

DESCRIPTION OF SUSSEX COUNTY RESOURCES

Natural Resources of Sussex County



Flatbrook

Photo by Donna Traylor

“Sussex County leads the nation in dragonfly and damselfly diversity with 142 documented species (5 globally rare; 64 state rare). These fascinating creatures have various common names that indicate their beauty (emeralds, amberwings, ruby spot, bluet, jewelwings) as well as their flying and aerial hunting prowess (sundragons, meadowhawks, cruisers, dancers, corporals)....Overall, the county has 29 species and communities that can be classified as globally rare.”

Report submitted by The Nature Conservancy, Skylands Regional Office, for the Sussex County Open Space and Recreation Plan, 2003

Sussex County is located in northwestern New Jersey. The county is bordered to the west by the Delaware River and Pennsylvania; to the north by Orange County, New York; to the east and southeast by Passaic and Morris Counties, respectively; and to the southwest by Warren County. Sussex County is approximately 343,445 acres, or 535 square miles, in area.¹ The County generally takes the shape of a north-south rectangle tilted 45 degrees to the east.

Sussex County’s topography is among the most diverse in the state. As **Map 1: Physiographic Provinces & Ridgelines in Sussex County** shows, the eastern one-third of the county lies in the Highlands physiographic province. The Highlands runs in a northeast belt from Reading, Pennsylvania, across New Jersey and into southern New York and western Connecticut. The region is characterized by forested ridges and glacially sculpted valleys that provide habitat for more than 240 species of wildlife. The

region also contains significant water resources affecting over 11 million residents. Over half of the county's municipalities fall within the Highlands.²

The remainder of the County falls within the Ridge and Valley physiographic province. This region is characterized by parallel northeast-southwest trending ridges with fertile valleys in between. The Ridge and Valley area of New Jersey is geologically similar to the Appalachian provinces of western Virginia, Maryland and Pennsylvania. The capstone of the Ridge and Valley in Sussex County is the Kittatinny Ridge. The Kittatinny Ridge runs approximately 40 miles through the county, hugging its western margin. The ridge has elevations generally between 1,200 and 1,500 feet above sea level, and an average width of five miles³. At High Point, which is the northernmost extent of the Kittatinny Ridge in Sussex County, the elevation tops out at 1,803 feet, the highest point in New Jersey.

The lowest points in Sussex County are along the Delaware River at the mouth of the Flat Brook (300 feet), and along the Walkkill River at the New York State line (380 feet). The Kittatinny Valley, located between the Highlands and the Kittatinny Ridge, has elevations generally between 600 and 700 feet. It is in this area that the county's agricultural economy is primarily based.

Geology

The Highlands

The Highlands is part of the larger New England Upland, which includes the Green Mountains of Vermont and the Berkshires of western Massachusetts.⁴ The Highlands cuts across parts of Hunterdon, Warren, Sussex, Somerset, Morris, Passaic and Bergen Counties, and is comprised of northeast-trending ridges that rise generally 300 to 500 feet above the parallel river valleys.

Bedrock Geology

Highlands bedrock is comprised predominantly of granite, gneiss and, to a lesser extent, marble (See **Map 2: Geology in Sussex County**). The rocks date to the Precambrian, and are the oldest in New Jersey. They formed between 1.3 billion and 750 million years ago.⁵ These igneous rocks were formed through the intense heat, compression and deformation of the preexisting rock. This process was the earliest event in the formation of the Appalachian Mountains.⁶

Within the general assemblage of Precambrian rock, there are several northeast-running belts of Paleozoic rocks, including sandstone, shale and limestone. The origin of these sedimentary rocks, which are much younger than the surrounding rock, can be traced to a series of gravel, sand and silt outwashes from nearby mountains, as well as from the calcareous sediments of marine animals deposited in inland seas created when the continent broke apart. These depositions occurred between 550 million and 350 million years ago, and completely covered the older Precambrian rock.⁷

Three mountain-building episodes, occurring about 1,000, 450, and 300 million years ago, shaped the current Highlands bedrock geology. Intense pressure folded the Highlands region and thrust the area westward on a series of faults. The first episode uplifted the landscape to elevations near those of the present-day Rocky Mountains.⁸ This action also had the effect of trapping the sedimentary Paleozoic rocks between faulted blocks of Precambrian rock. This assemblage of northeast-southwest running belts of Paleozoic rock within the larger Precambrian rock is the modern structure of the Highlands.⁹

Surficial Geology

Erosion of the Highlands province began in earnest in the Mesozoic, around 190 million years ago. However, it was not until 10 million years ago, in the Miocene, that the Highlands' present form began to take shape.

Originally, drainage patterns in the Highlands were to the southeast, but from 10 million years ago until 2 million years ago the pattern shifted gradually to the southwest, as streams and other forces eroded channels in the belts of weak sedimentary rocks. Once streams were entrenched in the southwest-trending valleys, stream erosion continued to

deepen the valleys. The Precambrian rock, being more resistant to erosion, eventually formed the ridges.

Rivers, such as the Musconetcong and the South Branch of the Raritan River and the Black River outside of Sussex County but within the Highlands region, exemplify this southwest pattern through broad river valleys. The Wallkill River and its valley also conform to this pattern, although it flows northeast rather than southwest.

Ridge and Valley

The Ridge and Valley physiographic province occupies a small portion of New Jersey. The eastern boundary of the Ridge and Valley extends northeasterly from the Delaware River north of Phillipsburg, to the New York State line approximately where the Wallkill River enters New York State.¹⁰

The Ridge and Valley province, so named for its topographic features of long parallel ridges and wide fertile valleys, extends southwestward into Pennsylvania where the Kittatinny Ridge continues nearly to Harrisburg. The Kittatinny Ridge becomes Blue Mountain in Pennsylvania, and the Blue Ridge further south in Maryland and Virginia. The Ridge and Valley province also extends northeastward into New York State, where the Kittatinny Ridge becomes Shawangunk Mountain.¹¹ The Ridge and Valley province in total extends from northeastern Alabama through Virginia, Pennsylvania, New Jersey, and north through the Hudson, Champlain and Saint Lawrence Valleys.¹²

Bedrock Geology

The land of New Jersey was originally part of a larger continent that broke up in Precambrian and Mesozoic time. As this occurred, ocean water infiltrated the rifts, depositing sand, silt and carbonate sediments. Because of this, the underlying rock of the Ridge and Valley is sedimentary. It consists primarily of sandstone, shale and limestone deposited between 550 and 350 million years ago (see **Map 2**).¹³

The rocks were flat-lying, until pressure from the southeast compressed them in a series of folds during the three major episodes of mountain-building. The most recent episode took place roughly 300 million years ago.¹⁴ Volcanic activity accompanied mountain building in Sussex County. Evidence of this activity can be found southwest of Colesville in Wantage Township, where the neck of an old volcano remains. The neck is the part of the volcano through which lava rises to the surface.¹⁵ Once the mountains were formed, erosion, weathering and glaciation shaped the landscape today.

Surficial Geology

As with the Highlands, the different rocks that comprise the Ridge and Valley have various degrees of resistance to weathering. The most resistant is conglomerate and sandstone, which not coincidentally underlies the Kittatinny Ridge and Walpack Ridge.

