The Natural Resource Inventory of Dutchess County, NY

November 2010

A Collaborative Project of:
Cornell Cooperative Extension Dutchess County (CCEDC) Environment and Energy Program
Cary Institute of Ecosystem Studies
Dutchess County Department of Planning and Development
Dutchess County Environmental Management Council (EMC)
Vassar College Environmental Research Institute

Cornell University Cooperative Extension Dutchess County
Dutchess County Department of Planning and Development
Vassar College Environmental Research Institute
Cary Institute of Ecosystem Studies

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Acknowledgements

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Chapter 1:
Introduction to the Natural Resource Inventory of Dutchess County, NY

Emily Vail, Neil Curri, Allison Chatrchyan, and Patrick Carroll[1]
November 2010

DEFINITION AND PURPOSE

Chapter Contents

Dutchess County, New York has a rich natural heritage that has enabled its communities to prosper and grow, and has contributed to a high quality of life for its residents. Diverse habitats, productive farmland, abundant water resources, and scenic landscapes are all distinctive characteristics of the region that have attracted new residents and have helped foster a strong sense of place.

Natural resources consist of living things and naturally occurring materials in the environment that sustain human life and economies. Natural resources include but are not limited to air, minerals, soils, sources of energy, water, fish, wildlife, and forests.

[1] This chapter was compiled from 2009 to 2010 by staff and interns of the Cornell Cooperative Extension Dutchess County (CCEDC) Environment Program. It is an updated and expanded version of the introductory chapter of the 1985 document, *Natural Resources, Dutchess County, New York* (NRI).

A natural resource inventory (NRI) is a document that catalogues the physical and biological characteristics of an area, collects the data in a usable format, and interprets the findings. An NRI can serve as a planning and project review tool for municipalities at the local level, as well as a tool for county or regional planning and project assessment (Ashton, Blair, & Kendall, 1997). A better understanding of natural resources enables communities to conserve its natural resources for current and future generations.

New York State Environmental Conservation Law (ECL) Article 47 on County and Regional Environmental Management Councils mandates the Dutchess County Environmental Management Council (DCEMC) to maintain an accurate inventory of natural resources of the county.[2] The DCEMC, in coordination with the Dutchess County Department of Planning and Development, first published a natural resource inventory in 1985 and made it available to municipal boards and conservation advisory councils (CACs) to inform local decision-making. The DCEMC also used the NRI as an educational tool, providing copies to schools and residents and developing NRI curriculum and presentations.

This document is an updated and expanded version of the 1985 natural resource inventory. It contains new information about Dutchess County's natural resources, including geographic information and references to research findings.

COUNTY PROFILE

This inventory describes the natural resources of Dutchess County, New York. Dutchess County is centrally located within the Hudson Valley region and is bordered by Connecticut to the east, Putnam County to the south, Columbia County to the north, and Orange and Ulster Counties across the Hudson River to the west. It covers approximately 801.6 square miles, including 20 square miles of the Hudson River.

[2] According to NYS ECL § 47-0107, "The council shall develop and maintain an inventory of natural resources within the county and such other environmental information as may be appropriate. Said inventory shall include wetlands and open spaces and may include, but not be limited to, factors relating to geology, soils, slope, water resources, vegetation, wildlife habitat, unique natural areas, and scenic, historic, and archaeological sites."

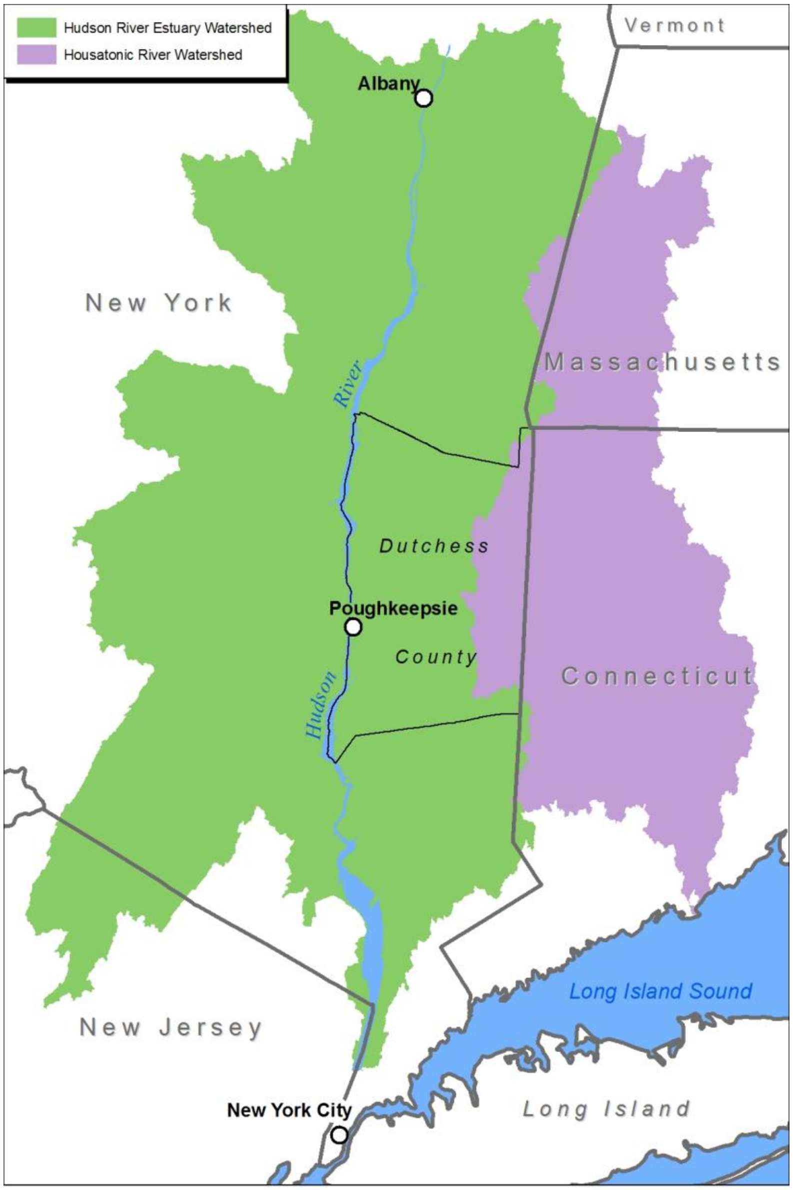


Figure 1.1: Dutchess County, New York and environs

The county seat is the City of Poughkeepsie, located on the shore of the Hudson River. Poughkeepsie is approximately equidistant from Albany and New York City. Most of the county lies within the watershed of the Hudson River Estuary, which extends 153 miles from Troy to New York Harbor (Figure 1.1). The eastern portion of the county lies in the Tenmile River watershed, which is part of the Housatonic River watershed in Connecticut (for more information, see NRI Chapter 5: Water Resources.)

The 2009 population estimate for Dutchess County, New York is 293,562 (U.S. Census Bureau, 2010). The population of the county has undergone a tremendous increase over the 20th century, especially over the last fifty years. Between 1790 and 1900 the population fell short of doubling in size, while between 1900 and 2008 the population increased over 3.5 times (Figure 1.2).

Most of the county's residents live along the Hudson River; the Route 9, Route 44 and Route 55 corridors; or in pockets of more dense settlements such as village hamlets (Figure 1.3). Approximately 75 percent of the population of the county lives in the southwest region of Dutchess County, including the cities of Beacon and Poughkeepsie, the villages of Fishkill and Wappingers Falls, and the towns of Beekman, East Fishkill, Fishkill, Hyde Park, LaGrange, Poughkeepsie, and Wappinger (Table 1.1). Several municipalities in Dutchess County have seen increasing urban and suburban development over time due to population growth and conventional development strategies.

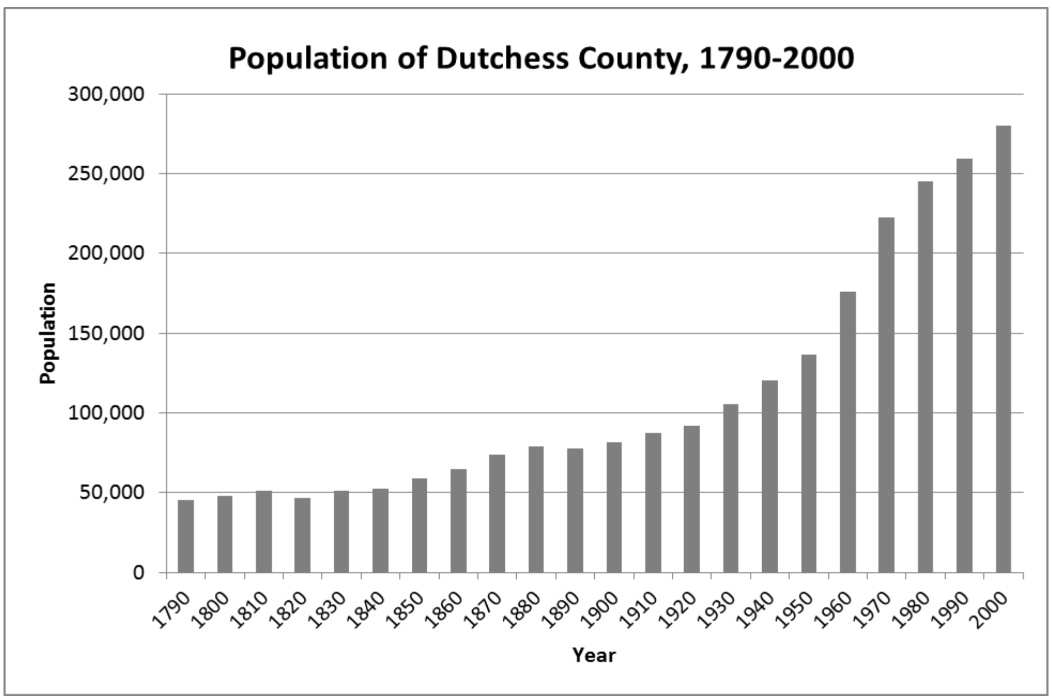


Figure 1.2: Population Growth in Dutchess County from 1790-2008 (from U.S. Census Bureau).

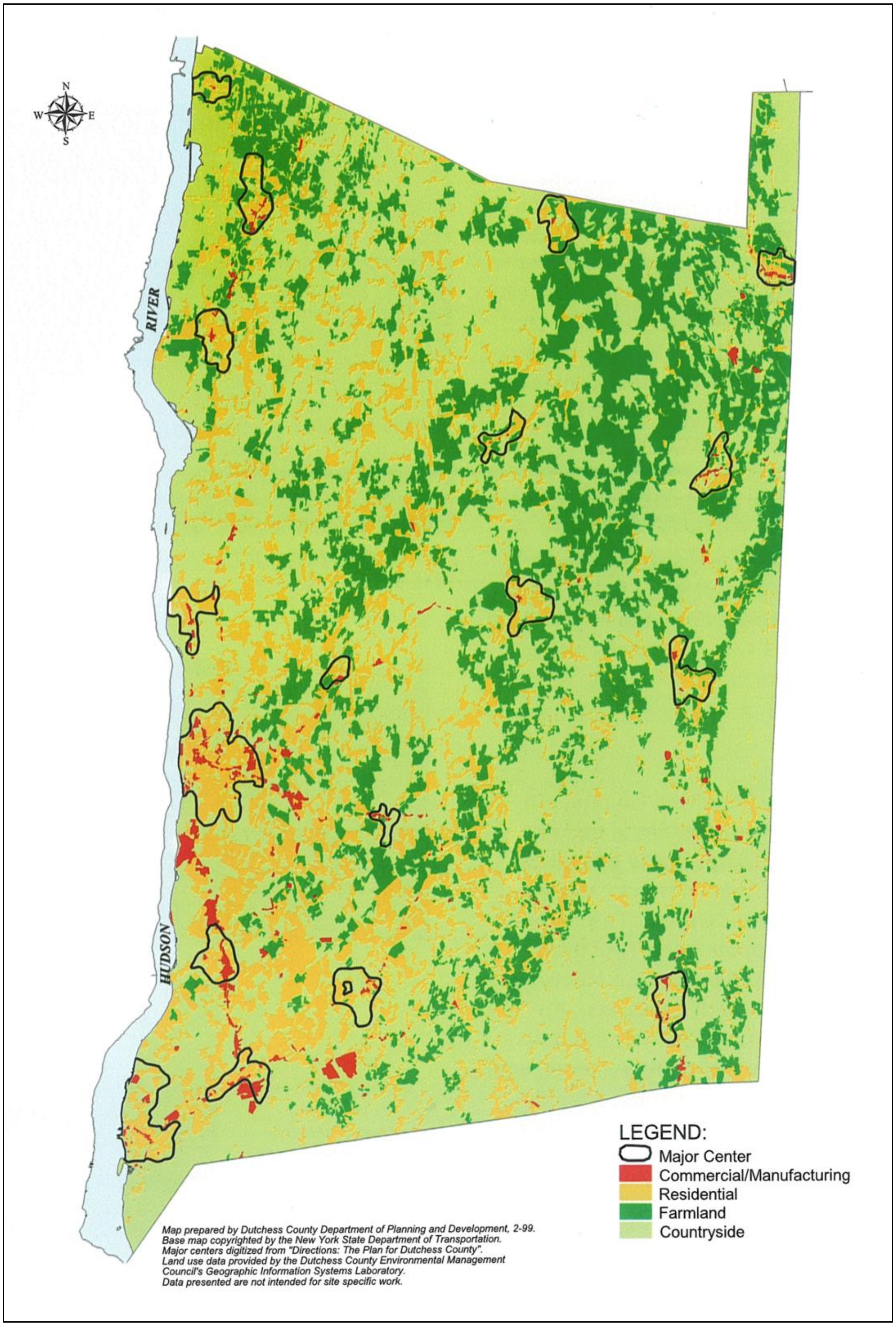


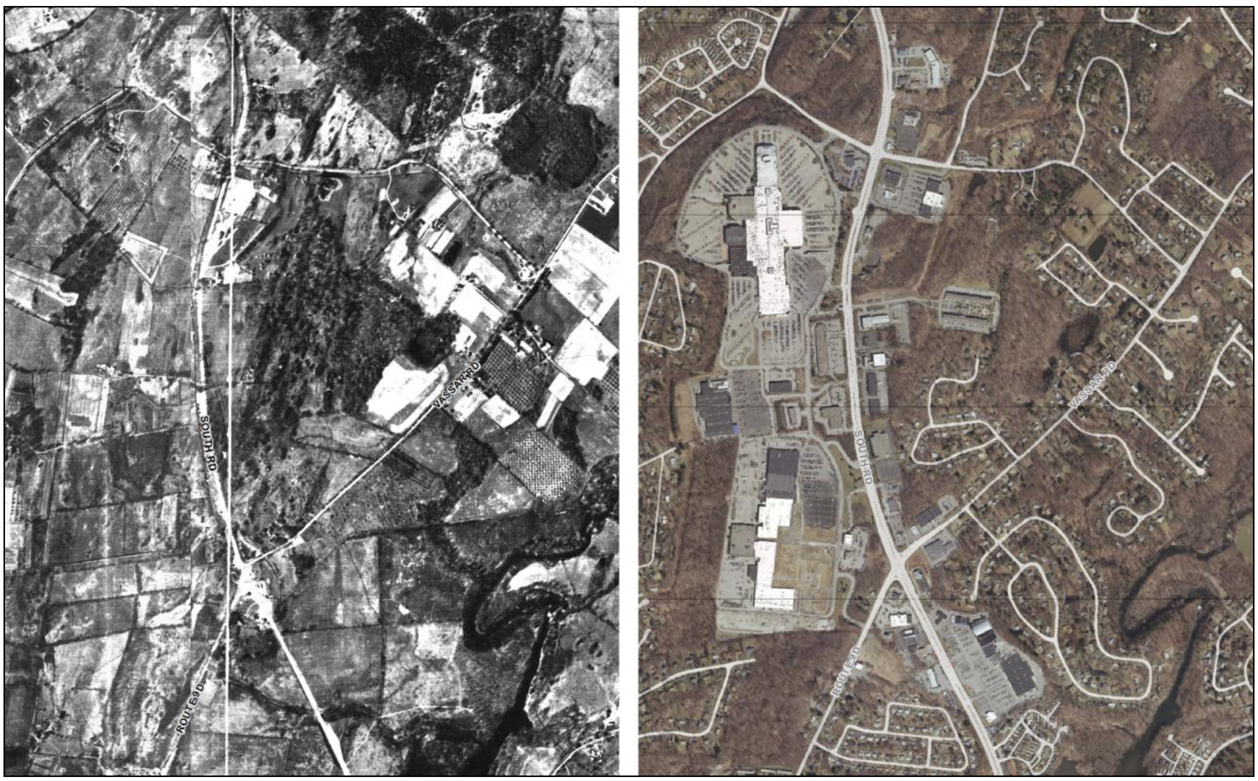
Figure 1.3: Settlement Patterns in Dutchess County (DCDPD, 2000).

Table 1.1: Change in Population of Dutchess County municipalities (Dutchess County Department of Planning and Development, 2010)

	1990	2000	Number	Percent
Dutchess County	259,462	280,150	20,688	7.97%
City of Beacon	13,243	13,808	565	4.27%
City of Poughkeepsie	28,844	29,871	1,027	3.56%
Town of Amenia	5,195	4,048	-1,147	-22.08%
Town of Beekman	10,447	13,655	3,208	30.71%
Town of Clinton	3,760	4,010	250	6.65%
Town of Dover	7,778	8,565	787	10.12%
Town of East Fishkill	22,101	25,589	3,488	15.78%
Town of Fishkill	15,698	18,523	2,825	18.00%
Town of Hyde Park	21,230	20,851	-379	-1.79%
Town of La Grange	13,274	14,928	1,654	12.46%
Town of Milan	1,895	2,356	461	24.33%
Town of North East	2,034	2,077	43	2.11%
Town of Pawling	3,973	5,288	1,315	33.10%
Town of Pine Plains	2,287	2,569	282	12.33%
Town of Pleasant Valley	8,063	9,066	1,003	12.44%
Town of Poughkeepsie	40,143	42,777	2,634	6.56%
Town of Red Hook	6,736	7,440	704	10.45%
Town of Rhinebeck	4,833	4,685	-148	-3.06%
Town of Stanford	3,495	3,544	49	1.40%
Town of Union Vale	3,577	4,546	969	27.09%
Town of Wappinger	22,292	22,322	30	0.13%
Town of Washington	3,140	3,313	173	5.51%
Village of Fishkill	1,957	1,735	-222	-11.34%
Village of Millbrook	1,339	1,429	90	6.72%
Village of Millerton	884	925	41	4.64%
Village of Pawling	1,974	2,233	259	13.12%
Village of Red Hook	1,794	1,805	11	0.61%
Village of Rhinebeck	2,737	3,077	340	12.42%
Village of Tivoli	1,035	1,163	128	12.37%
Village of Wappingers Falls				
Poughkeepsie	889	977	88	9.90%
Wappinger	3,716	3,952	236	6.35%

Source: U.S. Census Bureau

Dutchess County has also seen substantial changes in land use. Aerial photographs of Dutchess County from the 1930s show that majority of land was used for farming, with small hamlets and town centers (DCDPD, 2000) (Figure 1.3). Since the 1950s there has been a large shift from agriculture to suburban development, as many former farm fields have been sub-divided for use as housing and commercial developments (DCDPD, 2000). The most recent aerial photographs show in some cases dramatic land use conversion, such as along the Route 9 corridor in southern Dutchess County (Figure 1.4).



1936 **2009**

Figure 1.4: Land use changes in Dutchess County as seen in aerial photographs from 1936 to 2009.

KEY CONCEPTS

Ecosystems

An **ecosystem** is a biological community plus all of the non-living factors influencing that community (Molles, 2002). Together, the living and non-living components of ecosystems form one physical system, exchanging energy, water, and nutrients. For example, in a forest ecosystem, trees grow by incorporating water and nutrients from the soil and carbon dioxide from the air. When the trees drop their leaves in the fall, microorganisms and other decomposers break the material down. This can affect the availability of nutrients in the soil, which in turn can impact plant productivity, species composition, and many other factors. The quality and availability of soil, water, and air all play a role in how a forest ecosystem functions, as does the presence of other species including vegetation and wildlife.

Ecosystems can be as small as a community of microorganisms in a teaspoon of soil, or as large as the entire planet Earth, which is itself one whole ecosystem of interconnected living and non-living things. The size and complexity of ecosystems varies according to the scale at which we observe them. To aid in the development of conservation practices and policies at several scales, from national or continental to state and regional, scientists and policymakers group areas with similar ecosystems into **ecological regions**. At the most broad scale, Dutchess County is located within the eastern temperate forest ecological region (CEC, 1997), distinguished by its moderate to mildly humid climate, its relatively dense and diverse forest cover, and its high density of human inhabitants; this region includes most of the land from the Great Lakes to the Gulf of Mexico, from the Mississippi River to the Atlantic Ocean (CEC, 1997). At more local scales, topographic and rainfall patterns within different parts of Dutchess County support different types of vegetation and wildlife communities. For example, north-facing slopes and steeply sloping ravines support northern temperate forest tree species (such as hemlock, maple, beech, birch) while in lowland areas of the County one might find forests dominated more by oak and other Appalachian oak-hickory forests.

Interactions within ecosystems are affected by the geologic setting in which they occur. Geologic processes determine topography, soil structure, and the distribution and availability of water; these underlying conditions vary across the landscape, supporting different types of ecological communities. For example, some geological formations in Dutchess County create conditions that provide habitat for rare and unique species. These communities are discussed in more detail in NRI Chapter 6: Biological Resources and Biodiversity.

Ecosystem Services

Ecosystem processes provide clean water, clean air, sources of food, recreational resources, and other benefits to humans. The functions performed by ecosystems that directly or indirectly benefit humans are called **ecosystem services** (Campbell & Reece, 2007). These benefits include **provisioning services** such as food, water, timber, fiber, and other natural resources; **regulating services** that affect climate, floods, disease, wastes, and water quality; **cultural services** that provide recreational, aesthetic, and spiritual benefits; and **supporting services** such as soil formation (Millennium Ecosystem Assessment, 2005) (Figure 1.5).

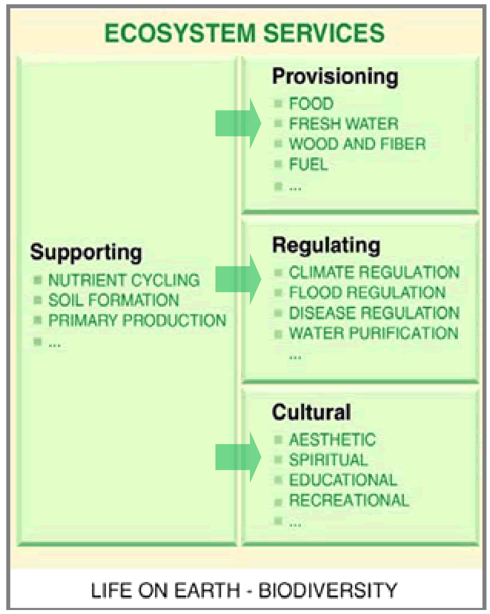


Figure 1.5: Types of ecosystem services; each has close ties to aspects of human well-being (from Millennium Ecosystem Assessment, 2005).

