average precipitation (calculated from Table A-1.1): 44.5 inches

Appendix 1 contains minimum and maximum temperature normals and precipitation normals from 1961-1990 for locations within WMA-1 that have readily available digital climate records from the NJ State Climatologist.

The highlands and mountains in this area help to make the climate of the Upper Delaware different from the rest of the state. Clouds and associated precipitation are enhanced by *orographic effects*. For instance, following a cold frontal passage, air forced to rise over the mountains can produce clouds and precipitation while the rest of the state may be enjoying clear skies. This phenomenon is due to subsiding air flowing off the higher elevations.

During the warm season, thunderstorms are responsible for most of the rainfall. Frontal passages are less frequent during this time. Thunderstorms formed in Pennsylvania and western New York often move over this area where they reach maximum development in the evening. The region has about twice as many thunderstorms as in the coastal region of New Jersey, where the adjacent ocean helps to stabilize the atmosphere.

The Upper Delaware has the shortest growing season in the state, about 155 days. The average date for the last killing frost is May 4. The first frost averages October 7. However, some valley locations have recorded killing frosts as early as mid September and as late as mid June.

Topography and Geology of the Upper Delaware Watershed

The topography of WMA-1 is dominated by valleys and ridges oriented southwest to northeast. Generally, the drainage patterns follow the same orientation, flowing southwest to the Delaware River. Elevations range from the highest spot in New Jersey, Sussex County's High Point which is 1803 feet above sea level, to approximately 120 feet in the Delaware Valley of southern Warren County. The land is rolling to steep, with two physiographic provinces represented, The Valley and Ridge and the Highlands. A *physiographic province* or region is defined as that portion of the landscape sharing similar topographic, climatic and geologic characteristics. Figure 2 shows the physiography of the watershed.

Valley and Ridge Province

This physiographic province covers about 7% (580 square miles) of the land area of New Jersey and 58% of the Upper Delaware Watershed. It is a portion of the Appalachian Valley and Ridge, which extends for 1,200 miles from Alabama to the St. Lawrence Valley in Canada. As the name suggests, it is characterized by a series of nearly parallel ridges and valleys. In the Upper Delaware the valleys and ridges are oriented in a northeast-southwest direction.

The landscapes of the valley and ridge province, which were developed by tectonic forces during the Paleozoic Era and later carved by fluvial and stream erosion, were modified by glaciation during the Cenozoic Era. The most recent ice sheet (Wisconsin) covered this region completely and deposited a terminal moraine at the southern terminus of the ice front when the rate of advance was balanced by melting. The terminal moraine can be found roughly along the Route 46 corridor from Belvidere to Buttzville and on past Hackettstown, traversing both the Valley and Ridge and Highlands physiographic provinces. This moraine is a clearly visible, low, irregular ridge of glacial till that ranges from 1/2 to 2 miles wide and 25 to 300 feet thick. Much of the land north of the moraine consists of a thin sheet of glacial till and ice-scoured bedrock surfaces.

The ridges, which include Walpack Ridge and Kittatinny Mountain, are underlain with northwestward dipping Silurian and Devonian era sandstones and conglomerates. Kittatinny Mountain, a generally even-crested ridge that averages 1,600 to 1,800 feet in elevation, is one of the most impressive topographic features in all of New Jersey. The Upper Delaware Valley is underlain with weak Devonian limestones and shales, while the Kittatinny Valley is underlain with folded Cambrian and Ordovician limestones and shales. The landscapes in the valley and ridge have been carved by a number of rivers whose development have been controlled both by the structure and the distribution of soft and hard geologic formations.

Some lakes of the region are glacial in origin: Catfish Pond, Sand Pond and others occur as ice-scoured basins in Kittatinny Valley and on Kittatinny Mountain. A large number of lakes have also resulted from the melting of buried ice blocks. This melting ice formed kettle lakes, which are widely distributed over the northern part of the state.

Highlands Province

Also known as the Reading Prong, this province makes up about 12% (900 square miles) of the land area of New Jersey and 42% of the Upper Delaware Watershed. It lies southeast of the Kittatinny Valley and forms a broad highland belt broken with intermountain valleys. The broad, flat-topped highlands are made up of broad, rounded, and flat topped ranges separated by deep narrow valleys lying 400 to 600 feet below the ridge tops oriented northeast to southwest. The ridges are underlain chiefly with Precambrian gneisses and schists, while the long, narrow valleys are underlain with fault block inliers of Paleozoic Kittatinny Limestone and Martinsburg shale. Small outcrop belts of Precambrian Franklin Limestone and infolds of Devonian sandstone and shale occur in some of the valleys.

The elevation of the Highlands region ranges from 1,496 feet near Vernon in Sussex County to about 120 feet in the lower Delaware River valley. Although not as dramatic as that found in the Valley and Ridge Province, the topography of the Highlands region in WMA-1 is one of considerable relief. The Musconetcong River and some smaller tributaries have carved deep valleys in the basins between the ranges. The limestone formations in several of the valleys are notable for the solution caverns that hold and transmit large quantities of water. The nature of these formations, allowing free water movement, means that there are unique considerations relating to surface water – ground water dynamics: potential is great for sinkhole formation and pollutant contamination of the underlying aquifer.

Soils

The characteristics of the soils in a watershed have a large bearing on all other resources. Features ranging from vegetation to land use are heavily influenced by soil properties. Dynamic hydrologic processes including infiltration and runoff are also dictated largely by the characteristics of soils. The soils in the Upper Delaware Watershed region are quite diverse. Many have been formed from glacial processes of grinding, mixing, and meltwater deposition of parent material. The variation in geologic material, topography, and hydrology create a unique and interesting mix of soil types.

The United States Department of Agriculture (USDA) Cooperative Soil Survey Program maps and categorizes soils in a county according to the most important characteristics. From a watershed management perspective, these would include infiltration/permeability, depth to bedrock or restrictive layer, depth to seasonal high water table, and slope. These characteristics are related to the processes and geologic material that formed the soils. Currently, the soil survey information in Warren and Sussex counties is being updated and revised. In the Upper Delaware Watershed, the following revised soil series associations have been mapped:

Soils formed in post-glacial alluvium:	Delaware-Unadilla-Colonie
Soils formed in glacial outwash:	Hazen-Hoosic-Otisville, Fredon-Halsey
Soils formed in organic deposits:	Carlisle-Adrian
Soils formed in young glacial till or in material weathered from bedrock:	Walpack-Lordstown-Manlius, Swartswood-Wurtsboro, Lackawanna-Oquaga-Rock outcrop, Arnot-Lordstown, Wassaic-Farmington-Galway, Nassau-Manlius, Hollis-Rock outcrop-Chatfield, Rockaway-Chatfield-Whitman, Rockaway-Rock outcrop.
Soils formed in material developed from bedrock or old glacial till:	Duffield-Washigton, Parker-Edneyville-Califon, Edneyville (Gladstone)-Parker, Annandale-Washington-Califon, Washington-Bartley, Bartley-Turbotville-Cokesbury
Soils formed in alluvial material:	Rowland-Birdsboro-Raritan

Appendix 2 contains brief descriptions of these major soil associations. The *existing published associations* are portrayed in the General Soils Map, Figure 3. Soil series differ slightly from those listed above. An updated map will be issued in the soils technical report to follow as part of the characterization effort. For technically complete published soils information, consult the USDA Cooperative Soil Surveys for Sussex, Warren, Hunterdon, and Morris Counties.

Vegetation of the Upper Delaware Watershed

At one time, virtually all of WMA-1 was covered with woodlands and wetlands. The native tribes made small clearings, but with the dawn of European settlement, much of the forest was cleared for farming, lumber, and fuel. Large acreages of wetland were drained for crop production. Now, the region is a mixture of forested and agricultural spaces, with patches of suburban development interspersed. The agricultural and developed areas have influenced plant communities through much of the region. Many plants associated with farm, pasture, and developed landscapes have become commonplace in edge ecosystems along forests.

Despite man's activities, woodlands are still a dominant land cover in the Upper Delaware, making up 53% of the total acreage. Mature forested areas are found on rocky ridges or in *drier* wetlands where farming was not successful. The predominant native ecosystem is the northeastern oak-hickory hardwood forest. Species that predominate in this region are red oak, hickory, sugar maple, birches, beech, white ash, and yellow poplar. Generally, the mature forest community in WMA-1 is dictated by soil drainage regime. Poorly drained soils produce red maple, pin oak, sweet gum, and other *swamp* hardwoods along with eastern hemlock. On the ridges with better drainage, red oak, black oak, hickory, and pitch pine predominate. In intermediate areas and sheltered slopes, major species are eastern hemlock, sugar maple, yellow poplar, white oak and black and yellow birches. Figure 4 portrays the generalized woodland communities of the region.

In some areas, the woodland that was cleared and farmed for centuries has been abandoned and is reverting to early-successional red cedar-black cherry-gray birch ecosystems representing the first stage of succession, returning to the original native hardwood forest community.

In transitional and drier areas, there are a number of native herbaceous plants that can be found along field edges. The plants more widespread and native to the Upper Delaware region include: bracken fern, hairgrass, wintergreen, wild sarsparilla, Canada mayflower, false Solomon's-seal, and Pennsylvania sedge.

Wetlands also play an important part in the vegetation regime of the watershed, making up 10% of the total area. Four major wetland types make up much of the total:

Deciduous wooded wetlands	26,736 acres or 54%
Herbaceous wetlands	6,983 acres or 14%
Modified agricultural wetlands	6,569 acres or 13%
Deciduous scrub/shrub wetland	5,810 acres or 12%.

The diversity of vegetation associated with wetlands is an important aspect of the wildlife habitat and the hydrologic properties of the region. The vast majority of wetlands can be found in the broader valleys of the Highlands, often associated with floodplains or the riparian corridors of tributaries. Some of the more prevalent wetland plants found in the watershed are cattail, phragmites, jewelweed, swamp loosestrife, tussock sedge, skunk cabbage, woolgrass, and many others. Wetland types of the watershed are shown in Figure 5.

Appendix 3 provides one list (Collins & Anderson, 1994) of the different plant communities present in WMA-1, indicating the more common trees, shrubs, herbs, and mosses of the Upper Delaware.

Fish and Wildlife Resources

The Upper Delaware Watershed is home to a diverse wildlife population. The tremendous variation in topography, soils, and vegetation communities combined historically with low human population to create optimal conditions for a number of wildlife species.

More than 200 species of birds are known to winter, breed, or migrate through the watershed. Reptiles and amphibians flourish in the varied habitats found within the watershed. Over 30 species of mammals, ranging from the economically important whitetail deer down to the shorttail shrew, make their home here. Some common species are black bear, woodchuck, rabbit, opossum, skunk, raccoon, gray squirrel, and chipmunk.

The whitetail deer, Canada goose, and black bear populations have grown to the point of nuisance levels in many portions of the watershed. Although no data currently exists that is watershed-specific, some state and county numbers have been generated to indicate the magnitude of the problem. In 2000, a Rutgers University survey showed that there was over \$200,000 damage to crops and landscape plantings, primarily by deer, in Sussex and Warren Counties. In 1995, the number of complaints about bear damage statewide was 295. In 2000, the number increased to 1,375. The bulk of these incidents are in "bear country" - Sussex, Warren, and western Morris and Passaic Counties. If suburban sprawl continues, more habitat will be compromised, and these numbers are likely to increase.

Water features of the region are a valuable habitat resource. The relatively clean, cold, swift streams of the Upper Delaware provide favorable conditions for aquatic species. Fish resources are important economically with shad, trout, bass, and other game fish sought nearly year-round in the upper Delaware itself and also the tributaries and impoundments. In fact, the overwhelming majority (64% of stream miles) of New Jersey FW-1 trout production waters are found in WMA-1. Most of the numerous lakes also provide excellent aquatic habitat, usually tending toward a warm water fishery, which includes bass, sunfish, perch, and pickerel.

Critical habitats such as wetlands, grasslands, and unbroken tracts of mature forest are present in this region, but are also being fragmented due to human encroachment. Protecting and managing the lands providing critical habitat is a stated priority of many of the federal, state, and local agencies and conservation groups that are active in the watershed region. Almost fifty species of state threatened or endangered wildlife species can be found within the Upper Delaware Watershed. Local threatened and endangered species as recognized by New Jersey Division of Fish and Wildlife are listed in Appendix 4.

The Landscape Project

In 1994 the N.J. Division of Fish and Wildlife's Endangered and Nongame Species Program (ENSP) adopted a landscape level approach to rare species protection. The goal is to protect New Jersey's biological diversity by maintaining and enhancing rare wildlife populations within healthy, functioning ecosystems. Since animals require large expanses of natural habitat for their long-term survival, the Landscape Project focuses on large areas called landscape regions that are ecologically similar with regard to their plant and animal communities. Utilizing an extensive database that combines rare species location information with land use/land cover classification data, ENSP has identified and mapped areas of critical habitat for rare species within each landscape region. These landscape maps provide a highly accurate, reliable and scientifically sound basis for habitat protection within each landscape.

The objective of the Landscape Project is to provide planners with an accurate, scientific basis for habitat protection efforts. A wildlife issues technical report utilizing this data in greater depth will be forthcoming as part of the Upper Delaware Watershed characterization and assessment process. The Landscape Project map for the watershed is shown in Figure 6.

Natural Heritage Database

Another useful source of wildlife habitat information can be found in the Natural Heritage Priority database administered by the NJDEP Office of Natural Lands Management. This data reflects sites of important

biodiversity and is portrayed in Figure 7. The New Jersey Natural Heritage Program identifies the state's most significant natural areas through a comprehensive inventory of rare plant and animal species and representative natural communities. From the inventory, the Natural Heritage Database compiles information on the distribution, biology, status, and preservation needs of these species and communities. Established in 1984 through a cooperative agreement between The Nature Conservancy, a private conservation organization, and the New Jersey Department of Environmental Protection (NJDEP), full administration of the program was assumed by the NJDEP in 1986. The New Jersey Natural Heritage Program is part of an international network including State Natural Heritage Programs and Conservation Data Centers all building on the same data collection methodology. The Database is updated continuously and is used to set state, national, and global priorities for the preservation of natural diversity.

Each site is ranked according to its significance for biological diversity using a scale developed by The Nature Conservancy and the network of Natural Heritage Programs. The ranks can be used to distinguish between sites that are of global significance for conservation of biological diversity vs. those that are of state significance. There are four significant categories:

Outstanding significance, generally the "last of the least" in the world, such as the only known occurrence of any element (species or natural community), the best or an excellent occurrence of an element ranked critically imperiled globally, or a concentration (4+) of good or excellent occurrences of elements that are imperiled or critically imperiled globally. The site should be viable and defensible for the elements or ecological processes contained. *This category makes up about 0.1% of the watershed.*

Very high significance, such as the most outstanding occurrence of any natural community. Also includes areas containing other occurrences of elements that are critically imperiled globally, a good or excellent occurrence of an element that is imperiled globally, an excellent occurrence of an element that is rare globally, or a concentration (4+) of good occurrences of globally rare elements or viable occurrences of globally imperiled elements. *This category makes up about 1% of the watershed.*

High significance, such as any other viable occurrence of an element that is globally imperiled, a good occurrence of a globally rare element, an excellent occurrence of any natural community, or a concentration (4+) of good or excellent occurrences of elements that are critically imperiled in the State. *This category makes up about 1.5% of the watershed.*

Moderate significance, such as a viable occurrence of a globally rare element, a good occurrence of any natural community, a good or excellent occurrence or only viable state occurrence of an element that is critically imperiled in the State, an excellent occurrence of an element that is imperiled in the State, or a concentration (4+) of good occurrences of elements that are imperiled in the State or excellent occurrences of elements that are rare in the State. *This category makes up about 2 percent of the watershed.*

Air Quality

Air quality in the Upper Delaware is generally very good. This is due to the low population, few industrial sites, and overall low automobile traffic density. Although no air monitoring stations exist within the watershed, the nearest ozone monitor (Flemington) in New Jersey has not recorded elevated levels regularly. Particulates are generally within acceptable limits at all times.

However, some air quality issues do exist. When atmospheric conditions permit, localized elevated levels of carbon monoxide and ground level ozone can exist due to heavy traffic along major routes and seasonal wood stove or fireplace smoke. Another intermittent air concern is that nitrous oxide and acid deposition, carried with the prevailing westerly winds, can be significant in this area and can impact aquatic ecosystems. In addition, the southwestern portion of Warren County has been exposed to levels of sulfur dioxide exceeding New Jersey air quality standards. An ongoing debate in the county continues about how to resolve the problem that has been reported to primarily originate from the Pennsylvania Power & Light plant in Martins Creek, Pa.

Water Quantity: Aquifers and Ground Water

There are two types of aquifers, water-bearing subsurface geologic formations, in WMA1: unconsolidated glacial sand and gravel (granular) and fractured bedrock aquifers.

Granular aquifers (unconsolidated glacial sand and gravel)

Ground water in granular aquifers is stored in the pore spaces between grains. These pore spaces generally contain open pores equal to about 25 percent of the volume of the aquifer. Glacial deposits consist of unconsolidated stratified (layered) and unstratified (mixed) deposits of gravel, sand, silt, and clay. The deposits that are primarily sand and gravel can generally yield useful volumes of water. The deposits that consist primarily of silt and clay generally do not yield water and impede the movement of ground water.