The weaker rocks are shale and limestone, and these underlie the upper Delaware Valley and the Kittatinny Valley.¹⁶

Within the Kittatinny Valley, there are two different elevation levels that correspond to the underlying material. Those parts of the Valley that are underlain by shale are several hundred feet higher than those underlain by limestone.¹⁷ Limestone areas in the Kittatinny Valley are the most erosion-prone rocks in the county. Because of their susceptibility to erosion, and their slight solubility in water, limestone areas in Sussex harbor great biological diversity and contain significant natural value. The Kittatinny Valley Limestone areas are among the most productive bedrock aquifers in the county.¹⁸

Water and Wind Gaps

For its entire 35-mile length in New Jersey, the Kittatinny Ridge is remarkably consistent. It is substantially broken only once over that length, at Culvers Gap. The other major gap in New Jersey is the Delaware Water Gap, located in Warren County at the New Jersey-Pennsylvania border. The Delaware Water Gap, which is a textbook example of a water gap, was formed when the Kittatinny Ridge rose around the pre-existing river. The river's power to cut through the emerging mountain was greater than the mountain's rise, and the Delaware maintained its course through the ridge.¹⁹

Culvers Gap was formed the same way as the Delaware Water Gap, most likely by a branch of the Paulins Kill cutting through the emerging Kittatinny Ridge. Over time the stream flowing through the gap was diverted, or captured, by the Flat Brook system, which flows on the west side of the Kittatinny Ridge and was eroding its headwall more quickly than the stream flowing through Culvers Gap. This had the effect of redirecting the stream into the Flat Brook, thus leaving Culvers Gap dry. Scenarios like this are quite common throughout the Appalachian Mountains. Wind gaps are formed wherever larger rivers erode their basins more quickly and capture the streamflow of smaller waterways by literally breaking through to a different drainage basin.²⁰

Glaciation

In addition to stream erosion, glaciers have given shape to the current landscape. Over the past 1.5 million years three distinct periods of glaciation have occurred in northern New Jersey, all of which have covered Sussex County's entire land area. The first two glacial episodes, called the pre-Illinoian and Illinoian, occurred more than 800,000 years ago and about 150,000 years ago, respectively. Little is known about these periods.²¹

The most recent glaciation was the Wisconsinan, occurring about 20,000 years ago.²² This episode has left the most profound mark on the Highlands and Ridge and Valley landscape. Ice in the Wisconsinan glacier is believed to have been almost 3,000 feet thick. The glacier flowed over northern New Jersey, scouring away pre-glacial soil from Wawayanda and Hamburg Mountains and the Kittatinny Ridge, exposing bedrock outcroppings. The Wisconsinan glacier also further defined pre-existing stream valleys by plucking out weaker rocks on the sides of the ridges and broadening the flood plains.²³

Throughout Sussex County many glacial features can be observed, indicating the extent to which glaciers have shaped the present landscape. Besides the craggy ridgetops previously mentioned, glaciers have created many features including drumlins, moraines and glacial lakes. Drumlins are tear-drop shaped mounds of till that indicate the direction in which glaciers flowed over the land. These are found throughout Kittatinny Valley and on Kittatinny Mountain in areas of thick till.

Moraines are mounds of till and other debris deposited at the end and sides of glaciers, as well as at points along the glaciers recession. There are two major recessional moraines in Sussex County: the Ogdensburg-Culvers Gap-Dingmans Ferry moraine and the Augusta-Montague moraine. Both of these moraines originate in Kittatinny Valley, cross Kittatinny Mountain and continue to the Delaware River.²⁴

Glacial Lakes were formed when till plugged river drainages. These lakes included Lake Wallkill, Lake Hamburg, Lake North Church and Lake Sparta, in the eastern part of the county, and Lakes Newton, Stillwater and Millbrook in the central and northwestern part. Most glacial lakes are gone; however, two that exist today are Swartswood Lake and Lake Owassa. The lakes are located on the eastern flank of the Kittatinny Ridge, in Stillwater and Frankford Townships, respectively.²⁵

A comparison of glaciated and non-glaciated landscapes reveals the extent to which the Wisconsin glacialiation has shaped the landscape. North of the Wisconsin's terminal moraine, the Highlands landscape is rugged, with thin soils and on ridgetops, steep-walled valleys and numerous bedrock outcroppings and glacial erratics. South of the moraine, the features are much gentler: river valleys are broad, ridgetops remain thickly forested and relief between valley and ridgetop is much less extreme.

The Ridge and Valley province contains similar features. The Kittatinny Ridge has thin, rocky soils, supporting pitch pine and chestnut oak, while the valleys contain glacial sediment and have developed productive agricultural economies based on the land's fertility. **Map 3: Glacial Sediment in Sussex County** depicts glacial remnants throughout the county. These features are an important component of the region's natural history.

Economic Resources

Beginning about the early 18th century humans began exploiting the rich deposits of iron, zinc and graphite in the Highlands.²⁶ Within the region's Precambrian rocks, many mines have operated over the last 250 years, extracting materials that have played important roles in American history. The most famous is the role of iron. The presence of magnetite iron ore deposits throughout the Highlands allowed numerous mines to flourish, and at one time New Jersey led the nation in production. Much of the raw material went to producing stoves, steel, guns, and munitions for the Revolutionary War effort.²⁷

Iron mines operated throughout the Highlands of Sussex County. Additionally, zinc was mined in Ogdensburg and Franklin. Franklin Mine and Sterling Hill Mine in Ogdensburg

are world famous for the minerals extracted there.²⁸ Over 300 minerals were discovered at Franklin and Sterling Hill, 42 of which were new to science.²⁹

Quarries were also common throughout the Highlands, and to a lesser extent, the Ridge and Valley. Precambrian granite and gneiss were quarried for crushed stone at Hamburg; marble was quarried extensively in the Franklin area north to McAfee. Paleozoic limestone and slate were quarried at numerous locations in the Ridge and Valley. Glacial sand and gravel pits were mined in the Highlands and Ridge and Valley.³⁰

Water Resources

Surface Water

The New Jersey Department of Environmental Protection (NJDEP) has organized New Jersey into 20 Watershed Management Areas (WMA) based on physical characteristics and stream drainage patterns. Each WMA is named for one or more prominent rivers that drain that particular watershed. Each WMA contains several sub-watersheds that highlight the importance of smaller streams in delivering water to the larger waterways of the watershed. The logic of approaching water quality from a watershed perspective is apparent. Only by considering all actions in upstream locations that drain to a common waterway can the true nature and extent of water quality impairment be analyzed.

Within Sussex County, there are four WMAs. These areas delineate the principal stream systems that drain the county's land area. The largest watershed in the county by area is WMA 1, the Upper Delaware River Watershed. The waters of WMA1 drain west and southwest to the Delaware River. Second in area in Sussex County is WMA 2, the Wallkill River Watershed. The Wallkill, which flows north into Orange County, New York, drains the north-central and northeastern section of Sussex County. WMA 3 (Pequannock River Watershed) and WMA 6 (Rockaway River Watershed) both drain to the southeast, and comprise small parts of the County. **Map 4: Watershed Management Areas in Sussex County** shows the location of Sussex County's four WMAs.

The Department of Environmental Protection has classified each of the state's freshwater bodies as either FW1 (Fresh Water 1) or FW2 (Fresh Water 2). FW1 waters are those that possess exemplary natural significance, aesthetic value or water supply significance and are to be "maintained in their natural state of quality and not subjected to any manmade wastewater discharges."³¹ These waters are all located wholly within publicly preserved lands. FW1 designation confers upon a water body the highest level of protection currently available in New Jersey. All other freshwater in New Jersey, with the exception of Pinelands waters, is classified as FW2. See **Map 5: FW1 and FW2 Surface Water in Sussex County**.

The designation of Category One (C1) and Category Two (C2) waters further defines surface water quality priorities. Surface waters can be named Category One based on a number of criteria including, but not limited to, scenic setting, recreational amenities,

ecological significance, water supply significance and water clarity or color. Once established, Category One waters are protected from measurable decreases in water quality. Unlike FW1 waters, however, Category One waters can, and often do, contain wastewater discharges. Category Two waters include all “waters not designated as Outstanding National Resource Waters (FW1 and Pinelands waters) or Category One” waters.³² See **Map 6: Category 1 & 2 Surface Water in Sussex County**.