These services have many linkages to human well-being. They provide the basic materials for life, including food, shelter, and livelihoods (Millennium Ecosystem Assessment, 2005). Healthy ecosystems offer security and stability, in part through access to resources, which in turn contributes to healthy social relations (Millennium Ecosystem Assessment, 2005). In addition, they benefit physical health by providing clean air, clean water, and other resources (Millennium Ecosystem Assessment, 2005).

It is important to understand how ecosystems function, especially to avoid sacrificing the ecosystem services on which we depend. Because components of ecosystems are interconnected, and these relationships may be complex, changes made to one part can have an impact on others. Conserving healthy, functioning ecosystems is essential to ensure that they continue to provide us with these invaluable services over time.

Sustainable Development

Sustainable development is development that "meets the needs of the present without compromising the ability of future generations to meet their own needs" (UN WCSD Brundtland Report, 1987). The actions that we take now may impact ecosystem services and natural resources in the future in either positive or negative ways. We must be proactive in planning for sustainability and recognize that the resources we currently have should not be taken for granted.

The extent and character of natural resources can impose limitations on land use and development. For example, while they may provide scenic views, steep slopes are often unsuitable for housing developments. Rich, low-lying land may be ideal for agricultural use, but may also be located within a floodplain, making it a poor choice for a building site. Groundwater is a key resource that can become contaminated or depleted if surrounding development is not properly managed. Many of the natural resources upon which we depend, including soil and groundwater, are not easily or quickly replaced once they have been depleted or degraded.

In addition to physical or engineering constraints, the goal of conserving ecosystem services can also present certain constraints. These are often "hidden" costs that appear in the long term, but it is crucial that we take them into consideration. For example, wetlands provide a number of ecosystem services, including groundwater recharge, filtering pollutants, and wildlife habitat. Activities such as filling and draining wetlands or impacts from surrounding land use practices can degrade those ecosystem services. However, by avoiding or mitigating impacts to wetlands through sustainable development practices, we can help maintain the ecosystem services wetlands provide.

The consequences of ignoring limiting characteristics and improperly using land resources through unsustainable practices are readily apparent. Fortunately, there are more sustainable alternatives, and informed decision-making can help us make the most of our natural resources now and for the future.

Sprawl and Smart Growth

Increasing **sprawl** – spread-out, automobile dependent development – has become a concern nationally and within Dutchess County (DCDPD, 2000; Stone, 2005). As our population has grown, many people have moved away from rural areas and city centers towards developments in outlying open areas. Sprawl is characterized by low-density residential and commercial areas extending far out of traditional settlement areas, and is often the result of poor or no land-use planning. Sprawl can cause many problems, including loss of a sense of place, habitat loss, threats to farmland, increased costs of services to local governments, and health impacts (DCPDD, 2000; Frumkin, 2002; EPA, 2001).

Sprawl patterns in Dutchess County are associated with the major transportation routes, such as Route 9, Route 44, Route 55, Route 52 and Interstate 84. Extensive commercial and residential development can be found along, and spread out from, each of these transportation corridors. Planners have become increasingly aware of the problems associated with sprawl, adopting or encouraging sustainable development practices such as **smart growth** (EPA, 2004; Stone, 2005). Smart growth includes focusing development in traditional settlement areas, taking advantage of existing infrastructure, maintaining open space, implementing zoning laws which allow for multiple uses within buildings and neighborhoods, and providing access to mass transit (EPA, 2004; Dutchess County Planning and Development, 2000). Examples of how to implement smart growth principles can be found in the Dutchess County *Greenway Compact Program and Guides for Dutchess County Communities*.

Climate Change

Climate change is a critical challenge that is already affecting human beings and the natural resources upon which we rely, both globally and locally. Climate change refers to major changes in temperature, rainfall, snow, or wind patterns lasting for decades or longer (USEPA, 2010). The International Panel on Climate Change (IPCC), an international body of scientists working through the United Nations, has concluded that the earth's climate is changing much more rapidly than ever before, and this change is very likely caused by the increase in atmospheric concentrations of greenhouse gases (GHGs) emitted by humans (IPCC, 2007).

Climatic changes are already occurring, on both a global and local scale. Since 1970, average temperature in the northeastern United States has increased by 2 degrees Fahrenheit, with winter temperatures rising twice this much (Global Climate Change Impacts, 2009). Even if humans reduce our emissions of greenhouse gases into the future, the climate of Dutchess County will continue to change, with predictions of higher average annual temperatures, decreased snowfall, and increases in extreme precipitation, punctuated by longer periods of dry conditions (Global Climate Change Impacts, 2009). These changes will have a profound effect on our water resources, soils, air quality, and biological resources. For further detail on how climate change will affect the climate and ecosystems in Dutchess County, see NRI Chapter 2: Climate and Air Quality. As local municipal officials plan for future land use and infrastructure, it will be increasingly important to consider scientifically based projections of climatic change in the northeastern United States and Hudson Valley region.

Summary

Ecosystems are dynamic communities that provide clean water, clean air, sources of food, recreational resources, and other invaluable services to humans, as well as having their own intrinsic value. As community members and elected and appointed officials at the local level, in whose control local land use planning decisions lie, it is important to recognize the impact our growth patterns can have on ecosystem functions and to consider sustainable development or smart growth alternatives. Officials should also begin to consider the short and long-term effects of climate change as they start planning to help their communities adapt to climate change and help ecosystems become more resilient. Local decision-makers should keep all of these concepts in mind in order to help communities utilize natural resources in a sustainable fashion, while at the same time preserving their quality, value, diversity, and abundance.

HOW TO USE THIS GUIDE

The Natural Resource Inventory of Dutchess County, NY (NRI) is an important tool for locally elected and appointed officials, educators, and the general public. The NRI is intended to be used as an advisory document for officials involved with land use and natural resource planning to make more informed decisions. We encourage elected and appointed officials, including planning and zoning boards, Conservation Advisory Councils or Boards, and the Environmental Management Council, to refer to this document as they consider the value of natural resources in their communities. The public can use the NRI to help inform them of their surrounding environment and local educators can use the document to create locally relevant lesson plans about the local environment.

Communities can use the NRI as a decision-making tool to:

- Develop a set of goals and strategies for natural resource conservation and management;
- Assess existing conditions, such as the current pattern of development and distribution of open space;
- Provide a baseline of information to assess the environmental impacts of proposed activities;
- Identify critical areas for conservation, such as wetlands, floodplains, or prime aquifer recharge areas;
- Identify threats to natural resources and plan for conservation and mitigation;
- Develop comprehensive plans that incorporate natural resource conservation; and
- Inform natural resource conservation policies, such as planning and zoning board procedures, zoning law, and ordinances.

The Natural Resource Inventory of Dutchess County, NY is formatted as an electronic document, available for download on the Dutchess County Planning and Development Department website. Periodic updates will be made as budgets and time allow. The maps and data provided in the NRI are not a substitute for site-specific studies; municipal-level or parcel-level issues may need to be examined on a site-specific basis. Municipalities may have their own natural resource inventories upon which to draw. For a more detailed discussion on the implications of the natural resource inventory for local land use decision-making, see NRI Chapter 9: Implications for Decision-Making.

OUTLINE OF THE INVENTORY

This Natural Resource Inventory includes descriptions of the major resources of Dutchess County: Climate and Air, Geology and Topography, Soils, Water Resources, Biological Resources and Biodiversity, Designated Significant and Protected Areas, Geospatial Resources, and Implications for Decision-Making. Each chapter follows a similar structure, including information on the current state of the resource; its value, classification, and regulation; trends and changes seen over time; implications for decision-making; resources for additional information; and references.

RESOURCES FOR ADDITIONAL INFORMATION

- **Dutchess County Department of Planning & Development** website: http://www.co.dutchess.ny.us/CountyGov/Departments/Planning/16138.htm

- **Minnesota Department of Natural Resources**, "Natural Resource Guide: A guide to Using Natural Resource Information in Local Planning": http://files.dnr.state.mn.us/assistance/nrplanning/community/nrig/fullguide/overview.html

- **1000 Friends of Minnesota**, "Conservation Design Scorecard": http://www.1000fom.org/sites/default/files/ConservationDesignScorecard1000FOM.pdf

- **New York, Smart Growth Communities**: http://smartgrowthny.org/

- **Pace University, Land Use Law Center**, dedicated to fostering the development of sustainable communities and regions through the promotion of innovative land use strategies and dispute resolution techniques: http://web.pace.edu/page.cfm?doc_id=23239

- **United States Environmental Protection Agency: Sustainability Program**, including information on ecosystem services, and water resources: http://www.epa.gov/sustainability/

- **New York State Hudson River Valley Greenway**
  - Community Planning Guide: http://www.hudsongreenway.state.ny.us/commcoun/commplnguide2ndedition.pdf
  - Hudson River Valley Greenway Compact Benefits: http://www.hudsongreenway.state.ny.us/commcoun/commbene.htm

REFERENCES

Ashton, James, Michael Blair and Barbara Kendall. "Natural Resource Inventory: A Guide to the Process." Ulster County Environmental Management Council, Dutchess County Environmental Management Council, Cornell Cooperative Extension Dutchess County, August 1997.

Campbell, Neil A. and Jane B. Reece. *Biology, 8th Edition*. San Francisco, CA: Benjamin Cummings, 2007.

Commission for Environmental Cooperation (CEC). "Ecological Regions of North America: Toward a Common Perspective." ISBN 2-922305-18-X. Montreal, Quebec, Canada, 1997.

Dutchess County Department of Planning and Development. "Greenway Connections: Greenway Compact Program and Guides for Dutchess County Communities." Poughkeepsie, NY, 2000.

Dutchess County Department of Planning and Development. "Population at a Glance." Accessed November 3, 2010.

Environmental Protection Agency (EPA). 2004. *Protecting Water Resources with Smart Growth*. EPA 231-R-04-002. Washington, DC, 2004.

Frumkin, Howard. "Urban Sprawl and Public Health." Atlanta, GA: Centers for Disease Control and Prevention. Public Health Reports 117 (2002).

Karl, Thomas R., Jerry M. Melillo and Thomas C. Peterson, eds. *Global Climate Change Impacts in the United States*. New York, NY: Cambridge University Press, 2009.

Molles, Manuel. *Ecology: Concepts and Applications, 2nd Edition*. New York, NY: McGraw-Hill, 2002.

NYS Environmental Conservation Law. ECL § 47-0107. "County and Regional Environmental Management Councils."

Stone, Jeremy, Ed. "Breaking Ground: Planning and Building in Priority Growth Districts." White Plains, NY: Land Use Law Center, Pace University School of Law and Yale School of Forestry and Environmental Studies, 2005.

United Nations World Commission on Environment and Development (WCED). "Report of the World Commission on Environment and Development." 1987.

United States Environmental Protection Agency. "Sustainable Communities." Washington, DC: EPA 843-F-01-002k, 2001.

United States Environmental Protection Agency. "Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990 – 2008." Washington, DC: EPA 430-R-10-006, 2010 (accessed 21 October 2010)

Millennium Ecosystem Assessment. *Ecosystems and Human Well-being: General Synthesis*. Washington, DC: Island Press, 2005.

Chapter 2:

Climate and Air Quality of Dutchess County, NY

Jase Bernhardt, Victoria Kelly, Allison Chatrchyan, and Art DeGaetano[1]
Written October 2008. Revised October 2010.

INTRODUCTION TO CLIMATE

Climate is the synthesis of long-term weather patterns in a given area. Temperature, wind, humidity, precipitation, and other climatic factors continually shape our lives and the environment. Climatic factors also continually shape the land and water resources and their uses. Climate is distinguished from weather based on the measure of time; weather refers to the day-to-day state of the atmosphere in a region, while climate is how the atmosphere behaves over relatively long periods of time.

Chapter Contents

[1] This chapter was compiled during the summer of 2008 and revised in 2010 by Jase Bernhardt (Cornell University student and Cornell Cooperative Extension Dutchess County summer 2008 intern), Victoria Kelly (Cary Institute of Ecosystem Studies), Allison Chatrchyan (Cornell Cooperative Extension Dutchess County), and Art DeGaetano (Cornell University and Director of the Northeast Regional Climate Center), with input from the NRI Steering Committee. The document was reviewed by John DeGilio (Dutchess County EMC), Scott Chase (Dutchess County Planning and Development), Steve Dirienzo (Service Hydrologist at the Albany National Weather Service Office), and Gary Lovett (Cary Institute of Ecosystem Studies). It is an updated and expanded version of the climate chapter of the 1985 document *Natural Resources, Dutchess County, NY* (NRI).

Dutchess County is located in the northern portion of the temperate climate zone, as shown below in Figure 2.1.

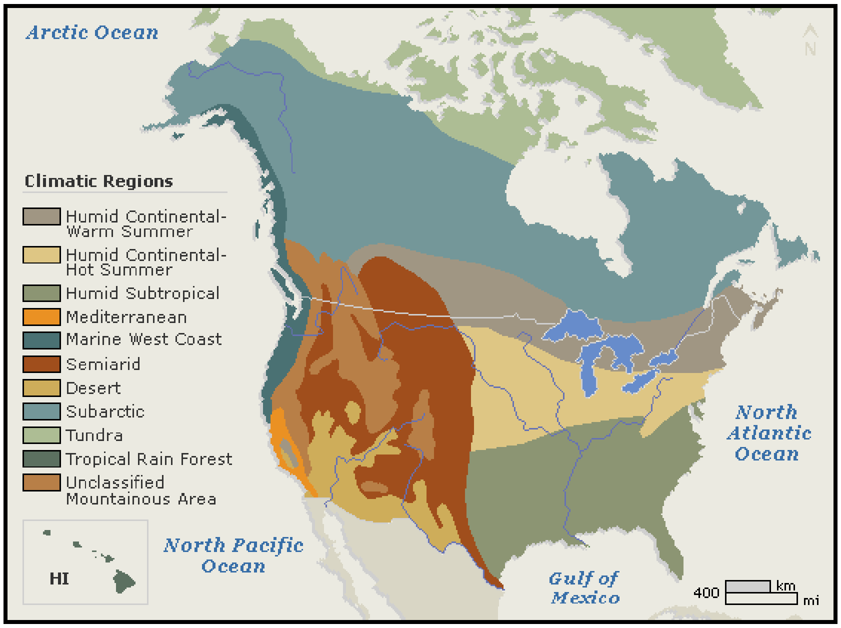


Figure 2.1: Climatic Regions of North America (Source: Microsoft Encarta, 2008).

The National Climatic Data Center divides New York State into 10 climate divisions, shown below in Figure 2.2. Dutchess County is located in Region #5, the Hudson Valley (National Oceanic and Atmospheric Administration [NOAA], "New York," 2008). These climate regions are used for various research purposes, including estimations of energy use, drought monitoring, studies of the variability of local weather, and analysis of long-term climate change.

Figure 2.2: Climate Divisions of New York State (Source: NOAA, "New York," 2008).

Specifically, Dutchess County's climate is humid continental, and is characterized by strong seasonal contrasts and highly variable weather. Major storm systems, which move through the continental United States or up the nearby Atlantic Coast, have a significant impact on the weather, especially during the fall, winter, and spring months. These systems provide ample precipitation for the region, supplemented by tropical, maritime air masses during parts of the summer. Polar air masses from Canada move southeast into the area and strongly influence winters (New York State Climatologist, 2008).

The relatively close proximity of Dutchess County to the Atlantic Ocean can have a moderating influence on the climate. The large-scale atmospheric circulation normally dominates the flow pattern near the surface. However, in the absence of strong circulation, the Atlantic can have a considerable effect on the local weather patterns, leading to relatively milder winter days and cooler days in the summer. In addition, the area generally has a slightly longer freeze-free season than places at similar latitudes farther inland, due to this moderating influence from the ocean.

Moderate temperatures and sufficient precipitation make Dutchess County an excellent location for farming, while seasonal variations help to attract tourists and recreational users. The county's relatively hot summers and cold winters result in substantial heating and cooling costs for homes and businesses.

TEMPERATURE

Temperature is a measure of the internal energy that a substance contains (NOAA, "NWS Glossary," 2008). The county's mean annual temperatures for the meteorological winter (December, January, and February) and meteorological summer (June, July, and August) are 27.3 and 69.5 degrees Fahrenheit, respectively. The highest and lowest temperatures ever reported at Poughkeepsie were 107 degrees in July 1966 and 21 degrees below zero in February 1897. The mean annual temperature of Poughkeepsie (48.8 degrees) and six major cities within 150 miles of Dutchess County are shown below (Figure 2.3), based on 30-year data from 1971-2000 (Northeast Regional Climate Center [NRCC], 2008).

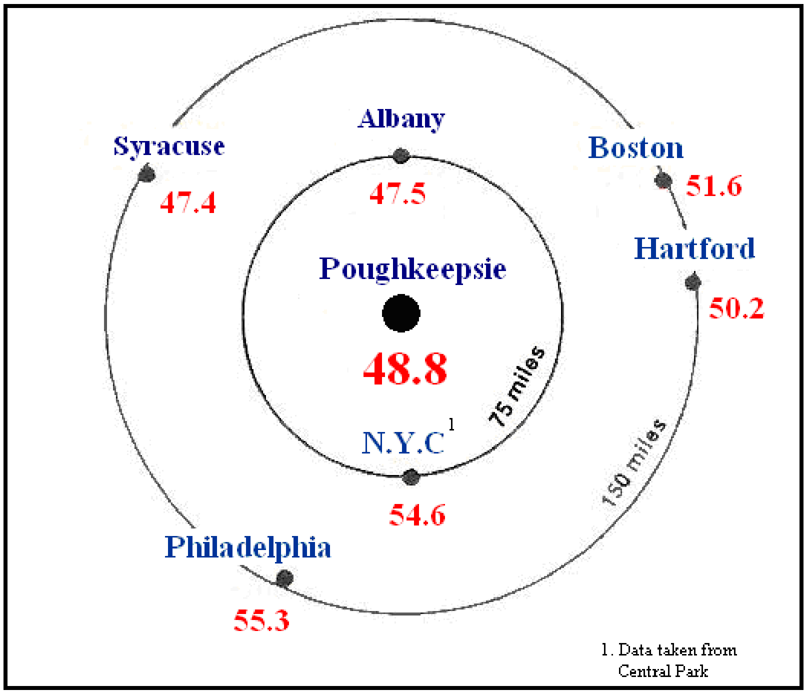


Figure 2.3: Mean Annual Temperature of Poughkeepsie and Nearby Cities (Source: NRCC, "CLIMOD System," 2008).

Temperatures at any one place in Dutchess County normally exceed 90 degrees Fahrenheit between 5 and 15 times during the summer. It is uncommon for air temperature to reach triple digits, occurring in Poughkeepsie roughly once every five years (NRCC, "CLIMOD System," 2008). However, hot temperatures combined with high summer humidity can lead to days that feel much hotter. The heat index is the combination of the dew point temperature (the amount of moisture in the air) and the air temperature, and measures how hot it actually feels (NOAA, "NWS Glossary," 2008). Nearly every summer in the county features one or more hot spells with high temperatures and high humidity leading to extremely uncomfortable conditions. On average, temperatures fall below zero degrees 5 to 10 times during the winter, primarily in January and February. During milder winters, temperatures may not drop into negative territory.

Figure 2.4 below shows the mean monthly temperatures in Dutchess County. The numbers are based on the average data collected at the three principal reporting stations in the county; Glenham, Millbrook, and Poughkeepsie/ Dutchess County Airport. The monthly temperature at each individual station, as well as the coordinates and elevation of all stations in Dutchess County, can be found later in this chapter.

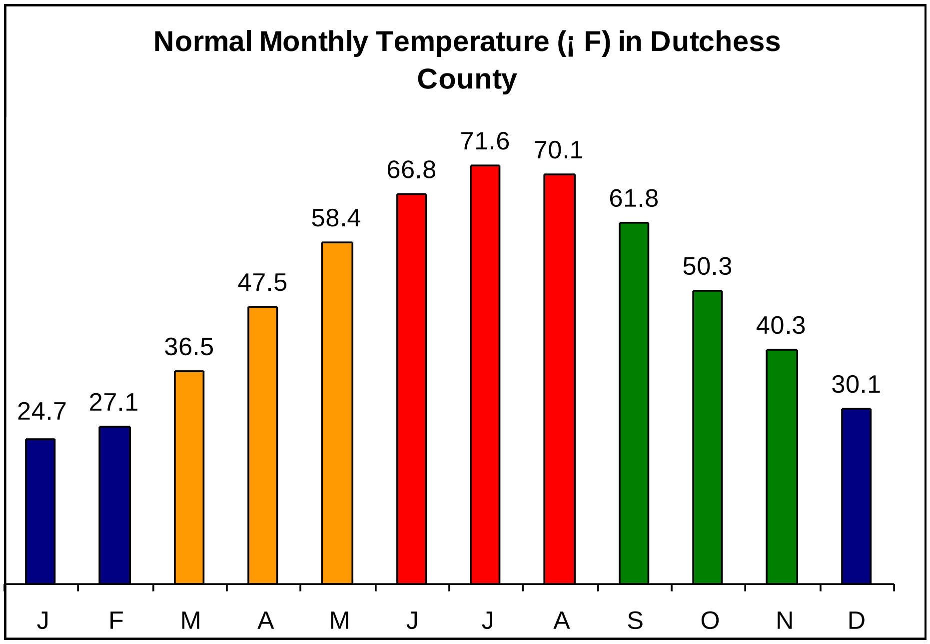


Figure 2.4: Normal Monthly Temperature in Dutchess County, 1971-2000 (Source: NRCC, "CLIMOD System," 2008).

It is important to note that the graph above does not take into account the many, varied local microclimates across the county. Areas along and just east of the Hudson River, including Red Hook, Rhinebeck, Hyde Park, Poughkeepsie, and Beacon, are generally milder than the rest of the county. Cooler temperatures prevail in higher elevations across the eastern and especially northeastern sections of Dutchess County. Finally, sheltered valleys such as the Harlem Valley also experience cooler conditions, especially at night.

Degree days are a measure that gauges building energy use for heating or cooling. Days with the average temperature above 65 are known as cooling degree days, while days with the average temperature below 65 are known as heating degree days. The number of heating degree days is the most important degree day index for Dutchess County since temperatures average below 65 degrees in all months except June, July, and August and space heating is normally required at temperatures below this level. A day with an average temperature of 65 degrees or more is said to have zero heating degree days, while a day with an average temperature of 50 degrees has 15 heating degree days (65-50=15 degrees). As the number of heating degree days increases, so does the use of energy to heat homes and businesses (NOAA, "Climate Prediction Center," 2008). Figure 2.5 below shows average monthly heating degree days in Poughkeepsie.