The thickest glacial deposits generally occur north of the Wisconsinian terminal moraine, which lies generally in an east-west orientation proximate to U.S. Route 46. North of this line, upland areas are generally covered by a thin layer of discontinuous glacial till (unstratified, mixed sediments), usually less than 50 feet thick. The valleys are filled with stratified drift and lake bed sediments. Depending on the composition, these glacial sediments may form either aquifers or confining units. These units may be up to 300 feet thick in bedrock valleys. The units that supply water in these valleys are sometimes called buried-valley aquifers. Recharge to buried-valley aquifers can occur where permeable units are exposed at the surface and are connected to the water-bearing sediments at depth, and a stream flows over the exposed units. Glacial aquifers supply important quantities of water in the Upper Delaware Watershed.

Fractured bedrock aquifers

Fractured bedrock aquifers store and transmit ground water through an interconnected network of cracks and crevasses. Much of the ground water in these aquifers comes from the overlying soil mantle. Generally, water moves slowly through the fractures, and well yields are usually less than in granular types. Bedrock aquifers provide the highest yields when there are the most extensive fractures, or when carbonaceous formations (limestone) are present, with inherent networks of large voids, or solution caverns. The limestone units in this region are more productive than the shale and sandstone due to their ability to store and transmit water in the vast voids. They are among the most prolific aquifers in the state. In some areas, there is a strong interconnection between the limestone formations and streams, meaning that significant interflow can occur. This is an important consideration for both baseflow and pollution potential.

Tables 1A-C show relative extent and yield of the aquifer types within the Upper Delaware Watershed. This data relates to the geology and aquifer map of the region found in Figure 8. The rankings are derived by New Jersey Geological Survey (NJGS) through ranking median yield of high-capacity wells, which are industrial wells that are cited and tested for maximum water yields that often far exceed domestic well yields for the same aquifer.

Tables 1 A-C: Upper Delaware Aquifer Data

Table 1A. Granular (Surficial) Aquifer Totals

GEONAME	Area (Acres)	Area (Square Miles)	Aquifer Rank
Lake-bottom Sediment	6537	10.2	E
Morainic Deposits	7841	12.2	D
Sand and Gravel	19570	30.5	B
Till	25302	39.5	D

Table 1B. Bedrock Aquifers

GEONAME	Area (Acres)	Area (Square Miles)	Aquifer Rank
Igneous and metamorphic rocks	138839	216.9	D
Jacksonburg Limestone, Kittatinny Supergroup, and Hardyston Quarzite	143380	224.0	C-B
Martinsburg Formation and Jutland Sequence	106494	166.4	D
Rocks of the Green Pond Mt. Region, Kittatinny Mt., and Minisink Valley	88536	138.3	D

Table 1C. Aquifer Rank

Aquifer Rank	Median Yield of High-Capacity* Wells (gpm)
A	> 500
B-A	>250
B	251 to 500
C-B	101 to 500
C	101 to 250
D	25 to 100
E-D	<100
E	<25

*High-capacity wells are industrial wells that are cited and tested for maximum water yields that often greatly exceed domestic well yields for the same aquifer.

Generally, the bedrock aquifers within the Upper Delaware consist of fractured rock formations of the Northwest New Jersey Sole Source Aquifer (SSA) system. *Sole-source aquifer* means that the aquifer contributes more than 50% of the drinking water to a specific area and the water would be impossible to replace if contaminated. These types of aquifers are defined by the U.S. Environmental Protection Agency (EPA) as authorized in section 1424(e) of the Safe Drinking Water Act of 1974. The designation protects an area's ground water resource by requiring U.S Environmental Protection Agency (EPA) review of any proposed projects within the designated area that are receiving federal financial assistance. All proposed projects receiving federal funds are subject to review to ensure they do not endanger the water source. Figure 9 denotes the SSA areas.

The NJDEP Geological Survey has developed a recharge model that uses natural resource and land use data to determine groundwater recharge rates. The recharge rates in the watershed range from 0-5 inches per year in wetlands to 18-22 inches per year in coarse soil or karst regions. This is depicted in Figure 10.

Water Supply

In the Upper Delaware Watershed, the majority of drinking water is obtained from individual or community ground water wells of varying depths. As the population of the Upper Delaware Watershed continues to grow and expand, demands on the surface and ground water supplies of the region will become critical. Both public and private wells will be affected by development and increased demand. Public supplies are a significant concern; there are 190 public community water supply wells in the watershed. Statewide, there are 2,434 of these wells.

NJDEP identifies a *public water system* as a system of piped water serving the public for human consumption, if such system has at least 15 service connections or regularly serves at least 25 individuals daily for at least 60 days in any given calendar year. A public water system is either a *community water system* or a *noncommunity water system*. Community water supplies generally supply a residential population. *Noncommunity water systems* supply entities other than year-round residents. Examples of noncommunity water systems would be found in private schools, offices, churches and businesses.

An integral part of watershed planning is analyzing aquifers and ground water supplies. As human activities alter the basic water cycle, the analysis of the changes in the flow of water becomes essential in understanding how to plan for future development and water use. Substantial development results in the creation of new artificial flow paths consisting of water supply and wastewater disposal networks that alter the natural flow paths. Often, water is delivered to developments from remote reservoirs or wells. Wastewater is disposed of via treatment plants that are not part of the local water regime. Pavement and rooftops create impervious areas that prevent rainfall from entering the ground, and instead is diverted to artificial disposal points. These processes can tremendously affect infiltration, stream flow, surface and ground water quality, and everything in between that depends on natural hydrology. The balance of water demand versus supply will be an important facet of future planning endeavors, and will be the topic of a technical report for the Upper Delaware Watershed Project.

The NJDEP Office of Environmental Planning in 1996 published a long-term water supply plan for the state. This report divides the state into Regional Water Resource Planning Areas (RWRPA) based on natural and demographic characteristics. Although these areas are not completely consistent with the NJDEP Watershed Management Area boundaries, the information is useful to evaluate. Table 2, below, provides data and projections from this plan relating to water supply and demand in the watershed. The data shows that the heaviest projected future demand in WMA-1 is in the Pequest and Paulinskill watersheds. The lightest demand should be in the Flat Brook.

Table 2. Available Water vs. Water Demand in NJDEP Regional Water Resource Planning Areas (RWRPA) totally or partially within the Upper Delaware Watershed (Million Gallons/Day)

RWPA Region Number	RWRPA Region Name	Net available water	1990 Demand	2010 Projected Demand	2040 Projected Demand
1	Middle Delaware Tributaries	20.1	13.6	14.2	15.2
2	Flat Brook	10.1	0.1	0.2	0.3
3	Wallkill/Pequest Paulinskill	88.5	22.3	28.3	35.7
7	Pohatcong	9.8	3.6	4.0	4.5
8	Musconetcong	26.8	5.8	6.7	8.1

Water Quality

Surface and ground water data for the watershed is derived from a network of monitoring sites. The monitoring sites are managed by the NJDEP Division of Watershed Management, Delaware River Basin Commission (DRBC), and the United States Geological Survey (USGS). Effluent, stream monitoring and water quality modeling is also done by water utilities, sewer authorities, health departments, volunteer citizen watershed groups, environmental commissions, or facilities which have regulatory permits from NJDEP.

Surface water

Monitoring efforts basically consist of two types: biological monitoring, which evaluates and ranks a site based on the aquatic life detected; and chemical monitoring, which relies on laboratory analysis of a stream sample. The data cited within this report is from eight sites of the NJDEP Ambient Surface Water Monitoring Network (ASMN), the 74 sites of the Ambient Biomonitoring Network (AMNET), Clean Lakes Program, and lake bathing beach monitoring program data.

ASMN

This statewide network was established in 1976 to determine status and trends of ambient surface waters in New Jersey. The network size went from 200 stations in its original configuration to a low of 78 stations in the mid 1990's. A complete revision of the network in 1997 resulted in a 115-station network. The original sampling frequency of five times per year was modified to four times per year in 1997. A wide range of conventional parameters such as metals, pesticides/volatile organic carbon (VOC's) and sediments are monitored in this program. Metals, pesticides/VOC's and sediments are monitored on a reduced sampling frequency.

From 1985 to 2000 there were 21 monitoring sites sampled in the Upper Delaware. There are currently eight sites undergoing chemical monitoring from the 1997 network in the project area; three are in the Musconetcong, two in the Paulins Kill, and one each in the Pequest, Pohatcong, and Flat Brook.

Appendix 5 summarizes important water quality parameters such as dissolved oxygen, total phosphorus, pH, fecal coliform and nitrogen for the 8 monitoring sites in the region. Despite the overall picture of good water quality, there are a number of monitored sites on rivers and in lakes that do not meet water quality standards for specific designated uses, based mostly on the detected levels of phosphorous or fecal coliform. This is discussed in the individual watershed group sections.

In October 2000 NJDEP initiated an Existing Water Quality (EWQ) network to provide supplemental data for the ambient surface water monitoring network. This monitoring program will continue for a two-year period with samples taken four times per year. This EWQ network will provide an additional 16 chemical monitoring sites to the existing network of 8 stations. With the addition of the 16 sites all major streams in the Upper Delaware will have chemical water quality data collected. All of the EWQ monitoring stations were selected at existing biological monitoring network locations (AMNET).

AMNET

Benthic macroinvertebrates (bottom dwelling organisms lacking a backbone) can be used as an indicator of water quality. In these benthic communities impairments may be manifested by the absence of pollution sensitive macroinvertebrate taxa such as Mayflies and Stoneflies, by the excessive dominance of certain taxa such as Midge or Aquatic Worm, or by shifts in the community structure relative to a reference condition. Since the early 1970s the New Jersey Department of Environmental Protection (NJDEP) has conducted biological monitoring of the state's water bodies. These biomonitoring studies, currently conducted by the Bureau of Freshwater and Biological Monitoring (BFBM), have included both long-term ambient monitoring and short-term intensive surveys. The information gathered contributes significantly to State water quality management and pollution mitigation efforts. The United States Environmental Protection Agency (USEPA) has recognized that a thorough program of monitoring aquatic biota can be a cost-efficient means of gauging the quality of water and watershed areas. Because flora and fauna often can integrate the effects of water quality or habitat changes over time, they become very effective pollution indicators. For lotic (running water) systems, analysis of benthic macroinvertebrate communities provides the principal means of achieving this. Macroinvertebrates are more stationary than fish, and less temporal than periphytic, that is, attached microscopic communities.

The 2000 NJDEP Surface Water Quality Inventory Report (305-b) shows that the predominant surface water quality of the watershed (72%) is good, meeting *biological* criteria for a "no impairment" designation. However, the biological data show there are a number (28%) of "moderate impairment" stations. Figures 11-15 depict the NJDEP AMNET monitoring sites and the most recent available biological monitoring results, along with stream classification, broken down by subwatershed group.

Under Section 303(d) of the Federal Clean Water Act, NJDEP is required to develop a Water Quality Limited Segments List that is a list of waterbodies whose water quality does not meet surface water quality standards. Surface Water Quality Standard (SWQS) criteria change based on the stream classification. For example in a trout production stream the SWQS criteria for temperature is <20 C whereas non-trout streams are allowed temperatures ranging from <27.8 C to <30 C depending on the fish species present. Stream classifications are described at the end of Appendix 5.

The Department is required to develop the Water Quality Limited Segments List (also known as the 303(d) List) biennially using all appropriate readily available data. In the Upper Delaware Watershed, there are a number of water bodies that are listed, including sections of the Flat Brook, Pequest, and Musconetcong. Table 3 lists the impaired waterbodies from the 1998 report, which is most currently available.

Table 3. Violations of Surface Water Quality Standards

Waterbody	Reach location	Water Quality Violation	Use Impairment
Flat Brook	Near Flatbrookville	Temperature, fecal coliform	Primary contact Aquatic life support
Paulins Kill	At Balesville	Temperature, fecal coliform, total phosphorous	Primary contact Aquatic life support
Paulins Kill	At Blairstown	Temperature, fecal coliform	Primary contact Aquatic life support
Swartswood Lake	Swartswood Lake	Phosphorous, depressed dissolved oxygen	Fishing, swimming, boating, fish consumption
Pequest River	At Pequest	Temperature, fecal coliform	Primary contact Aquatic life support
Pohatcong Creek	At New Village	Temperature, fecal coliform	Primary contact Aquatic life support
Merrill Creek Reservoir	Merrill Ck. Reservoir	Mercury in fish tissue	Fish consumption
Musconetcong River	Outlet of Lake Hopatcong	Temperature, fecal coliform	Primary contact Aquatic life support
Musconetcong River	Lockwood	Temperature, fecal coliform	Primary contact Aquatic life support
Musconetcong River	Beattystown	Temperature, fecal coliform	Primary contact Aquatic life support
Musconetcong River	Bloomsbury	Temperature, fecal coliform	Primary contact Aquatic life support
Musconetcong River	Riegelsville	Temperature, fecal coliform	Primary contact Aquatic life support
Lake Hopatcong	Lake Hopatcong	Phosphorous, sedimentation, depressed dissolved oxygen	Fishing, boating, fish consumption
Cranberry Lake	Cranberry Lake	Phosphorous, bacteria, depressed dissolved oxygen	Fishing, boating, primary contact recreation
Lake Musconetcong	Lake Musconetcong	Phosphorous, sedimentation, bacteria	Fishing, swimming, boating

Source: 1998 NJDEP 303-d Report, Appendix A

Clean Lakes

The Clean Lakes Program was designed by EPA to facilitate identification and remediation of impaired public lakes. Lake associations, municipalities or other entities identified public lakes with water quality issues. Studies were conducted to characterize water quality and as funding was available, remediation projects were conducted. Also during the 1980's and early 1990's, NJDEP collected water quality data on a number of public lakes. Data collection included a suite of indicators such as total phosphorus, Secchi disk transparency and chlorophyll *a* levels to determine the trophic state of lakes. Much of the impairments brought to the Department's attention through the Clean Lakes Program centered around nuisance algal growth impairing swimming and in some cases boating. The program monitors for parameters associated with lake trophic analysis: nutrients, dissolved oxygen (DO), pH, and algal identification and chlorophyll *a*. This monitoring showed that all of the lakes monitored are classified as "eutrophic", with impairments related mostly to algae and macrophytes. Five lakes including Cranberry, Marcia, Steenykill, Stony and Ghost were cited for exceeding standards for total phosphorous levels.

Lake Bathing Beach Monitoring Program

In addition, there are ongoing lake bathing beach water assessments done under the program of the New Jersey Department of Health and Senior Services (NJDHSS). The sanitary quality of water at the bathing beach is monitored by the entity responsible for operating the beach, including county and local health agencies and private entities. Some lakes included in this assessment are privately owned and operated, including camps, private schools or lake associations. NJDHSS regulations govern the collection of these data and beach closures based on elevated levels of fecal coliform (FC). Under these regulations, fecal coliform bacteria are monitored at least weekly during the bathing season (typically Memorial Day to Labor Day). If concentrations exceed 200 FC/ 100 ml sample, the beach is sampled again the following day and is closed and remains closed until levels meet the standard. The most recent (2000 305-b Report) results of this monitoring indicate the water quality at the 79 monitored lake bathing beaches is good, with 86% sampled having "full support" for contact (swimming) recreation. In fact, if Lake Hopatcong is excluded, 93% of the other sampled beaches had a "full support" designation. Lake Hopatcong showed the most water quality impairment with 68% of the beaches having full support.

Point source regulation

Point source discharges are defined as those potential pollutant flows that come from the end of a pipe or ditch. NJDEP 2001 data show there are 73 (surface and ground water) regulated point source discharge facilities in the Upper Delaware Watershed. These are regulated through the New Jersey Department of Environmental Protection New Jersey Pollutant Discharge Elimination System (NJPDDES) Permit program and are closely monitored. The Standards for Individual Subsurface Disposal Systems (N.J.A.C. 7:9A) requires all facilities with a design flow in excess of 2,000 gallons per day to apply for an individual NJPDDES-DGW permit. Many of these permitted sites release treated municipal or industrial wastewater to surface waters. The location of these currently permitted sites can be found in Figure 16.

Special Protection Waters

The Delaware River Basin Commission (DRBC) has adopted "Special Protection Waters" regulations designed to protect existing high water quality in the upper region of the Delaware River Basin. The regulations apply to a 107-mile stretch of the Delaware River from Hancock, N.Y. downstream to the Delaware Water Gap, including both the Upper and Middle Delaware Scenic and Recreational Rivers and an eight-mile reach between Millrift and Milford, Pa. Portions of tributaries located within the boundaries of the Delaware Water Gap National Recreation Area and the Upper Delaware Scenic River corridor also are included. Unlike most Scenic Rivers, the two Scenic River reaches of the Delaware, added to the National Wild and Scenic Rivers System by Congress in 1978, are located near heavily populated areas, being within several hours drive of about 20% of the U.S. population.