NJDEP has also classified all freshwater bodies in New Jersey as either “non-trout,” “trout maintenance” or “trout production.”³³

- “Non trout” waters are those that do not support trout because of physical, biological or chemical characteristics.
- “Trout-maintenance” waters are those that support trout throughout the year.
- “Trout production” waters are used by trout “for spawning or nursery purposes during their first summer.”³⁴

Trout is used as an indicator species for water quality because of its sensitivity to certain water quality factors, such as water temperature and dissolved oxygen. Trout presence in a stream, or its use of that stream for reproduction directs the state’s water quality goals for that particular stream segment.

The state has set three baseline water quality standards for the three “trout” classes. “Non-trout” waters are the least stringent and “trout production” waters are the most stringent. Criteria for the baselines include: dissolved oxygen; ammonia; temperature; and suspended solids. All waters must meet at least the minimum standards for its classification.³⁵ See **Map 7: Trout/Non-Trout Surface Water in Sussex County** for the location of trout waters throughout the county.

The Delaware River is managed outside of the above-mentioned scheme, by the Delaware River Basin Commission (DRBC). The DRBC was established in 1961 to consolidate the management of the Delaware River and its drainage basin, which span 330 miles and four states. Roles of the Commission include: “water quality protection, water supply allocation, regulatory review (permitting), water conservation initiatives, watershed planning, drought management, flood control, and recreation.”³⁶ The Delaware River is the longest un-dammed river east of the Mississippi.³⁷

Watershed Management Area 1 – Upper Delaware River

Located in the western and southern sections of Sussex County, the Upper Delaware River Watershed comprises greater than half of the county’s land area. All precipitation that falls within WMA 1 drains to the Delaware River. Principal waterways in Sussex County’s portion of WMA 1, listed north to south in the order in which they meet the Delaware River, include: the Flat Brook; the Paulins Kill; the Pequest River and a short stretch of the Musconetcong River. All of these waterways run southwesterly, roughly parallel to one another. See **Map 4**.

Montague and Sandyston contain the largest number of FW1 waterways. These streams are part of the Big and Little Flat Brook systems. The upper half of the Big Flat Brook flows through High Point State Park and Stokes State Forest. Clove Brook, and Mill Brook also contain FW1 stretches. Further south in Walpack Township, tributaries of the Flat Brook draining the west slope of the Kittatinny Ridge have been designated FW1. See **Map 5**.

Category 1 freshwater bodies are located throughout WMA1. Almost the entire Flat Brook system is designated C1, as well as Mill Brook and Clove Brook in Montague Township. In addition, several stretches and tributaries of the Paulins Kill, Pequest River and Musconetcong River in Stillwater, Fredon, Green and Byram Townships have been designated as C1 waters. See **Map 6**.

The western slope of the Kittatinny Ridge is also where the highest concentration of trout waters can be found. Upstream of the confluence of the Big and Little Flat Brooks, both rivers are classified trout production waters. Other trout production waters include Clove Brook, which flows north into New York near Port Jervis, and branches of the Paulins Kill. Trout maintenance waters of WMA 1 include several stretches of the Flat Brook below the confluence of the Little Flat Brook and the Flat Brook, as well as parts of Pequest River, Kymer Brook, Lubbers Run and the Paulins Kill. See **Map 7**.

Watershed Management Area 2 – Wallkill River

The Wallkill River watershed occupies the northern and northeastern parts of Sussex County, extending south through Sparta and northern Byram Townships. The Wallkill River flows northeast into New York State, where it empties into the Hudson River near Kingston.

Major tributaries of the Wallkill River include Papakating Creek, which begins its run in Frankford Township, and Clove Brook, which flows south from northern Wantage Township. Pochuck Creek, which drains parts of Vernon and Hardyston Townships east of Pochuck Mountain, enter the Wallkill several miles into New York State. See **Map 4**.

Hamburg Mountain Wildlife Management Area in Vernon and Hardyston Townships contains FW1-classified streams. Small sections of Waywayanda Creek and the headwaters of Pochuck Creek also contain FW1 waters. The upper reaches of Clove Brook in Wantage Township are classified as FW1. See **Map 5**.

Clove Brook in Wantage also has C1 classifications in the northwestern corner of the Township. In Vernon, parts of Pochuck Creek and Waywayanda Creek have been designated C1 waters. Additionally, tributaries of the Wallkill River draining Sparta and Hamburg mountains are designated C1. See **Map 6**.

The Wallkill River and the majority of its tributaries are non-trout streams. The exceptions are those tributaries that drain forested, hilly areas. Clove Brook and its tributaries in Wantage are trout maintenance waters. Several branches of Black Creek in

Vernon are also trout maintenance waters. Several branches of Waywayanda Creek are trout production waters. See **Map 7**.

Watershed Management Area 3 – Pequannock River

The Pequannock River Watershed occupies a small area of eastern Sussex County. Flowing south out of Vernon Township, the Pequannock River continues into Hardyston Township where it turns southeast, forming the border between Morris and Passaic Counties. The Pequannock's confluence with the Passaic River occurs at the eastern end of Great Piece Meadows, where Morris, Passaic and Essex counties meet. For most of its run in Sussex County the Pequannock River flows through Newark's water supply management lands. Although these lands are not protected in perpetuity, there is a current state moratorium on the sale of water supply management lands. The Pequannock contains relatively few tributaries in Sussex County. See **Map 4**.

A stretch of the upper Pacack Brook and almost the entire main stem of the Pequannock River in Sussex County are classified as FW1 streams. A tributary to the Pequannock, located in Hardyston Township, has been designated a C1 stream. The entire main stem of the Pequannock contains trout production waters. Its few tributaries in Sussex County are mostly classified as trout production and trout maintenance waters, except for the waters that flow into Canistear Reservoir. See **Map 5, 6 and 7**.

Watershed Management Area 6 – Rockaway River

Although the Rockaway River itself begins in Jefferson Township, the river system's upper reaches are in eastern Sparta Township, where several streams merge to form Russia Brook. Russia Brook flows into Jefferson where it meets the Rockaway below Lake Swannanoa. From there the Rockaway River flows to the Passaic River. See **Map 4**.

None of the Rockaway River's tributaries in Sussex County contain a C1 or FW1 designation. Additionally, they are all classified as "non-trout." See **Maps 5, 6 and 7**.

Reservoirs and Lakes

Sussex County's lakes are found generally in two areas of the county: along the eastern slope of the Kittatinny Ridge and in the Highlands province of eastern Sussex County. It is here that topography and geology support the development of lakes. Most of Sussex County's lakes serve recreational purposes, and were developed as vacation areas in years past. The most prominent lakes in the county are Lake Hopatcong, Culvers Lake, Lake Owassa, Big Swartswood Lake, Lake Mohawk, Highland Lake, and Wawayanda Lake. Lake Hopatcong is the largest lake in New Jersey.

In addition to the larger recreational lakes just mentioned, the five following surface water bodies are used for potable water supply purposes. See **Map 4**.