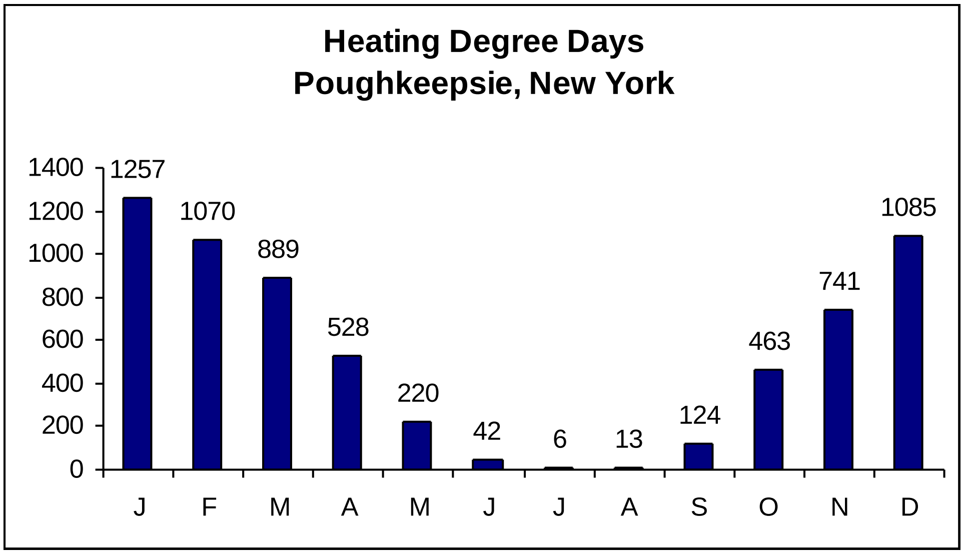


Figure 2.5: Heating degree days in Poughkeepsie, 1971-2000 (Source: NRCC, "CLIMOD System," 2008).

Poughkeepsie has an annual average of 6,438 heating degree days. The number varies with mean temperature across the county; for example, Glenham averages 5,813 heating degree days, while Millbrook averages 7,074. There is an average of 550 cooling degree days annually in Poughkeepsie. This number ranges from 312 cooling degree days in Millbrook to 790 in Glenham. With the advent of climate change, the number of degree days each year has changed due to warming temperatures. The number cooling degrees has gradually increased during the past 60 years, including a record 1,049 in Poughkeepsie during 2005. Similarly, the number of heating degree days has decreased over the same period. In 2006, there was a record low of just 5,406 heating degree days in Poughkeepsie (NRCC, "CLIMOD System," 2008).

Another type of degree day is the growing degree day. Growing Degree Days relate plant development and insect emergence to environmental air temperature to indicate which plants may be grown in a particular area (Cornell University, 2008). For example, most varieties of peas need 1,200 to 1,800 growing degree days (based on a 40-degree threshold) to reach maturity, so they can usually be grown only in areas that accumulate that many growing degree days or more. The most common threshold temperatures for measuring growing degree days are 40 degrees and 50 degrees. These are generally accepted as temperatures required for growing economically important plants. When using a 40-degree base, annual growing degree days range from roughly 4,000 days in the eastern part of the county to 5,000 near the Hudson River. When using the 50-degree base, the number of days varies between about 2,000 in the east to almost 3,000 near the Hudson (NRCC, "CLIMOD System," 2008). Growing degree days in Dutchess County are shown in Figure 2.6 below.

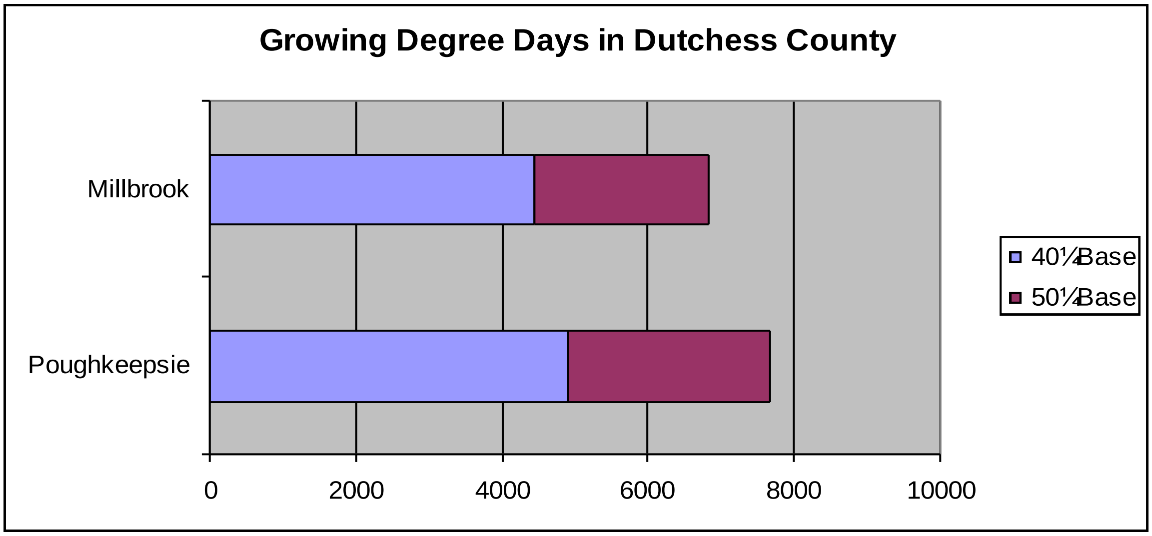


Figure 2.6: Growing Degree Days in Dutchess County, 1971-2000 (Source: NRCC, "CLIMOD System," 2008).

Information about growing degree days is useful to farmers, nurseries, research and extension specialists, and home gardeners. It is especially helpful in crop selection and in determining schedules for planting, pesticide application, and harvesting.

Figure 2.7: Agricultural fields in Dutchess County.

The growing season is primarily dictated by the period between the last spring frost and first fall frost. A **frost** occurs when surface temperatures fall to 32 degrees Fahrenheit or below (NOAA, "NWS Glossary," 2008). Knowing approximately when the first and last frost will happen and the normal length of the "frost free" season is critical for determining what types of crops are best suited for a particular area and when they can be safely planted. Generally, the frost free season in the county lasts from early May through late September or early October. Table 2.1 below shows normal frost data for Dutchess County based on the 30-year period from 1971-2000.

Table 2.1: Frost Data in Dutchess County (Source: NRCC, "CLIMOD System," 2008).[2]

Station	Mean Date of Last Frost	Absolute Date of Last Frost	Absolute Date of First Frost	Mean Date of First Frost	Mean Number of Frost Free Days	Data Record Period
Poughkeepsie	May 3	May 28 (1949)	September 15 (1963)	October 9	159	1949-2007
Millbrook	May 9	June 11 (1980	September 7 (1984)	September 30	142	1943-2001

PRECIPITATION

Precipitation is the process where water vapor condenses in the atmosphere to form water droplets that fall to the earth as rain, snow, sleet, or hail (NOAA, "NWS Glossary," 2008). Mean annual precipitation in Dutchess County ranges from 38 to 46 inches (Urban-Mead, 2006). During the growing season (May through September), total precipitation averages between 18 and 22 inches, a sufficient amount to support the wide variety of vegetation found in the county (NRCC, "CLIMOD System," 2008). One or more short periods of no rainfall occur during most summers.

Table 2.2 below presents both the mean monthly temperatures and total precipitation in Dutchess County over a 30-year period at various weather stations in the county.

Table 2.2: Mean temperatures and total precipitation in Dutchess County, 1971-2000 (Source: NRCC, "CLIMOD System," 2008).

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean Temp (°F)													
Glenham	26.6	29.2	38.5	49.5	60.7	69.5	74.3	72.7	64.7	53.0	42.9	32.2	51.2
Millbrook	22.9	25.2	34.7	45.5	56.1	64.1	68.7	67.0	58.8	47.9	37.7	28.1	46.4
Poughkeepsie	24.5	26.8	36.4	47.4	58.4	66.9	71.9	70.5	62.0	50.1	40.4	30.0	48.8
Total Precipitation (inches)													
Glenham	3.48	2.90	3.49	3.95	4.50	4.11	4.65	3.92	4.11	3.70	3.69	3.29	45.8
Millbrook	3.05	2.62	3.07	3.40	4.34	3.96	4.37	4.24	3.82	3.61	3.12	2.99	42.59
Poughkeepsie	3.19	2.53	3.59	3.79	4.73	3.73	4.72	3.83	3.69	3.56	3.53	3.23	44.12

[2] Mean dates based on data from 1971-2000.

Figure 2.8 below shows mean annual precipitation for Dutchess County, as well as the locations of weather reporting stations in the county.

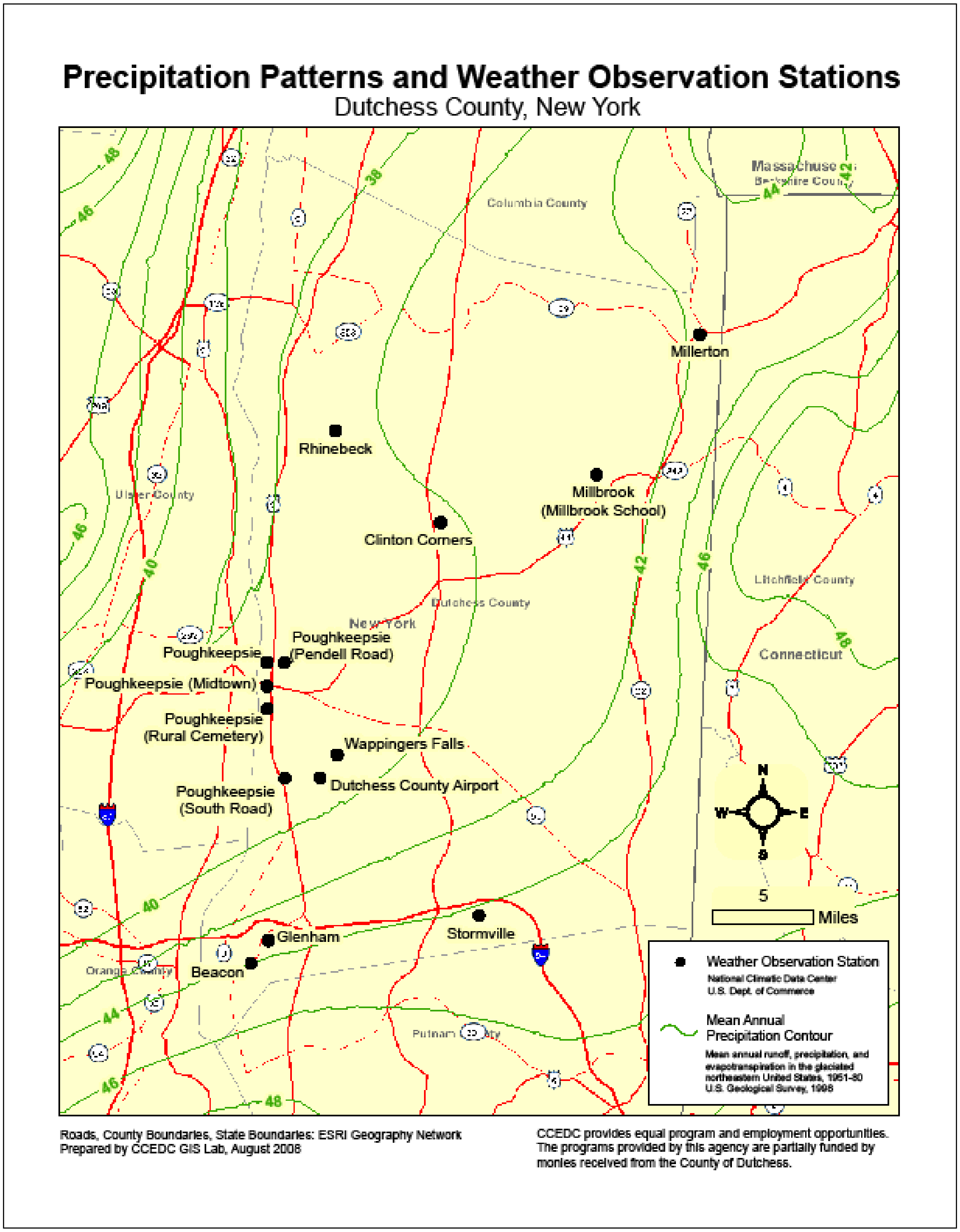


Figure 2.8: Mean Annual Precipitation in Dutchess County.

The significant differences in precipitation between various parts of the county can primarily be attributed to the topographical profile of the region. The eastern half of Dutchess County receives the most rain due to its higher elevation on the uphill slopes of the Taconic Mountains. As the prevailing northerly and westerly winds reach this area, air is forced upward. As the air rises, it expands and cools. The cooler air cannot hold as much moisture, so the relative humidity increases, leading to the formation of clouds and precipitation. During large storms, total rain or snow will often be greater in these areas due to this effect. The Hudson Highlands have a similar impact on the extreme southern portions of the county. The opposite effect causes lower precipitation in northwestern Dutchess County. As air is transported over the Catskill Mountains, it sinks on the down sloping side of the mountains. Sinking air warms and loses moisture, which lowers relative humidity and leads to dry conditions. A rain or snow "shadow" can often be observed in these areas during major storms, resulting in considerably less precipitation.

Figure 2.9 below depicts the mean monthly precipitation (rain and melted snow) in Dutchess County. The numbers are based on the average of data collected at the three official reporting stations in the county; Glenham, Millbrook, and Poughkeepsie/ Dutchess County Airport (NRCC, "CLIMOD System," 2008).

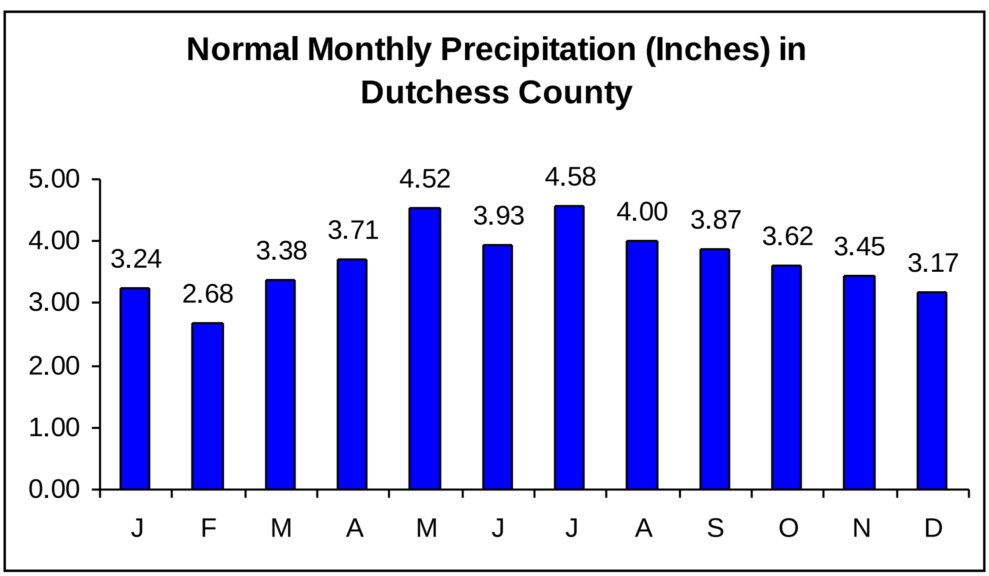


Figure 2.9: Normal Monthly Precipitation in Dutchess County, 1971-2000 (Source: NRCC, "CLIMOD System," 2008).

Much of the precipitation in the northeastern United States comes from the Gulf of Mexico and the Atlantic Ocean, and is transported by major atmospheric storm systems. These systems develop less frequently during the summer, but local convective activity in the form of thunderstorms produces significant amounts of summer rain. Local topographic variations also influence precipitation.

Figure 2.10 traces the pattern of annual precipitation in Poughkeepsie from 1931 to 2000. The graph clearly shows the extended drought that affected the area during the early and middle 1960s. In fact, the Hudson Valley experienced drought conditions every single month from June 1962 through February 1967. The worst conditions occurred between July 1964 and February 1966, as every month during that period was spent in extreme drought environments (NOAA, "Historic Palmer," 2008). In fact, 1964 was by far the driest year of this 62-year period, with only 24.52 inches of precipitation. Furthermore, the next two years were the third and fifth driest years during this time. The drought is the only one between 1931 and 2000 that persisted through several consecutive growing seasons and reached severe levels before a return to normal precipitation (NRCC, "CLIMOD System," 2008). The red line on the graph in Figure 2.10 is a best-fit line, which illustrates the trend in yearly precipitation data over the 62-year period. It shows there has been a gradual increase in annual precipitation to about 43.8 inches of rain per year (NRCC, "CLIMOD System," 2008).

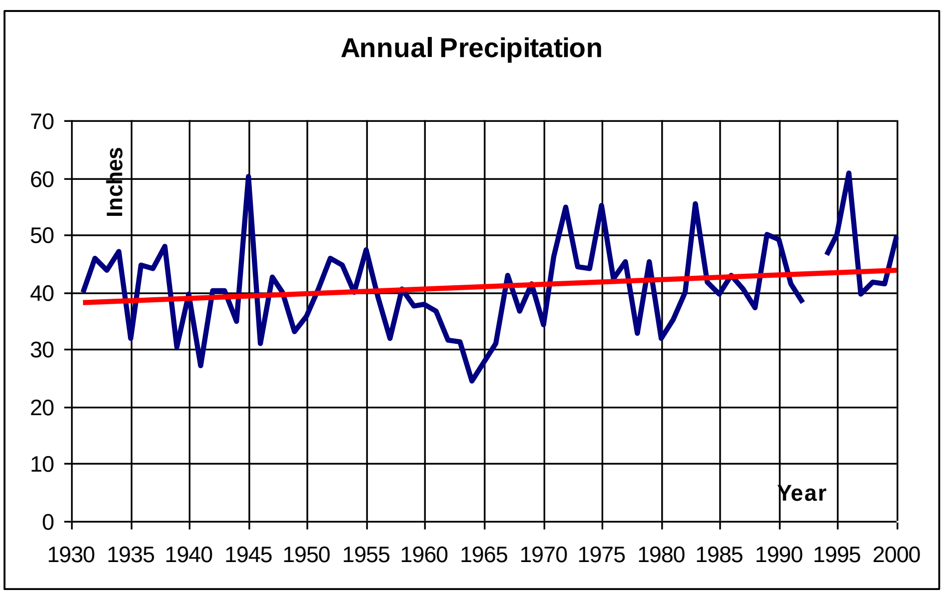


Figure 2.10: Annual Precipitation in Dutchess County (Source: NRCC, "CLIMOD System," 2008).[3]

Snow is precipitation in the form of ice crystals, formed from water vapor as it freezes in the air (NOAA, "NWS Glossary," 2008). Dutchess County receives a moderate amount of snowfall, with roughly 30 to 50 inches throughout the county. Higher elevations in the northeast section of the county may receive 60 inches of snow in a given year. Storms bringing at least six inches of snow to the region are frequent and normally occur at least once in most winters (NRCC, "CLIMOD System," 2008). Mean monthly snowfall for Poughkeepsie and Millbrook is provided in Figure 2.11 below.

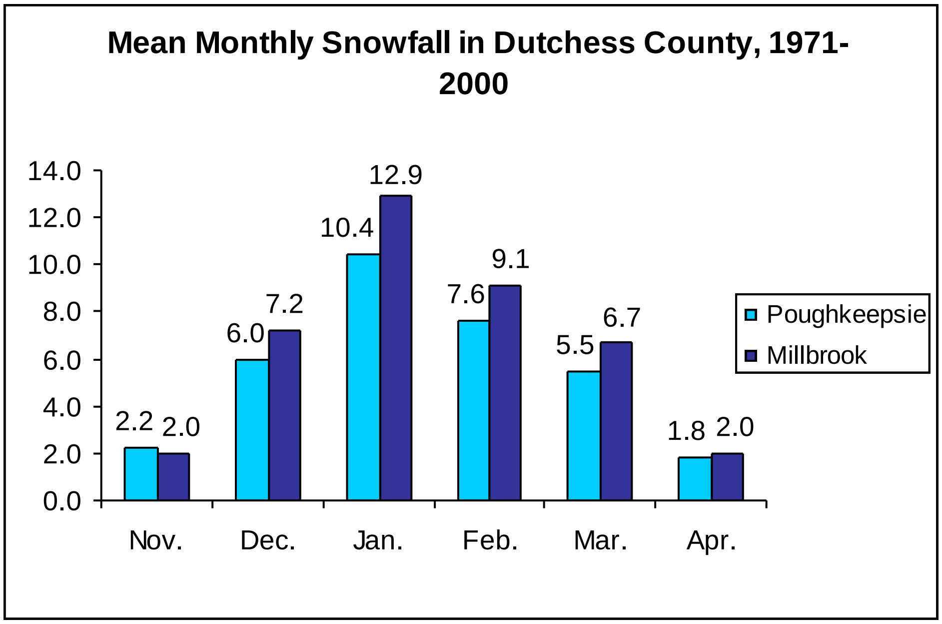


Figure 2.11: Mean Monthly Snowfall in Dutchess County, 1971-2000 (Source: NRCC, "CLIMOD System," 2008).

Relative humidity is the ratio of the amount of moisture present in the atmosphere to the amount of moisture that the air can hold at any given temperature (expressed as a percent) (NOAA, "NWS Glossary," 2008). Mean annual relative humidity in Dutchess County is between 66 and 75 percent (NOAA, "Mean Relative Humidity," 2008).

[3] Note: 1931-52 data collected in Poughkeepsie, 1953-2000 at the Dutchess County Airport.

BAROMETRIC PRESSURE

Pressure is the exertion of force upon a surface by a fluid in contact with it. Atmospheric pressure refers to the pressure the atmosphere exerts on the Earth's surface (NOAA, "NWS Glossary," 2008). Surface barometric pressure measurements are usually converted to mean sea level pressure, which standardizes the observation so that pressure can be measured on the same scale regardless of altitude. This conversion is done to make pressure readings a useful weather and climate tool. Otherwise, barometric pressure readings at a high elevation location such as Denver, Colorado would always be lower than the readings at locations near or at sea level. The mean annual pressure in Dutchess County is about 1017 millibars, or 30.04 inches of mercury (NOAA, "Annual Mean Sea Level Pressure," 2008). The lowest pressure in the county normally occurs during violent weather such as severe thunderstorms and coastal storms. The highest pressure is observed when large high-pressure areas move over the region, bringing fair weather and low humidity. Differences in pressure cause winds in the atmosphere and the sharper the change in pressure is over a given distance, the stronger the winds will be.