The commission's regulations, adopted in 1992, created a "Special Protection Waters" classification designed to prevent degradation in streams and rivers considered to have "exceptionally high scenic, recreational, ecological or water supply values..." The regulations discourage, but do not ban, direct discharges of wastewater to the designated waterways, stipulating that "no new or expanded wastewater discharges or expansions of existing discharges shall be permitted in Special Protection Waters until all

non-discharge/load reduction alternatives have been fully evaluated and rejected because of technical and/or financial infeasibility."

DRBC is also engaged in water quality monitoring in the basin, with efforts concentrating primarily on determining whether a tributary improves or decreases the Delaware River water quality. The DRBC monitoring network consists of 14 tributary monitoring sites and 16 Delaware River Sites in the Upper Delaware Watershed Management Area. The 14 monitoring sites are located on Shimers Brook, Flat Brook, Little Flatbrook, Van Campens Brook, Dunnfield Creek, Stony Brook, Paulins Kill, Delawanna Creek, Pequest River, Pophandusing Brook, Buckhorn Creek, Lopatcong Creek, Pohatcong Creek, and the Musconetcong River. At a minimum, samples at these sites are taken monthly during the growing season from May to September.

Ground water

Ground water quality is a critical concern in the watershed, with the majority of drinking water derived from private and community wells. Most of the wells are quite deep, which helps improve the probability of safe water. Water quality in the glacial aquifers in New Jersey is generally suitable for most uses. However, concentrations of some constituents and parameters may locally exceed secondary drinking water standards for iron, dissolved solids and hardness (Miller, 1974). Many of these aquifers have ground-water pollution problems because of their shallow depth.

Chemical analyses of samples collected from 97 wells in the major bedrock aquifers of the Highlands and Valley and Ridge Physiographic Provinces in New Jersey indicate that ground-water quality is very good for most purposes (Serfes, NJGS in press). However, locally some wells may require treatment for undesirable characteristics and constituents. The most common quality problems are associated with the state recommended secondary drinking water standards. The table below shows the percentage of samples exceeding the secondary drinking water standard in the (1) Middle Proterozoic metamorphosed crystalline rocks, (2) Cambro-Ordovician sedimentary rocks of the Kittatinny Supergroup and (3) Martinsburg Formations.

Table 4: Percentage of samples that exceed the secondary drinking water standard
(Serfes, 2001)

Formation Name	Hardness % less than 50 mg/L	Hardness % greater than 250 mg/L	Iron % greater than .300 mg/L	Manganese % greater than .05 mg/L	pH % less than pH 6.5	pH % greater than pH 8.5	Sodium % greater than 50 mg/L
Middle Proterozoic	13	4.5	6.7	16.3	30.2	0	0
Cambro-Ordovician	0	30.8	3.8	7.7	0	7.7	0
Martinsburg	11.5	11.5	0	23.1	0	15.4	15.4

The Major Subwatersheds of the Upper Delaware Watershed

The Upper Delaware River Watershed basin is made up of a number of important sub-basins. Sequentially from north to south, they are:

- 1) Shimers Brook/Clove Brook
- 2) Flat Brook
- 3) Trout Brook
- 4) Paulinskill River
- 5) Van Campens/Dunnfield Creek
- 6) Bear Creek
- 7) Beaver Brook
- 8) Pequest River
- 9) Pohatcong Creek
- 10) Lopatcong Creek
- 11) Musconetcong River
- 12) Smaller, direct drainages to the Delaware including Stony Brook, Delawanna Creek, Pophandusing Brook, and Buckhorn Creek

Watershed Groupings

To facilitate regional discussion of the subwatershed area's issues, the subwatersheds have been grouped into 5 larger units in this watershed characterization effort. For reports developed as part of this effort, smaller subwatersheds that have similar natural resource and human-based elements are considered together to provide a foundation for more cohesive watershed planning and assessment within each region. Consequently, the subwatershed breakdown often used will be:

- 1) Shimers-Clove-Flat Brook-Van Campens-Dunnfield (Figure 11)
- 2) Paulinskill-Trout-Delawanna-Stony (Figure 12)
- 3) Pequest-Beaver-Bear (Figure 13)
- 4) Pohatcong-Lopatcong-Pophandusing-Buckhorn (Figure 14)
- 5) Musconetcong (Figure 15)

Figures depicting the named streams and surface water quality for each of the five watershed groups are found in Figures 11-15. The following general descriptions cover these major subwatershed groupings within the Upper Delaware Region. The major streams in these networks have readily available water quality data available for analysis. Additional descriptions will be added for the smaller tributaries as data becomes available during the characterization and assessment process.

Flat Brook Watershed Group

Including Shimers Brook, Clove Brook, Van Campen's Brook, Dunnfield Creek, and Stony Brook

The Flat Brook Group (Figure 7) and tributaries drain an area of 130 square miles in Sussex and Warren Counties. The major water features are the listed streams and Little Flat Brook, Parker Brook, Tilghman Brook, and several small lakes and ponds. The watershed land cover is primarily comprised of forested (78.5%), mountainous terrain that falls within several federal and state protected areas. These include

the Delaware Water Gap National Recreation Area, High Point State Park, Stokes State Forest, Hainesville State Wildlife Management Area, Flatbrook State Wildlife Management Area and Walpack State Wildlife Management Area.

Up until the establishment of the Delaware Water Gap National Recreation Area, a significant amount of cropland could be found within the Flat Brook and Little Flat Brook valleys. Most of the formerly agricultural land is now in various stages of natural succession. This land use data is shown in Table 4a along with a square mile graphic comparison. There are 7 NJDEP New Jersey Pollution Discharge Elimination System (NJPDES)-permitted point source wastewater discharges. Following is a break down of land use in the group. In the period 1986-1995/97, there were not critical shifts in land use, with urban land only increasing by 0.5%. Descriptions of the categories can be found in the Land Use section on page 21. The land use/land cover map for the subwatershed can be found in Figure 17.

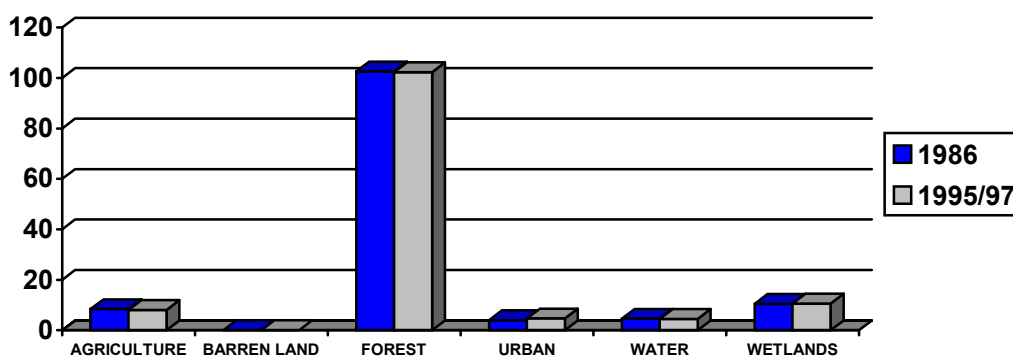
Table 5a. NJDEP Land Use/Land Cover for the Flat Brook Watershed Group

Total Area – 83,384 Acres

1986				
Land Use/Land Cover	Total Acres	Square Miles	Percent of Watershed	Estimated Impervious Surface (Acres)
AGRICULTURE	5376	8.4	6.5	N/A
BARREN LAND	64	0.1	0.1	N/A
FOREST	65691	102.6	78.8	N/A
URBAN	2563	4.0	3.1	N/A
WATER	2940	4.6	3.5	N/A
WETLANDS	6746	10.54	8.1	N/A

1995/97					
Land Use/Land Cover	Total Acres	Square Miles	Percent of Watershed	Percent change from 86 to 95/97	Estimated Impervious Surface (Acres)
AGRICULTURE	5194	8.1	6.2	- 0.3	21.2
BARREN LAND	79	0.1	0.1	0	7.2
FOREST	65453	102.3	78.5	- 0.3	62.7
URBAN	2975	4.7	3.6	+ 0.5	413.7
WATER	2900	4.5	3.5	0	0.0
WETLANDS	6778	10.6	8.1	0	0

Land Use/Land Cover in Square Miles



Water Quality

According to the NJDEP 2000 Water Quality Inventory Report, the Flat Brook watershed contains among the highest quality surface water in the state. The Flat Brook is monitored chemically (ASMN) at Flatbrookville (located a short distance above the Delaware River confluence). There, fecal coliform monitoring indicates full support for primary contact recreation, and has acceptable nutrient levels. There are 11 biological (AMNET) monitoring sites in this watershed group. Data from 1998 shows all 9 in the Flat Brook drainage are non-impaired. Although water quality is considered to be good, some reaches of the Flat Brook are experiencing significant streambank erosion problems. In addition, water quality problems are clearly evident in the Clove Brook watershed, with both biological monitoring sites having “moderately impaired” results.

Paulins Kill Watershed Group

Including Trout Brook, Delawanna Brook, and Stony Brook

The Paulins Kill Watershed Group (Figure 9) and tributaries drain an area of 197 square miles. The 39-mile long Paulins Kill begins near Ross Corner and the intersection of State Highway 15 and US Highway 206, and flows to the Delaware River at Columbia. Major tributaries include Yards Creek, Blair Creek, Trout Brook, Moses Brook and Culver Brook. Numerous lake and ponds are found throughout the watershed, the largest of these being Culvers Lake, Swartswood Lake, Lake Owassa, Paulins Kill Lake, and Yards Creek Reservoir.

Major population centers include Newton and Blairstown. There are 34 NJDEP New Jersey Pollution Discharge Elimination System (NJPDES)-permitted point source sites in this region. Land cover within the region is primarily forested (52.5%) with significant agricultural (17%) and scattered suburban development (13.8%) located mostly proximate to the Rt. 94 corridor. Table 4b shows land use/cover data along with a square mile graph. The biggest change in the period 1986 - 1995/97 showed a 2.4% increase in urban land, coming primarily from converted farmland. The land use/land cover map for the subwatershed can be found in Figure 18.

Table 5b. NJDEP Land Use/Land Cover for the Paulinskill Watershed Group

Total Area – 125,846 Acres

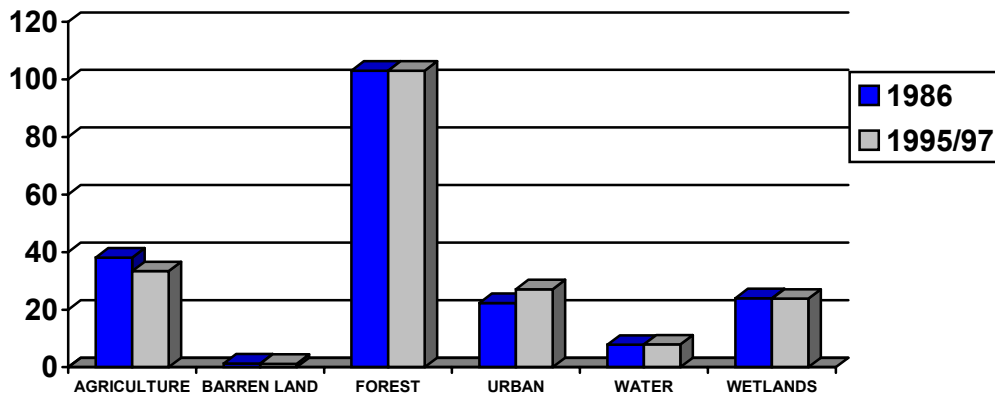
1986				
Land Use/Land Cover	Total Acres	Square Miles	Percent of Watershed	Estimated Impervious Surface (Acres)
AGRICULTURE	24407	38.1	19.4	N/A
BARREN LAND	842	1.3	0.7	N/A
FOREST	65951	103.1	52.4	N/A
URBAN	14304	22.4	11.4	N/A
WATER	4973	7.8	3.9	N/A
WETLANDS	15360	24.0	12.2	N/A

Table 5b. NJDEP Land Use/Land Cover for the Paulinskill Watershed Group (continued)

1995/97

Land Use/Land Cover	Total Acres	Square Miles	Percent of Watershed	Percent change from 86 to 95/97	Estimated Impervious Surface (Acres)
AGRICULTURE	21382	33.4	17	- 2.4	142
BARREN LAND	779	1.2	0.6	- 0.1	32
FOREST	66053	103.2	52.5	+ 0.1	117
URBAN	17345	27.1	13.8	+ 2.4	3292
WATER	5038	7.9	4.0	+ 0.1	0.0
WETLANDS	15241	23.8	12.1	- 0.1	1

Land Use/Land Cover in Square Miles



Water Quality

According to the NJDEP 2000 Water Quality Inventory Report water quality in the Paulins Kill ranges from fair to good. There are two chemical (ASMN) monitoring stations, located at Balesville and Blairstown. Phosphorous levels are elevated to non-attainment of Surface Water Quality Standards (SWQS) at

Balesville. Fecal coliform levels were elevated at both stations: Balesville showed non-attainment, and Blairstown showed partial attainment. There are 23 biological (AMNET) monitoring stations in the Paulins Kill watershed group. Data from 1998 indicates that 14 stations had non-impaired conditions. The remainder showed moderately impaired conditions. The moderately impaired sites are distributed throughout the watershed, but often are found immediately downstream of impoundments. This may indicate that development and surface warming may have an effect on the monitoring results. In addition, the Paulins Kill watershed may be experiencing localized effects of runoff associated with suburban development and agriculture.

Pequest River Watershed Group

Including Bear Creek and Beaver Brook

The Pequest River Watershed Group (Figure 10) encompasses 157 square miles in Sussex and Warren Counties. The Pequest River itself begins just south of Newton and flows 32 miles to the Delaware River at Belvidere. Major tributaries include Beaver Brook, Trout Brook, Furnace Brook and Bear Creek. There are many small lakes and ponds within the watershed with the majority located in the Pequest headwaters. The larger impoundments are Mountain Lake, Allamuchy Pond, and Wawayanda Lake.

Population centers within the watershed include Belvidere, Andover, Hope and Oxford. There are 16 NJDEP New Jersey Pollution Discharge Elimination System (NJPDES)-permitted point source sites in this region. Land cover within the region is primarily forested (48.1%) and agricultural (21.2%). A significant portion has been developed (12.2%). The most heavily forested areas are within Jenny Jump State Forest, a portion of Allamuchy State Park, Pequest Wildlife Management Area, and Whittingham Wildlife Management Area. Notably, Bear Swamp, an extensive area of wetlands, is located in the upper Pequest watershed. In the period 1986 - 1995/97, urban land increased by 2.3%, primarily taking from agricultural land. Table 4c shows this data along with a square mile graph comparison. The land use/land cover map for the subwatershed can be found in Figure 19.

Table 5c. NJDEP Land Use/Land Cover for the Pequest Watershed Group

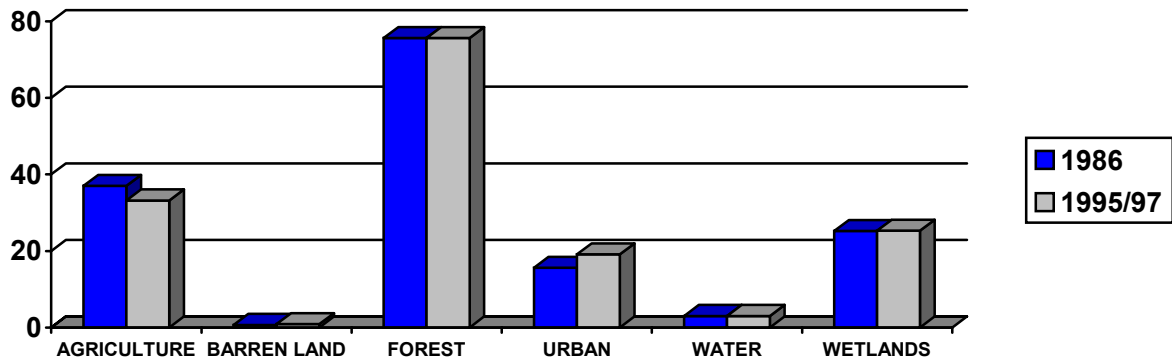
Total Area – 100,542 Acres

1986				
Land Use/Land Cover	Total Acres	Square Miles	Percent of Watershed	Estimated Impervious Surface (Acres)
AGRICULTURE	23701	37.0	23.6	N/A
BARREN LAND	416	0.7	0.4	N/A
FOREST	48362	75.6	48.1	N/A
URBAN	9982	15.6	9.9	N/A
WATER	1946	3.0	1.9	N/A
WETLANDS	16135	25.2	16.1	N/A

1995/97

Land Use/Land Cover	Total Acres	Square Miles	Percent of Watershed	Percent change from 86 to 95/97	Estimated Impervious Surface (Acres)
AGRICULTURE	21274	33.2	21.2	- 2.4%	117.3
BARREN LAND	581	0.9	0.6	+ 0.4%	14.5
FOREST	48401	75.6	48.1	0%	102.6
URBAN	12244	19.1	12.2	+ 2.3%	2316.3
WATER	1935	3.0	1.9	0%	0.0
WETLANDS	16108	25.2	16.0	- 0.1%	3.1

Land Use/Land Cover in Square Miles



Water Quality

According to the NJDEP 2000 Water Quality Inventory Report overall water quality at the only chemical (ASMN) monitoring station at Pequest shows non-attainment levels of fecal coliform and partial attainment for total phosphorous. There are 15 biological (AMNET) monitoring stations. 1998 data shows that 12 indicate that the watershed is nonimpaired, with the remainder moderately impaired. The Pequest may be impacted by agriculture and the suburban development occurring throughout the watershed. It should also be noted that natural aquatic habitat was greatly altered by the 1950's channelization of the Pequest between Allamuchy and the Townsbury area.