- Morris Lake, in Sparta – used by Newton.
- Lake Rutherford, in Wantage – used by Sussex Borough.
- Branchville Reservoir, in Frankford – used by Branchville.
- Franklin Pond, in Franklin – used by Franklin as an emergency water supply.
- Lake Hopatcong - an emergency water supply for several towns.
- Canistear Reservoir, in Vernon – contained on the Newark water supply management lands.
- Heaters Pond, in Ogdensburg – an emergency water supply

Groundwater

Groundwater is any precipitation that percolates into the soil. Groundwater recharge is water that moves as subsurface runoff to wetlands, springs, streams etc., or into water filled layers of porous geologic formations called aquifers. In New Jersey, aquifers might be a few feet below the surface of the Earth, or several hundred feet underground, depending on underlying geologic formations. The rate at which groundwater reaches an aquifer is influenced by natural features such as soil type and bedrock geology. Human influence also has an affect; impervious surfaces, for example, will change the way water flows or will prevent storm water from soaking directly into the ground to become groundwater.

Approximately 95% of Sussex County residents rely on groundwater for consumption.³⁸ Groundwater is pumped to County residents from aquifers through either private on-site wells, community wells, or municipal wells. The long-term sustainability of the county's groundwater supply will depend on safeguarding water quality and quantity by employing the proper land use practices in areas with high groundwater recharge and aquifer productivity. Safeguarding community and municipal well heads is also an important component of long-term sustainability.

Groundwater Recharge

Groundwater recharge has been estimated by the New Jersey Geological Survey using 1995/97 Landuse/Landcover data, soils data, and local climatological data. This information was combined to generate an estimated groundwater recharge in inches per year, which was then converted to a ranking system of eight categories (A-E, L, W and X).

The highest estimated recharge occurs in two parallel belts through the county. See **Map 8: Groundwater Recharge in Sussex County**. The first runs northeasterly through the western margin of the county, in Walpack Valley and the Upper Delaware Valley. The largest areas of that belt are located in northwestern Sandyston and western Montague Townships. The second belt runs northeasterly through the east-central region of the county, along the base of Sparta, Hamburg and Wawayanda mountains. This belt is generally located in the upper Wallkill Valley and Vernon Valley. The second tier of

estimated groundwater recharge is located throughout the remainder of the county in isolated patches. Two notable concentrations, however, are in Stillwater and Hampton Townships, and in Sandyston and Montague Townships. The lowest estimated groundwater recharge occurs along the Kittatinny Ridge and in the Highlands, where soils have been scoured away by glacial activity, exposing numerous bedrock outcroppings.

Aquifer Rank

The New Jersey Geological Survey ranks aquifers by their ability to yield groundwater to high capacity wells. This rank corresponds to the median yield an aquifer can be expected to produce and is expressed in gallons per minute. The yield of an aquifer is also taken as a reliable indicator of the aquifer's ability to absorb, store and transmit water. Aquifer rank is broken into five categories (A through E) corresponding to a range of gallons per minute. There is no aquifer in Sussex County in the A range. Thus in Sussex County aquifers are ranked B through E; Sussex County's highest-ranking aquifers are not commensurate with the highest ranking aquifers statewide.

As with groundwater recharge, the areas of highest aquifer rank also include parts of the Walpack Valley, Upper Delaware Valley, Wallkill Valley and Vernon Valley. Several areas throughout the Kittatinny Valley contain the highest rank as well. Two belts of the second tier of aquifer rank in Sussex County run through eastern Stillwater, central Hampton and Frankford Townships, and along the base of Allamuchy, Sparta, Hamburg and Wawayanda mountains, becoming smaller and more discontinuous in the northern part of the county. Part of the latter belt is interwoven with areas of highest aquifer yield. The vast majority of the remainder of the county contains the third level of aquifer rank. See **Map 9: Aquifer Rank in Sussex County**.

Potential Aquifer Recharge

Although groundwater recharge data is a good indicator of rates of infiltration, it does not necessarily represent areas where precipitation will percolate to an aquifer. However, by combining groundwater recharge data with aquifer rank data, the relative value of potential aquifer recharge areas can be delineated. The logic of this model is that the greatest potential for aquifer recharge is likely to be located where a high amount of groundwater recharge occurs, and also where aquifer rank (yield) is high. One important assumption of this model however, is that all groundwater reaches the underlying aquifer, when in fact some will discharge as subsurface runoff to streams, wetlands etc.

No absolute numbers are provided for potential aquifer rank; rather the data is depicted as areas where groundwater recharge ranks (A-E, L, W and X) intersect with aquifer ranks (B-E). This produces 19 relative values for potential aquifer recharge in Sussex County (There are not 20 because there is no area overlap of the E groundwater recharge and E aquifer rank).

The highest potential aquifer recharge areas are located along the Delaware River, and along the run of the Big and Little Flat Brook, extending north into Montague Township.

Western Sparta and western Hardyston Townships also contain the highest potential aquifer recharge. Several small, isolated patches in the central valley round out the highest areas of potential aquifer recharge.

Two large belts, which correspond almost exactly with the aquifer rank data, provide a second tier of potential aquifer recharge. One belt runs northeast through eastern Stillwater, central Hampton and southern Frankford Townships; another runs along the base of Allamuchy, Sparta, Hamburg and Wawayanda Mountains, becoming patchy and discontinuous towards the northern end of the county. See **Map 10: Aquifer Recharge Potential in Sussex County**.

Land Use

The New Jersey Department of Environmental Protection has developed a Geographic Information System (GIS) data layer called 1995/97 Landuse/Landcover.³⁹ This layer was created from the analysis and interpretation of color infrared (CIR) imagery from 1995/97 and contains detailed information regarding vegetation type and land use in New Jersey. At present this GIS data layer is the most accurate and up-to-date source for land use/land cover information in New Jersey. **Maps 11, 13, 15 and 17**, as well as the information and statistics that follow are all derived from this data layer (except where noted), which lists the total acreage of Sussex County as 343,445 acres.⁴⁰ (Please note: any changes in land use that have occurred after 1997 are not reflected in the following information.)

Forest

In 1995/97 Sussex County had 194,259 acres in upland forest; this amounts to 57% of the County's land area.⁴¹ This is the largest land cover type in Sussex County. These forested areas include upland forest only, and do not include forested wetlands. Sussex County is the most forested county in New Jersey by percentage of land in forest.⁴²

According to **Map 11: Upland Forest in Sussex County**, the majority of upland forest falls within the state and federal parks in the eastern and western section of the county. Throughout the county's central section, forested areas are less frequent, occurring in discontinuous patches.

Limestone Forests

Although forested areas in general provide wildlife habitat and water quality protection, limestone forests have unique characteristics that make them especially important. Limestone forests occur in karst landscapes, which are underlain by limestone bedrock and contain sinkholes, sinkhole ponds, caves and springs. These communities support rare plant and animal species adapted to the soils and water cycle of the hydro-geologically dynamic region. Limestone outcroppings within the forests provide habitat for ferns, worts and other rare native plants as well as migratory birds and raptors.⁴³

Data for **Map 12: Potential Locations of Limestone Forest in Sussex County**, is sourced from NJGS's geologic data and the NJDEP's 1995/97 Landuse/Landcover data.

It represents all forested lands that overlay limestone bedrock and thin glacial till. This map has not been field verified and provides an indication of potential areas where limestone forest is located.

According to **Map 12**, limestone forests occur in three distinct regions in Sussex County. The first is located adjacent to the Delaware River, on the western slope of the Kittatinny Ridge. This area extends from the Walpack Bend north into Montague. The second area extends northward from southeastern Stillwater through Hampton into southern Branchville. The third area extends northward from Green through to Vernon with concentrated areas located in the Green, Fredon, Andover region, the Lafayette, Hardyston, Hamburg, Franklin region and central Vernon.