WIND

Wind is the horizontal motion of air past a given point. It is caused by differences in air pressure and can also be affected by heating differences of the air and the physical profile of the earth's surface (NOAA, "NWS Glossary," 2008). Northerly and westerly winds dominate Dutchess County at an average annual velocity of 5.4 miles per hour (MPH). Winds are usually strongest during the winter and early spring, averaging 6-7 MPH. During the summer months, winds are weaker, on the order of 4-4.5 MPH, and have more of a southerly component (NRCC, "Wind Summary for Dutchess County," 2008). The wind rose diagram below (Figure 2.12) shows the average wind speed and direction at the Poughkeepsie/Dutchess County Airport during the ten-year period from 1997-2007. The numbers around the circle indicate the wind direction (0 = North, 90 = East, 180 = South, and 270 = West), while the colored bars indicate the percentage the winds occurred at a certain speed.

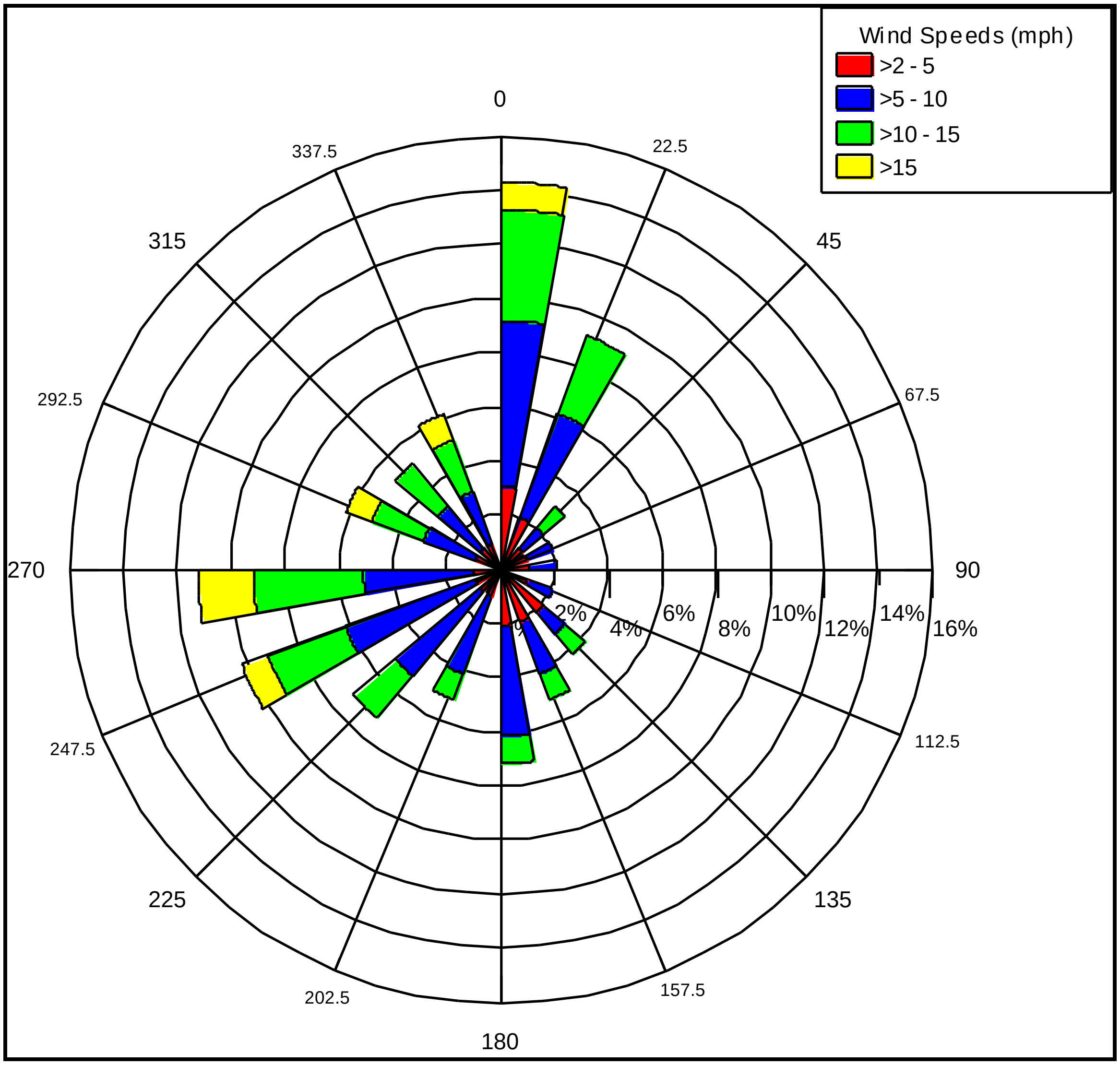


Figure 2.12: Wind Rose for Poughkeepsie, New York, 1997-2007.[4]

Under normal atmospheric conditions, winds are strongest during the day and weaken as the sun sets and daytime heating is lost. Severe winds are rare in Dutchess County. Most high wind events are caused by localized, quick-moving severe thunderstorms. Longer, more widespread wind events occur occasionally and are due to larger mid-latitude cyclones such as nor'easters.

The strongest and most frequent winds generally come from the west because Dutchess County is located in the westerly wind belt, which can be found at the middle latitudes of the earth. The westerlies are just one of the components of global circulation patterns.

[4] V. Kelly. Wind Rose created from data from the Poughkeepsie FAA Airport, latitude 41.63 degrees, longitude -73.88 degrees, elevation 155 feet.

SUN CLOUD COVER

The ratio of actual bright sunshine to the total possible amount of sunshine in a location is known as **percentage of possible sunshine** (NRCC, "Percent of Possible Sunshine," 2008). In New York State, this value ranges from 46 percent in Syracuse to 58 percent in New York City. The location of Dutchess County between New York City and Albany (53 percent) means that the area receives some of the highest amounts of sunshine in the state. Sunshine is at a maximum during July, August, and September, with clouds most prevalent in January and March (NOAA, "Percentage of Possible Sunshine," 2008). The graph below (Figure 2.13) shows the percentage of possible sunshine as measured at Poughkeepsie/Dutchess County Airport during the ten-year period of 1997-2007.

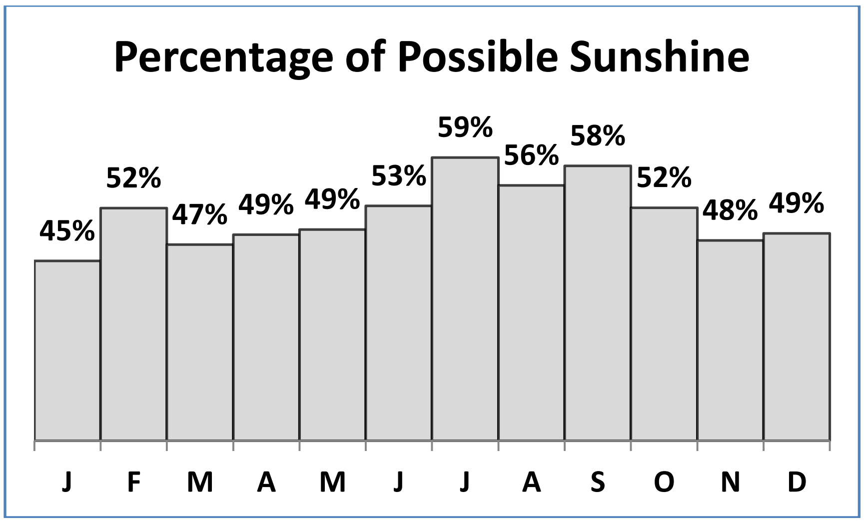


Figure 2.13: The percentage of possible sunshine by month at Poughkeepsie, New York, 1997-2007.[5]

SEVERE WEATHER

Thunderstorms, tornadoes, winter storms, hurricanes, floods, and droughts have all impacted Dutchess County. Many of these storms have left behind considerable damage and in a few cases proven fatal. The NOAA Storm Prediction Center in Norman, Oklahoma monitors severe weather and issues real-time watches, forecasts and discussions.

[5] Poughkeepsie FAA Airport, latitude 41.63 degrees, longitude -73.88 degrees, elevation 155 feet.

Thunderstorms are relatively common in Dutchess County, primarily during the fall, spring and summer. Thunderstorms can be accompanied by lightning, hail, torrential rains, violent winds, and tornadoes. The time of greatest occurrence for **severe thunderstorms** is during the late spring and summer. The National Weather Service defines a thunderstorm as severe if it produces at least one of the following: 1) winds of at least 58 miles per hour, 2) hail at least ¾ inch in diameter, or 3) a tornado. The National Weather Service issues a **severe thunderstorm warning** if severe thunderstorms are imminent or occurring. Additionally, a **severe thunderstorm watch** is issued when severe weather is possible but not yet occurring (The Weather Channel, 2008). Between 1955 and 2007 there were 71 large hail (at least ¾ inch diameter) events in Dutchess County, or about one to two per year (NOAA, "NCDC Storm Events," 2008). Thunderstorms are also capable of producing urban and small stream flooding, uprooting trees, widespread power outages, and damage to structures.

A tornado is a rotating column of air with a circulation reaching the ground (NOAA, "NWS Glossary," 2008). The intensity of tornadoes is measured by the Fujita Scale, with an F0 being the weakest and F5 the strongest. An update to the old Fujita Scale, the Enhanced Fujita Scale, was implemented in 2007. Tornadoes are rare but not unheard of in New York State. A total of 11 tornadoes have been reported in Dutchess County since 1950 (NOAA, "NCDC Storm Events," 2008). All of the tornadoes have been either an F0 or Fl on the Fujita Scale, causing light to moderate damage with winds of up to 112 miles per hour (NOAA, "Storm Prediction Center," 2008). The National Weather Service issues a **tornado warning** if Doppler radar indicates the presence of a tornado or if a spotter has sighted one. Additionally, a **tornado watch** is issued if conditions are favorable for the development of tornadoes (Florida Division of Emergency Management, 2008).

A variety of winter storms can affect Dutchess County. Heavy snowstorms bringing several inches of snow are common. True blizzard conditions in the area are extremely rare since they require strong winds of at least 35 miles per hour and extreme blowing and drifting of the snow (NOAA, "NWS Glossary," 2008). Storms occurring with mixed precipitation often wreak havoc on Dutchess County. Rain, snow, sleet, and freezing rain may all occur as part of the same storm system. **Freezing rain**, rain that freezes on contact with the ground (NOAA, "NWS Glossary," 2008), is especially problematic, as it can lead to icy roads as well as downed trees and power lines, which may cause widespread power outages. On average, Dutchess County receives 12-18 hours of freezing precipitation (rain and drizzle) per winter (Dirienzo, 2008).

Hurricanes are tropical cyclones with sustained winds of at least 74 miles per hour. **Tropical storms** are also tropical systems but weaker than hurricanes, with sustained winds between 39 and 73 miles per hour (NOAA, "National Hurricane Center," 2008). Hurricanes, tropical storms, and their remnants occasionally affect Dutchess County. Several tropical storms and four hurricanes have made landfall in New York State since 1950 (NOAA, "Continental United States Hurricane Strikes," 2008). Since Dutchess County is well north of the Atlantic Coast, the primary impacts from tropical cyclones are heavy rain and flooding. In 1999, Tropical Storm Floyd brought torrential rain to the county as it passed through Long Island and southeast New England. There were widespread reports of over 4.5 inches of rain, with 11.02 inches recorded in Stormville (NOAA, "Floyd Deluges Eastern New York," 2008). The National Hurricane Center in Miami, Florida monitors tropical weather in the Atlantic and eastern Pacific Oceans and issue all pertinent watches, warnings and advisories.

Floods occur with relative frequency in Dutchess County, with roughly three floods of varying degrees reported each year in the county (National Climatic Data Center Storm Events Database). Each major stream in Dutchess County has a significant number of flood prone areas and certain areas are prone to annual flooding. The probability of flooding is greatest from December to April. Runoff from melting snow and ice often causes minor spring floods. Ice flows and heavy rainfall sometimes aggravate spring runoff conditions, producing severe floods in low-lying areas.

Figure 2.14: Recent Flooding in Dover, NY, Dutchess County (Town of Dover, 2009).

Most major floods in Dutchess County are triggered by coastal storms, while some are caused by tropical storms. Widespread flooding occurred in September 1938 due to the Great Hurricane of 1938, which made landfall in Long Island and Connecticut. In August 1955, Hurricane Diane passed just to the south of the region, leading to record flooding of the Tenmile River and Wappinger Creek.

Severe nor'easters may also produce floods in the county. In April 2007, an area of low pressure intensified rapidly as it moved from the southern Appalachians to the Long Island coast. The storm brought two days of heavy precipitation, which brought about extensive flooding of small streams and creeks in the county. Record flooding occurred on the Wappinger Creek at Wappingers Falls, which crested at 15.06 feet, 7.06 feet above the flood stage of 8.0 feet. Moderate flooding was also recorded along the Ten Mile River at Webatuck, which crested at 11.23 feet. The storm produced three to eight inches of rain throughout the county, including 4.99 inches in Poughkeepsie and 6.83 inches in Rhinebeck (NOAA, "Past Storm Events," 2008).

Flash flooding is a rapid water level rise in a stream or creek above a predetermined flood level (NOAA, "NWS Glossary," 2008). Flash floods can occur any time of year in Dutchess County. On average, there are about ten days a year when at least one inch of rain falls (NRCC, "CLIMOD System," 2008). These days are most common between May and October, and the rain usually occurs because of strong thunderstorms which can often lead to flash flooding. Rapid snowmelt in association with strong precipitation events may also lead to flash flooding during the late winter and early spring.

A **drought** is a deficiency in moisture that results in adverse effects on people, animals, or vegetation over a sizeable area (NOAA, "NWS Glossary," 2008). The county's major drainage basins have sufficient capacity to sustain some flow even during severe droughts, such as the aforementioned drought from 1962-1967. For a period of 29 months between May 1964 and September 1966, the lowest Palmer Drought Severity Index (PDSI) value was -6.66 in November 1964. Serious droughts are rare; brief dry spells are far more common. Dry periods temporarily place crops under stress and often force restrictions in the recreational uses of forested lands because of fire hazards. Mandatory or volunteer water restrictions may also be put in place by local municipalities. Further information about droughts can be found on the Northeast Regional Climate Center's Northeast Drought Page.

AIR QUALITY & POLLUTION

The major air pollutants in Dutchess County are ground-level ozone, particulate matter and acid deposition. Because some of these pollutants are transported across state and county lines, the federal Clean Air Act was enacted to control these pollutants at the state and federal geographic scale. It's important to remember that some pollutants measured in Dutchess County are not emitted here. Likewise, some pollutants emitted in Dutchess County affect downwind areas outside of Dutchess County.

Overview of Clean Air Act

The principle statutory authority for controlling air pollution at the Federal and State level is contained in the Clean Air Act (CAA), which was enacted by Congress and signed into law in 1970. Although subsequently amended, the core provisions of the 1970 Clean Air Act are still in effect. In Section 109 of the law, the United States Environmental Protection Agency (EPA) is directed to establish National Ambient Air Quality Standards (NAAQS) for six specific criteria pollutants:

1. Carbon Monoxide
2. Lead
3. Nitrogen Oxides (NOx)
4. Ozone (or smog)
5. Particulate Matter and
6. Sulfur Dioxide (SO_2)[6]

For each of the six criteria pollutants, NAAQs are set by EPA at a level designed to protect public health with an adequate margin of safety (Brownell, 1993). One set of limits, the primary standard, protects health. Another set of limits, the secondary standard, is intended to prevent environmental and property damage (United States Environmental Protection Agency, 1993).

Under section 110 of the Clean Air Act, each state is required to submit a "State Implementation Plan," commonly known as the "SIP" to the EPA, which details how the state will implement,

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[6] Although greenhouse gases that contribute to climate change are not yet regulated under the Clean Air Act as of October 2010, they will likely be regulated in the future, due to the US Supreme Court ruling *Massachusetts v. EPA*, 549 U.S. 497 (2007), in which the Supreme Court found that greenhouse gases are air pollutants covered by the Clean Air Act, and subsequent Endangerment and Cause or Contribute Findings issued by the EPA under Section 202(a) of the Clean Air Act in 2009 (http://www.epa.gov/climatechange/endangerment.html#back).

maintain, and enforce the primary and secondary NAAQS in each air quality control region within the State (United States Code of Federal Regulations, 2006). As the regulatory authority for New York State, the NYS Department of Environmental Conservation (DEC), working with local authorities, drafts the SIPs for submission to the EPA to meet the requirements of the Clean Air Act in New York State.

Upon passage of the CAA Amendments of 1990, several changes were put in place, including new designation of areas of the country not meeting the NAAQS for each criteria pollutant, also known as Areas of Non-Attainment. Under the CAA, a geographic area that meets or does better than the primary standard is called an Attainment Area; areas that do not meet the primary standard are called Non-Attainment Areas (United States Environmental Protection Agency, 1993). For areas that are in Non-Attainment for any one of the six NAAQS for criteria pollutants, Title 1 of the 1990 CAA Amendments imposes deadlines for meeting the NAAQS that vary with the severity of pollution problems, and requires states to submit revised SIPs – which require that the states make "measurable progress" in meeting the NAAQS.

Ozone

One of the most critical criteria pollutants, ground level ozone, is the main harmful component of smog. It is a highly reactive gas that consists of 3 oxygen atoms. Ozone is not emitted directly, but is formed through chemical reactions between precursor emissions of Volatile Organic Compounds (VOC) and Nitrogen Oxides (NOx) in the presence of sunlight. These reactions are stimulated by sunlight and high temperature, which is why peak ozone levels occur during summer and the warmest period of the day. The VOC and NOx precursors to ozone are produced by the combination of pollutants from many sources, including smokestacks, cars, paints and solvents (Figure 2.15). According to the EPA, when a car burns gasoline, releasing exhaust fumes, or a painter paints a house, smog-forming pollutants rise into the sky (United States Environmental Protection Agency, 1993).

The initial NAAQS for ozone was a maximum 1-hour average not to exceed 0.12 parts per million (ppm) (United States Code of Federal Regulations, 2006). In 1997, the EPA established a new NAAQS for ozone. To attain this standard, the 3-year average of the fourth-highest daily maximum 8-hour average ozone concentrations measured at each monitor within an area over each year must not exceed 0.08 ppm. In May 2008, that standard was lowered from 0.08 ppm to 0.075 ppm. Standards are periodically changed because the Clean Air Act requires the EPA to review and revise standards as new information develops about public health, safety and environmental and property effects of criteria pollutants.

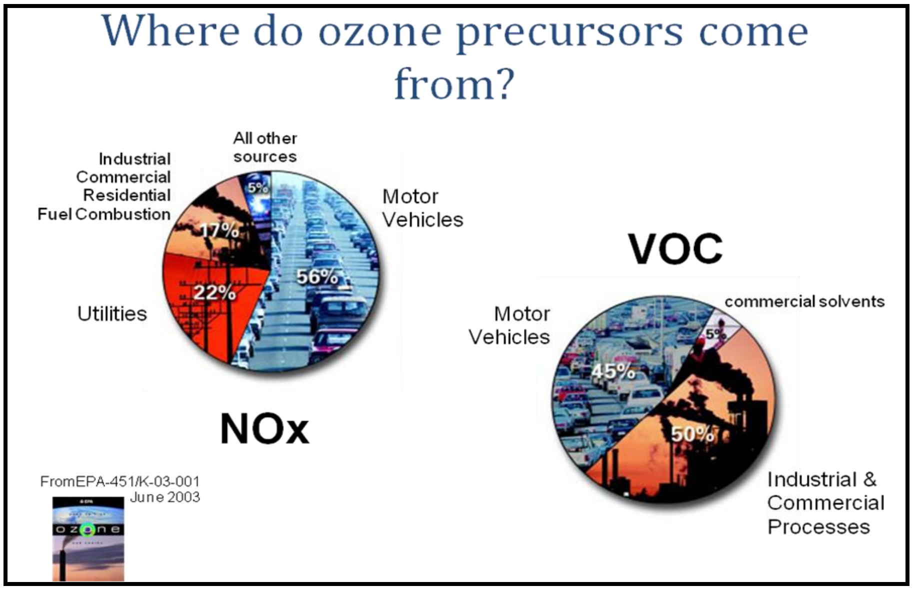

Figure 2.15: Sources of Ozone (Source: USEPA, 2003).

Ozone in Dutchess County

The United States EPA and New York State DEC maintain a network of air quality monitoring for the United States and New York State, respectively. According to EPA, the EPA's ambient air quality monitoring program is carried out by State and local agencies (United States Environmental Protection Agency, 2006). The New York State DEC measures air pollutants at more than 80 sites across the state, using continuous and/or manual instrumentation, as part of the federally-mandated National Air Monitoring Stations Network (NYS DEC, 2007). Continuous air quality monitoring of DEC's Region 3 - the Hudson Valley - occurs at several sites, including White Plains in Westchester County, Mt. Ninham in Putnam County, Valley Central in Orange County, and Belleayre Mt. in Ulster County. The only monitoring station in Dutchess County is site #132801, which is maintained at the Cary Institute of Ecosystem Studies in Millbrook, NY. The DEC's Division of Air Resources maintains accurate hourly, daily, monthly and yearly air quality data and forecasting, and information is available from the NYS DEC website. According to the DEC, in 2007, compliance with the existing NAAQS for ozone was met at the Millbrook station in Dutchess County (see Table 2.3).

Table 2.3: Comparison between NYS Ambient Air Quality and Ambient Air Quality Standards for 2007 for Ozone for NYSDEC Region 3 (Source: NYS DEC, 2007)[7]

Station	2007 One Hour Averages					4th Highest Daily Maximum 8-Hour Average –Not to exceed an avg. of 0.08 ppm during the last 3 years*			
	Number of Observations > 0.12 ppm	Highest Values, ppm							
		1st	2nd	3rd	4th	2005	2006	2007	Avg.
White Plains	3	0.138+	0.127+	0.126+	0.121	0.095	0.083	0.095	0.091+
Valley Central	2	0.145+	0.131+	0.116	0.093	0.087	0.077	0.084	0.082
Millbrook	0	0.114	0.107	0.097	0.090	0.082	0.064	0.078	0.074
Mt. Ninham	1	0.126+	0.111	0.108	0.108	0.096	0.074	0.086	0.085+
Belleayre Mt.	0	0.088	0.084	0.083	0.082	0.080	0.077	0.073	0.076

Particulate Matter

Particulate Matter (PM) includes dust, dirt, soot, smoke and liquid droplets. It can be formed by condensation or transformation of gases. There are two size classifications for particulates: 10 microns (PM10), which are particles that are less than 10 microns in size and 2.5 microns (PM2.5), which are particles that are less than 2.5 microns in size. The PM2.5 size class causes decreased lung function that can have serious effects on individuals with asthma, bronchitis or other airway diseases. PM2.5 is most commonly the result of combustion, including fossil fuel burning, and transformation of gases such as sulfur dioxide, nitrogen oxides, and volatile organic compounds. The National Ambient Air Quality Standards (NAAQS) for PM2.5 include a 24-hour average and annual average, which are not to exceed 35 and 15 $\mu g/m^3$, respectively.