Pohatcong-Lopatcong Creek Watershed Group

Including Buckhorn Creek and Pophandusing Brook

The Pohatcong Creek Group (Figure 11) begins with the headwaters of the Pohatcong in Independence Township and flows 28 miles to the Delaware River below Phillipsburg. The 106 square mile Pohatcong Group watershed is located entirely within Warren County. Major tributaries along with the listed streams include Brass Castle Creek, Shabbecong Creek, and Merrill Creek. Completed in 1989, the 650 acre Merrill Creek Reservoir is the largest impoundment in the Pohatcong watershed. Merrill Creek reservoir was constructed to supplement stream flows when power companies utilize water in the downstream reaches of the Delaware River.

Land cover in the region is predominantly cropland (36.6%) with forested (35.7%) areas concentrated in the upper watershed as well as along the prominent ridges that parallel the valley. Urban developed land is significant, however (18.5%). Population centers include Alpha Borough, Stewartville and Washington Borough. There are 19 NJDEP New Jersey Pollution Discharge Elimination System (NJPDES)-permitted point source sites in this region. Land use changes for the period 1986-1995/97 were significant in this watershed. Rapid suburban development has recently occurred in Greenwich and Pohatcong Townships in the vicinity of Rt. 22 and 519. Overall, urban land increased by 3.6%, with the majority converted from agricultural land. This data can be found in Table 4d and the associated square mile graph. The land use/land cover map for the subwatershed can be found in Figure 20.

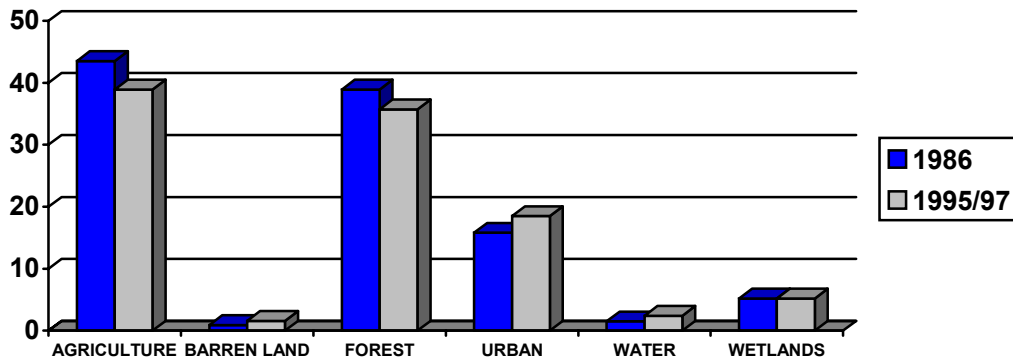
Table 5d. NJDEP Land Use/Land Cover for the Pohatcong-Lopatcong Watershed Group

Total Area – 67,925 Acres

1986				
Land Use/Land Cover	Total Acres	Square Miles	Percent of Watershed	Estimated Impervious Surface (Acres)
AGRICULTURE	27832	43.5	40.9	N/A
BARREN LAND	564	0.9	0.8	N/A
FOREST	24873	38.9	36.6	N/A
URBAN	10118	15.8	14.9	N/A
WATER	976	1.5	1.4	N/A
WETLANDS	3562	5.6	5.2	N/A

1995/97					
Land Use/Land Cover	Total Acres	Square Miles	Percent of Watershed	Percent change from 86 to 95/97	Estimated Impervious Surface (Acres)
AGRICULTURE	24866	38.9	36.6	- 4.3%	144.9
BARREN LAND	1092	1.7	1.6	+ 0.8%	19.1
FOREST	24270	37.9	35.7	- 0.9%	47.3
URBAN	12565	19.6	18.5	+ 3.6%	3337.2
WATER	1632	2.5	2.4	+ 1.0%	0.0
WETLANDS	3499	5.5	5.2	0%	0.0

Land Use/Land Cover in Square Miles



Water Quality

There is one chemical (ASMN) sampling site on the Pohatcong at New Village. According to the NJDEP 2000 Water Quality Inventory Report, the Pohatcong Creek is non-supporting for the primary contact designated use because of high fecal coliform levels. Nutrient enrichment (nitrate and phosphorous) also is currently being observed. There are 12 biological (AMNET) sites in this watershed group. Data from 1998 shows that 8 are non-impaired. The remainder are moderately impaired and distributed throughout the watershed. Housing construction and suburban surface runoff are suspected to be contributing to the local declines in water quality. The Pohatcong Creek is also heavily impacted by agricultural runoff and sedimentation.

Musconetcong Watershed

The Musconetcong Watershed (Figure 12) drains a 156 square mile watershed area. For its entire length the Musconetcong River forms the boundary between Morris and Sussex, Hunterdon and Warren, and Morris and Warren Counties. The Musconetcong River begins in the boroughs of Netcong and Stanhope, and flows 42 miles to the Delaware River at Riegelsville. Major tributaries include Lubbers Run, Mine Brook, Hances Brook and several smaller streams. The major impoundments are located in the upper watershed and include Lake Hopatcong (New Jersey's largest lake), Lake Musconetcong, Cranberry Lake, Lake Lackawanna, Cranberry Reservoir, and several other impoundments.

The Musconetcong watershed contains two distinct regions. The upper Musconetcong watershed is primarily forested with significant development occurring along the shores of many of the lakes. The lower Musconetcong watershed is primarily agricultural land with forested areas concentrated along the ridges. Population centers in the watershed include Hackettstown, Mt. Olive, Stanhope, Netcong, Hopatcong and Bloomsbury. The single largest center of employment in the Upper Delaware, the International Trade Zone in Mt. Olive Township, is located in the watershed. Currently, there are 38 NJDEP New Jersey Pollution Discharge Elimination System (NJPDES)-permitted point source sites in the watershed. Combined, the two regions consist primarily of forest (49.5%), urban land (19.5%), and cropland (17.8%). The urban land percentage is the highest of the 5 subwatershed groups in the Upper Delaware. In the period 1986-1995/97 urban land use increased 2.8%, converting agricultural and forested lands. Land use data is in Table 4e and the associated square mile graph. The land use/land cover map for the subwatershed can be found in Figure 21.

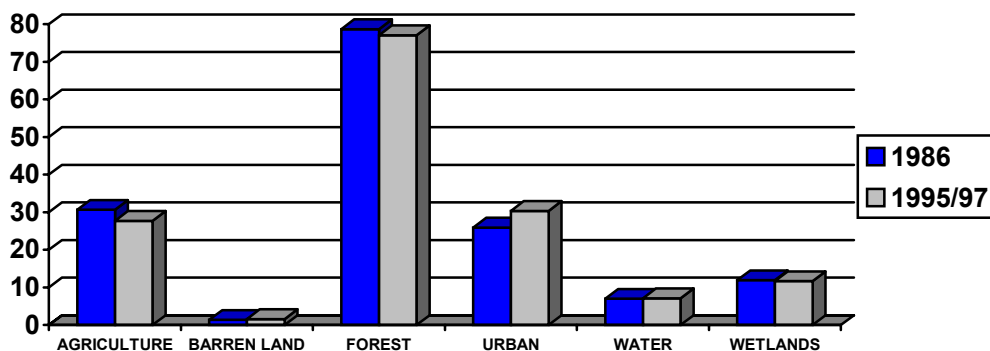
Table 5e. NJDEP Land Use/Land Cover for the Musconetcong Watershed

Total Area – 99,550 Acres

1986				
Land Use/Land Cover	Total Acres	Square Miles	Percent of Watershed	Estimated Impervious Surface (Acres)
AGRICULTURE	19617	30.7	19.7	N/A
BARREN LAND	884	1.4	0.9	N/A
FOREST	50341	78.7	50.6	N/A
URBAN	16586	25.9	16.7	N/A
WATER	4482	7.0	4.5	N/A
WETLANDS	7632	11.9	7.7	N/A

1995/97					
Land Use/Land Cover	Total Acres	Square Miles	Percent of Watershed	Percent change from 86 to 95/97	Estimated Impervious Surface (Acres)
AGRICULTURE	17741	27.7	17.8	-1.9%	102.9
BARREN LAND	1026	1.6	1.0	+0.1%	13.2
FOREST	49321	77.1	49.5	-1.1%	64.2
URBAN	19422	30.3	19.5	+2.8%	5053.9
WATER	4550	7.1	4.6	+0.1%	0.0
WETLANDS	7482	11.7	7.5	-0.2%	2.3

Land Use/Land Cover in Square Miles



Water Quality

According to the NJDEP 2000 Water Quality Inventory Report, all three chemical (ASMN) monitoring stations at Beattystown, Bloomsbury, and Riegelsville show non-attainment of SWQS for fecal coliform levels. Fecal coliform, in particular, is a problem at several beaches in Lake Hopatcong. The report also indicates that nitrate is somewhat elevated and increasing. There are 13 biological (AMNET) stations in

the Musconetcong watershed. 1998 data shows that 10 are non-impaired; the other 3 are in the upper half of the watershed and are moderately impaired. Urban runoff and construction activities resulting in nutrients and bacteria from lawns and septic systems, sediment, and road salt, oil & grease from highway runoff may be contributing to the decline in stream water quality. Resident Canada geese may be another source of fecal bacteria. Agricultural runoff is also impacting the Musconetcong, most notably in the form of excess sediment and nutrients.

Lakes of the Upper Delaware Watershed

In addition to the streams and rivers, there are a number of significant lakes in the region. The majority are located in Sussex County. Many are the natural product of glaciation. The larger lakes are heavily used for recreation. The lands surrounding many of the larger lakes have been developed with seasonal and year round dwellings. Significant water quality risks exist in some areas from septic systems and runoff from lawns and impervious surfaces. Power boating-related pollutants such as fuels, oils, greases, and solvents can be a problem in high motor boat recreational use waters.

NJDEP monitoring data for these lakes show that all are classified as eutrophic. This means that both natural aging processes and the activities of man are combining to add sediment and nutrients to the lakes. In summer, this often means that the shallower portions of these lakes can have reduced dissolved oxygen and accelerated aquatic weed and algae growth. Fish kills due to these dissolved oxygen fluctuations may occur. In general, eutrophic conditions lower the recreational and aesthetic condition of a lake. Despite this, most of the lakes in WMA-1 are classified by NJDEP as “fully supporting but threatened.” The 2000 305-b data indicates that 86% of the bathing beach areas in the lakes of the watershed fully support swimming. 2000 NJDEP Clean Lakes Program data for several of the lakes can be found in Appendix 5.

Many of the larger lakes have formed associations. These associations seek to maintain or improve lake water quality through education, maintenance, and management measures. The largest lakes of the Upper Delaware region are:

Lake Hopatcong (largest lake in the state)	2658 acres
Culvers Lake	692 acres
Merrill Creek Reservoir	650 acres
Swartswood Lake	505 acres
Lake Musconetcong	329 acres
Lake Owassa	265 acres
Little Swartswood Lake	200 acres
Cranberry Lake	179 acres
Mountain Lake	122 acres
Lake Aeroflex	117 acres
Lake Lackawanna	110 acres
Fairview Lake	110 acres

Socioeconomic Characteristics of the Upper Delaware Watershed

Transportation Network

The “oldest commercial road in America” is the Old Mine Road in the Delaware Water Gap National Recreation Area, created 350 years ago by Dutch settlers for ore transportation between the Water Gap area and Kingston, NY. Soon, more dirt roads crossed the region to connect the settlements such as Washington, Hackettstown, Phillipsburg, Belvidere, Newton, and others that were beginning to develop. The Morris Canal came next, crossing the region between Phillipsburg and Hopatcong, providing an east-west water route. Then came the railroads through the region, moving people, coal, lumber, produce, and other goods through the area, connecting points west to the urban centers to the east.

Today, the Upper Delaware region is served by a number of Federal, State, and local transportation corridors, which have increased suburban sprawl and development pressure on the land. Figure 22 depicts the major roadways.

Interstate highways:

- Route 80, which bisects the region east to west from Columbia to Netcong. Route 80 in its entirety bisects the United States from San Francisco to New York City.
- Route 78, which crosses the region in the southern tip in the Bloomsbury area, connects New York City with Interstates 81 and 76 (Pennsylvania Turnpike) in the Harrisburg, PA area.

Both of these highways, completed through the region within the past 30 years, have greatly accelerated commercial and residential development of WMA-1 by increasing access to New York City and eastern New Jersey. Route 78 in particular is a major commerce route heavily used by interstate trucking for movement of goods through the region.

Federal, State and local roads:

A number of significant state and local roads cross through the Upper Delaware. Major north-south roads are: NJ State Highways 31, 94, 23 and 15 and U.S Route 206. Major east-west roads are US Route 46 and State Highway 57.

Rail lines:

Historically, several railways providing movement of freight and commuters have served the WMA-1 region. These railroads shaped much of the growth and economy of the region. In the early years, the Erie-Lackawanna Railroad was the primary rail line serving the region. This line connected the New York Metro area to the coal mining regions of northeastern Pennsylvania, and contributed to the industry and settlement of the area. Today, a NJ Transit passenger rail line services Hackettstown, and the NJ Department of Transportation has developed plans to extend existing New York metropolitan rail service to Phillipsburg, Sparta Junction, and Stroudsburg, PA. by the year 2020. Freight movement continues to traverse the region on the Conrail and New York, Susquehanna & Western railroad lines. A great many rail systems and rights-of way exist from the past, and could be redeveloped into active routes as demand dictates. Figures 8-12 depict the major transportation routes through the region.

Watershed Land Use

Figures 23 and 24 show a comparison of land use changes between 1986 and 1995/97. Figure 23 shows those areas that changed with their 1986 land use. Figure 24 depicts those same areas and their 1995/97 land use. These figures show the pattern of growth that has occurred in the region, and is accelerating at present time. Historically, the land use has been dictated by the topography and

transportation network of the region with the ridgetops and upper hillsides in forest, and the valleys in agricultural and developed land uses.

The New Jersey Department of Environmental Protection's 1986 and 1995/97 land use/land cover (LU/LC) coverages show that in that period, over 10,475 acres of agricultural lands and over 300 acres of wetlands have been lost in the Upper Delaware Watershed. The state's coverage also shows that there is an increase in urban areas of over 10,997 acres. This is a significant change to the region, and likely will negatively impact water quality and quantity trends. The loss in farmland over the past 10 years has been due to the ever-increasing development pressure for housing and retail space, the relative ease of developing farmland, reduction in the profitability of farming, and the declining trend of family farms being passed along to the next farming generation.

Table 6. Land Use/Land Cover (LU/LC) for Entire WMA-1.

1986 LU/LC		1995/97 LU/LC	
AGRICULTURE	21%	AGRICULTURE	19%
BARREN LAND	1%	BARREN LAND	1%
FOREST	53%	FOREST	53%
URBAN	11%	URBAN	14%
WATER	3%	WATER	3%
WETLANDS	10%	WETLANDS	10%

This digital land use data was generated from 1985 and 1995-97 NJDEP aerial photogrammetry. For clarification purposes, definitions for each of the land use and land cover categories as defined by the NJDEP Geographic Information System Digital Data are provided below:

- Agricultural land includes all lands used primarily for the production of food and fiber and some of the structures associated with this production. Categories of agricultural land include: cropland and pastureland; orchards; vineyards; nurseries and horticultural areas; and confined feeding operations.
- Barren lands are characterized by thin soil, sand or rocks and a lack of vegetative cover in a non-urban setting. Barren land such as beaches and rock faces are found in nature, but also result as a product of human activities. Extraction mining operations, landfills and other disposal sites compose the majority of human-altered barren lands.
- Forest land contains any lands covered by woody vegetation other than wetlands. These areas are capable of producing timber and other wood products, and of supporting many kinds of outdoor recreation. Land use categories under forestland are deciduous; coniferous; mixed deciduous-coniferous; and brushland.
- Urban land is characterized by intensive land use where the landscape has been altered by human activities. Although structures are usually present, this category is not restricted to traditional urban uses. Urban land includes the following categories: residential; commercial and service; industrial; transportation; communication and utilities; industrial and commercial complexes; mixed urban or built-up; other urban or built-up; and recreational areas.
- Water areas are all areas that are periodically covered by water including streams and canals, natural lakes, artificial lakes, bays and estuaries. Not included in this category are water treatment and sewage treatment facilities.
- Wetlands are those areas that are inundated or saturated by surface or ground waters at a frequency and duration sufficient to support vegetation adapted for life in saturated soil conditions. Included in this category are naturally vegetated swamps, marshes, bogs and savannas which are normally associated with topographically low elevations but may be located at any elevation where a perched water table is present. Wetlands that have been modified for recreation, agriculture or industry are not included in this definition.