Wetlands

Wetlands are the next most frequent land cover. In 1995/97, a total of 47,670 acres, or 14%, of the County land area was wetland.⁴⁴ Of this total wetland acreage, 30,744 acres, or 9% of the County is forested wetland, and 16,926 acres, or 5% of the County is other wetland such as herbaceous wetland, disturbed wetland or agricultural wetland.⁴⁵

Map 13: Wetlands in Sussex County illustrates the location of forested wetland and ‘other’ wetland. The largest concentration of wetlands occurs along the Wallkill River. Following the river for about 8 miles upstream from its entrance into New York State—along the Wantage-Vernon border—the Wallkill River has a large floodplain with wetland areas. Other prominent areas of wetlands include the region surrounding the Paulins Kill in Hampton, Andover Township and Lafayette, the region surrounding Pochuck Creek in central Vernon, the region surrounding the Wallkill River in Sparta and Ogdensburg and along the Papakating Creek in Wantage Township.

Limestone Fens and Sinkhole Ponds

Portions of the valleys in Sussex County are underlain by limestone, creating the potential for sinkhole ponds and limestone fens. Limestone fens are similar to limestone forests except that they are related to wetland complexes as opposed to forested areas. Although fens can occur on other geologic units, the greatest extent of these unique features are found where glacial till overlies limestone formations in the Ridge and Valley physiographic province. This unique environment supports plants that tolerate alkaline conditions and other species associated with these plants⁴⁶.

Data for Map 14: Potential Locations of Limestone Fens & Ponds in Sussex County, is sourced from NJGS’s geologic data and NJDEP’s soils data. It represents areas where Carlisle muck soils overlay limestone bedrock and thin glacial till (as fen sites are muck based⁴⁷). This map indicates the *possible occurrence* of limestone fens and sinkholes; the data has not been field verified and fens may exist on other geologic units.

As **Map 14** illustrates, potential locations for limestone fen and sinkhole ponds are scattered across the county, although there are three general groupings. The first grouping is scattered along the Kittatinny Ridge from Walpack to Montague. The second area is

located from southeastern Stillwater through the central region of Hampton and into Frankford. The last grouping is scattered in a wider northeast trending band from Fredon to Vernon.

Agriculture

Tilled Agriculture Land

Land in agricultural use occupies almost as much acreage in the county as wetlands. In 1995/97, 44,075 acres, or 13%, of Sussex County consisted of agricultural lands.⁴⁸ According to **Map 15: Agriculture in Sussex County**, this land occurs in two general regions. The most prominent region is located in the Kittatinny Valley, in municipalities such as Wantage, Frankford, Lafayette, Hampton, Fredon and Green Townships. The second region is on the west slope of the Kittatinny Ridge, in Walpack, Sandyston and Montague Townships.

The data that NJDEP derived from the interpretation of color infrared imagery can only account for pasture, cropland and buildings associated with agriculture such as barns or greenhouses. It does *not* take into account areas that are under woodland management (these areas are considered forested on infrared images) and which are considered to be ‘farmland’ or ‘agriculture’ from a legal standpoint (e.g. tax assessment). Therefore, although the 1995/97 Landuse/Landcover data provides an account of ‘tilled’ agriculture, it does not illustrate all ‘farmland’ or farm assessed property in the county.

Farm Assessed Property & Woodland Management

A more inclusive source for the total acreage of farmland is county tax records. Tax data for 2002 indicate that a total of 115,127 acres of land is assessed as Class 3A and 3B farm assessed property. This total includes ‘tilled’ lands as well as woodland managed lands, which, as previously mentioned, are forested. **Map 16: Farm Assessed Property in Sussex County** shows similar trends as **Map 15** but includes more land throughout the Kittatinny Valley and in Highlands municipalities such as Byram, Hardyston and Sparta Townships.

Land that is under woodland management receives the favorable farmland tax assessment rate in exchange for the planned harvest of the property’s timber resources. According to the New Jersey Department of Agriculture’s New Jersey Farmland Data Report for the tax year 2002, a total of 56,272 acres in Sussex county are classified as woodland/wetlands and 35,129 of these acres are non-appurtenant woodlands, i.e. those not attached to other lands that are farmed.⁴⁹

Urban Land / Barren Land / Water

Urban land accounts for 42,445 acres, or 12% of Sussex County’s land area.⁵⁰ Included in the ‘Urban’ category are any anthropogenic features or structures. This includes roads, parking lots, homes, offices, schools, stores and utility facilities.

The remaining 4% of the county is comprised of ‘Water’ and ‘Barren Land’. ‘Water’, which includes lakes, rivers, ponds and reservoirs, accounts for 12,827 acres.⁵¹ ‘Barren Land’ accounts for 2,169 acres and includes any land devoid of vegetative cover.⁵² This includes mines and quarries, such as those located on the Sparta/Hopatcong border and in Hardyston as illustrated by **Map 17: Urban Land, Barren Land & Water in Sussex County**.

A summary of land use according to data derived from the NJDEP’s 1995/97 Landuse/Landcover data layer is as follows:

Total Upland Forest:	194,259 acres	57%
Total Wetlands:	47,670 acres	14%
Forested Wetlands	(30,744 acres	9%)
Herbaceous Wetlands	(16,926 acres	5%)
Tilled Agriculture:	44,075 acres	13%
Urban Land:	42,445 acres	12%
Water:	12,827 acres	4%
Barren Land:	2,169 acres	<1%
Total: 343,445 Acres		100%

Steep Slopes

Occurring across all of the previously mentioned land use/land cover categories are steep slopes. The benefit of mapping steep slopes lies in the ability to catalog topographic trends and to use that information in making informed land use decisions.

According to **Map 18: Slope Categories in Sussex County**, the most striking occurrence of steep slopes is along Kittatinny Mountain, and along the escarpment of Sparta, Hamburg and Wawayanda Mountains. A third area of steep slopes occurs throughout the Pochuck Mountain area of northwest Vernon Township. In these areas slopes exceed 25%, indicating a rapid elevation change over a short distance.

Slopes of 15% to 25% are less predictable throughout the county. They occur more frequently in the county’s eastern, northern and western areas, but are found throughout Sussex County.

Threatened and Endangered Species

Sussex County’s diverse topography and land use patterns provide excellent habitat for many plant and animal species. Many of the species found in the county, such as deer, game birds and several species of fish, provide abundant hunting and fishing opportunities. Other habitat types contain non-game threatened and endangered species. Certain of these species are considered to be important indicators of the overall health of the ecosystems they inhabit. Therefore, taking steps to conserve threatened and endangered species habitat will provide benefits for many other species in the county.

There are two state-maintained databases that highlight important habitat for threatened and endangered species: the Natural Heritage Database and the Landscape Project. Information from the Natural Heritage Database is used to map Natural Heritage Priority Sites which identify some of the best and most viable occurrences of endangered and threatened plant, animal and natural communities in New Jersey. These sites do not encompass all known habitat for endangered or threatened species; rather, they identify sites where rare species or natural communities are known to exist. The Landscape Project takes a somewhat broader view; it seeks to map all critical habitat for rare animal species by habitat type. These habitats are identified according to the conservation status (federal/state, endangered/threatened/of concern/suitable habitat) of species present.

Natural Heritage Priority Sites

The Natural Heritage Database (maintained by NJDEP’s Office of Land Management’s NJ Natural Heritage Program) is a continuously maintained and updated inventory which is used to identify Natural Heritage Priority Sites. In New Jersey, 389 Natural Heritage Priority Sites have been mapped, representing “...some of the best remaining habitat for rare species and exemplary natural communities in the state”⁵³. This information is intended for use by planners, developers, conservation organizations and government agencies to make informed land use decisions. Land within Natural Heritage Priority Sites is not necessarily permanently preserved, although several Priority Sites do occur within existing federal, state and local parkland.