Particulate Matter in Dutchess County

PM2.5 is not currently monitored in Dutchess County. The closest monitoring sites are Newburgh and Albany. PM2.5 was monitored in Poughkeepsie between 1999 and 2002 and was compliant within NAAQS during that time. Although Dutchess County is currently within compliance for

7 *NYS and Federal Ambient Air Quality Standard. + Denotes a contravention of Federal AAQS.

PM2.5, development and vehicular travel should be controlled to ensure that it remains in compliance.

Air Quality Index

The Air Quality Index (AQI) is an index that illustrates the level of each of the criteria pollutants. For Dutchess County, AQI's for ozone and PM2.5 are forecast on a daily basis by the NYS DEC. The AQI was created as an easy way to correlate levels of different pollutants to one scale; the higher the AQI value, the greater the health concern. When levels of ozone and/or PM2.5 are forecast to exceed an AQI value of 100, an Air Quality Health Advisory is issued alerting sensitive groups to take the necessary precautions. AQI alerts are reported via media outlets and weather forecasting facilities. For real-time air quality data and forecasts for the Hudson Valley visit the NYS DEC Air Quality Forecast for New York State.

Acid Precipitation

Acid precipitation refers to rain, snow or ice that is more acidic than what is normal for a given area. In the northeastern United States, normal precipitation pH is about 5.2. The pH scale is a measure of acidity ranging from 0 to 14, with pH 7 being neutral, pH less than 7 is acidic, and pH greater than 7 is basic. The pH scale is logarithmic, which means that each pH unit is 10 times that of its neighbor. So a solution with pH 4 is 10 times more acidity than a solution with pH 5. In Millbrook in Dutchess County, the average precipitation pH between 1984 and 2007 was 4.31 (Cary Institute of Ecosystem Studies, 2008).

Acid precipitation most commonly forms from sulfur dioxide (SO_2) and oxides of nitrogen (NOx). Most SO_2 is emitted by coal burning power plants while NOx most commonly comes from car exhaust and other industrial processes as well as coal burning. In the atmosphere, the SO_2 and NOx transform to sulfate (SO_4^{2-}) and nitrate (NO_3^-) which combine with hydrogen ions (H^+) to form sulfuric acid (H_2SO_4) and nitric acid (HNO_3). Acid precipitation is more correctly called acid deposition. There are 2 forms of acid deposition: wet deposition, which is deposition in the form of rain, snow or ice, and dry deposition, which is deposition in the form of gases or particles. By far, most acid deposition falls as wet deposition. H_2SO_4 is the most important component of acid deposition although HNO_3 is also important. Because the prevailing wind direction for Dutchess County is southwest, as it is for most of the northeastern US, we are upwind of the midsection of the country where many coal burning power plants are. Our air and precipitation largely originates in areas with high emissions of the acid deposition precursor SO_2.

Acid deposition and other pollutants harm natural ecosystems and threaten biological diversity. Acid deposition acidifies soils, lakes and streams and enhances the process that makes toxic mercury (another pollutant emitted during the burning of coal) available to organisms. Acid deposition also enhances the mobilization of toxic aluminum from soils to tree roots, increases leaching of sulfate and nitrate to soils and surface waters and promotes the loss of important buffering nutrients from soils. In aquatic systems, aluminum can kill fish and other aquatic organisms, reducing fish species richness. The increased acidity in lakes and other surface waters can reduce ecosystem productivity. While existing acid precipitation regulations are necessary, they are insufficient to conserve natural ecosystems and their valuable services (Lovett and Tear, 2008).

Title IV of the 1990 Clean Air Act Amendments (CAAA) mandates requirements for the control of acid deposition. The CAAA set a goal of reducing annual SO_2 emissions by 10 million tons below 1980 levels. To achieve these reductions, the law required a two-phase tightening of the restrictions placed on the highest emitting fossil fuel-fired power plants. Phase I began in 1995 and Phase II began in the year 2000. The Act also called for a 2 million ton reduction in NOx emissions by the year 2000.

Acid Precipitation in Dutchess County

Figure 2.16 illustrates the decline in the acidity of precipitation at the Cary Institute of Ecosystem Studies in Dutchess County between 1984 and 2007. Notice, however, that the red line, which represents the acidity of normal precipitation, is still far below our rain's acidity today.

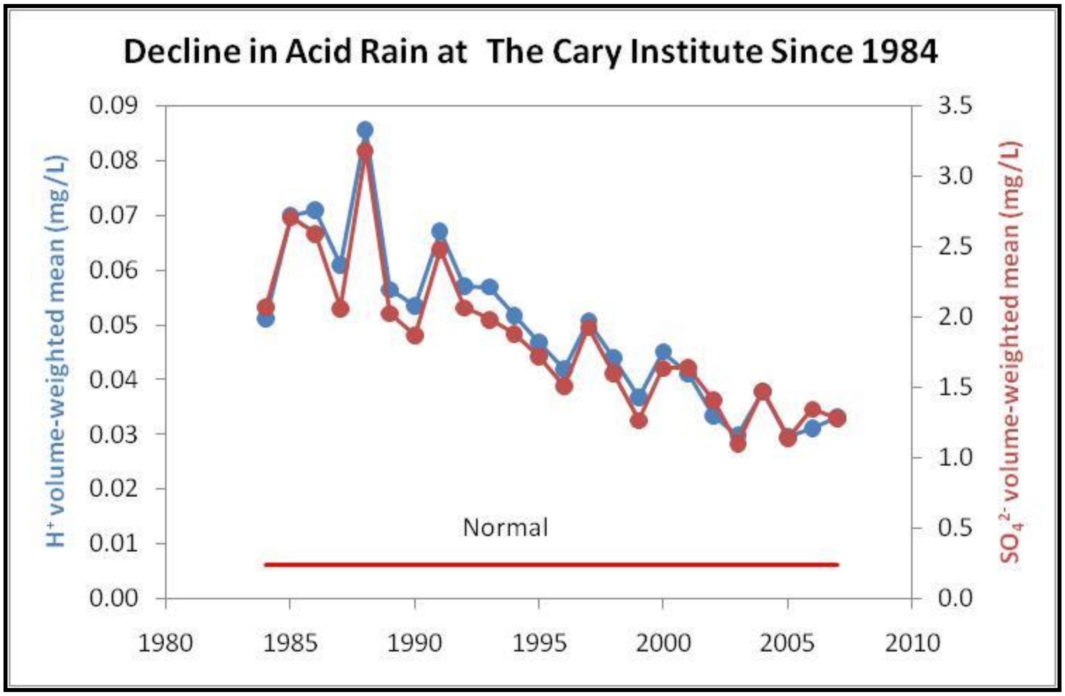

Figure 2.16: Acid Rain Measurements at the Cary Institute, 1984-2007.

CLIMATE CHANGE

Climate change is defined as any significant change in measures of climate (such as temperature, precipitation, or wind) lasting for an extended period of time (decades or longer). The global climate can change because of natural factors (such as changes in the sun's intensity); natural processes within the climate system; or human activities that change the atmosphere's composition (such as through the burning of fossil fuels) (EPA, 2010). Until the advent of the industrial revolution, global climate change occurred over long periods of time and was caused by a variety of natural factors. However, the International Panel on Climate Change (IPCC), an international body of scientists working through the United Nations, has concluded that the earth's climate is changing much more rapidly than ever before, and this change is very likely caused by the increase in atmospheric concentrations of greenhouse gases (GHGs) emitted by humans (IPCC, 2007).

The current atmospheric concentration of carbon dioxide is about 385 parts-per-million (ppm), the highest level in over 700,000 years. Most of this increase is due to the combustion of fossil fuels by humans (NOAA, "Carbon Dioxide, Methane Rise Sharply," 2008). Natural carbon dioxide and other gases such as methane contribute to the greenhouse effect. The greenhouse effect is necessary to maintain the earth's atmosphere at a reasonably mild temperature by allowing solar radiation to pass through unimpeded, and simultaneously absorbing outgoing radiation. However, the greenhouse effect is being enhanced as the concentration of GHGs in the atmosphere is increasing (Pidwirny, 2006).

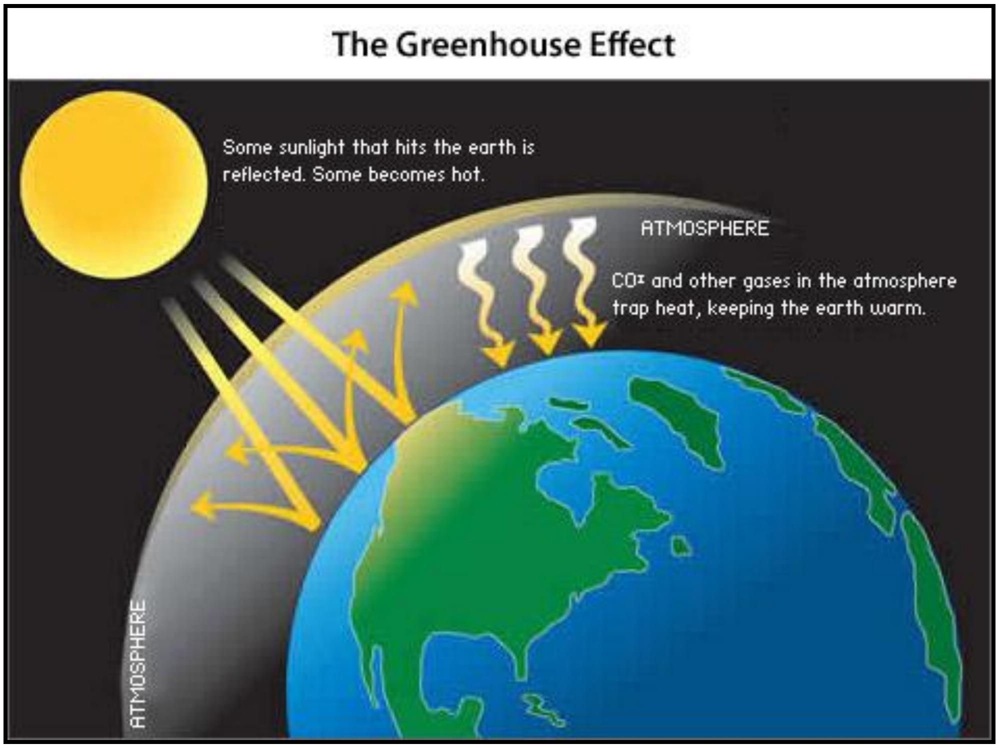

Figure 2.17: The Greenhouse Effect (Source: US Department of Energy, 2008).

Average global temperatures have risen by 1.3 degrees Fahrenheit over the past century. According to the National Oceanic and Atmospheric Administration (NOAA), seven of the eight warmest years on record have occurred since 2001. As a result, the IPCC has concluded that warming of the Earth's climate system is now unequivocal (USEPA, FAQs, 2009).

Since 1970, average temperature in the northeastern United States has increased by 2 degrees Fahrenheit, with winter temperatures rising twice this much (Global Climate Change Impacts, 2009). This warming has already brought about numerous noticeable changes to the climate of New York State and Dutchess County, which are detailed below. Estimates of continued climate change in the future are heavily dependent on the rate of human's GHG emissions. According to the USEPA, "if humans continue to emit GHGs at or above the current pace, we will probably see an average global temperature increase of 3 to 7 degrees Fahrenheit by 2100," while global temperature increases would be lower with lower GHG emissions. However, even if humans were to drastically reduce their GHG emissions, the earth would still warm about 1 degrees Fahrenheit over the next 100 years, due to the long lifetime of many GHGs and the slow cycling of heat from the ocean to the atmosphere (USEPA, FAQs, 2009).

Changing Temperatures and Seasons in the Northeast and Hudson Valley

Dutchess County is already experiencing a rise in temperature. The mean annual temperature in Poughkeepsie has generally increased during the past 55 years, as evidenced by the Figure 2.18 below. There has been an overall increase of about 1.1 degrees Fahrenheit during this time period (NRCC, "CLIMOD System," 2008).

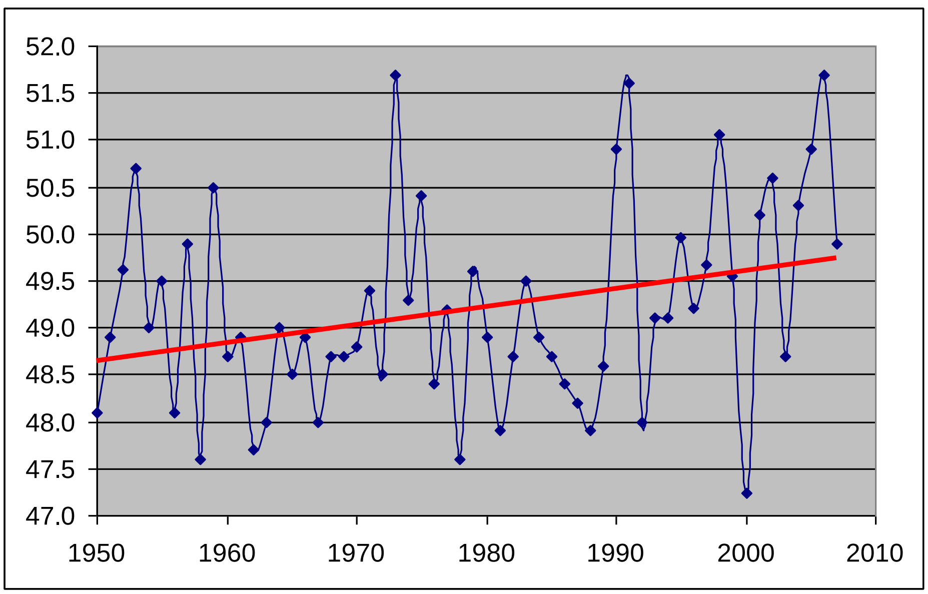

Figure 2.18: Mean Annual Temperature in Poughkeepsie, 1950-2007 (Source: NRCC, "CLIMOD System," 2008).

Mean temperatures are expected to rise an additional 1.5 to 3 degrees Fahrenheit in the Hudson Valley by 2020, and by 3.0 to 7.5 degrees Fahrenheit by 2050. By the close of the century, mean temperatures are expected to increase by 4.0 to 8.0 degrees Fahrenheit by 2080, depending on how much GHGs humans continue to emit (draft New York State ClimAid Report, 2010). Summers are projected to warm slightly more than winters, and the combination of warmer temperatures and high humidity may cause summer days to feel substantially warmer than at the present-comparable to the current climate of South Carolina (United State Global Change Research Program, 2009).

The timing of the seasons will also continue to be affected by climate change. The growing (frost-free) season has already increased by over 20 days in Dutchess County over the past 60 years, as shown in Figure 2.19 below (NRCC, "CLIMOD System," 2008).

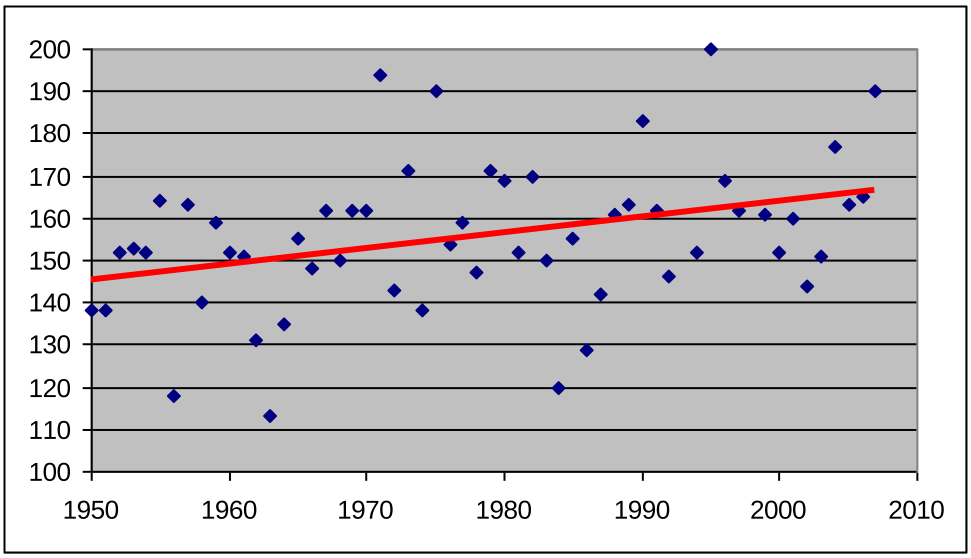

Figure 2.19: Frost Free Season in Poughkeepsie (number of days), 1950-2007 (Source: NRCC, "CLIMOD System," 2008).

This trend is expected to continue and by the close of the century in the Northeastern US, the growing season may be 4 to 5 weeks longer than it is currently (United State Global Change Research Program, 2009).

Precipitation and climate change

While there has been no discernable trend in annual precipitation in New York State over the past several decades, annual precipitation is expected to gradually increase through 2100 in the Northeastern US due to climate change. Precipitation in the Hudson Valley region is projected to increase by +0 to 5% by 2020; +0 to 10% by 2050; and +5 to 10% by 2080 (draft New York State ClimAid Report, 2010).

The most striking trend is the observed and projected increase in frequency and intensity of extreme precipitation events, especially under the high emissions scenario. In Poughkeepsie, the average number of days per year with at least 2 inches of rain has increased from one to two and a half, as shown below in Figure 2.20. In 2005, six of these extreme precipitation events occurred during the year, a record during this period (NRCC, "CLIMOD System," 2008).

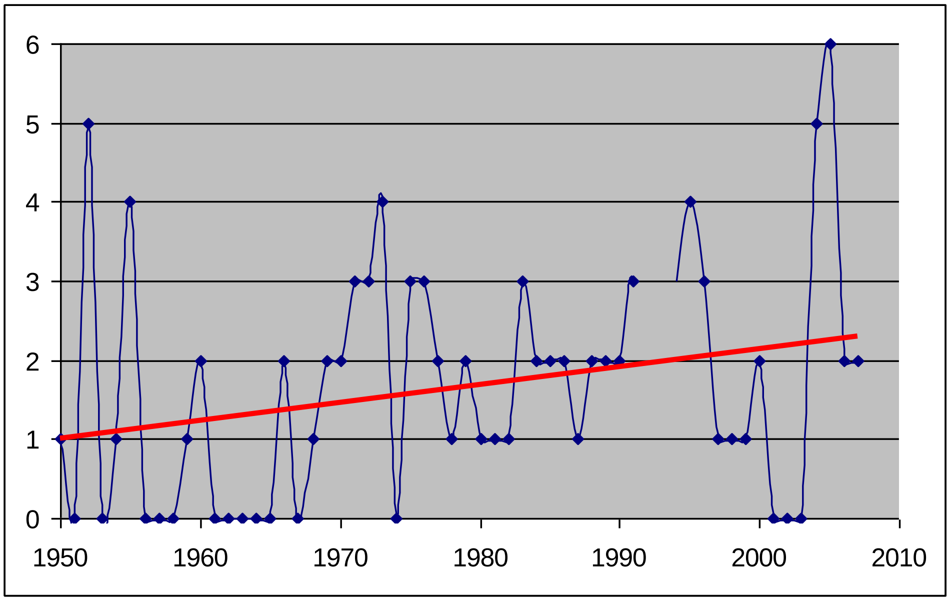

Figure 2.20: Extreme Precipitation Events in Poughkeepsie, 1950-2007 (Source: NRCC, "CLIMOD System," 2008).

By the end of the century, there will be one to two more days each year of at least two inches of rain, and on average 12 percent more rain during these events (United State Global Change Research Program, 2009). Sea level rise will affect the Hudson River in the Mid-Hudson Valley, and the level of the Hudson River is projected to be increase by +1 to 4 inches by 2020; +5 to 9 inches by 2050; and +8 to 18 inches by 2080 (draft New York State ClimAid Report, 2010).

Climate change has already had a considerable effect on the amount of snowfall and snow cover in the northeastern United States, and will continue to do so. The number of days with snow cover has already been decreasing across the Northeast. For example, in Poughkeepsie, the number of days with at least one inch of snow on the ground has decreased by about 33 percent the past 60 years (NRCC Climod System).Throughout the rest of the century, the number of days with snow cover is expected to continue diminishing, with 4-8 fewer snow-covered days per month during the winter in the Northeast. The overall snow season will also shorten, with snowfall arriving later and leaving earlier. As temperatures rise, the snow that does fall will become "slushier"- wetter, heavier, and more dense. Furthermore, winter storms which once brought the area just snow will now be more likely to produce sleet, freezing rain, and rain with less, if any snowfall (United State Global Change Research Program, 2009).

According to the United State Global Change Research Program, climate change is already affecting the water resources, agriculture, ecosystems, energy resources, transportation and health in the northeastern United States. Over the next few decades and to the end of the century, the projected climate changes for the region include increasing adverse health effects from extreme heat and declining air quality, especially in urban areas; changes to agricultural production, including dairy, fruit, and maple syrup, as climates shift; increasing frequency of flooding due to sea-level rise and heavy downpours; and adverse impacts on winter recreation due to projected reductions in snow cover (U.S. Global Change Research Program, 2009, Global Climate Change Impacts in the United States: Northeast Region). While the exact impacts of climate change on Dutchess County are not entirely certain, recent trends and current research indicates that the climate and therefore the ecosystems and natural resources of the county will be altered substantially in the future, especially if humans continue to emit greenhouse gas emissions at the current rate.

CLIMATE DATA

The **National Climatic Data Center**, located in Asheville, North Carolina, is the world's largest active archive of weather data. The NCDC archives 99 percent of all NOAA data, adding 224 gigabytes of new data daily. The center's stated mission is "to provide access and stewardship to the Nation's resource of global climate and weather related data and information, and assess and monitor climate variation and change" (NOAA, "What is NCDC?," 2008). The NCDC also manages six regional climate centers that disseminate climate data, research, and applications at a regional and local level. Figure 2.21 shows a map of the coverage areas of each regional climate center in the United States. The **Northeast Regional Climate Center (NRCC)**, located in the Department of Earth and Atmospheric Sciences at Cornell University, covers Dutchess County (NOAA, "Regional Climate Centers," 2008).

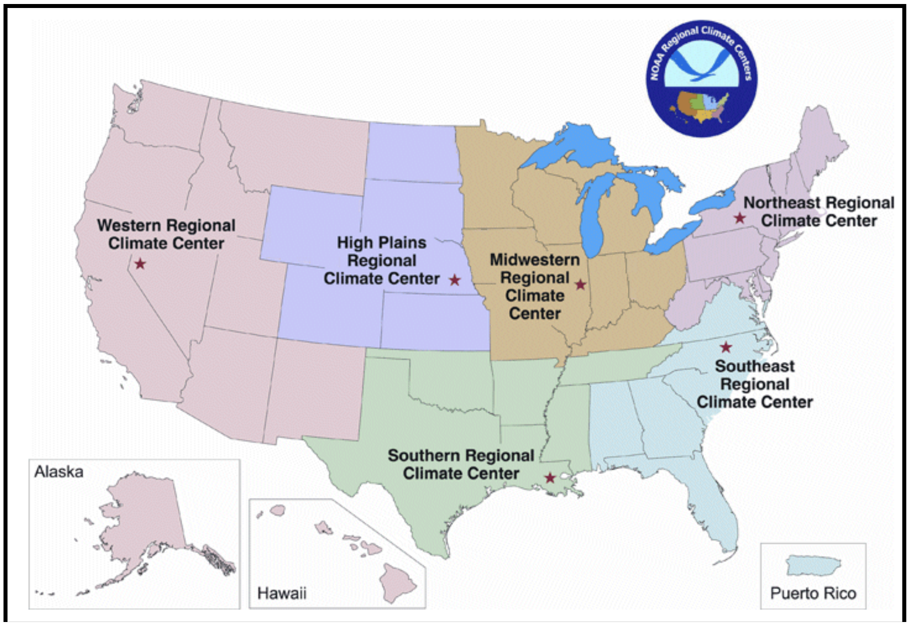

Figure 2.21: NOAA Regional Climate Centers (Source: NOAA, "Regional Climate Centers," 2008).