* Land use data broken down by the five major subwatershed units can be found in each section, pp. 17-24.

The data shows that agriculture and woodland are still the predominant land uses. Trends in agriculture show a general decline in agricultural acreage and a precipitous decline in the number of dairy farms in the watershed.

The New Jersey State Plan

Initially presented in 1992 and revised in 2000, the State Development and Redevelopment Plan was approved in 2001. Generally, this voluntary plan is intended to guide local municipalities and land use decision makers toward “smart growth”, directing development toward “centers” and redevelop existing areas while discouraging sprawl development in open areas.

The State Development and Redevelopment Plan designates lands for five different categories in WMA 1 based on the natural and sociological resources in place. These categories are:

Planning Area (PA)

PA1	Metropolitan Planning Area
PA 2	Suburban Planning Area
PA 3	Fringe Planning Area
PA 4	Rural Planning Area
PA 5	Environmentally Sensitive Planning Area

The portion of the State Plan covering WMA 1 can be found in Figure 25. Table 7 shows the percentages of these Planning Areas in the Upper Delaware:

Table 7. Extent of State Plan Areas in WMA-1

Planning Area		ACRES	Percent of Basin
1	METROPOLITAN	4201	0.9%
2	SUBURBAN	4423	0.9%
3	FRINGE	2153	0.5%
4	RURAL	82579	17.3%
4B	RURAL ENV. SENSITIVE	119808	25.1%
5	ENVIRONMENTALLY SENSITIVE	162701	34.1%
6	PARK 1ST PLAN	3192	0.7%
7	FEDERAL PARK	31203	6.5%
8	STATE PARK	61768	12.9%
11	WATER	2396	0.5%

Note that Planning Area categories 4 (Rural), 4B (Rural Environmentally Sensitive), and 5 (Environmentally Sensitive) make up 76% of the watershed.

In the Rural Planning Area (4), the State Plan’s intention is to:

- maintain the Environs as large contiguous areas of farmland and other lands;
- revitalize cities and towns;

- accommodate growth in Centers;
- promote a viable agricultural industry;
- protect the character of existing stable communities; and
- confine programmed sewers and public water services to Centers.

Some lands in the Rural Planning Area (4) have one or more environmentally sensitive feature qualifying for delineation as Rural/Environmentally Sensitive (4B). This sub-area contains valuable ecosystems or wildlife habitats. Rural/Environmentally Sensitive Planning Areas are supportive of agriculture and other related economic development efforts that ensure diversity within New Jersey.

In the Environmentally Sensitive Planning Area (5), the State Plan's intention is to:

- protect environmental resources through the protection of large contiguous areas of land;
- accommodate growth in Centers;
- protect the character of existing stable communities;
- confine programmed sewers and public water services to Centers; and
- revitalize cities and towns.

The plan has not generally been successful in curbing sprawl due to its non-regulatory nature. Currently, counties within the Upper Delaware Watershed are reviewing the revised Plan. There is disagreement at the local level with the Plan, and communication with the Office of State Planning is underway to resolve the differences between the state vision and local objectives.

Open Space

As development pressures increase in this region so to does the amount of non-point source pollution from storm water run-off flowing over impervious surfaces and managed turf areas. Although good planning can reduce the amount of degradation to the water resources, protecting environmentally sensitive lands is the only long-term method for preserving them and the quality of water.

Over the past 30 years, Federal, state, county, municipal and non-profit groups have worked to preserve not only farmland and environmentally sensitive areas, but also historic, cultural and recreational lands. As census reports predict increased population and development, more preservation initiatives have begun. However, keeping up with the ever-changing landscape and preserving priority areas has become a difficult challenge for many of these preservation groups. Often, lack of planning, funding, and expertise in negotiating and closing land protection deals compound the challenge. Some problems have also arisen in how the lands were managed once they were preserved.

The Upper Delaware region is endowed with a great deal of protected open space controlled and managed by all levels of government. A mapping effort is underway in the Upper Delaware to compile a complete inventory of open space and preserved farmland. The total protected open space in WMA-1as of the 11/6/01 inventory is 125,608 acres. Of this, the total Preserved Farmland in WMA-1 is 8,518 acres. The dominant open space parcel is the nearly 32,000-acre Delaware Water Gap National Recreation Area, administered by the National Park Service, U.S. Department of the Interior.

The State of New Jersey controls most of the other notable tracts:

Stokes State Forest	15,735 acres
High Point State Park	14,193 acres
Allamuchy Mountain State Park	6,965 acres
Worthington State Forest	5,878 acres
Jenny Jump State Forest	2427 acres
Kittatinny Valley State Park	1692 acres
Swartwood State Park	1,357 acres
Stephens State Park	727 acres

The NJDEP Division of Fish & Game manages a number of significant tracts within the watershed as Wildlife Management Areas, used extensively for hunting and fishing. Some significant areas are:

Bear Swamp Wildlife Management Area	2054 acres
Columbia Lake Wildlife Management Area	654 acres
Flatbrook State Wildlife Management Area	2081 acres
Hainesville State Wildlife Management Area	282 acres
Pequest Wildlife Management Area	3941 acres
Walpack State Wildlife Management Area	388 acres
Whittingham Wildlife Management Area	1929 acres
Weldon Brook Wildlife Management Area	829 acres

Notable county tracts are:

Musconetcong Gorge Preserve	Hunterdon County	405 acres
Point Mountain Preserve	Hunterdon County	697 acres
Mahlon Dickerson Reservation	Morris County	3,200 acres (portion outside watershed)

Notable private open space tracts include:

- Merrill Creek Reservoir lands
- Fairview Lake YMCA Camp
- Yards Creek Boy Scout Reservation
- Over 8,500 acres of state-preserved farmlands

By November of 2000, 25 of the 54 townships and all 4 counties in WMA1 had approved and/or implemented dedicated taxes for open space and farmland preservation. Table 8 depicts the approximate number of preserved acres of open space and farmland in WMA1's drainage basins.

Table 8. Open Space of the Upper Delaware Watershed

Drainage Basin	Total Area of Basin (Acres)	Preserved Open Space (Acres)	Percentage of Basin as Open Space	Percentage of Preserved Farmland (Acres)	Percentage of Basin as Preserved Farmland
Flat Brook Watershed Group	83384	63966	77%	211	0%
Paulins Kill Watershed Group	125845	17047	14%	2076	2%
Pequest Watershed Group	100542	15952	16%	2527	3%
Pohatcong-Lopatcong Watershed Group	67925	6792	10%	1022	2%
Musconetcong Watershed	99555	21851	22%	2682	3%
Total	477251	125608	26%	8518	2%

Figure 26 illustrates those preserved lands in the region, according to the latest available data.

Recreation

The Upper Delaware Region in New Jersey offers exceptional opportunities for outdoor recreation both in terms of the quantity and quality of public recreational lands and facilities. There are approximately 106,000 acres of federal, state, county and municipal owned public lands comprising 22% of the Upper Delaware Watershed area.

Recreational amenities include the nationally famous Appalachian Trail and Delaware Water Gap National Recreation Area. There are 18 state-managed parks, forests and wildlife management areas within the region, as well as several municipal parks and preserves.

The mountainous terrain, mature forests, and numerous lakes and high quality trout streams of the Upper Delaware Region attract millions of recreational users to the region each year, making resource-based tourism and recreation a major part of the local economy. According to the report entitled *1999 Travel and Tourism in New Jersey* commissioned by the New Jersey Commerce and Economic Growth Commission, recreational-based tourism generated \$38,000,000 within the counties of Warren and Sussex during 1999. The report identified 4 destinations located within the Upper Delaware Region on a state-wide list of *“Places Visited – Overnight Trips”* including Delaware Water Gap National Recreation Area, High Point State Park, Lake Hopatcong and Waterloo Village. These 4 destinations alone accounted for just over one million overnight trips.

The primary resource-based recreational activities, defined as those activities that are dependent on natural habitats, include camping, birding, boating, fishing, hiking, hunting, and swimming. During the watershed characterization & assessment process, new data on water-based recreational activities will be collected and evaluated. This data will be the basis for another technical report within this project.

Water-based recreational activities are directly tied to watershed management issues through the Federal Clean Water Act and State Surface Water Quality Standards. National water quality goals state that “waters should be fishable, swimmable and potable.” State Surface Water Quality Standards establish criteria designated to protect both primary contact recreational uses (swimming, wading) and secondary contact uses (fishing and boating). Swimmable use support is based on fecal coliform concentrations. Fecal coliform bacteria levels in water provide an indication of pollution from fecal material, which may contain organisms that are harmful to human health.

Recreational use assessment for swimming is classified as follows:

Full Support: The fecal coliform (FC) geometric average was less than 200 MPN/100ml and less than 10 percent of individual samples exceeded 400 MPN/100 ml.

Full Support but Threatened: FC levels meet full support but statistically significant adverse trends indicate full support will not be attained in 2 years.

Full Support but Partial Support: The FC geometric average was less than 200 MPN/ 100 ml, and more than 10 percent of individual samples exceeded 400 MPN/100 ml.

Full Support but No Support: The FC geometric average exceeded 200 MPN/100 ml and more than 10 percent of individual samples exceeded 400 MPN/ 100 ml.

Notes: Adapted from: EPA Guidance for Preparation of Water Quality Inventory Reports, EPA, 1997. Compared to New Jersey SWQS for FW2; Secondary contact uses are considered to be met if SWQS for primary contact is met.

The 2000 NJDEP Surface Water Quality Inventory Report (305-b) shows the status of swimmable use attainment, based on fecal coliform concentrations, for specific locations along several Upper Delaware tributaries as follows:

Swimmable Support Status:

Flat Brook near Flatbrookville	Full Support
Paulins Kill at Balesville	No Support
Paulins Kill at Blairstown	Partial Support
Pequest River at Pequest	No Support
Pohatcong Creek at New Village	No Support
Musconetcong River at Beattystown	Partial Support
Musconetcong River Bloomsbury	No Support
Musconetcong River Riegelsville	No Support

Clearly, there are some serious problems in this regard. Possible sources for the problem are septic systems, livestock waste, and wildlife and waterfowl, especially Canada geese.

Lakes are monitored for fecal coliform extensively during the summer months for swimmable status. The most recent (2000 305-b Report) results of this monitoring indicate the water quality at the 79 monitored lake bathing beaches is good, with 86% sampled having "full support" for contact (swimming) recreation. In fact, if Lake Hopatcong is excluded, 93% of the other sampled beaches had a "full support" designation. Lake Hopatcong showed the most water quality impairment, with 68% of the beaches having full support.

The Fishable Use support is defined by the *Fish Consumption Designated Use Assessment*, which measures for the absence or presence of toxics in fish tissue. Consumption advisories for mercury have been issued for largemouth bass and chain pickerel for all freshwater bodies in the state, with elevated levels documented by NJDEP in Cranberry Lake, Lake Hopatcong, Swartswood Lake, and Merrill Creek Reservoir.

There are many other environmental issues that relate to recreational uses such as cultural eutrophication of lakes and attendant impacts on fisheries and boating. Eight of the nine lakes within the Upper Delaware Region that are monitored through the Clean Lakes Program have been identified as supporting excessive aquatic plant growth (macrophytes), a primary symptom of eutrophication. Excessive aquatic plant growth negatively impacts both water quality and recreational boating. This data could suggest that many of the non-monitored lakes share the same problem.

Turning the issue around, recreational activities themselves can contribute to water quality degradation. On the region's larger lakes the impact of motorized boats illegally discharging their sewage into the lakes may in turn be exacerbating the cultural eutrophication problems. Other boating and marina related pollutants such as fuels, fuel additives, oils, greases, and solvents impact some lake waters. Soil erosion problems exist in some areas, caused on streambanks by heavy fishing access and wave action and in woodlands by steep hiking and mountain bike trail sections.

Population and Employment

Population

Prehistoric native tribes roamed this region at the first retreat of the glaciers, using forest resources for tool making, shelter, food, and fuel. Small scale fuel burning then expanded to slash and burn agriculture and small native settlements in the fertile valleys.

With the arrival of European settlers, the next phase involved mining and quarrying of chert and quartzite for tool and weapon making. Major economic changes began early in the 1600's, when large numbers of Dutch settlers began to colonize the Delaware and Kittatinny valleys, engaging in extensive iron and copper mining along with some agriculture. After the mining industry declined, the primary way of making a living was through agriculture: farming and farm-related support businesses, such as limekilns and supply sales. Later, other industries such as logging and manufacturing were established. Following the industrialization of western civilization in the mid 1800's, manufacturing of goods and provision of support services proliferated. Development of railroad lines, improved roads, and the Morris Canal all contributed to increased and diversified employment opportunities.

The population growth of the Upper Delaware Watershed region has been slower than in many other portions of New Jersey, owing both to its rugged terrain and distance from New York and Philadelphia. Generally speaking, the steep, rocky slopes discouraged transportation and development; while the broader valleys did the opposite. Industrial-age manufacturing, mining, and agriculture largely fueled the early population centers of Phillipsburg, Washington, Hackettstown, and Newton. As time passed and the transportation system of road and rail developed, population began to radiate outward from these centers into the open lands that were devoted to farming, or in woodland. This population migration pattern is similar to many other areas, with today's faster growing areas occurring in previously rural environments.

Figures 27-29 depict the 1960-2000 population migration pattern for the Upper Delaware. Figure 27 shows the 1960 population density, Figure 28 the 2000 population density, and Figure 29 the 1960-2000 population density change. Appendix 6 shows the recent population history and projections for the municipalities of the region. According to the most recent available census figures, the fastest growing municipalities for the period 1990-2000 were:

- Greenwich, Warren County with an increase in population of 130% between 1990-2000.
- Independence, Warren County, increase of 42%
- Alexandria, Hunterdon County, increase of 31%
- Oxford Twp, Warren County, increase of 29%

By way of contrast, in the same period, the municipalities showing the least growth were:

- Walpack, Sussex County, lost 39% of its 1990 population.
- Mansfield, Warren County, lost 7%
- Pohatcong, Warren County, lost 5%
- Phillipsburg, Warren County, lost 4%

Much of this population shift underscores the move out of urban areas to sprawling development.

Employment

Agriculture is still a significant land use, with the region leading the state in production of milk, dairy cattle, field corn and eggs. However, it is no longer a major industry in the region in terms of *employment*. In fact, nonagricultural employment comprises 96% of Warren County employment. Today, the leading employers in the region are manufacturing, retail sales, and education based. The largest single employment center is the International Trade Zone in the Musconetcong watershed. This extensive facility is the location of occupations primarily in office and light assembly, and has greatly improved the economy and tax base of the Byram-Mt.Olive Township area. Other large employers in the watershed are M&M Mars in Hackettstown; Hoffmann-LaRoche in Belvidere; Ingersoll-Rand in Phillipsburg; Baker Chemical, Phillipsburg; and Mobil Chemical, Washington. According to the 2000 data from Workforce New Jersey (NJ Dept. of Labor) for a majority of the watershed, the leading occupations in terms of *total employment* for the period 1996-2006 are predicted to be:

- Retail salespersons
- Cashiers
- Business technical support, secretarial
- Teachers
- General Office clerks
- Marketing/sales supervisors
- Secretarial

This data reflects the transition of the region to a technology and production workforce rather than one historically dominated by mining, agricultural production and associated support services. An important point to remember is that the majority of residents in the Upper Delaware do *not* work in the region, instead commuting considerable distances to their places of employment to the east. This aspect adds greatly to the daily traffic congestion on the major state and federal transportation routes.

Summary

The Upper Delaware Watershed region is generally regarded as among the most pristine in New Jersey. The geology, topography, soils, vegetation, and water resources are unique. These natural resources have created an environment replete with inspiring scenery, clean waters, abundant wildlife, and diverse recreational opportunities. Much of the region is still undeveloped, with agriculture, forest and wetlands combining for 82% of the total land cover. Of this, 25% of the total watershed is in some form of protected open space. Biological monitoring of streams show 72% of the sampling points are considered to be non-impaired. Lake monitoring shows that nearly 90% have full recreational use water quality.

However, despite the wealth of protected lands and relatively low population density, a significant number of monitoring stations on streams in the watershed exhibit water quality that does not support all designated uses. Water quality impairments are documented for fecal coliform and nutrients. Development pressures will continue to have a potential impact on both water quality and water supply, contributing sediment, nutrients, and other pollutants related to lawns and pavement.

The time has come for a meaningful and comprehensive watershed management effort to ensure that the critical natural resources of this region are protected now and for future generations. This Settings Report is intended as an initial step in the process characterizing and assessing the watershed. As the basis for the Upper Delaware Watershed Characterization and Assessment process, a series of technical reports will be developed examining the critical natural resource issues of the area. Future reports will be completed characterizing Water Quality & Quantity, Wildlife Issues, Forest Cover, Riparian Areas, Wetlands, Soils, Recreation, Impervious Cover, and Open Space.