Sussex County has one of the largest concentrations of Natural Heritage Priority Sites in New Jersey. There are a total of 77 Priority Sites in Sussex County, or roughly 20% of total Sites. The Sites in Sussex County are also among the largest geographically, indicating the extent to which the county’s natural communities are still intact.

The State has given each priority site a biodiversity ranking from B1 to B5, indicating the relative importance of that particular area. The following table defines each biodiversity ranking, and indicates the number of Natural Heritage Priority Sites in Sussex County with each particular ranking.⁵⁴

<i>Biodiversity Rank</i>	<i>Definition of Rank</i>	<i>Number in Sussex</i>
B1	Outstanding significance, the last of the least in the world	2
B2	Very high significance, most outstanding occurrence of something	6
B3	High significance, viable occurrence of globally imperiled community	17
B4	Moderate significance, viable occurrence of globally rare community	36
B5	Of general biodiversity interest	16
	<i>Total:</i>	77

According to **Map 19: Natural Heritage Priority Sites in Sussex County**, there are six large Natural Heritage Priority Sites located in the county. The Kittatinny Mountain Macrosite and High Point Macrosite occur along the Kittatinny Ridge and are largely contained in already preserved lands. The Walkkill River Macrosite, much of which falls within preserved lands, and the adjacent Papakating Creek, an unpreserved region, fall in the central valley. Wawayanda Macrosite and the adjoining Bearfort Mountain Macrosite

are located in northeastern Sussex County in the Highlands. These sites are partly contained in already preserved areas and watershed lands.

Landscape Project

The New Jersey Department of Environmental Protection's Division of Fish and Wildlife maintains a database listing endangered and threatened species in New Jersey (this information is also used by the Office of Land Management for Natural Heritage Priority Site locations). These lists are used by the Division of Fish and Wildlife to determine protection and management actions necessary to ensure the survival of the State's endangered and threatened wildlife. Endangered species are defined as those whose prospects for survival in New Jersey are in immediate danger because of a loss or change in habitat, over-exploitation, predation, competition, disease, disturbance, or contamination.⁵⁵ Threatened species are those who may become endangered if conditions surrounding them begin to, or continue to, deteriorate.⁵⁶

To better manage the state's endangered and threatened animal species, the Division of Fish and Wildlife's Endangered and Nongame Species Program, has produced 'The Landscape Project'. The Project is a Geographic Information System (GIS) mapping tool that delineates critical habitat where federal and state threatened and endangered animal species have been sighted, as well as habitat that is suitable for these species to survive but where known sightings have not occurred. Given that 'The Landscape Project' maps suitable habitat, the scope of this available data is broader than the boundaries of Natural Heritage Priority sites which map known sites only. However, 'The Landscape Project' does not include rare botanical species as Natural Heritage Priority Sites do; by using both databases together a more comprehensive overview of endangered species and the ecosystems necessary for their survival can be obtained.

The Landscape Project is publicly available and can be a useful tool for public and private organizations when decisions about prioritizing land preservation or land use are made. The goal of the project is to protect biological diversity in New Jersey, "...by maintaining and enhancing rare wildlife populations within healthy, functioning ecosystems."⁵⁷

Data from the Landscape Project may be used in a number of different ways. For example, it is possible to determine if sightings of endangered species have been made in a particular region, or it can be used to rank different regions against each other according to the conservation category of endangered species (eg. federally endangered or state threatened) located there.

To determine what kinds of endangered and threatened species exist in Sussex County, it is useful to break the county into three regions, the Kittatinny Ridge, the Kittatinny Valley and the Highlands, which, respectively, lie west to east in the county.

The largest of these areas is the Kittatinny Valley, which occupies approximately half of the county's land area. This is also the area of the county with the least amount of protected land. The landscape in this section is comprised of farm fields, wooded ridges and numerous stream corridors. The grasslands of abandoned and fallow farmland

provide excellent habitat for threatened and endangered grassland bird species, such as bobolink, Savannah sparrow, vesper sparrow and grasshopper sparrow. The edge environments afforded by agricultural landscapes also foster larger mammals, such as coyote, bobcat and deer. Despite its human-sculpted appearance, the Kittatinny Valley is a region of tremendous biological diversity.

The western and eastern margins of the county—the Kittatinny Ridge and the Highlands—are forested and mountainous. These regions harbor concentrations of forest dwelling species, such as black bear, timber rattlesnake, barred owl and the elusive bobcat. These species thrive on large, contiguous patches of habitat. Nearly the entire extent of the Kittatinny Ridge is protected by federal and state agencies. In the Highlands, however, select state parks, wildlife management areas and water supply management lands protect discontinuous patches of habitat.

The following table lists threatened and endangered species by county region.⁵⁸

<i>Endangered and Threatened Wildlife of Sussex County</i>		
Region of Sussex County		
Kittatinny Ridge	Kittatinny Valley	Highlands
Timber rattlesnake (SE)	Wood turtle (SE)	Timber rattlesnake (SE)
Wood turtle (SE)	Bog turtle (SE)	Wood turtle (SE)
Bog turtle (SE)	Bobcat (SE)	Bog turtle (SE)
Bobcat (SE)	Great blue heron (ST)	Bobcat (SE)
Red-shouldered hawk (SE, Br)	Barred owl (ST)	Red-shouldered hawk (SE, Br)
Great blue heron (ST)	Northern harrier (SE, Br)	Great blue heron (ST)
Barred owl (ST)	Cooper’s hawk (ST)	Barred owl (ST)
Northern goshawk (SE, Br)	Bobolink (ST)	Northern goshawk (SE, Br)
	Savannah sparrow (ST, Br)	Northern harrier (SE, Br)
	Vesper sparrow (ST, NB)	Bobolink (ST)
SE = State Endangered Species ST = State Threatened Species Br = Breeding Population Only NB=Non-breeding Population Only	Grasshopper Sparrow (ST, Br)	Savannah sparrow (ST, Br)
	Red-headed woodpecker (ST)	Vesper sparrow (ST, NB)
		Grasshopper sparrow (ST, Br)
		Pied-billed grebe (SE, Br)

In order to evaluate the importance of different regions according to the conservation status of species present, The Landscape Project divides critical habitat into five habitat types: forest, grassland, forested wetland, emergent wetland and beach and dune. Each type is then ranked according to the conservation status of species present. The rank of conservation status for all habitat types from highest to lowest is as follows: federally threatened and endangered species, state endangered species, state threatened species, species of special concern and suitable habitat. Therefore, it is possible to identify and map which areas of forest habitat contain federally threatened or endangered species, which contain state endangered species and so on.

Maps 20, 21, 22, & 23 identify, delineate and rank habitat type as outlined above. This information allows users to identify the locations of critical habitat for federal and state

endangered and threatened species, along with habitat for species of concern and areas that might be suitable as habitat.

Map 20: Forested Habitat for Threatened & Endangered Species in Sussex County outlines and ranks the location of critical habitat for forest dependent species. There is one large area of the highest ranking critical forest habitat for federal threatened and endangered species. This area is located in the eastern region of Sparta and the southern region of Hardyston. Much of this region is encompassed by Sparta Mountain Wildlife Management Area, the Wallkill River Preserve and Weldon Brook Wildlife Management Area.

The second highest ranking critical forest habitat for state endangered species encompasses a large portion of the county. The largest area of this ranking runs in a large swathe along the Kittatinny Ridge and falls within the Delaware Gap National Recreation Area, High Point State Park, Stokes State Forest, Flatbrook Wildlife Management Area and Walpack Wildlife Management Area. Another area of this ranking is located in eastern Vernon and Hardyston, parts of which are included within Waywayanda State Park and Hamburg Mountain Wildlife Management Area. A third area of critical habitat for state endangered species is located at the southern tip of the county, centered around Byram. A fourth area is located in western Vernon Township near the Wallkill River National Wildlife Refuge. Other smaller areas of this ranking are scattered through the Kittatinny Valley in central Sussex County.