The NCDC and the regional climate centers support the American Association of State Climatologists, an organization composed of state climatologists and the directors of the six regional climate centers. The **New York State Climate Office** is also located with the NRCC at Cornell University.

The National Weather Service's **Cooperative Observer Program** is a climate observing network of over 11,000 volunteers throughout the country. Data is used for NWS products and archived at the National Climatic Data Center (NOAA, "NWS Cooperative Observer Program," 2008). There have been 15 cooperative reporting stations in Dutchess County at one time or another. Eight stations currently operate in the county and are listed in Table 2.4 below.

Table 2.4: Weather station locations in Dutchess County (Source: NRCC, "CLIMOD System," 2008).[8]

Station	Latitude	Longitude	Elevation (ft.)	Years in Service
Beacon	41° 30' N	73° 57' W	322	1930-1935
Clinton Corners	41° 49' N	73° 46' W	280	1971- Present
Glenham	**41° 31' N**	**73° 56' W**	**275**	**1948-1996**
Millbrook (Millbrook School)	**41° 51' N**	**73° 37' W**	**820**	**1948- Present**
Millbrook (Institute of Ecosystem Studies)	*41° 47' N*	*73° 45' W*	*413*	*2004- Present*
Millerton	41° 57' N	73° 31' W	732	1948-1985
Poughkeepsie (South Road)	41° 38' N	73° 55' W	170	1993- Present
Poughkeepsie (Rural Cemetery)	41° 41' N	73° 56' W	102	1948-1974
Poughkeepsie	41° 43' N	73° 56' W	50	1962- Present
Poughkeepsie/ Dutchess County Airport	**41° 38' N**	**73° 53' W**	**166**	**1932- Present**
Poughkeepsie (Midtown)	41° 42' N	73° 56' W	10	1960-1974
Poughkeepsie (Pendell Road)	41° 43' N	73° 55' W	220	1965-1976
Rhinebeck	41° 53' N	73° 52' W	301	1989- Present
Stormville	41° 32' N	73° 44' W	915	1990- Present
Wappingers Falls	41° 39' N	73° 52' W	114	1948- Present

IMPLICATIONS FOR DECISION-MAKING

Climate, the synthesis of long-term weather patterns, contributes to many facets of life in Dutchess County. The county has a humid continental climate, with hot, humid summers, cold winters, and generally sufficient precipitation. Severe weather such as thunderstorms, winter storms, and floods occasionally affect the county. The climate and air quality of the county have had several important ramifications for life in the county. Historically, Dutchess County's climate has been very favorable for the production of a variety of agriculture products, including milk and dairy products, equine, nursery and floriculture, vegetables and potatoes, and fruits and nut production (USDA, 2009). The moderate climate, location near major waterways and major metropolitan areas has been a decisive factor in human settlement patterns in the region. As the county continues to grow, it will be important to plan for appropriate development in order to protect the county's air quality and to help mitigate and adapt to climate change.

[8] Bold Stations denote NCDC principal reporting stations for 1971-2000 data period. *Italics* denote a member of the US Climate Reference Network.

Air Quality

The air we breathe is a vital resource that we should not take for granted. It is essential for the health of human life as well as the natural world around us. Without clean air, not only will our own breathing be compromised, but the health of our forests, fields and all of the animals and plants that they sustain will be threatened. For this reason, it is essential that we protect this important resource.

Some pollutants such as ground-level ozone and acid deposition have improved in Dutchess County in the last several decades. However, the current levels of these pollutants are still a long way from normal. Additionally, the latest health research indicates that our standards for pollutants such as ozone and particulate matter have been set too high to adequately protect human health. As a result, the EPA has adopted lower concentration limits for ground level ozone. The combination of the new EPA standard for ozone, together with the fact that Dutchess County is grouped regionally with Putnam and Orange Counties, has resulted in the EPA designation of nonattainment for ozone for the Dutchess/Putnam/Orange County Area. The take home message is that pollutants such as ozone and particulate matter can easily become more critical in Dutchess County, especially as the population in the county grows and development occurs.

Currently ozone, particulate matter and acid deposition are regulated at the federal level. Because those pollutants, or their precursors, are to a large extent, produced at a regional scale larger than Dutchess County, indeed larger than the state of New York, they are regulated by the federal government via the Clean Air Act and its amendments. The precursors to ozone, acid deposition and some particulate matter are produced in areas upwind from Dutchess County. As a result, we rely on our state and federal governments to regulate these pollutants in order to keep the air in Dutchess County clean. It is important to remember, however, that just as there are sources of pollutants upwind from us, there is an area downwind of us, where the pollutants that we produce will settle. Therefore, we should not only be concerned about the pollutants that come from our neighbors upwind, but we should also remember that it is our responsibility to control our own air pollutant emissions for the sake of our downwind neighbors.

What are the options or tools available at the municipal or county level for the protection of our air quality? Many pollutants or precursors to pollutants are produced by motor vehicles. Therefore, reducing our dependence on cars will help protect our air quality, and it is critical to ensure that there are alternative means of transportation available. Providing and maintaining safe bicycle routes and adequate public transportation are two ways local governments and agencies can reduce pollution produced by vehicle exhaust. Volatile Organic Compounds (VOC) are important precursors to ozone, and one source of VOC is gasoline vapors. Our neighbors in Westchester and Putnam Counties have required gaskets on all gasoline pumps to prevent the escape of vapors. Dutchess County should consider the same or similar requirements to reduce ozone formation. Some municipalities in New York have considered ordinances to restrict emissions from outdoor wood burning furnaces, which can produce high concentrations of particulates. While manufacturers of indoor woodstoves are currently required by EPA to certify that stoves for sale in the United States comply with the EPA particulate emissions guidelines in the Clean Air Act, outdoor wood burners are not currently regulated at the federal level. Taking steps at the local level not only ensures cleaner air for Dutchess County, but also for our downwind neighbors.

Local legislation often serves as the impetus for more regional legislative action. For example, climate change legislation enacted by New York and California may serve as a template for federal climate change legislation. When local communities take steps to address regional issues, it sends the message to representatives in higher legislative offices that constituents want action, and more encompassing legislation often follows. Although local ordinances may seem limited in the short-term, they can have a more broad effect in the long-term, thus making them worthwhile for regional as well as local communities.

Climate Change

As detailed above, the climate of New York State and Dutchess County is already changing due to the affects of global climate change. These observed changes include increased temperature in the summer, milder temperatures in the winter (with less snow cover and decreased icing over of the Hudson River, more extreme precipitation events, and a longer growing season). The observed changes are already affecting facets of life in Dutchess County, whether or not they are broadly perceptible to the public and municipal officials. For example, there are fewer opportunities now than in the past for popular winter recreational activities such as skiing, ice yachting and sledding as winters are warmer and there is less snow and ice cover. Increasingly hot and humid summer temperatures and increasing "hot spells" above 90 degrees mean that more people are using air conditioning and installing central air conditioners in their homes.

Dutchess County's climate will continue to change in the future, and these changes will be more extreme if human GHG emissions continue unabated or increase into the future. Climate change will have far-reaching effects on many sectors. New York State and many local governments, organizations and businesses around New York have already started to reduce their emissions of GHGs (through climate mitigation, or the actions taken to permanently eliminate or reduce the long-term risk and hazards of climate change to human life and property) by improving their energy efficiency in various operations and increasing the use renewable energy.

Business and municipal leaders also need to start planning for climate adaptation, or planning for the changes to the climate that will occur and taking into account the future risks of climate change when planning and making decisions. Those involved in agriculture, insurance, transportation and many other sectors must be cognizant of the latest climate change information and future projections (Sussman and Freed, 2008). According to the US Global Change Research Program's Climate Literacy Guide, reducing our vulnerability to climate change will require changes to our economy and infrastructure, as well as individual attitudes, societal values, and government policies to ensure the stability of both human and natural systems (2009).

Communities may want to adopt "win-win" strategies for climate change adaptation. These are actions that would be beneficial for the community and ecosystem *even if* the climate does not change as much as scientists are projecting. These win-win strategies may include:

- Adopting a local climate change action plan that describes the policies and measures that the municipality will enact to reduce greenhouse gas emissions and adapt to climate change. One example is a program through the New York State Department of Environmental Conservation, for communities to adopt the New York State Climate Smart Communities Pledge;
- Working on long-term infrastructure planning that takes into account changing climate models for precipitation, sea level rise and rising temperatures and their possible impacts on drinking water supplies and water treatment plants, roads and bridges and energy supplies.

- Planning to assure a continuous supply of the basic needs that may be affected by climate change, including a secure regional food system, clean water, and renewable energy.
- Establishing and enhancing riparian buffers and protecting wetlands and open space in order to prepare for possible increased high-intensity storm events;
- Working with private forest owners to protect and sustainably manage forested areas;
- Including protection of open space, biodiversity, and wetlands/watercourses in comprehensive plans, zoning and local ordinances, and incorporate smart growth and low impact development principles into planning decisions;
- For more adaptation strategies, see the NYS Open Space Conservation Plan, Climate Change Adaptation Recommendations, at: see: http://www.dec.ny.gov/docs/lands_forests_pdf/osp09chapter3a.pdf.

RESOURCES FOR ADDITIONAL INFORMATION

- **Albany National Weather Service Forecast Office:** The office provides weather forecasts, observations, and climate data for Dutchess County and surrounding locations in Eastern New York and Western New England. See: http://www.erh.noaa.gov/er/aly/.
- **Cary Institute of Ecosystem Studies**: Provides real-time and summarized climate data from Millbrook, NY through the Cary IES Environmental Monitoring Program, at: http://ecostudies.org/emp_daily.html.
- **ICLEI Local Governments for Sustainability:** http://www.icleiusa.org/programs/climate ICLEI is a membership association that provides tools to local governments committed to climate protection and sustainability.
- **Jet Stream:** Many of the hyperlinks in this document link to **Jet Stream**, an online weather course for the general public from the National Weather Service. The homepage is: http://www.srh.noaa.gov/jetstream/index.htm.
- **National Climatic Data Center**: Provides climate data free of charge, at: http://www.ncdc.noaa.gov/oa/mpp/freedata.html.
- **New York State Department of Environmental Conservation, Climate Smart Communities Program**: http://www.dec.ny.gov/energy/50845.html.

- **Northeast Climate Data Center, Cornell Dept of Earth and Atmospheric Sciences:** http://www.nrcc.cornell.edu/**.**
- **US Environmental Protection Agency:** http://www.epa.org includes comprehensive information on air quality and climate change.
- **US Global Research Program**: http://www.globalchange.gov/. The national and northeast reports "Global Climate Change Impacts in the United States" present current and future climate changes in the United States and regions.

REFERENCES

Brownell, F. William. "Clean Air Act." *Environmental Law Handbook: Twelfth Edition*. Rockville, MD: Government Institutes, Inc., 1993.

Cary Institute of Ecosystem Studies. "Environmental Monitoring Program." 2008.

Cornell University, Department of Entomology. "Growing Degree Days." (accessed July 2008).

DeGaetano, Art. "Climate Change Projections for the Hudson Valley." Department of Earth & Atmospheric Science, Cornell University, 2010.

Dirienzo, Stephen. Personal communication. Albany, NY: National Weather Service, July 2008.

Florida Division of Emergency Management. "Tornadoes." Accessed July 29, 2008.

Karl, Thomas R., Jerry M. Melillo, and Thomas C. Peterson, Eds. *Global Climate Change Impacts in the United States*. San Francisco, CA: Cambridge University Press, 2009.

Lovett, G.M., and T.H. Tear. "Threats from Above: Air Pollution Impacts on Ecosystems and Biological Diversity in the Eastern United States." The Nature Conservancy and the Cary Institute of Ecosystem Studies, 2008.

Microsoft Encarta Images. "Climatic Regions of North America." Accessed August, 2008.

National Oceanic and Atmospheric Administration (NOAA). "Carbon Dioxide, Methane Rise Sharply in 2007." *NOAA News,* accessed July 24, 2008.

National Oceanic and Atmospheric Administration (NOAA). "Annual Mean Sea Level Pressure." National Climatic Data Center, accessed August 8, 2008.

National Oceanic and Atmospheric Administration (NOAA). "Continental United States Hurricane Strikes, 1950-2007." National Climatic Data Center, accessed July 29, 2008.

National Oceanic and Atmospheric Administration (NOAA). "Historic Palmer Drought Indices." National Climatic Data Center , accessed July 29, 2008.

National Oceanic and Atmospheric Administration (NOAA). "Mean Relative Humidity (Annual)." National Climatic Data Center , accessed July 28, 2008.

National Oceanic and Atmospheric Administration (NOAA). "New York." National Climatic Data Center , accessed July 31, 2008.

National Oceanic and Atmospheric Administration (NOAA). "Percentage of Possible Sunshine." National Climatic Data Center , accessed July 28, 2008.

National Oceanic and Atmospheric Administration (NOAA). "Regional Climate Centers." National Climatic Data Center , accessed July 31, 2008.

National Oceanic and Atmospheric Administration (NOAA). "NCDC Storm Events," National Climatic Data Center , accessed July 29, 2008.

National Oceanic and Atmospheric Administration (NOAA). "What is NCDC?" National Climatic Data Center , accessed July 31, 2008.

National Oceanic and Atmospheric Administration (NOAA). "Weekly & Monthly Degree Days Summaries Explanations." Climate Prediction Center, accessed July 25, 2008.

National Oceanic and Atmospheric Administration (NOAA). "Saffir Simpsons Hurricane Scale." National Hurricane Center, accessed July 29, 2008.

National Oceanic and Atmospheric Administration (NOAA). "Floyd Deluges Eastern New York and Western New England." National Weather Service (NWS), accessed July 29, 2008.

National Oceanic and Atmospheric Administration (NOAA). "NWS Cooperative Observer Program." National Weather Service (NWS), (accessed July 31, 2008).

National Oceanic and Atmospheric Administration (NOAA). "NWS Glossary." National Weather Service (NWS), accessed August, 2008.

National Oceanic and Atmospheric Administration (NOAA). "Past Storm Events." National Weather Service (NWS), accessed July 29, 2008.

National Oceanic and Atmospheric Administration (NOAA). "Fujita Tornado Damage Scale." Storm Prediction Center, accessed July 29, 2008.

New York State Climatologist. "The Climate of New York." Accessed July 25, 2008.

New York State Department of Environmental Conservation (NYS DEC). "Ambient Air Quality Monitoring Program." Division of Air Resources, Bureau of Air Quality Surveillance, accessed January 2007.

New York State Department of Environmental Conservation (NYS DEC). 2007. *New York State Ambient Air Quality Report for 2007*. Accessed July 2008.

Northeast Regional Climate Center (NRCC). "CLIMOD System." Accessed July 25, 2008.

Northeast Regional Climate Center (NRCC). "Northeast Drought Page." Accessed August 2008.

Northeast Regional Climate Center (NRCC). "Percent of Possible Sunshine." Accessed July 28, 2008.

Northeast Regional Climate Center (NRCC). "Wind Summary for Dutchess County Airport." July 22, 2008.

Pidwirny, M. "The Greenhouse Effect," *Fundamentals of Physical Geography, 2nd Edition*. (2006) accessed July 24, 2008.

Sussman, Frances and J. Randall Freed. *Adapting to Climate Change: A Business Approach*. Arlington, Virginia: Pew Center on Global Climate Change, April 2008.

Town of Dover, NY. "Damage from Recent Storms." Highway Department, accessed July 2009.

United Nations Intergovernmental Panel on Climate Change (IPCC). *Climate Change 2007: Synthesis Report, Summary for Policy Makers*. Valencia, Spain (2007) 5.

United States Code of Federal Regulations (US CFR). 2006. 40 C.F.R 50.9.

United States Code of Federal Regulations (US CFR). 2006. 40 C.F.R. 50.10.

United States Code of Federal Regulations (US CFR). 2006. 40 C.F.R 81.333.

United States Code of Federal Regulations (US CFR). 42 U.S.C. 7410.

United States Department of Agriculture (USDA). "Dutchess County Farm Statistics." National Agricultural Statistics Service (NASS) (2009), accessed October 5, 2010.

United States Department of Energy. "The Greenhouse Effect." Energy Efficiency and Renewable Energy, accessed July 2008.

United States Environmental Protection Agency (USEPA). "Climate Change Basic Information." Accessed October 5, 2010.

United States Environmental Protection Agency (USEPA). "Frequently Asked Questions About Global Warming and Climate Change: Back to Basics." Office of Air and Radiation, EPA-430-R08-016 (April 2009), accessed 5 October 2010.

United States Environmental Protection Agency (USEPA). "Ambient Air Monitoring Program." Office of Air and Radiation, accessed January 24, 2007.

United States Environmental Protection Agency (USEPA). April 2007. *The Plain English Guide to the Clean Air Act*. Publication No. EPA-456/K-07-001 (April 2007), accessed January 24, 2007.

US Global Change Research Program. *Climate Literacy Guide*. Washington, DC: March 2009.

Urban-Mead, Russell B. *Dutchess County Aquifer Recharge Rates & Sustainable Septic System Density Recommendations*. The Chazen Companies: Poughkeepsie, New York (2006), 46.

The Weather Channel. "Storm Encyclopedia." Accessed July, 28, 2008.

Chapter 3:
Geology and Topography of Dutchess County, NY

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May 2010

INTRODUCTION

Chapter Contents

The topography, settlement patterns, and mineral resources of Dutchess County are all influenced by the underlying geology. For example, the highest mountains contain the hardest rocks, communities in the county are generally located in areas of sand and gravel because of the relatively level terrain and abundant water supplies they contain, and construction aggregates are mined where suitable deposits are found. Understanding geologic materials and processes is essential to sound resource management because the geology affects the

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quality and quantity of groundwater resources, the migration of pollutants, potential hazards to inhabitants, drainage patterns, mineral resources, and soil characteristics.

Geology is the study of the earth, including all materials found at and below the earth's surface. Geologists analyze the composition, origin, and ongoing changes in the rocks and sediments that compose the earth. The natural processes that shape the land – uplift, erosion, deposition of sediments, and faulting – are as vigorous today as they were in the past. These processes have resulted in a continual recycling of materials formed over the past 4.6 billion years of Earth's history. Here in Dutchess County we can see the effects of this **rock cycle** in the ancient gneisses exposed in Stissing Mountain and the Hudson Highlands, in the **schists** and **marbles** of the Harlem Valley, in the **sandstone** and **shale** that underlie Rhinebeck, and in the glacial deposits found throughout the county.

The geologic structure of Dutchess County is complex. Its history extends over one and a half billion years and has included several periods of major mountain building, ocean invasion and retreat, and **glaciation**. These events are part of the dynamic evolution of the earth's crust. However, there are also large gaps in the record of the geological history of the county; vast segments of time are unaccounted for within its borders due to erosion or simply lack of deposition. Today's topography is the result of the interaction between internal forces that uplift the land and external elements (weather, water, gravity, and human efforts) that continually erode it away.

GEOLOGIC HISTORY

All of the rocks in Dutchess County were formed during the Precambrian Eon (pre-Archaean, Achaean, and Proterozoic time intervals in Figure 3.1), and the Cambrian and Ordovician periods of the early Paleozoic Era, or between about 1,500 million years and 400 million years ago. Detailed descriptions of the rocks of Dutchess County are given in the *Bedrock Formations* section of this chapter.

EON	ERA	PERIOD	MILLIONS OF YEARS AGO
Phanerozoic	Cenozoic	Quaternary	1.6
		Tertiary	66
	Mesozoic	Cretaceous	138
		Jurassic	205
		Triassic	240
	Paleozoic	Permian	290
		Pennsylvanian	330
		Mississippian	360
		Devonian	410
		Silurian	435
		Ordovician	500
		Cambrian	570
Proterozoic	Late Proterozoic Middle Proterozoic Early Proterozoic		2500
Archean	Late Archean Middle Archean Early Archean		3800?
Pre-Archean			

Figure 3.1: Geologic time scale (US Geological Survey, 2010)

The oldest rocks in the county were deposited as sediments one and a half billion (1,500,000,000) years ago. One billion (1,000,000,000) years ago these sediments were caught in a collision between ancestral North America and another continent (perhaps an ancestral version of Europe or Africa, Figure 3.2). The collision, resulting in a mountain-building event that is referred to as the **Grenville Orogeny**, caused the sediments to be deformed, heated, and changed into the high-grade metamorphic rock known as **gneiss**. In places, the sediments were heated to the point of melting and an igneous rock known as **granite** was formed. The resulting mixture of granite and gneiss, designated pЄg on Map 3.1, is very resistant to erosion and forms the bedrock of the Hudson Highlands in the southern portion of the county and throughout neighboring Putnam County.

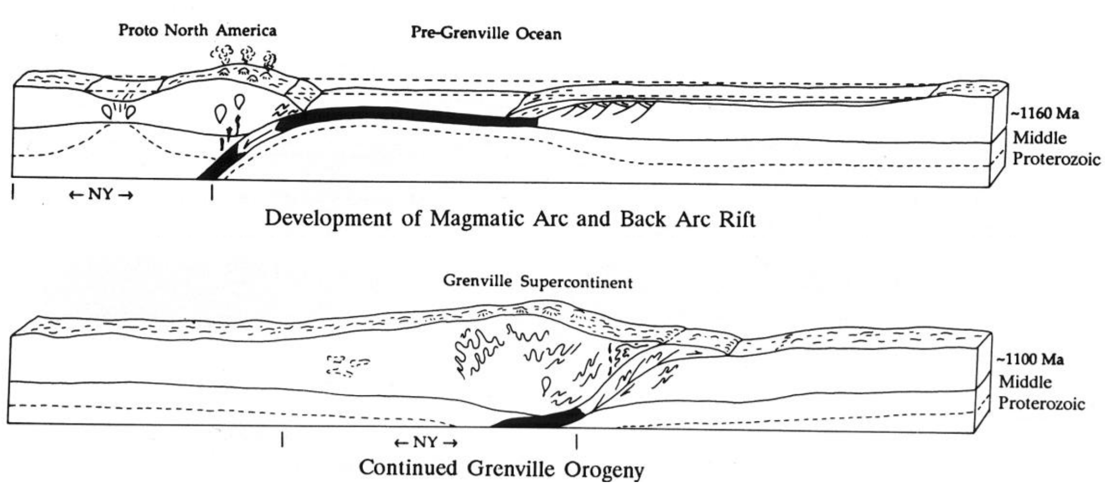


Figure 3.2: Diagram of Grenville Orogeny (from Isachsen et al., 1991).