Glossary of Terms

Alluvium	material, such as sand, silt, or clay, deposited on land by streams.
Aquifer	any water-saturated zone in sedimentary or rock stratum which is significantly permeable so that it may yield sufficient quantities of water from wells or springs in order to serve as a practical source of water supply.
Colluvium	soil material, rock fragments, or both moved by creep, slide or local wash and deposited at the base of steep slopes.
Consolidated deposits	deposits of sand, gravel, silt or clay that have been compressed to form solid material or rock.
Floodplain	the areas adjacent to a stream or river that are subject to flooding or inundation during severe storm events. [Often referred to as a 100-year floodplain, it would include the area or flooding that occurs, on average, once every 100 years].
Groundwater	that portion of water beneath the land surface that is within the zone of saturation (below the water table) where pore spaces are filled with water.
Headwaters	the beginnings or sources for water courses. Typically the land surrounding the point in the landscape where sufficient runoff collects to form an intermittent stream.
Impervious Cover	any surface in the urban landscape that cannot effectively absorb or infiltrate rainfall.
Karst	Terrain with special landforms and drainage characteristics due to greater solubility of certain rocks (notably carbonate rocks such as <u>limestone</u> , <u>dolomite</u> or <u>magnesite</u>) in natural waters. Derived from the geographical name "krs" from part of the karst terrain in Slovenia
Orographic effects	Also referred to as the Rain Shadow effect, it is caused as air is forced upward over mountains, it cools, causing water vapor to condense and rain out; precipitation caused by the lifting of moist air over a mountain barrier
Physiographic provinces	the distribution of land area in New Jersey into distinct physiographic land divisions that have been determined by New Jersey's geologic history.
Subwatershed	a smaller geographic section of a larger watershed.
Surface waters	water at or above the land's surface which is neither ground water nor contained within the saturated zone. Surface waters include, but are not limited to, the ocean and its tributaries, all springs, streams, rivers, lakes, ponds, wetlands, and artificial waterbodies.
Unconsolidated deposits	recent deposits of clays, silts, sands and gravels that are not cemented together.
Watershed	a hydrologic unit in which all surface water runoff egresses through a single, natural hydrologic outlet, and as delineated in the Statewide Water Quality Management Plan.

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Appendix

Appendix 1 Climate Data for the Upper Delaware Watershed

Appendix Table A-1.1: Precipitation Normals (Inches)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Branchville	3.08	2.71	3.38	3.90	4.30	4.10	4.31	4.12	3.72	3.21	3.87	3.31
Newton	3.04	2.70	3.33	3.85	4.25	4.28	4.42	4.47	3.86	3.29	3.82	3.30
Sussex	3.35	2.98	3.51	4.01	4.42	4.44	4.47	4.20	3.80	3.41	3.94	3.52
High Point	2.86	2.16	3.27	3.77	4.44	4.13	3.86	3.84	3.91	3.22	4.11	3.19

Appendix Table A-1.2: Minimum Temperature Normals (Degrees F°)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
High Point	12.1	13.6	23.4	34.3	45.1	54.0	59.0	57.1	49.6	39.1	30.2	18.4
Newton	12.7	14.7	24.9	34.7	44.4	53.6	58.2	56.5	48.2	36.5	29.8	19.6
Sussex	12.2	14.0	24.5	34.4	44.1	53.4	58.3	56.5	48.4	36.8	29.5	19.1

Appendix Table A-1.3: Maximum Temperature Normals (Degrees F°)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
High Point	31.1	33.3	42.9	55.8	67.1	74.7	79.6	77.8	70.8	60.2	47.7	35.7
Newton	33.4	36.3	46.8	58.8	70.2	78.5	83.3	81.3	74.0	62.8	50.8	38.2
Sussex	33.5	36.4	46.6	58.7	70.0	78.1	82.9	81.1	73.9	63.1	51.1	38.2

Appendix 2 Updated Soils Associations of the Upper Delaware Watershed

Prepared by USDA Natural Resources Conservation Service based on updated soils mapping currently underway in Warren and Sussex Counties (10/01)

Sussex County:

Soils formed in post-glacial alluvium

Delaware-Unadilla-Colonie association: these are nearly level, very deep, well drained to excessively drained loamy and sandy soils found on terraces along the Delaware River. Much of this area was cleared for farming, but some has now reverted to woodland. These soils are generally well suited to farming and community development, but are federally owned in the Delaware Water Gap National Recreation Area (DWGNRA).

Soils formed in glacial outwash

Hazen-Hoosic-Otisville association: nearly level to very steep, very deep, well to excessively drained soils in major glacial outwash valleys. The well drained Hazen soil generally is on the nearly level summit and valley bottom areas. The somewhat excessively drained Hoosic and excessively drained Otisville soils generally are on the steeper slope areas. Much has been used for farming, and is also suited for development.

Fredon-Halsey association: nearly level, very deep, somewhat poorly to very poorly drained soils in major outwash valleys. The somewhat poorly drained Fredon soil generally is on floodplains and on toe slopes above floodplains. The very poorly drained Halsey soil generally is on floodplains in depressions and drainageways. Development is not feasible.

Soils formed in organic deposits

Carlisle association: nearly level, very deep, very poorly drained soil in depressions and drainageways on till and outwash plains. Some of this soil has been drained and farmed. Development is not feasible.

Soils formed in young glacial till or in material weathered from bedrock

Walpack-Lordstown-Manlius association: gently sloping to very steep, moderately deep and deep, well drained loamy soils on hilltops and hillsides of Walpack Ridge, near the Delaware River. Most of the area is woodland, some previously farmed, in the Delaware Water Gap National Recreation Area.

Swartswood-Wurtsboro association: nearly level to very steep, deep, well to moderately well drained soils on the western slope of the Kittatinny Ridge. The well drained Swartswood soil generally is on gently sloping to very steep sloping areas. The moderately well drained Wurtsboro soil generally is on the nearly level areas on summits and valley bottoms. These soils have been cleared for agriculture in many areas and may be developed in less steep sites. Most of this association lies outside the boundary of the Delaware Water Gap National Recreation Area.

Lackawanna-Oquaga-Rock outcrop association: on northwestern slope of Kittatinny Ridge within the Delaware Water Gap National Recreation Area. Gently sloping to very steep, deep and moderately deep, well drained to somewhat excessively drained soils. Most of this area is too steep and stony for farming and development.

Arnot-Lordstown association: nearly level to very steep, shallow to moderately deep, well drained soils on the main crest of the Kittatinny Ridge. Both the shallow Arnot soil and the moderately deep Lordstown soil generally are on nearly level summits to very steep side slope areas. This association is dominantly in state forest and in state and federal parks.

Wassaic-Farmington-Galway association: nearly level to steep, shallow to moderately deep, well drained soils in Kittatinny Valley on areas of limestone bedrock. The moderately deep Wassaic soil generally is found on nearly level summit areas. The shallow Farmington soil generally is found on nearly level summit areas to steep side slope areas. The moderately deep Galway soil generally is found on nearly level summit areas to steep side slope areas. These soils are dominantly woodland and recreational; however, some areas are being presently being used for agriculture or development.

Nassau-Manlius association: nearly level to very steep, shallow to moderately deep, well to somewhat excessively drained soils in Kittatinny Valley on areas of slaty shale bedrock. The shallow, somewhat excessively drained Nassau soil generally is found on nearly level summit areas to very steep side slope areas. The moderately deep, well drained Manlius soil generally is found on nearly level summit areas to strongly sloping side slope areas. These soils are presently being used for agriculture and development, with some of the steeper sloping areas being dominantly in woodlands.

Hollis-Rock outcrop-Chatfield association: Gently sloping to very steep, moderately deep and shallow soils with rock outcrops and small areas of very poorly drained soils. Mostly in woodland, it is poorly suited to development.

Rockaway-Chatfield-Whitman association: Gently sloping to very steep, deep to moderately deep, well drained to very poorly drained soils on sideslopes in the highlands. Much of this land was historically used for farming, but has reverted to woodland or been developed.

Warren County:

Soils formed in glacial outwash

Hazen-Hoosic-Otisville association: nearly level to very steep, very deep, well to excessively drained soils in major outwash valleys. The well drained Hazen soil generally is on the nearly level summit and valley bottom areas. The somewhat excessively drained Hoosic and excessively drained Otisville soils generally are on the steeper slope areas. Much has been used for farming, and is also suited for development.

Fredon-Halsey association: nearly level, very deep, somewhat poorly to very poorly drained soils in major outwash valleys. The somewhat poorly drained Fredon soil generally is on floodplains and on toe slopes above floodplains. The very poorly drained Halsey soil generally is on floodplains in depressions and drainageways. Development is not feasible.

Soils formed in organic deposits

Carlisle-Adrian association: These are deep, very poorly drained organic soils located in depressions at the lowest points in the landscape. Commonly, these soils are found in long, narrow, or elliptical depressions where the water table is near the surface due to poor drainage. Many of these areas have been drained and used to produce vegetables or sod. This association is not suited to community development.

Soils that formed in young glacial till or in material weathered from bedrock:

Swartswood-Wurtsboro association: nearly level to very steep, deep, well to moderately well drained soils on the western slope of the Kittatinny Ridge. The well drained Swartswood soil generally is on gently sloping to very steep sloping areas. The moderately well drained Wurtsboro soil generally is on the nearly level areas on summits and valley bottoms. These soils have been cleared for agriculture in many areas and may be developed in less steep sites. Most of this association lies outside the boundary of the Delaware Water Gap National Recreation Area.

Lackawanna-Oquaga-Rock outcrop association: on northwestern slope of Kittatinny Ridge within the Delaware Water Gap National Recreation Area and Worthington State Forest. Gently sloping to very

steep, deep and moderately deep, well drained to somewhat excessively drained soils. Most of this area is too steep and stony for farming and development

Arnot-Lordstown-Rock outcrop association: nearly level to very steep, shallow to moderately deep, well drained soils on the main crest and southeast slope of Kittatinny Ridge. Both the shallow Arnot soil and the moderately deep Lordstown soil generally are on nearly level summits to very steep side slope areas. This association is dominantly in state forest and in state and federal parks.

Wassaic-Farmington-Galway association: nearly level to steep, shallow to moderately deep, well drained soils in Kittatinny Valley on areas of limestone bedrock. The moderately deep Wassaic soil generally is found on nearly level summit areas. The shallow Farmington soil generally is found on nearly level summit areas to steep side slope areas. The moderately deep Galway soil generally is found on nearly level summit areas to steep side slope areas. These soils are dominantly woodland and recreational; however, some areas are being presently being used for agriculture or development.

Nassau-Manlius association: nearly level to very steep, shallow to moderately deep, well to somewhat excessively drained soils in Kittatinny Valley on areas of slaty shale bedrock. The shallow, somewhat excessively drained Nassau soil generally is found on nearly level summit areas to very steep side slope areas. The moderately deep, well drained Manlius soil generally is found on nearly level summit areas to strongly sloping side slope areas. These soils are presently being used for agriculture and development, with some of the steeper sloping areas being dominantly in woodlands.

Hollis-Rock outcrop-Chatfield association: Gently sloping to very steep, moderately deep and shallow soils with rock outcrops and small areas of very poorly drained soils. Mostly in woodland, it is poorly suited to development.

Rockaway-Chatfield-Whitman association: Gently sloping to very steep, deep to moderately deep, well drained to very poorly drained soils on sideslopes in the highlands. Much of this land was historically used for farming, but has reverted to woodland or been developed.

Soils formed from material weathered from bedrock or old glacial till

Edneyville (Gladstone)-Parker association: this group consists of deep excessively to well drained very steep gravelly sandy loams on uplands in the southern half of the county. These soils are characterized by excessive stoniness and some rock outcrops. Most of this association is in woodland. It is generally unsuitable to farming or development.

Annandale-Washington-Califon association: these soils are on broad upland plains and valley slopes in the southern half of the county. They are deep and well drained to somewhat poorly drained loamy soils that have been historically cleared for farming, are also well suited to development.

Washington-Bartley association: These soils are nearly level to steep, deep, generally well drained loamy soils on uplands in the southern and southeastern parts of the county. These are good soils for agricultural uses, although development in Washington soils is severely limited by underlying cavernous limestone bedrock. Sinkholes are fairly common and can be very hazardous to development.

Hunterdon County:

1. Soils formed in alluvial material

Rowland-Birdsboro-Raritan association: This association consists of deep, nearly level to gently sloping, well drained to somewhat poorly drained, nonstony soils located on flood plains and river terraces. The flood plain soils have severe limitations for development and related uses. The terrace soils are less problematic. Both have been used successfully for farming.

2. Soils formed in material developed from bedrock or old glacial till

Duffield-Washington association: these are deep, gently sloping to moderately steep, well drained soils containing some rocky areas on uplands. Much has been used for agriculture, and is well suited for development. *Parker-Edneyville-Califon association:* these soils are generally gently sloping to steep excessively drained to somewhat poorly drained, primarily gravelly cobbly, or stony soils on uplands. This association occurs on Musconetcong Mountain and is primarily wooded with light residential development. Historically, some was farmed, but these soils are difficult to work, and much cleared land has reverted to woodland. A critical limitation of this association, because of the lack of fractures and fissures in the gneiss parent material, is the limited ground water available for residential wells.

Morris County:

1. Soils formed in young glacial till

Rockaway-Rock outcrop association: these soils formed in stony to extremely stony sandy loam glacial till. The association is deep and well drained, strongly sloping overlying granitic gneiss, and located on uplands. The soils are poorly suited for farming or development. Most is in woodland, which is the most appropriate use.

2. Soils formed from material weathered from bedrock or old glacial till

Parker-Gladstone association: this group consists of deep, excessively to well drained very steep gravelly sandy loams on uplands. These soils are characterized by excessive stoniness and some rock outcrops. Most of this association is in woodland. It is generally unsuitable to farming or development.

Bartley-Turbotville-Cokesbury association: these soils are deep, moderately well drained, generally gently sloping loams and gravelly loams that overlie limestone or granitic gneiss. These are among the better soils in the watershed for farming and development, although the Cokesbury soils are limited by poor drainage.

Appendix 3 Common Vegetation of the Upper Delaware Watershed Plant Communities

Adapted from: Collins, Beryl R., Anderson, Karl H. 1994. *Plant Communities of New Jersey: A Study in Landscape Diversity*. Rutgers University Press, New Brunswick, NJ.

A. Chestnut oak forest: higher slopes

Dominant trees	Other important trees	Shrubs and vines	Herbs
Chestnut oak	Black oak	Black huckleberry	Wild sarsparilla
Red oak	White oak	Lowbush blueberry	Bracken fern
	Red maple	Deerberry	Whorled loosestrife
	Black birch	Mountain laurel	Hairgrass
	Scarlet oak	Sweetfern	
		Shagbark hickory	
		Sassafras	
		Black cherry	

B. Mixed Oak Forest: moderately to well-drained uplands

Dominant trees	Other important trees	Shrubs and vines	Herbs
Black oak	Chestnut oak	Maple-leaf viburnum	Mayapple
Red oak	Scarlet oak	Arrowwood	Wild sarsparilla
White oak	Shagbark hickory	Mountain laurel	False Solomon's-seal
	Sugar maple	Virginia creeper	Jack-in-the-pulpit
	Red maple		White baneberry
	Black birch		
	American beech		
	White ash		
	Black cherry		
	Flowering dogwood		

C. Hemlock-Mixed Hardwood Forest: cooler, moist ravine slopes

Dominant tree	Other important trees	Shrubs and vines	Herbs and mosses
Eastern Hemlock	Black birch	Maple-leaf viburnum	Spotted wintergreen
	Yellow birch	Mountain laurel	Star flower
	Sugar maple	Lowbush blueberry	Canada mayflower
	Red maple	Spicebush	Christmas fern
	American beech	Witch hazel	Broom moss
	Red oak		Tree moss
	Black oak		Fern moss
	Basswood		

D. Sugar Maple-Mixed Hardwood Forest: fertile limestone valleys

Dominant tree	Other important trees	Shrubs and vines	Herbs
Sugar maple	White oak	Maple-leaf viburnum	Mayapple
	Red oak	Arrowwood	Bloodroot
	Black oak	Spicebush	Hepatica
	Black birch	Witch hazel	Wood anemone
	Yellow birch		Jack-in-the-pulpit
	Red maple		Wild ginger
	Shagbark hickory		
	American beech		
	Tulip poplar		
	White ash		
	Black cherry		

E. Successional Uplands: abandoned fields

Dominant tree	Other important trees	Shrubs	Herbs
Gray birch		Staghorn sumac	Common ragweed
Black cherry		Multiflora rose	Yellow foxtail
Trembling aspen		Black raspberry	Large crabgrass
Eastern red cedar		Gray dogwood	Wild carrot
		Autumn olive	Horseweed
			Common mullein
			Goldenrod (varieties)
			Canada thistle
			Timothy
			Orchardgrass

F. Pitch pine-scrub oak forest: highest ridgetops

Dominant tree	Other important trees	Shrubs and vines	Herbs
Pitch pine	Red maple	Scrub oak	Wild sarsparilla
	Chestnut oak	Black huckleberry	Bracken fern
	Black oak	Lowbush blueberry	Canada mayflower
	White oak	Deerberry	Rattlesnake weed
	Black birch	Mountain laurel	False Solomon's-seal
	Sassafras	Sweetfern	Wintergreen
		Black chokeberry	