The remaining rankings, which include state threatened species, species of special concern and areas of suitable habitat for forest dependent species are also predominantly located in the Kittatinny Valley. A significant swathe of habitat for state threatened species runs southwest from the Borough of Franklin through to Green. A further area of state threatened species is located in Hampton reaching southwest through Stillwater and Fredon. There is one small patch of species of special concern located in Fredon and areas of suitable habitat scattered throughout the valley.

Map 21: Forested Wetland Habitat for Threatened & Endangered Species in Sussex County outlines and ranks the location of critical habitat for forested wetland dependent species. There may be areas of overlap between forested habitat and forested wetland; some species are exclusively dependent on each habitat type. To generate accurate information, these habitat types are mapped separately, as is emergent wetland habitat.

There are a number of small patches of the highest ranking habitat for federally threatened and endangered species scattered throughout the county. The larger areas are located along Mill Brook in Montague and along the Flat Brook in Sandyston and Walpack. Other significant patches are located in eastern Hampton, north-central Lafayette, in Sparta and Ogdensburg and northern Hardyston.

Habitat for state endangered species is predominantly located along the eastern border of Sussex County from Vernon through Sparta. These habitats are mainly located within already preserved areas such as Wawayanda State Park, Sparta Mountain and Weldon

Brook WMA's. Smaller, more disconnected patches are scattered along the western border of the county, many within the preserved area that stretches north to south from High Point State Park to the Delaware Water Gap.

Habitat for state threatened species is also scattered however there are four large patches; the first located along the Wallkill River in Vernon, the second is associated with Crandon Lakes in Hampton, the third and fourth are along the Paulins Kill in the Andover, Hampton, Lafayette region and along the Pequest River at the Green and Fredon border respectively.

Rankings of habitat for species of special concern and suitable habitat are scattered throughout the county.

Map 22: Emergent Wetland Habitat for Threatened & Endangered Species in Sussex County outlines and ranks the location of critical habitat for herbaceous wetland dependent species. Critical emergent herbaceous wetland is predominantly associated with waterways and occurs in smaller, often contiguous patches in the eastern section of the county. Along the Pochuk Creek in central Vernon there are significant contiguous (or almost contiguous) areas of habitat for federally threatened and endangered species, state endangered, and state threatened species; some of which falls within preserved areas associated with the Appalachian Trail. Similarly, there are large areas of critical habitat for federally threatened and endangered species, state endangered, state threatened and species of special concern located along the Wallkill River within the Wallkill River WMA.

A significant habitat area for federally threatened and endangered species is located in Lafayette Township. Much of this area is located in municipally preserved open space or preserved farmland.

There are also two sizeable habitat areas for state threatened species. The first is located along the Hampton, Andover Township and Newton border; the second spans border between Fredon and Green and is encompassed within Whittingham WMA.

Habitat for species of special concern and areas of suitable habitat are scattered in smaller disconnected patches, mostly within the Kittatinny Valley and Highlands region of the county.

Map 23: Grassland Habitat for Threatened & Endangered Species in Sussex County outlines and ranks the location of critical habitat for grassland dependent species. Much of the critical grassland habitat in Sussex County is located in the Kittatinny Valley. Smaller areas are located in the Pochuk Mountain region in Vernon, with still smaller areas located along the western side of the Kittatinny Ridge.

A significant area of habitat for federally threatened and endangered species, and state endangered and state threatened species is located in Wantage. There is also a large patch of these rankings located in the center of the county, encompassing parts of

Frankford, Lafayette, Hardyston, Hampton, Andover and Sparta Townships. A smaller patch of these rankings is located in the Pochuk Creek area of central Vernon Township.

In northern Montague significant areas of habitat exists for federal threatened and endangered species and state threatened species. Similar areas can also be found in western Sandyston and Walpack Townships.

Vernal Pools

New Jersey has recently adopted legislation to protect vernal pools. These pools are “confined wetland depressions, either natural or man-made, that hold water for at least two consecutive months out of the year, and are devoid of breeding fish population....These unique ecosystems provide habitat to many species of amphibians, insects, reptiles, plants and other wildlife.”⁵⁹ As of August 2003, initial research by Rutgers University to identify the location of these special resources has found 840 sites in the Ridge and Valley geophysical region and 728 in the Highlands. Many of these sites are located in Sussex County.

Biodiversity

A report compiled in 2003 by The Nature Conservancy for the Sussex County Open Space and Recreation Plan further identifies the biodiversity enjoyed in the County. Sussex County has 29 species and communities that can be classified as globally rare. The county leads the nation in dragonfly and damselfly diversity with 142 documented species. The county also supports a high concentration of breeding birds. The Kittatinny Ridge and Delaware River serve as important routes for neotropical migrants and migrating raptors. Sussex County is home to over 160 species of birds, 72 fish species, 49 species of amphibians/reptiles, 83 butterfly species, 292 species of trees and shrubs, and 33 mammals including black bear, red fox, gray fox, bobcat and coyote.⁶⁰

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- ¹ Traylor, Donna. personal communication. March 2003; New Jersey Department of Environmental Protection (NJDEP). “1995/97 Landuse/Landcover by Watershed Management Area”. <http://www.state.nj.us/dep/gis/>. Accessed: January – June 2003..
- ² United States Forest Service. *New York – New Jersey Highlands Regional Study: 2002 Update*. Newtown Square, PA: 2002.
- ³ Lucey, Carol S. *Geology of Sussex County in Brief*. Trenton, NJ: New Jersey Department of Environmental Protection, 1978.
- ⁴ Widmer, Kemble. *The Geology and Geography of New Jersey*. Princeton, NJ: D. Van Nostrand Company, Inc., 1964.
- ⁵ New Jersey Geological Survey. “Geologic Map of New Jersey.” 2001.
- ⁶ Stanford and Richard A. Volkert. Brochure: “*Geology of the New Jersey Highlands*.” Trenton, NJ: New Jersey Geological Survey, 1994.
- ⁷ Witte, Ron W. and Don H. Monteverde. “*Geology and Scenery of High Point State Park, Sussex County, New Jersey and Field Trip Guide*.” Trenton, NJ: New Jersey Geological Survey.
- ⁸ Volkert, Richard A. “*A Geologic Excursion Through the New Jersey Highlands*”. Sterling Hill Mining Museum Newsletter, Fall/Winter 2001. Vol. 10, No. 2. pp. 20-22.
- ⁹ Stanford and Richard A. Volkert. Brochure: “*Geology of the New Jersey Highlands*.” Trenton, NJ: New Jersey Geological Survey, 1994.
- ¹⁰ New Jersey Geological Survey. “Geologic Map of New Jersey.” 2001.
- ¹¹ Stansfield, Charles A., Jr. *A Geography of New Jersey*. New Brunswick, NJ: Rutgers University Press, 1998.
- ¹² Widmer, Kemble. *The Geology and Geography of New Jersey*. Princeton, NJ: D. Van Nostrand Company, Inc., 1964.
- ¹³ Witte, Ron W. and Don H. Monteverde. “*Geology and Scenery of High Point State Park, Sussex County, New Jersey and Field Trip Guide*.” Trenton, NJ: New Jersey Geological Survey.
- ¹⁴ New Jersey Geological Survey. “Geologic Map of New Jersey.” 2001.
- ¹⁵ Lucey, Carol S. *Geology of Sussex County in Brief*. Trenton, NJ: New Jersey Department of Environmental Protection, 1978.
- ¹⁶ New Jersey Geological Survey. “Geologic Map of New Jersey.” 2001.
- ¹⁷ Widmer, Kemble. *The Geology and Geography of New Jersey*. Princeton, NJ: D. Van Nostrand Company, Inc., 1964.
- ¹⁸ Lucey, Carol S. *Geology of Sussex County in Brief*. Trenton, NJ: New Jersey Department of Environmental Protection, 1978.