Half a billion (500,000,00) years ago, the Grenville Supercontinent formed by the Grenville Orogeny broke apart nearly along the trace of the present Atlantic coast, forming a proto-Atlantic Ocean called the Iapetus Ocean (Figure 3.3). (In Greek mythology Iapetus was the father of Atlas, for whom the Atlantic Ocean is named.) The edge of the North American continent was near the present location of Dutchess County, and as sea level rose and fell, different kinds of sediments were deposited depending on the depth of the water.

Before the sea inundated the region, coarse sands and gravels were deposited on the land. After the area was inundated, but while sea level was still relatively low, the Dutchess County area was covered by shallow waters at the edge of the sea, and **limestones** rich in the carbonate minerals calcite and dolomite were deposited in coral reefs and carbonate banks much like the Bahamas today.

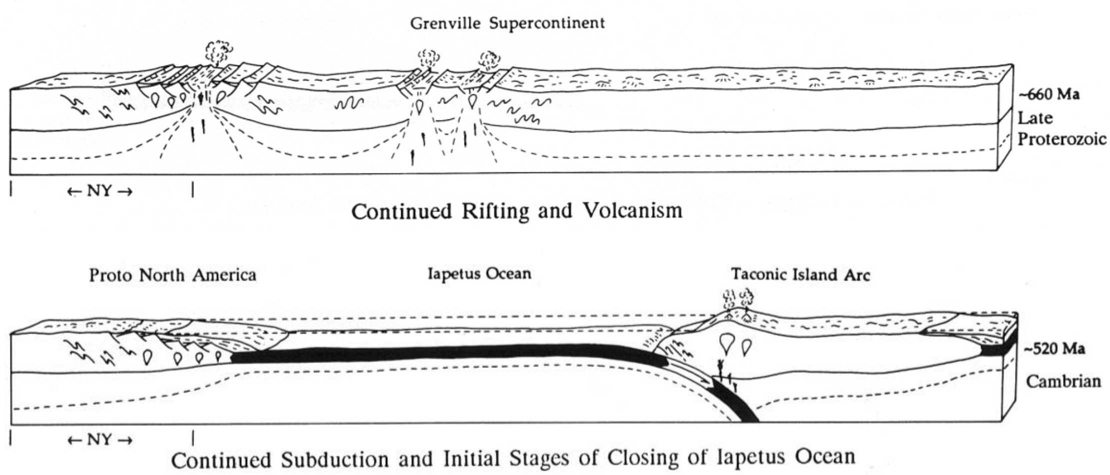


Figure 3.3: Diagram of rifting of the Grenville Supercontinent and formation of the Iapetus Ocean (from Isachsen et al. 1991).

At times when sea level was high, Dutchess County was covered by deeper water, and fine-grained black shales were formed, representing deposition in deep ocean waters of the abyssal plain (the deepest and flattest part of the ocean basins). These shales underlie much of the county, but since they are relatively soft they are not often seen at the surface. Both the limestones and shales are **autochthonous**, meaning that they were formed in their present location.

About 450 million (450,000,000) years ago the Iapetus Ocean began to close, and the east coast of North America began to feel the effects of a collision of continental plates that would continue in two major pulses over the next 200 million (200,000,000) years. During the initial stages of the collision (known as the **Taconic Orogeny**, Figure 3.4), interbedded **sandstones** and shales were deposited by submarine landslides along the continental shelf and slope. Later, large masses of sandstone and shale deposited in the open ocean at or just beyond the edge of the continental shelf were pushed from an area far to the south and east up and over the autochthonous shales and limestones of Dutchess County in a process known as **thrust faulting**. The **Taconic Allochthon** (allochthon means formed far away and transported to the present site), which was created by this thrust faulting, formed a high range of mountains (the ancestral Taconic Mountains) in the vicinity of the present New York-Connecticut border. The thrust faults that bound the allochthon are shown in Figure 3.10.

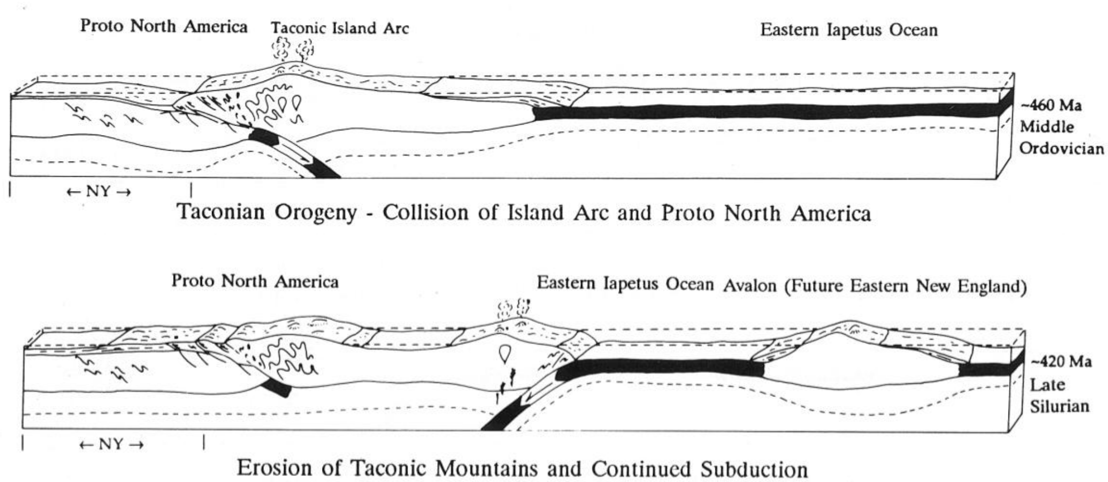


Figure 3.4: Diagram of Taconic Orogeny and erosion of the Taconic Mountains (from Isachsen et al., 1991).

In front of and just below the advancing allochthon, a mixture of different materials, including both allochthonous and autochthonous rocks, was deposited. The result was a chaotic mixture, known as **melange,** composed of large blocks of many different kinds of rock in a matrix of autochthonous shale.

The mountain building of the Taconic Orogeny squeezed and heated rocks caught within the collision zone causing them to be changed or "metamorphosed." The limestones in the western part of the county were metamorphosed to become the marbles today found in the Harlem Valley. Shales in the northwest part of the county were gradually metamorphosed to become **schists** and gneisses in the vicinity of Pawling. The intensity of metamorphism of the rocks increases from northwest to southeast with low-grade metamorphism in the northwestern part of the county (mostly shale), medium-grade metamorphism in the central part of the county, (mostly schist), and high-grade metamorphism in the southeastern part of the county (gneiss).

Several episodes of continental collision after the Taconic Orogeny resulted in the formation of a supercontinent called Pangea. Pangea broke apart during the Mesozoic Era, and subsequent drifting of landmasses has created the configuration of continents we see today. These tectonic events affected the rest of North America, but did not affect Dutchess County. While the county once lay at the margin of the North American tectonic plate, the edge of the plate is now located far to the east, in the middle of the Atlantic Ocean. As a result, our region has been very quiet tectonically for the past 300 million years, as North America has drifted westward from Europe and Africa. During this time, the area has been subject to erosion and development of the topographic features we see today.

The latest notable geologic force to influence Dutchess County was the advance of the massive Laurentide ice sheet southward out of Canada, which extended as far south as Long Island approximately 20,000 years ago (Figure 3.5). The retreat of the ice sheet left behind the surficial deposits of the county and the topography that we see today.

Figure 3.5: Over the last 2.75 million years, continental ice sheets have repeatedly waxed and waned in the northern hemisphere. The most recent ice sheet, called the Laurentide ice sheet, peaked around 20,000 years ago and extended as far south as Long Island in New York State. (from Tasa Graphic Arts, Inc.)

As the Laurentide Ice Sheet retreated, it left behind sediment ridges that dammed glacial meltwater to form lakes. The largest of these lakes occupied the Hudson River valley and was called Lake Albany (Figure 3.6). It gradually lengthened as the ice margin retreated northward, eventually merging with a precursor of Lake Champlain called glacial Lake Vermont (Rayburn et al., 2005). A much larger lake, Lake Iroquois, to the west of Lake Albany formed in the area where Lake Ontario exists today. At around 13,000 years ago, the ice dam separating the two lakes was breached, leading Lake Iroquois to catastrophically drain through Lake Albany to the south, breaching the moraine dam that impounded Lake Albany and scouring out the lake sediments within the Hudson Valley (Donnelly et al., 2005).

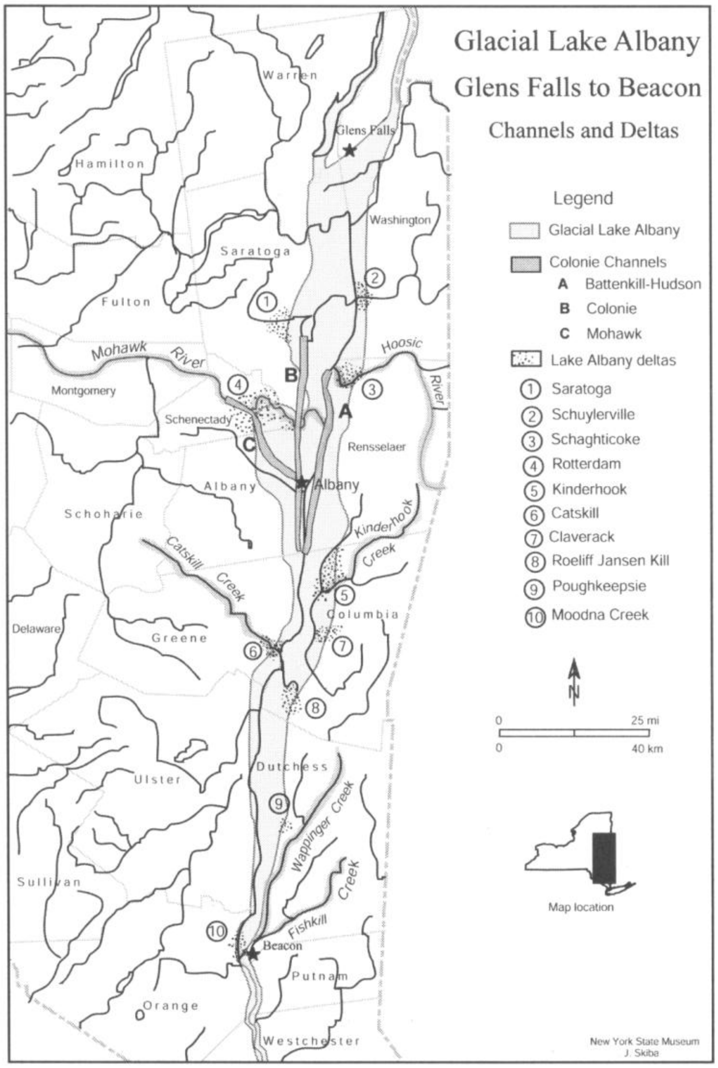


Figure 3.6 – Extent of glacial Lake Albany in the Hudson Valley (from Cadwell et al., 2003).

BEDROCK FORMATIONS

Dutchess County contains rocks from all three of the major rock groups: metamorphic, sedimentary, and igneous. **Metamorphic rocks** are those that have been changed in texture and composition by heat, pressure, or chemically active solutions deep within the earth but without melting. In contrast, **igneous rocks** are formed from the solidification of molten material, either at Earth's surface (volcanic rocks), or deep in Earth's interior (plutonic rocks). **Sedimentary rocks** are formed at or near the earth's surface by depositional and biological processes. **Clastic sedimentary rocks** are composed of rock fragments and clay minerals that have been cemented together and include shale and sandstone. **Carbonate rocks** (sedimentary rocks composed of calcium carbonate) may be formed by biological or processes, such as the formation of coral reefs, or by physical processes, such as the precipitation of carbonate minerals out of saturated sea water. Carbonates that contain a significant component of calcium-magnesium carbonate are labeled "dolomite" or "dolostone." For a more in-depth treatment of these concepts see: http://geomaps.wr.usgs.gov/parks/rxmin/rock.html.

The **bedrock** of Dutchess County includes all of the solid rocks found in road cuts, valleys, and mountaintops. It can be divided into two basic groups: 1) older, highly altered (metamorphosed) former sedimentary and igneous rocks found primarily in the Hudson Highlands and in scattered outcrops elsewhere in the county, and 2) younger, slightly- to highly-metamorphosed sedimentary rocks found throughout the rest of the county. As mentioned in the geologic history section, the degree of **metamorphism** in the younger rocks increases from the northwest (Red Hook and Rhinebeck) to the southeast (Dover and Pawling). The rocks with the highest metamorphic grade (most altered) are found in the uplands east of the Harlem Valley. A simplified view of the bedrock types found in Dutchess County is shown in Map 3.1.

It is common for geologists to attach proper names to each distinctive geological unit. For example, there are many carbonates in the world, but only one Wappinger Group. The names come from localities were the unit was first or best described. There are many exposures of the Wappinger Group throughout the county, but the formation was first described in and around the Town of Wappinger.

Bedrock formations of Dutchess County are described in the following sections (detailed descriptions of the geologic units in New York are cataloged by the US Geological Survey).

Older metamorphic rocks of the County (map symbol pЄg)

The oldest rocks in Dutchess County are in the Hudson Highlands, an upland area composed primarily of various **gneisses** (metamorphic rocks made up of discrete bands of light and dark minerals). These rocks (pЄg on Map 3.1), which were formed more than one billion years ago during the Grenville Orogeny (Isachsen et al, 1991), are most common along the southern border of Dutchess County, between the Hudson River and the western border of the town of Pawling. The second largest occurrence of these rocks underlies a group of prominent hills, the Housatonic Highlands, east of Dover Plains. Isolated, uprooted blocks of gneiss also crop out at Todd Hill along the Taconic Parkway in the town of LaGrange, Corbin Hill north of the Village of Pawling, Stissing Mountain in the Town of Pine Plains, and in a series of small fault slivers between the City of Beacon and the Town of Fishkill.

Most of the gneiss consists of light and dark colored minerals arranged in layers with a banded, streaky, or speckled appearance. Gneisses containing light colored minerals such as quartz, feldspar, and muscovite (white mica) predominate. Various types of gneisses containing dark minerals such as hornblende, garnet, and biotite (black mica) also occur. Extensive outcrops of gneiss are generally more resistant to weathering than sedimentary rocks. As a result, gneiss outcrop areas are usually part of more rugged terrain and exist at higher elevations. Granitic gneiss, which occurs at North Beacon Mountain, is the most durable of these types and is sometimes quarried for crushed stone and building stone.

Younger sedimentary/metamorphic rocks (map symbols Є and O)

The younger sequence of bedrock units in the county includes:

1. Carbonate rocks of the **Wappinger Group** (**OЄw** on Map 3.1) and its metamorphic equivalent, the Stockbridge marble)
2. **Poughquag quartzite** (Єp), a body of sandstone known from its extensive outcrops near the hamlet of Poughquag
3. Metamorphosed clastic sedimentary rocks (now schists) of the **Taconic Sequence** (**Єt**), which were deposited at a point several hundred kilometers east of North America and were subsequently shoved over younger rocks to their present position. The Taconic sequence is very similar to the clastic rocks that it rests upon (Osh) which were deposited in about the location we find them now. The Osh rocks are **autochthonous** shales, whereas the Taconic sequence is **allochthonous** shales.

4. Relatively unaltered to moderately metamorphosed autochthonous clastic sedimentary rocks, including the **Poughkeepsie** (or **Taconic**) **Melange** (**Otm**) and the **Austin Glen greywacke** (**Oag**)

Carbonate rocks

Carbonate rocks are formed primarily from the precipitation of calcium and magnesium carbonate in seawater, commonly through the action of algae and other organisms like corals and mollusks. The Wappinger Group, found in the central and western part of the county, consists of Cambrian- and Ordovician-age carbonate **strata** (rocks composed of layered sediments). Its metamorphic equivalent, the Stockbridge marble, underlies the Harlem Valley. Outcrops of carbonate rocks are found scattered throughout the southern, central, and eastern parts of the county. In the southeast, carbonate rocks form valleys, as the marble is softer and more susceptible to erosion than the surrounding metamorphic rocks. Elsewhere, the carbonates form small ridges, as they are relatively harder than the adjacent unmetamorphosed clastic rocks. Some of these rocks can be seen south of Poughkeepsie in road cuts along Route 9 near the Galleria and South Hills Malls, and along the river in the large quarry operating at Clinton Point.

Carbonate rocks are economically important in Dutchess County as a source of construction aggregate. One of the largest quarries in New York State is located in the Town of Poughkeepsie at Clinton Point. Glimpses of the carbonate rocks and the quarry operations can be seen from the Metro-North train between Poughkeepsie and New Hamburg. The carbonate rock of this quarry has an average magnesium carbonate content of about 40 percent. For this reason it is classified not as a limestone, but as a dolostone, which is slightly harder than limestone. The rock is blasted, crushed, and sorted to sizes ranging from large individual rock fragments (riprap) weighing up to 15 tons each, to sand used in the production of asphaltic paving and the manufacturing of concrete blocks. Most of the production from the quarry is shipped by barge to New York City. Carbonate rocks are also mined in the Town of Pleasant Valley to produce construction aggregate. During World War II, marble in the Town of Dover was mined to recover magnesium for the war effort.

The metamorphism of the Wappinger Group generally increases in intensity from the northwest to the southeast. In the town of Milan and the valley of the Wappinger Creek, the original bedding (layering) is readily visible because the rocks are relatively unaltered. Farther east, in the Harlem Valley, the formation has been metamorphosed into marble and the beds are severely folded. The marble in the southeastern part of the county has been deformed several times by plastic flow so that it appears to wrap around stronger rocks. South of Pawling, masses of schist (a metamorphic rock made of parallel layers of mica and other minerals) have been folded and shoved into the carbonate, appearing as inclusions.

It is difficult to determine the exact thickness of the carbonate rocks because of the amount of faulting and metamorphism that have occurred. However, these rocks are believed to be approximately 1,000 feet thick in the western part of the county, and to thicken to the east. A thickness of 2,800 feet has been measured near Stissing Mountain (Knopf, 1962), and they are estimated to be nearly 4,000 feet thick in the Harlem Valley (Isachsen et al., 1991).

Carbonate rocks are susceptible to internal erosion by the movement of groundwater along fractures and faults. Groundwater dissolves carbonate deposits, producing solution channels and voids; these openings provide storage cavities for groundwater supplies. This stored water can easily be polluted by contamination sources, such as septic tanks, where there are not enough sediment deposits on top of the carbonate bedrock to filter the waste materials. Although cave-ins may occur elsewhere in carbonate rocks, they are rare in Dutchess County.

Clastic Rocks

Clastic sedimentary rocks were formed by the compaction and cementing together of muds and sands at shallow depths beneath the Earth's surface. All of the clastic rocks of Dutchess County were originally formed in an ocean; however, much of the Catskill Mountains, to the west, is composed of clastic rocks formed on land.

There are two distinct groups of clastic rocks in the county. These are: the Poughquag quartzite, found in close proximity to the Wappinger Group carbonate rocks, and shales and clay-rich sandstones (and their metamorphic equivalents) found throughout the county.

Poughquag Quartzite

The Poughquag quartzite (**Ꞓ**p on the map) is a very hard, compact, white to gray sandstone with a quartz content greater than 90 percent. Very clean sandstones (almost pure quartz) are typically believed to be former beach deposits; winnowing by waves removed clays and other minerals. The quartzite is so hard that Native Americans mined it for stone tools and points. Although it is relatively thin (less than 50 feet), equivalent sedimentary layers extend across the United States as far west as Nevada.

Shales and clay-rich sandstones

Most of Dutchess County is occupied by what were originally shales and clay-rich sandstones (map units **Ꞓ**t-allochthonous Taconic sequence, **O**sh-autochthonous shales, and **O**ag-Austin Glen formation) (Figure 3.7). These are found throughout the county, extending into Columbia County to the north, and Orange and Ulster counties to the west. Like the carbonates, the intensity of metamorphism increases from the northwestern part of the county to the southeast. These rocks were originally formed in relatively deep water, during or after the Taconic Orogeny (see *Geologic History* section), as muds derived from land settled in ocean water.

Figure 3.7: Excellent exposure of relatively unaltered sandstone and shale of the Austin Glen formation (map unit Oag) along Route 199, between Route 9G and the Hudson River

A distinct subset of these rocks is the Poughkeepsie or Taconic Melange (map unit **O**tm). This unit formed as the westward-moving allochthons slid into a deep basin lying in the approximate position of the Hudson River, forming a jumbled mix of sandstone blocks in a matrix of mud. Good exposures of the melange are seen in Kaal Rock Park, at the eastern end of the Mid-Hudson Bridge (Figure 3.8). The melange also underlies much of the bank of the Hudson River from Poughkeepsie to Hyde Park.

Figure 3.8: Sandstone blocks in Taconic melange; Kaal Rock Park (Jeff Walker)

The mineral composition and structure of the shale and sandstone units change from the northwest to the southeast. Quartz and mica are found chiefly in the northwest and central parts of Dutchess County. Feldspar is an additional component in the southeast. Bedding plane openings that serve as channels for the storage and movement of groundwater are apparent between the Fishkill Creek and Wappinger Creek valleys. Also between the two creeks, slaty cleavage (a texture produced by rock compression) has resulted in numerous small, closely spaced parallel fractures within the rock. Such cleavage is absent and the rocks are more massive in the southeastern part of the county. Garnet has been mined in the Harlem Valley, as described below. Because these garnet-bearing rocks are relatively soft, they are not used commercially except locally as fill.

A variety of names have been applied to the clay-rich rocks in the county, which may have formed at different times and in different geologic settings. The lack of well-preserved fossils or other diagnostic features, combined with the complex deformation to which they have been subjected, has resulted in less certainty as to the correlation amongst the various named units. Generally, the rocks located in the higher elevations east of the Taconic Parkway are allochthonous (moved), whereas those west of the Parkway are autochthonous (in-place).

STRUCTURAL GEOLOGY

Although sedimentary rocks are generally formed in horizontal layers, parallel to the Earth's surface, today we find them oriented in many directions. Their present configuration is the result of multiple mountain-building events, as described in the section on *Geologic History*. Additional signs of mountain building are found in folds and faults that can be observed in road cuts throughout the county (Figure 3.9). Similar, but larger-scale features can be inferred from the distribution of different types of bedrock. For example, higher-grade metamorphic schists overlie lower-grade slates in the eastern part of the county. Although the contacts between these contrasting rock types are only exposed in a few places, they are inferred to be low-angle thrust faults (faults that allow one rock unit to ride up and over another rock unit, a movement that occurs during the compression associated with mountain building).