G. Rock outcrops: high elevations

Dominant tree	Other important trees	Shrubs	Herbs and mosses
Pitch pine		Lowbush blueberry	Wild sarsparilla
Chestnut oak		Black huckleberry	Bracken fern
Black birch		Mountain laurel	Pennsylvania sedge
		Winged sumac	Little bluestem
		Scrub oak	Sweet goldenrod
			White moss

H. Wetlands and floodplains

Dominant tree

Red maple
Yellow birch
Eastern hemlock
White ash
Sweet gum

Other important trees

Sycamore
American larch
Black spruce

Shrubs and vines

Buttonbush
Silky dogwood
Smooth alder
Winterberry
Highbush blueberry

Herbs

Cattail (varieties)
Skunk cabbage
Swamp loosestrife
Phragmites
Tussock sedge
Jewelweed
Sensitive fern
Cinnamon fern
Woolgrass
Common rush
Spike rush
Tickseed-sunflower

Appendix 4 Rare Wildlife Species

Appendix Table A-4a: Rare Wildlife Species Presently Recorded in the New Jersey Natural Heritage Database

NAME	COMMON NAME	FEDERAL STATUS	STATE STATUS
*** Vertebrates			
ACCIPITER COOPERII	COOPER'S HAWK		E
ACCIPITER GENTILIS	NORTHERN GOSHAWK		T/T
ACRIS CREPITANS CREPITANS	NORTHERN CRICKET FROG		U
AMBYSTOMA JEFFERSONIANUM	JEFFERSON SALAMANDER		D
AMBYSTOMA LATERALE	BLUE-SPOTTED SALAMANDER		E
AMBYSTOMA MACULATUM	SPOTTED SALAMANDER		D
AMBYSTOMA OPACUM	MARBLED SALAMANDER		D
AMMODRAMUS HENSLOWII	HENSLOW'S SPARROW		E
AMMODRAMUS SAVANNARUM	GRASSHOPPER SPARROW		T/T
ARDEA HERODIAS	GREAT BLUE HERON		T/S
ASIO OTUS	LONG-EARED OWL		T/T
BARTRAMIA LONGICAUDA	UPLAND SANDPIPER		E
BOTAURUS LENTIGINOSUS	AMERICAN BITTERN		T/S
BUTEO LINEATUS	RED-SHOULDERED HAWK		E/T
CISTOTHORUS PLATENSIS	SEDGE WREN		E
CLEMMYS INSCULPTA	WOOD TURTLE		T
CLEMMYS MUHLENBERGII	BOG TURTLE	LT	E
CROTALUS HORRIDUS HORRIDUS	TIMBER RATTLESNAKE		E
DOLICHONYX ORYZIVORUS	BOBOLINK		T/T
EMPIDONAX ALNORUM	ALDER FLYCATCHER		S/S
EURYCEA LONGICAUDA LONGICAUDA	LONGTAIL SALAMANDER		T
HALIAEETUS LEVCOCEPHALUS	BALD EAGLE	LT	E
HEMIDACTYLIUM SCUTATUM	FOUR-TOED SALAMANDER		D
LYNX RUFUS	BOBCAT		E
MELANERPES ERYTHROCEPHALUS	RED-HEADED WOODPECKER		T/T
MYOTIS LEIBII	EASTERN SMALL-FOOTED MYOTIS		U
NEOTOMA MAGISTER	ALLEGHENY WOODRAT		E
PASSERCULUS SANDWICHENSIS	SAVANNAH SPARROW		T/T
PETROCHELIDON PYRRHONOTA	CLIFF SWALLOW		T/S
PODILYMBUS PODICEPS	PIED-BILLED GREBE		E/S
POOECETES GRAMINEUS	VESPER SPARROW		E
SOREX DISPAR	LONG-TAILED OR ROCK SHREW		U
STRIX VARIA	BARRED OWL		T/T
VERMIVORA CHRYSOPTERA	GOLDEN-WINGED WARBLER		D/S
VIREO SOLITARIUS	SOLITARY VIREO		S/S

FEDERAL STATUS CODES

The following U.S. Fish and Wildlife Service categories and their definitions of endangered and threatened plants and animals have been modified from the U.S. Fish and Wildlife Service (F.R. Vol. 50 No. 188; Vol. 61, No. 40; F.R. 50 CFR Part 17). Federal Status codes reported for species follow the most recent listing.

- LE --Taxa formally listed as endangered.
- LT -- Taxa formally listed as threatened.
- PE -- Taxa already proposed to be formally listed as endangered.
- PT -- Taxa already proposed to be formally listed as threatened.
- C -- Taxa for which the Service currently has on file sufficient information on biological vulnerability and threat(s) to support proposals to list them as endangered or threatened species.
- S/A -- Similarity of appearance species.

STATE STATUS CODES

The state status codes and definitions provided reflect the most recent lists that were revised in the New Jersey Register, Monday, June 3, 1991.

- EX -- Extirpated species-a species that formerly occurred in New Jersey, but is not now known to exist within the state.
- E -- Endangered species-an endangered species is one whose prospects for survival within the state are in immediate danger due to one or many factors - a loss of habitat, over exploitation, predation, competition, disease. An endangered species requires immediate assistance or extinction will probably follow.
- T -- Threatened species-a species that may become endangered if conditions surrounding the species begin to or continue to deteriorate.
- D -- Declining species-a species which has exhibited a continued decline in population numbers over the years.
- S -- Stable species-a species whose population is not undergoing any long-term increase/decrease within its natural cycle.
- INC -- Increasing species-a species whose population has exhibited a significant increase, beyond the normal range of its life cycle, over a long term period.
- P -- Peripheral species-a species whose occurrence in New Jersey is at the extreme edge of its present natural range.
- U -- Undetermined species-a species about which there is not enough information available to determine the status.
- I -- Introduced species-a species not native to New Jersey that could not have established itself here without the assistance of man.

Status for animals separated by a slash(/) indicate a dual status. First status refers to the state breeding population, and the second status refers to the migratory or winter population.

Appendix 5 Selected 2000 NJDEP Water Quality Data for 305b Water Quality Inventory Report

(Explanatory notes follow final table)

Appendix Table A-5a: Dissolved Oxygen Attainment in WMA 1 Rivers and Streams

Station Name	SWQS Class	DO Criteria	DO-Mean	Attainment
BIG FLATBROOK AT FLATBROOKVILLE	FW2-TM	>5.0 ppm	10.9	Not Impaired
PAULINS KILL AT BALESVILLE	FW2-TM	>5.0 ppm	10.3	Not Impaired
PAULINS KILL AT BLAIRSTOWN	FW2-TM	>5.0 ppm	10.4	Not Impaired
PEQUEST R AT PEQUEST	FW2-NT (C1)	>4.0 ppm	10.6	Not Impaired
POHATCONG CK AT NEW VILLAGE	FW2-TM	>5.0 ppm	10.9	Not Impaired
MUSCONETCONG R AT BEATTYSTOWN	FW2-TM	>5.0 ppm	11.0	Not Impaired
MUSCONETCONG R NR BLOOMSBURY	FW2-TM	>5.0 ppm	11.1	Not Impaired
MUSCONETCONG R AT RIEGELSVILLE	FW2-TM	>5.0 ppm	10.8	Not Impaired

Appendix Table A-5b: Total Phosphorus Attainment in WMA 1 Rivers and Streams

Station Name	TP-Mean	TP-Criteria	TP % Exceed	Trend (no Q)	TP SWQS Status
BIG FLATBROOK AT FLATBROOKVILLE	0.013	0.10	0.0%	NSIG	Full
PAULINS KILL AT BALESVILLE	0.042	0.05	21.4%	DOWN	Partial
PAULINS KILL AT BLAIRSTOWN	0.028	0.10	0.0%	DOWN	Full
PEQUEST R AT PEQUEST	0.065	0.10	14.3%	NSIG	Partial
POHATCONG CK AT NEW VILLAGE	0.105	0.10	38.5%	NSIG	None
MUSCONETCONG R AT BEATTYSTOWN	0.032	0.10	0.0%	DOWN	Full
MUSCONETCONG R NR BLOOMSBURY	0.021	0.10	0.0%	DOWN	Full
MUSCONETCONG R AT RIEGELSVILLE	0.038	0.10	7.1%	DOWN	Full

Appendix Table A-5c: pH Attainment Status in WMA 1 Rivers and Streams

Station Name	pH –Mean	pH Criteria	pH % exceed	pH Attainment
BIG FLATBROOK AT FLATBROOKVILLE	7.92	6.5 – 8.5	11.1%	Impaired
PAULINS KILL AT BALESVILLE	8.04	6.5 – 8.5	0.0%	Not Impaired
PAULINS KILL AT BLAIRSTOWN	8.13	6.5 – 8.5	0.0%	Not Impaired
PEQUEST R AT PEQUEST	8.24	6.5 – 8.5	7.1%	Not Impaired
POHATCONG CK AT NEW VILLAGE	8.08	6.5 – 8.5	23.1%	Impaired
MUSCONETCONG R AT BEATTYSTOWN	8.13	6.5 – 8.5	7.1%	Not Impaired
MUSCONETCONG R NR BLOOMSBURY	8.26	6.5 – 8.5	21.4%	Impaired
MUSCONETCONG R AT RIEGELSVILLE	8.14	6.5 – 8.5	0.0%	Not Impaired

Appendix Table A-5d: Fecal Coliform (FC) Attainment Status in WMA 1 Rivers and Streams (1995-97)

Station Name	FC-geomean	FC Criteria	FC % exceed	Trend (no Q)	FC SWQS Attainment
PAULINS KILL AT BALESVILLE	279.4	<400/100 ml	35.7%	NSIG	None
PAULINS KILL AT BLAIRSTOWN	96.6	<400/100 ml	28.6%	NSIG	Partial
PEQUEST R AT PEQUEST	335.3	<400/100 ml	28.6%	NSIG	None
POHATCONG CK AT NEW VILLAGE	700.8	<400/100 ml	71.4%	NSIG	None
MUSCONETCONG R AT BEATTYSTOWN	124.9	<400/100 ml	14.3%	NSIG	Partial
MUSCONETCONG R NR BLOOMSBURY	296.7	<400/100 ml	42.9%	NSIG	None
MUSCONETCONG R AT RIEGELSVILLE	283.9	<400/100 ml	42.9%	NSIG	None

Appendix Table A-5e: Maximum NO3 Concentrations (1995-97) and NO3 Trends (1986-95)

StationName	NO3-Mean (mg/l)	NO3 % exceed	Trend (No Q)	Overall Trend
Big Flatbrook - Flatbrookville	0.148	0.0%	NSIG	NSIG
Paulins Kill - Balesville	1.001	0.0%	NSIG	NSIG
Paulins Kill - Blairstown	0.573	0.0%	DOWN	DOWN
Pequest R - Pequest	1.190	0.0%	NSIG	NSIG
Pohatcong Creek - New Village	2.023	0.0%	UP	UP
Musconetcong R - Beattystown	1.381	0.0%	UP	UP
Musconetcong R - Bloomsbury	1.889	0.0%	NSIG	NSIG
Musconetcong R - Riegelsville	1.833	0.0%	UP	UP

2000 NJDEP Clean Lakes Water Quality Data

Appendix Table A-5f: Lakes Assessed By The Clean Lakes Program, Trophic Categorization

County	Surface Area (acres)	Name	Total Phosphorus	Trophic Index	Trophic State
Sussex	321	Musconetcong	0.04	Macrophytes, Algae	Eutrophic
Sussex	296	Cranberry	0.07	Macrophytes, Total Phosphorus	Eutrophic
Sussex	19.2	Marcia	0.03	Total Phosphorus	Eutrophic
Sussex	20	Sawmill	0.03	Macrophytes, Algae	Eutrophic
Sussex	37	Steenykill	0.14	Macrophytes, Total Phosphorus	Eutrophic
Sussex	15.5	Stony	0.14	Macrophytes, Total Phosphorus	Eutrophic
Sussex	505	Swartswood	0.06	Algae, Macrophytes	Eutrophic
Warren	30	Columbia	0.07	Algae, Macrophytes	Eutrophic
Warren	7	Ghost	0.06	Macrophytes, TotalPhosphorus	Eutrophic

Notes on NJDEP data:

Water Classifications: Surface waters are grouped into classifications as follows:

- FW1: Fresh Water 1: Fresh surface waters that are to be maintained in their natural state and not subjected to man-made wastewater discharges or increases from runoff from anthropogenic activities.
- FW2: Fresh Water 2: General fresh surface water classification applied to fresh waters that are not FW1 or Pinelands Waters.
- FW- TP: Fresh Water: Trout Production waters are designated for trout spawning/nursery during their first year.
- FW- TM: Fresh Water: Trout Maintenance waters are designated for the support of trout throughout the year.
- FW- NT: Fresh Water: Non Trout: fresh surface waters that have not been designated TM or TP. These waters are generally unsuitable for trout because of their physical, chemical, or biological species, but are suitable for a wide variety of other fish species.
- ND: Nondegradation waters are waters set aside for posterity because of their clarity, color, scenic setting, other characteristic of aesthetic value, unique ecological significance, or exceptional water supply significance. These include all waters designated as FW1 in this report.
- C1: Category 1 waters are designated for implementation of antidegradation policies for protection from any measurable change in water quality. C1 may be applied to any surface water classification except those designated as FW1 or PL. Note: the Department is currently proposing a clarification between the definition of ND and C1 antidegradation policies
- C2: Category 2 waters are waters that are not designated as Outstanding Natural Resource Water (i.e., FW1 or PL) or C1 for implementation of antidegradation policies.
- SWQS: Surface Water Quality Standards
- Trend: "no Q" means trends without flow adjustment.
- Designations: NSIG-not significant; NT-not tested; UP-increasing concentration; DOWN-decreasing concentration
- % exceed: percent of samples taken that exceed the surface water quality criteria
- mean mg/l: average concentration of samples

Use Support Assessment

full support
partial support
no support

Rapid Bioassessment Rating

non-impaired
moderately impaired
severely impaired

Appendix 6: Population Data for Municipalities of the Upper Delaware Watershed

Appendix Table A-6a: Population 1940-2020

MUNICIPALITY	COUNTY	AREA SQ. MILES	AREA ACRES	Population 1940	Population 1950	Population 1960	Population 1970	Population 1980	Population 1990	Population 2000	Projected Population 2020
ALEXANDRIA TWP	HUNTERDON	27.7	17714	1186	1369	1629	2127	2798	3594	4698	6988
ALLAMUCHY TWP	WARREN	20.7	13257	686	736	973	1138	2560	3484	3877	5622
ALPHA BORO	WARREN	1.7	1099	2301	2117	2406	2829	2644	2530	2482	2817
ANDOVER BORO	SUSSEX	1.8	1158	512	560	734	813	892	700	700	713
ANDOVER TWP	SUSSEX	20.9	13352	591	1052	2177	3040	4506	5438	6033	7917
BELVIDERE TOWN	WARREN	1.3	856	2060	2406	2636	2722	2475	2669	2771	3272
BETHLEHEM TWP	HUNTERDON	20.8	13280	791	857	1090	1385	3045	3104	3820	5092
BLAIRSTOWN TWP	WARREN	31.5	20149	1449	1571	1797	2189	4360	5331	5747	8423
BLOOMSBURY BORO	HUNTERDON	0.9	596	704	722	838	879	864	890	886	1258
BRANCHVILLE BORO	SUSSEX	0.6	354	715	810	963	911	870	851	845	883
BYRAM TWP	SUSSEX	21.7	13893	373	761	1616	4592	7502	8048	8254	11109
FRANKFORD TWP	SUSSEX	35.3	22588	1244	1530	2170	2777	4654	5114	5420	6759
FRANKLIN TWP	WARREN	23.9	15300	1540	1530	1729	1973	2341	2404	2768	3607
FREDON TWP	SUSSEX	18.0	11494	478	584	804	1372	2281	2763	2860	4317
FRELINGHUYSEN TWP	WARREN	23.5	15044	715	779	845	1118	1435	1779	2083	3136
GLEN GARDNER BORO	HUNTERDON	1.6	1002	536	654	787	874	834	1665	1902	2439
GREEN TWP	SUSSEX	16.3	10409	540	596	854	1343	2450	2709	3220	4460
GREENWICH TWP	WARREN	10.4	6682	1125	1217	1397	1482	1738	1899	4365	6169
HACKETTSTOWN TOWN	WARREN	3.8	2404	3289	3894	5276	9472	8850	8120	10403	9294
HAMPTON BORO	HUNTERDON	1.5	983	864	975	1135	1386	1614	1515	1546	1689
HAMPTON TWP	SUSSEX	25.1	16056	611	668	1174	2091	3916	4438	4943	5839
HARDWICK TWP	WARREN	38.7	24786	439	437	433	619	973	1255	1464	2293
HARDYSTON TWP	SUSSEX	32.6	20851	1034	1279	2206	3499	4553	5275	6171	8652
HARMONY TWP	WARREN	24.3	15539	1465	1763	2039	2195	2592	2653	2729	3213
HOLLAND TWP	HUNTERDON	24.0	15364	1150	1341	2495	3587	4593	4892	5124	6718
HOPATCONG BORO	SUSSEX	12.2	7808	660	1173	3391	9052	15531	15586	15888	17186
HOPE TWP	WARREN	18.7	11942	646	681	833	1140	1468	1719	1891	2564