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- ¹⁹ Press, Raymond Siever. *Understanding Earth*. New York: W. H. Freeman and Company, 2001.
- ²⁰ Judson, S., and Kauffman, M.E. *Physical Geology, 8th edition*. Englewood Cliffs, NJ: Prentice Hall, 1990.
- ²¹ Witte, Ron W. Information Circular: “*Glacial Sediment and the Ice Age in New Jersey*.” New Jersey Geological Survey, 1998.
- ²² Stanford and Richard A. Volkert. Brochure: “*Geology of the New Jersey Highlands*.” Trenton, NJ: New Jersey Geological Survey, 1994.
- ²³ Volkert, Richard A. “*A Geologic Excursion Through the New Jersey Highlands*”. Sterling Hill Mining Museum Newsletter, Fall/Winter 2001. Vol. 10, No. 2. pp. 20-22.
- ²⁴ Witte, Ron W. “Late Wisconsinan Glacial History of the Upper Part of Kittatinny Valley, Sussex and Warren Counties, New Jersey.” *Northeastern Geology and Environmental Sciences*, 1997. 19, pp. 155-169.
- ²⁵ Witte, Ron W. “Late Wisconsinan Glacial History of the Upper Part of Kittatinny Valley, Sussex and Warren Counties, New Jersey.” *Northeastern Geology and Environmental Sciences*, 1997. 19, pp. 155-169.
- ²⁶ Lenik, Edward J. *Iron Mine Trails*. New York: New York–New Jersey Trail Conference, 1996.
- ²⁷ Cummings, Warren D. *Sussex County: A History*. Newton, NJ: Rotary Club of Newton, 1964.
- ²⁸ Wolfe, Peter E. *Geology and Landscapes of New Jersey*. New York City, NY: Crane Russak, 1977.
- ²⁹ Lucey, Carol S. *Geology of Sussex County in Brief*. Trenton, NJ: New Jersey Department of Environmental Protection, 1978.
- ³⁰ Volkert, Richard A. New Jersey Geological Survey, personal communication. February 2003.
- ³¹ New Jersey Department of Environmental Protection. *Surface Water Quality Standards (N.J.A.C. 7:9B)*. 2003.
- ³² New Jersey Department of Environmental Protection. *Surface Water Quality Standards (N.J.A.C.7:9B)*. 2003, p. 3.
- ³³ New Jersey Department of Environmental Protection. *Surface Water Quality Standards (N.J.A.C. 7:9B)*. 2003.
- ³⁴ New Jersey Department of Environmental Protection. *Surface Water Quality Standards (N.J.A.C.7:9B)*. 2003, p. 10.
- ³⁵ Hammond, Debra. Bureau of Water Quality Standards and Assessment, personal communication. June 4, 2003.
- ³⁶ Delaware River Basin Commission (DRBC). “DRBC Overview”. <http://www.state.nj.us/drbc/over.htm>. Accessed June 23, 2003.
- ³⁷ DRBC. “The Delaware River Basin”. <http://www.state.nj.us/drbc/thedrb.htm>. Accessed June 23, 2003.
- ³⁸ United States Department of Agriculture, Soil Conservation Service. *Soil Survey of Sussex, New Jersey*.

New Jersey Agricultural Experiment Station and Cook College, Rutgers University, 1970. page 115.

- ³⁹ New Jersey Department of Environmental Protection (NJDEP). “1995/97 Landuse/Landcover by Watershed Management Area”. <http://www.state.nj.us/dep/gis/>. Accessed January – June 2003.
- ⁴⁰ New Jersey Department of Environmental Protection (NJDEP). “1995/97 Landuse/Landcover by Watershed Management Area”. <http://www.state.nj.us/dep/gis/>. Accessed January – June 2003.
- ⁴¹ New Jersey Department of Environmental Protection (NJDEP). “1995/97 Landuse/Landcover by Watershed Management Area”. <http://www.state.nj.us/dep/gis/>. Accessed January – June 2003.
- ⁴² Widmann, Richard H. *Trends in New Jersey Forests*. Newtown Square, PA: United States Forest Service, 2002.
- ⁴³ Ridge and Valley Conservancy. “Limestone Forest Preserve”. <http://www.rvlandtrust.org>. Accessed March 10, 2003.
- ⁴⁴ New Jersey Department of Environmental Protection (NJDEP). “1995/97 Landuse/Landcover by Watershed Management Area”. <http://www.state.nj.us/dep/gis/>. Accessed January – June 2003.
- ⁴⁵ New Jersey Department of Environmental Protection (NJDEP). “1995/97 Landuse/Landcover by Watershed Management Area”. <http://www.state.nj.us/dep/gis/>. Accessed January – June 2003.
- ⁴⁶ Canace, Bob. Personal communication. April 2003.
- ⁴⁷ Canace, Bob. Personal communication. April 2003.
- ⁴⁸ New Jersey Department of Environmental Protection (NJDEP). “1995/97 Landuse/Landcover by Watershed Management Area”. <http://www.state.nj.us/dep/gis/>. Accessed January – June 2003.
- ⁴⁹ New Jersey Department of Agriculture (NJDOA) “New Jersey Farmland Data Report- Tax Year 2002- State Summary” January 2003.
- ⁵⁰ New Jersey Department of Environmental Protection (NJDEP). “1995/97 Landuse/Landcover by Watershed Management Area”. <http://www.state.nj.us/dep/gis/>. Accessed January – June 2003.
- ⁵¹ New Jersey Department of Environmental Protection (NJDEP). “1995/97 Landuse/Landcover by Watershed Management Area”. <http://www.state.nj.us/dep/gis/>. Accessed January – June 2003.
- ⁵² New Jersey Department of Environmental Protection (NJDEP). “1995/97 Landuse/Landcover by Watershed Management Area”. <http://www.state.nj.us/dep/gis/>. Accessed January – June 2003.
- ⁵³ New Jersey Department of Environmental Protection. *Atlas of Natural Heritage Priority Sites*. 1999.
- ⁵⁴ New Jersey Department of Environmental Protection. *Atlas of Natural Heritage Priority Sites*. 1999.
- ⁵⁵ New Jersey Division of Fish and Wildlife. “Endangered and Threatened Wildlife of New Jersey.” <http://www.state.nj.us/dep/fgw/tandespp.htm>. Accessed January - June 2003.
- ⁵⁶ New Jersey Division of Fish and Wildlife. “Endangered and Threatened Wildlife of New Jersey.” <http://www.state.nj.us/dep/fgw/tandespp.htm>. Accessed January - June 2003.
- ⁵⁷ New Jersey Division of Fish and Wildlife. “The Landscape Project.” 2002.

⁵⁸ New Jersey Division of Fish and Wildlife. “The Landscape Project.” 2002.

⁵⁹ “New Jersey’s Vernal Pools” by Jason Tesauro. Report available from <http://www.dberssa.rutgers.edu/im/vernal> accessed in August 2003, page 1.

⁶⁰ “Sussex County Biodiversity,” a report by Michael Van Clef, Director of Science & Stewardship, The Nature Conservancy, Skylands Regional Office, submitted to Morris Land Conservancy for the Sussex County Open Space and Recreation Plan, May 2003.