MUNICIPALITY	COUNTY	AREA SQ. MILES	AREA ACRES	Population 1940	Population 1950	Population 1960	Population 1970	Population 1980	Population 1990	Population 2000	Projected Population 2020
INDEPENDENCE TWP	WARREN	19.9	12759	1046	1169	1509	2057	2829	3940	5603	9808
JEFFERSON TWP	MORRIS	42.3	27103	1548	2744	6884	14122	16413	17825	19717	19353
KNOWLTON TWP	WARREN	25.0	16022	1084	1260	1442	1738	2074	2543	2977	4134
LAFAYETTE TWP	SUSSEX	18.3	11739	803	836	1100	1202	1614	1902	2300	3264
LEBANON TWP	HUNTERDON	31.9	20411	1437	1971	2841	4235	5459	5679	5816	7938
LIBERTY TWP	WARREN	12.0	7701	441	529	760	1229	1730	2493	2765	4182
LOPATCONG TWP	WARREN	7.3	4683	1450	1737	2703	3144	4998	5052	5765	6919
MANSFIELD TWP	WARREN	29.5	18877	1254	1497	2130	3546	5780	7154	6653	10749
MONTAGUE TWP	SUSSEX	46.1	29504	621	602	879	1131	2066	2832	3412	4198
MOUNT ARLINGTON BORO	MORRIS	2.9	1860	456	639	1246	3590	4251	3630	4663	6004
MOUNT OLIVE TWP	MORRIS	31.4	20107	1526	2597	3807	10394	18748	21282	24193	23354
NETCONG BORO	MORRIS	0.8	484	2157	2284	2765	2858	3557	3311	2580	3083
NEWTON TOWN	SUSSEX	3.1	1991	5533	5781	6563	7297	7748	7521	8244	8378
OXFORD TWP	WARREN	6.2	3940	1548	1489	1657	1742	1659	1790	2307	2416
PHILLIPSBURG TOWN	WARREN	3.3	2107	18314	18919	18502	17849	16647	15757	15166	16148
POHATCONG TWP	WARREN	13.7	8766	2029	2540	3543	3924	3856	3591	3416	3796
ROXBURY TWP	MORRIS	21.7	13884	4455	5707	9983	15754	18878	20429	23883	27362
SANDYSTON TWP	SUSSEX	42.5	27192	651	829	1019	1303	1485	1732	1825	2158
SPARTA TWP	SUSSEX	40.0	25581	1729	3021	6717	10819	13333	15157	17631	23724
STANHOPE BORO	SUSSEX	2.3	1464	1100	1351	1814	3040	3638	3393	3584	3874
STILLWATER TWP	SUSSEX	30.2	19298	679	816	1339	2158	3887	4253	4267	5196
WALPACK TWP	SUSSEX	23.1	14803	207	204	248	384	150	67	41	48
WANTAGE TWP	SUSSEX	67.3	43045	2376	2543	3308	4329	7268	9487	10387	14348
WASHINGTON BORO	WARREN	2.0	1254	4643	4802	5723	5943	6429	6474	6712	6825
WASHINGTON TWP	MORRIS	44.4	28417	1870	2147	3330	6962	11402	15592	17592	20623
WASHINGTON TWP	WARREN	17.8	11398	1320	1765	3055	3585	4243	5367	6248	9231
WHITE TWP	WARREN	27.8	17794	1335	1536	1832	2326	2748	3603	4245	6608

Appendix Table A-6b: Population Density 1940-2020, people per square mile

MUNICIPALITY	COUNTY	Population Density 1940	Population Density 1950	Population Density 1960	Population Density 1970	Population Density 1980	Population Density 1990	Population Density 2000	Projected Population Density 2020
ALEXANDRIA TWP	HUNTERDON	43	49	59	77	101	130	170	252
ALLAMUCHY TWP	WARREN	33	36	47	55	124	168	187	271
ALPHA BORO	WARREN	1340	1233	1401	1648	1540	1474	1446	1641
ANDOVER BORO	SUSSEX	283	310	406	449	493	387	387	394
ANDOVER TWP	SUSSEX	28	50	104	146	216	261	289	379
BELVIDERE TOWN	WARREN	1540	1798	1970	2034	1850	1995	2071	2445
BETHLEHEM TWP	HUNTERDON	38	41	53	67	147	150	184	245
BLAIRSTOWN TWP	WARREN	46	50	57	70	138	169	183	268
BLOOMSBURY BORO	HUNTERDON	756	776	900	944	928	956	952	1351
BRANCHVILLE BORO	SUSSEX	1291	1462	1738	1644	1570	1536	1525	1594
BYRAM TWP	SUSSEX	17	35	74	212	346	371	380	512
FRANKFORD TWP	SUSSEX	35	43	61	79	132	145	154	192
FRANKLIN TWP	WARREN	64	64	72	83	98	101	116	151
FREDON TWP	SUSSEX	27	33	45	76	127	154	159	240
FRELINGHUYSEN TWP	WARREN	30	33	36	48	61	76	89	133
GLEN GARDNER BORO	HUNTERDON	342	418	503	558	533	1063	1215	1557
GREEN TWP	SUSSEX	33	37	53	83	151	167	198	274
GREENWICH TWP	WARREN	108	117	134	142	166	182	418	591
HACKETTSTOWN TOWN	WARREN	876	1037	1405	2522	2356	2162	2770	2474
HAMPTON BORO	HUNTERDON	563	635	739	902	1051	986	1007	1100
HAMPTON TWP	SUSSEX	24	27	47	83	156	177	197	233
HARDWICK TWP	WARREN	11	11	11	16	25	32	38	59
HARDYSTON TWP	SUSSEX	32	39	68	107	140	162	189	266
HARMONY TWP	WARREN	60	73	84	90	107	109	112	132
HOLLAND TWP	HUNTERDON	48	56	104	149	191	204	213	280
HOPATCONG BORO	SUSSEX	54	96	278	742	1273	1277	1302	1409
HOPE TWP	WARREN	35	37	45	61	79	92	101	137
INDEPENDENCE TWP	WARREN	52	59	76	103	142	198	281	492
JEFFERSON TWP	MORRIS	37	65	163	333	388	421	466	457

MUNICIPALITY	COUNTY	Population Density 1940	Population Density 1950	Population Density 1960	Population Density 1970	Population Density 1980	Population Density 1990	Population Density 2000	Projected Population Density 2020
KNOWLTON TWP	WARREN	43	50	58	69	83	102	119	165
LAFAYETTE TWP	SUSSEX	44	46	60	66	88	104	125	178
LEBANON TWP	HUNTERDON	45	62	89	133	171	178	182	249
LIBERTY TWP	WARREN	37	44	63	102	144	207	230	348
LOPATCONG TWP	WARREN	198	237	369	430	683	690	788	945
MANSFIELD TWP	WARREN	43	51	72	120	196	243	226	364
MONTAGUE TWP	SUSSEX	13	13	19	25	45	61	74	91
MOUNT ARLINGTON BORO	MORRIS	157	220	429	1235	1462	1249	1604	2065
MOUNT OLIVE TWP	MORRIS	49	83	121	331	597	677	770	743
NETCONG BORO	MORRIS	2849	3017	3653	3775	4699	4374	3408	4073
NEWTON TOWN	SUSSEX	1779	1858	2110	2346	2491	2418	2650	2693
OXFORD TWP	WARREN	251	242	269	283	269	291	375	392
PHILLIPSBURG TOWN	WARREN	5563	5747	5620	5422	5057	4786	4607	4905
POHATCONG TWP	WARREN	148	185	259	287	282	262	249	277
ROXBURY TWP	MORRIS	205	263	460	726	870	942	1101	1261
SANDYSTON TWP	SUSSEX	15	20	24	31	35	41	43	51
SPARTA TWP	SUSSEX	43	76	168	271	334	379	441	594
STANHOPE BORO	SUSSEX	481	590	793	1329	1590	1483	1566	1693
STILLWATER TWP	SUSSEX	23	27	44	72	129	141	142	172
WALPACK TWP	SUSSEX	9	9	11	17	6	3	2	2
WANTAGE TWP	SUSSEX	35	38	49	64	108	141	154	213
WASHINGTON BORO	WARREN	2370	2451	2921	3034	3282	3305	3426	3484
WASHINGTON TWP	MORRIS	42	48	75	157	257	351	396	464
WASHINGTON TWP	WARREN	74	99	172	201	238	301	988	518
WHITE TWP	WARREN	48	55	66	84	99	130	153	238

Appendix Table A-6c: Population Change 1940-2020, people per square mile

Municipality	COUNTY	Pop Change 1940 to 1950	Percent Change 1940 to 1950	Pop Change 1950 to 1960	Percent Change 1950 to 1960	Pop Change 1960 to 1970	Percent Change 1960 to 1970	Pop Change 1970 to 1980	Percent Change 1970 to 1980	Pop Change 1980 to 1990	Percent Change 1980 to 1990	Pop Change 1990 to 2000	Percent Change 1990 to 2000	Projected Pop Change 2000 to 2020	Estimated Percent Change 2000 to 2020
ALEXANDRIA TWP	HUNTERDON	183	15%	260	19%	498	31%	671	32%	796	28%	1104	31%	2290	49%
ALLAMUCHY TWP	WARREN	50	7%	237	32%	165	17%	1422	125%	924	36%	393	11%	1745	45%
ALPHA BORO	WARREN	-184	-8%	289	14%	423	18%	-185	-7%	-114	-4%	-48	-2%	335	13%
ANDOVER BORO	SUSSEX	48	9%	174	31%	79	11%	79	10%	-192	-22%	0	0%	13	2%
ANDOVER TWP	SUSSEX	461	78%	1125	107%	863	40%	1466	48%	932	21%	595	11%	1884	31%
BELVIDERE TOWN	WARREN	346	17%	230	10%	86	3%	-247	-9%	194	8%	102	4%	501	18%
BETHLEHEM TWP	HUNTERDON	66	8%	233	27%	295	27%	1660	120%	59	2%	716	23%	1272	33%
BLAIRSTOWN TWP	WARREN	122	8%	226	14%	392	22%	2171	99%	971	22%	416	8%	2676	47%
BLOOMSBURY BORO	HUNTERDON	18	3%	116	16%	41	5%	-15	-2%	26	3%	-4	0%	372	42%
BRANCHVILLE BORO	SUSSEX	95	13%	153	19%	-52	-5%	-41	-5%	-19	-2%	-6	-1%	38	4%
BYRAM TWP	SUSSEX	388	104%	855	112%	2976	184%	2910	63%	546	7%	206	3%	2855	35%
FRANKFORD TWP	SUSSEX	286	23%	640	42%	607	28%	1877	68%	460	10%	306	6%	1339	25%
FRANKLIN TWP	WARREN	-10	-1%	199	13%	244	14%	368	19%	63	3%	364	15%	839	30%
FREDON TWP	SUSSEX	106	22%	220	38%	568	71%	909	66%	482	21%	97	4%	1457	51%
FRELINGHUYSEN TWP	WARREN	64	9%	66	8%	273	32%	317	28%	344	24%	304	17%	1053	51%
GLEN GARDNER BORO	HUNTERDON	118	22%	133	20%	87	11%	-40	-5%	831	100%	237	14%	537	28%
GREEN TWP	SUSSEX	56	10%	258	43%	489	57%	1107	82%	259	11%	511	19%	1240	39%
GREENWICH TWP	WARREN	92	8%	180	15%	85	6%	256	17%	161	9%	2466	130%	1804	41%
HACKETTSTOWN TOWN	WARREN	605	18%	1382	35%	4196	80%	-622	-7%	-730	-8%	2283	28%	-1109	-11%
HAMPTON BORO	HUNTERDON	111	13%	160	16%	251	22%	228	16%	-99	-6%	31	2%	143	9%
HAMPTON TWP	SUSSEX	57	9%	506	76%	917	78%	1825	87%	522	13%	505	11%	896	18%
HARDWICK TWP	WARREN	-2	0%	-4	-1%	186	43%	354	57%	282	29%	209	17%	829	57%
HARDYSTON TWP	SUSSEX	245	24%	927	72%	1293	59%	1054	30%	722	16%	896	17%	2481	40%
HARMONY TWP	WARREN	298	20%	276	16%	156	8%	397	18%	61	2%	76	3%	484	18%
HOLLAND TWP	HUNTERDON	191	17%	1154	86%	1092	44%	1006	28%	299	7%	232	5%	1594	31%
HOPATCONG BORO	SUSSEX	513	78%	2218	189%	5661	167%	6479	72%	55	0%	302	2%	1298	8%
HOPE TWP	WARREN	35	5%	152	22%	307	37%	328	29%	251	17%	172	10%	673	36%
INDEPENDENCE TWP	WARREN	123	12%	340	29%	548	36%	772	38%	1111	39%	1663	42%	4205	75%

Municipality	COUNTY	Pop Change 1940 to 1950	Percent Change 1940 to 1950	Pop Change 1950 to 1960	Percent Change 1950 to 1960	Pop Change 1960 to 1970	Percent Change 1960 to 1970	Pop Change 1970 to 1980	Percent Change 1970 to 1980	Pop Change 1980 to 1990	Percent Change 1980 to 1990	Pop Change 1990 to 2000	Percent Change 1990 to 2000	Projected Pop Change 2000 to 2020	Estimated Percent Change 2000 to 2020
JEFFERSON TWP	MORRIS	1196	77%	4140	151%	7238	105%	2291	16%	1412	9%	1892	11%	-364	-2%
KNOWLTON TWP	WARREN	176	16%	182	14%	296	21%	336	19%	469	23%	434	17%	1157	39%
LAFAYETTE TWP	SUSSEX	33	4%	264	32%	102	9%	412	34%	288	18%	398	21%	964	42%
LEBANON TWP	HUNTERDON	534	37%	870	44%	1394	49%	1224	29%	220	4%	137	2%	2122	36%
LIBERTY TWP	WARREN	88	20%	231	44%	469	62%	501	41%	763	44%	272	11%	1417	51%
LOPATCONG TWP	WARREN	287	20%	966	56%	441	16%	1854	59%	54	1%	713	14%	1154	20%
MANSFIELD TWP	WARREN	243	19%	633	42%	1416	66%	2234	63%	1374	24%	-501	-7%	4096	62%
MONTAGUE TWP	SUSSEX	-19	-3%	277	46%	252	29%	935	83%	766	37%	580	20%	786	23%
MOUNT ARLINGTON BORO	MORRIS	183	40%	607	95%	2344	188%	661	18%	-621	-15%	1033	28%	1341	29%
MOUNT OLIVE TWP	MORRIS	1071	70%	1210	47%	6587	173%	8354	80%	2534	14%	1892	9%	-839	-3%
NETCONG BORO	MORRIS	127	6%	481	21%	93	3%	699	24%	-246	-7%	2911	88%	503	19%
NEWTON TOWN	SUSSEX	248	4%	782	14%	734	11%	451	6%	-227	-3%	-731	-10%	134	2%
OXFORD TWP	WARREN	-59	-4%	168	11%	85	5%	-83	-5%	131	8%	517	29%	109	5%
PHILLIPSBURG TOWN	WARREN	605	3%	-417	-2%	-653	-4%	-1202	-7%	-890	-5%	-591	-4%	982	6%
POHATCONG TWP	WARREN	511	25%	1003	39%	381	11%	-68	-2%	-265	-7%	-175	-5%	380	11%
ROXBURY TWP	MORRIS	1252	28%	4276	75%	5771	58%	3124	20%	1551	8%	3454	17%	3479	15%
SANDYSTON TWP	SUSSEX	178	27%	190	23%	284	28%	182	14%	247	17%	93	5%	333	18%
SPARTA TWP	SUSSEX	1292	75%	3696	122%	4102	61%	2514	23%	1824	14%	2474	16%	6093	35%
STANHOPE BORO	SUSSEX	251	23%	463	34%	1226	68%	598	20%	-245	-7%	191	6%	290	8%
STILLWATER TWP	SUSSEX	137	20%	523	64%	819	61%	1729	80%	366	9%	14	0%	929	22%
WALPACK TWP	SUSSEX	-3	-1%	44	22%	136	55%	-234	-61%	-83	-55%	-26	-39%	7	17%
WANTAGE TWP	SUSSEX	167	7%	765	30%	1021	31%	2939	68%	2219	31%	900	9%	3961	38%
WASHINGTON BORO	WARREN	159	3%	921	19%	220	4%	486	8%	45	1%	238	4%	113	2%
WASHINGTON TWP	MORRIS	277	15%	1183	55%	3632	109%	4440	64%	4190	37%	2000	13%	3031	17%
WASHINGTON TWP	WARREN	445	34%	1290	73%	530	17%	658	18%	1124	26%	881	16%	2983	48%
WHITE TWP	WARREN	201	15%	296	19%	494	27%	422	18%	855	31%	642	18%	2363	56%