Figure 3.9: Folding in the Austin Glen Formation, Noxon Road (Jeff Walker)

The distribution of rock units generally forms a northeast to southwest pattern across the county, as depicted in Map 3.1. Areas of similar bedrock types are inferred to be bounded by faults that separate them from areas of differing bedrock types. No doubt there are many faults within the blocks of similar rock types, but it is difficult to identify them because of the soil and vegetative cover.

The fracturing and crushing that occurs along faults creates channels that can carry large volumes of groundwater. These channels may be enlarged in carbonate rocks as a result of dissolution from acidic waters. As a result, wells drilled into fault and fracture zones may yield large quantities of water.

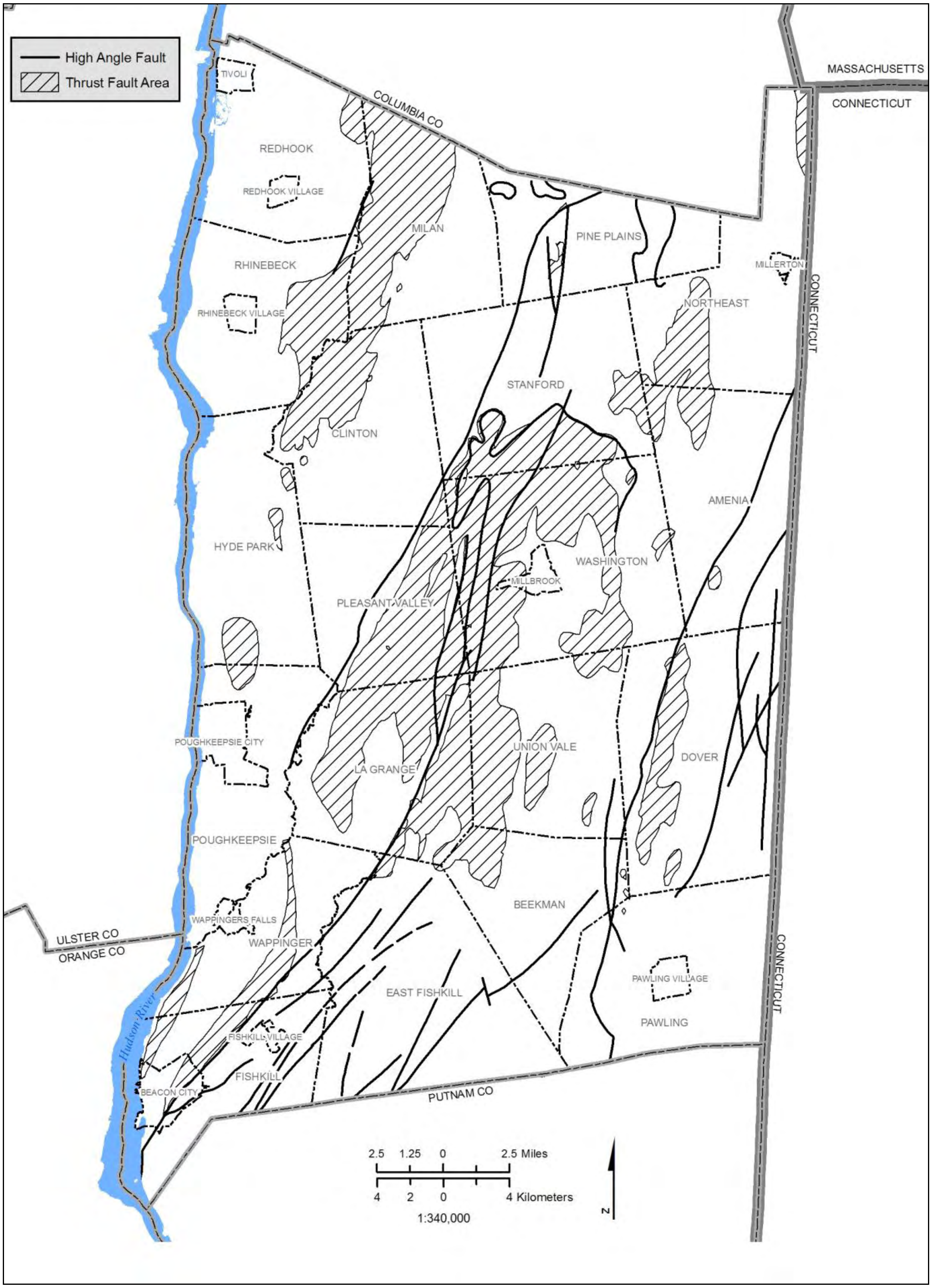


Figure 3.10: Map of faults within Dutchess County

The faults in the region are very old and considered to be inactive. They were formed more than 200 million years ago and have experienced little or no activity since then. Consequently, the county has historically had very few, mostly small, earthquakes.

The tectonic history of the Taconic Orogeny has resulted in a complex structural picture for Dutchess County. A schematic cross section approximately along the line of Route 55 is shown in Figure 3.11. Formation names and symbols are the same as in Map 3.1. The map and the cross section indicate a number of faults where rock masses have moved in relation to one another during the long geologic history of the area.

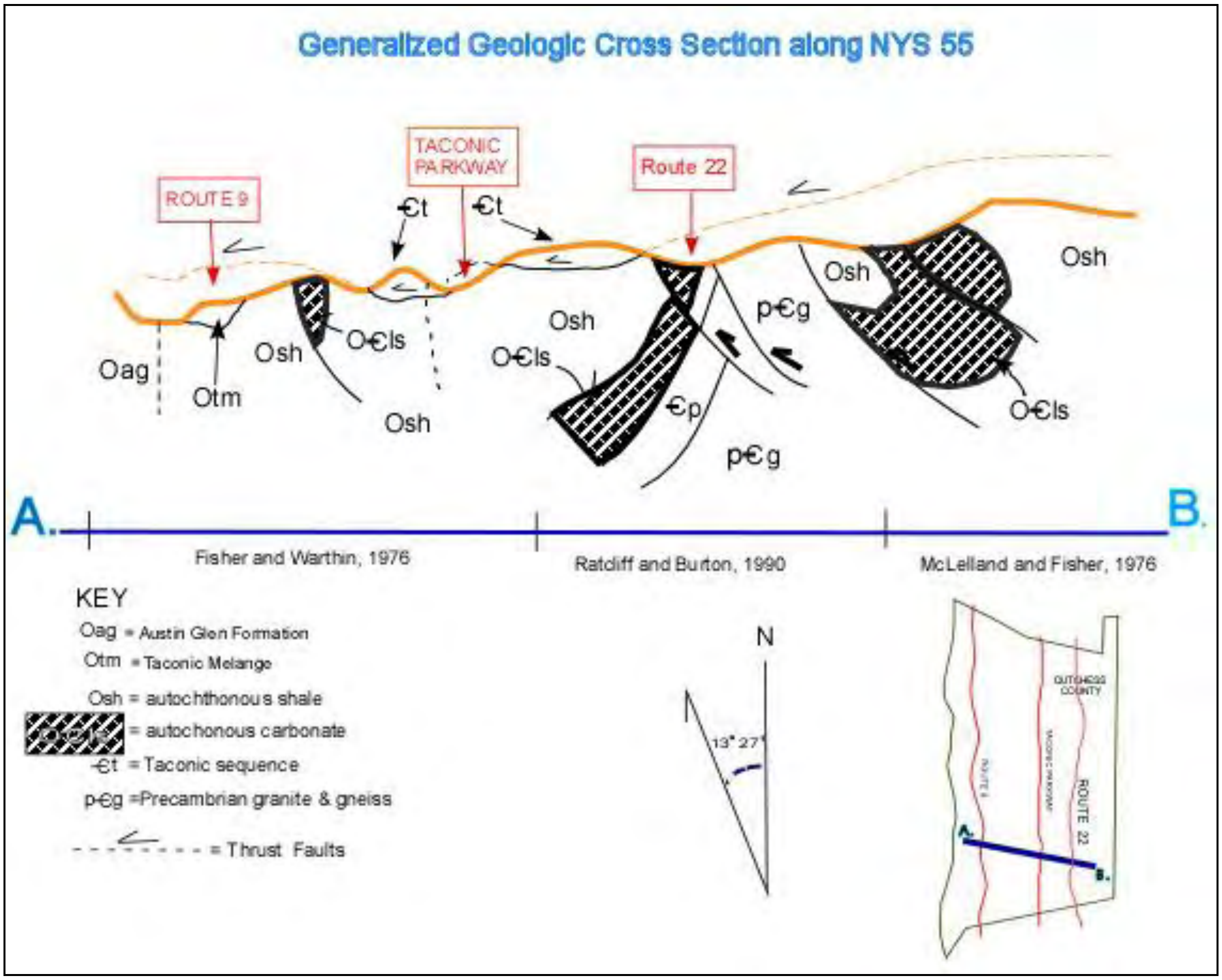


Figure 3.11: Generalized geologic cross-section along Route 55 (interpreted by Jeff Walker; drafted by John DeGilio).

Important features of the cross section include remnants of the Taconic Allochthon (labeled Ɛt in Figure 3.11), which underlie topographic highs in the central part of the county. These remnants are floored by relatively low-angle thrust faults active during the Taconic Orogeny. Also shown are relatively high-angle reverse faults, another type of faulting typical of the compressional forces active during mountain building events. These faults bring very old Precambrian gneisses and their Paleozoic cover rocks, including the Poughquag quartzite (Ɛp), Wappinger Group limestones (OƐw), and autochthonous shales (Osh), to the surface at various places across the county. Some of these faults may have originally formed as extensional fractures known as normal faults during the initial breakup of North America 500 million years ago, and may have been reactivated during the Taconic Orogeny (400 million years ago) as reverse faults. During the breakup of Pangea (200 million years ago) they may have become normal faults once again (Isachsen, et al., 1991). The location of and sense of motion on the faults is largely conjectural since the faults themselves are rarely exposed at the surface.

In addition to faults, the cross-section in Figure 3.11 shows several large folds that bend the autochthonous rock into downwarps known as **synclines**. Finally, the cross section suggests an interesting topographic inversion whereby the limestones are ridge-forming units in the western part of the county because the limestone is more resistant to erosion than the surrounding shales, and valley-forming units to the east where the situation is reversed. In the humid northeast United States it is more common for limestones to floor valleys because they are more susceptible to weathering and erosion than other rock types.

SURFICIAL DEPOSITS

Unconsolidated materials overlie the bedrock in most parts of the county. These include glacial deposits formed during by the Laurentide ice sheet during the last Ice Age as well as more recent stream deposits. Many of the surficial geologic deposits have been altered to produce soils, which are discussed in NRI Chapter 4: Soils.

The sedimentary deposits (Map 3.2) produced by the advance and retreat of ice sheets vary depending on whether the deposits were formed under the ice sheet or adjacent to it as climate warmed and the ice margin retreated northward (Figure 3.12). Rocks embedded in the bottom of ice sheets were pushed over the underlying landscape, scratching bedrock surfaces and creating particles that range in size from large boulders (erratics) to fine clay. Resulting glacial deposits are classified into three main categories: 1) till, 2) outwash, and 3) clay. Unlike the bedrock, the processes that formed Dutchess County's glacial deposits can be observed today in association with modern glaciers, streams, and lakes.

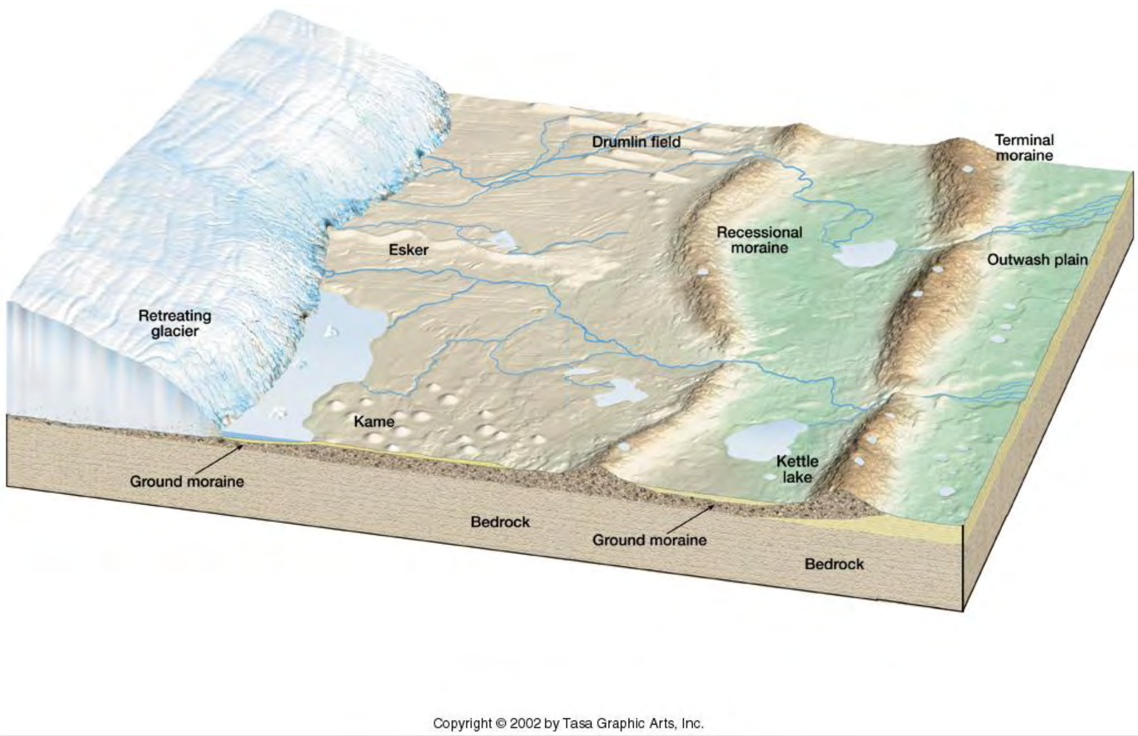


Figure 3.12: Deposits left behind by continental ice sheets vary depending on whether they were formed underneath the ice sheet, adjacent to it, or in front of it. Additional controls on deposit type include whether the sediments were deposited by the ice directly or by meltwater streams. (from Tasa Graphic Arts, Inc.)

Till

Unsorted mixtures of fine material, sand, and larger cobble-sized rocks make up glacial **till** found throughout the county (Figure 3.13). This material blankets the hills of the county and underlies the other glacial deposits in the valleys. It was deposited directly from the melting ice without further modification by moving water. In some areas, till was pushed up into linear ridges (moraines, Figure 3.12) by the episodic re-advance of the ice sheet.

Figure 3.13: Glacial till. Note the mixture of grain sizes from large rocks to fine sands, silts, and clays that indicate no reworking by water. (from http://nesoil.com/images/tillcut.htm, 2010).

Outwash

Meltwater issuing from the edge of a glacier can transport large volumes of debris, much as modern streams do during flooding. The coarser-grained fraction of the stream load is deposited where the flow velocity of the stream ebbs because it enters a lake or flood plain. In contrast, fine-grained sediments are carried far away. The resulting glacial **outwash** is relatively free of very large boulders and fine silts and clays.

During the retreat of the Laurentide ice sheet, sands and gravels were deposited in deltas where meltwater streams issuing from the front of the ice sheet entered glacial lakes and dropped their coarse-grained loads. These deposits are characterized by stratification (layering) that is inclined at 5 to 30 degrees from horizontal (Murray, 1976; Figure 3.14).

Figure 3.14: Delta foreset beds (from http://academic.emporia.edu/aberjame/ice/lec06/lec6.htm, 2010)

Outwash also fills many of the major valleys of the county, including those currently occupied by Wappinger Creek and the Tenmile River. Horizontally stratified sand and gravel were deposited on flood plains of the glacial predecessors of these modern streams. The layers within the outwash terraces reflect changes in grain size due to changes in stream flow volume and velocity.

Lacustrine (lake) Clay

Finer silt- and clay-sized particles, winnowed from the sand and gravel fraction of stream loads, were carried farther downstream, eventually being deposited into local lakes and ponds. These deposits are very dense and uniform in grain-size, although some of the lake deposits are finely layered (varved), possibly reflecting seasonal changes in flow. The lake deposits are located in the lowest parts of the glacial terrain, and are commonly found above a thin layer of till and beneath glacial outwash or modern wetland soils.

Remnants of Lake Albany sediments can today be found along the river's edge on the lands of many of the large estates, such as the Franklin Delano Roosevelt home, the Vanderbilt Mansion, and Locust Grove. Additional lake sediments underlie the Vassar College farm, the Dutchess Plaza shopping center in the Town of Poughkeepsie, and the athletic fields of the Dutchess Day School in Millbrook.

MINERAL RESOURCES

Mineral resources have played an important role in the development of Dutchess County since its settlement. Many of the oldest buildings in the county (including the 1765 stone Clinton House and the 1767 brick Glebe House) were constructed of locally mined materials. Historically, significant resources have included: construction aggregate (crushed stone, sand, and gravel), metallic minerals, and non-metallic minerals.

Such resources can only be utilized where suitable deposits occur. Thus, gravel mines can only be located where there is a substantial reserve of gravel, and rock quarries must be situated where the bedrock has characteristics appropriate for the purpose to which it is to be put. As a result, resource-rich towns such as Amenia and Fishkill have had a more active mining industry than resource-poor towns, such as Wappinger. Unfortunately, as residential development has spread across the county, land-use conflicts have arisen and many potentially valuable resources have been lost.

Construction Aggregate

Sand and Gravel

Sand and gravel are mined for construction aggregate throughout New York and are an important economic resource in Dutchess County. Significant sand and gravel reserves are found primarily along stream valleys, where glacial outwash is located. The valley of Wappinger Creek (in the central part of the county) and the Harlem Valley are notable for their thick outwash deposits. These relatively level gravel terraces are the greatest areas of land use conflict because they are also valuable as farmland and suitable for easy residential development.

The unconsolidated sand and gravel is extracted from open pits, processed on site, and shipped by truck to its point of use. These uses include: construction of septic systems, erosion and stormwater management projects, sand filters for purifying water, concrete for houses and roads, and ice-control sand for reducing hazardous winter driving conditions.

Crushed Stone

Rock aggregate, produced by crushing bedrock, is currently the leading mineral commodity in New York State. There are four active quarries in Dutchess County at this time. These are: the Clinton Point quarry (carbonate, Town of Poughkeepsie), Dutchess Quarry (carbonate, Pleasant Valley), the Thalle Industries quarry (gneiss, Fishkill), and the Wingdale Materials quarry (schist, Dover). Historical records indicate that numerous, small quarry operations produced crushed rock and building stone in the county. The Clinton Point (locally known as "Trap Rock") quarry was started in 1888 for this reason.

Much of the production from the quarries is used in highway construction. The non-carbonate aggregate is especially useful for creating relatively skid-resistant road surfaces.

Metallic Minerals

Iron

At one time, iron ore constituted the most valuable metallic mineral resource found in New York State. From the mid-1800s to the early 1900s the resource was very actively exploited, with approximately 40 iron mines in operation in the Hudson Highlands and Harlem Valley. The iron ore in the Harlem Valley was found in the metamorphic schists, near the contact with the marble. Bog iron was also a source of raw materials for Dutchess County iron works. This iron was precipitated in wetlands where iron-rich groundwater discharged to the oxygen-rich surface environment.

The burgeoning demand for iron and steel during the Second Industrial Revolution and advances in technology encouraged the exploitation of lower grade ores in Minnesota and the abandonment of the mines in Dutchess County and vicinity. Iron furnaces are still visible in the Harlem Valley, however, such as along Dover Furnace Road.

Silver and Lead

Reserves of other metallic minerals are lacking in the county. There have been historic reports of small silver and lead mines, but these were primarily prospects without significant economic production.

Non-metallic Minerals

Garnet

The aluminum-rich mineral garnet is found in high-grade metamorphic schists in the uplands adjacent to the Harlem Valley in the towns of Amenia, Dover, and Pawling. This very hard mineral is commonly used as an industrial abrasive. Garnet is recovered as a by-product of crushed stone production at the Wingdale Materials quarry in Dover. The sale of the garnet helps to offset the costs of operating this underground mine.

Clay

Hudson Valley brick manufacturers primarily used clay from relict glacial lake sediments located along riverbanks. Away from the rivers, clay-rich glacial till was also mined to create bricks. The largest brickyards were located in the Beacon area. The Dennings Point Brick

Works produced as many as 400,000 bricks a day in the late 19th century. The Brockway Brick Company had a yard north of Beacon. Another brickyard existed in the area presently occupied by the Dutchess Plaza shopping area in the Arlington neighborhood in the Town of Poughkeepsie. The brickyards closed in the early 20th century because of changing economic conditions.

DUTCHESS COUNTY TOPOGRAPHY

Topographic Relief

Most of Dutchess County is part of the Mid-Hudson Valley and therefore at relatively low elevations. Exceptions include the Hudson Highlands along the southern edge of the county, the Taconic Mountains in eastern Dutchess County, and Stissing Mountain in Pine Plains. While hilltop elevations in the lowlands are generally below 500 feet above sea level, some elevations in the highlands exceed 1,500 feet.

Topography is intimately related to the underlying geology. Much of the Mid-Hudson Valley is underlain by soft shale or carbonate bedrock, while the Hudson Highlands and the Taconic Hills are underlain by much harder granites, gneisses, schists, and other hard rocks. Carbonate rocks often form localized valleys in the eastern part of the county and ridges in the west. For example, the Harlem and Clove Valleys in the east, as well as the ridge beneath the Galleria Mall in Poughkeepsie, are all under underlain by carbonates. Major streams commonly occur over soft carbonate rocks in Dutchess County. Webatuck Creek, Wappinger Creek, and Fishkill Creek in southwestern Dutchess County all occur on carbonate bedrock.

Dutchess County has extensive low and relatively flat terrain (Map 3.3). These areas include the Fishkill Creek/Sprout Creek Valley in southwestern Dutchess, the Wappinger Creek Valley in west-central Dutchess, the Harlem Valley in eastern Dutchess, Clove Valley in Union Vale and Beekman, and the plain created by a glacial melt-water lake west of Red Hook and Rhinebeck. While the valley bottoms have low relief, adjacent areas are often hilly with relief of several hundred feet. High terrain in the county includes the Hudson

Highlands along the southern boundary of Dutchess, the Taconic Mountains in eastern Dutchess, and Stissing Mountain in Pine Plains. The crest of South Beacon Mountain in the Hudson Highlands is 1,602 feet above sea level while Brace Mountain in the Taconic Mountains has a crest of 2,311 feet.

Glacial Landforms

Glacial topographic features are superimposed on the larger-scale topography of the region. In some places, glacial till was sculpted into ridges parallel to the margin of the Laurentide ice sheet, known as **glacial moraines** (Figure 3.15). These ridges reflect both the bulldozing of material by the advancing glacier and the continuous delivery of new material to the glacier's edge by the movement of ice as the edge remained fixed in position for centuries. In Dutchess County, these moraines are traceable for 5 to 15 miles from west to east and rise up to 180 feet above the surrounding landscape (Connally & Sirkin, 1986).

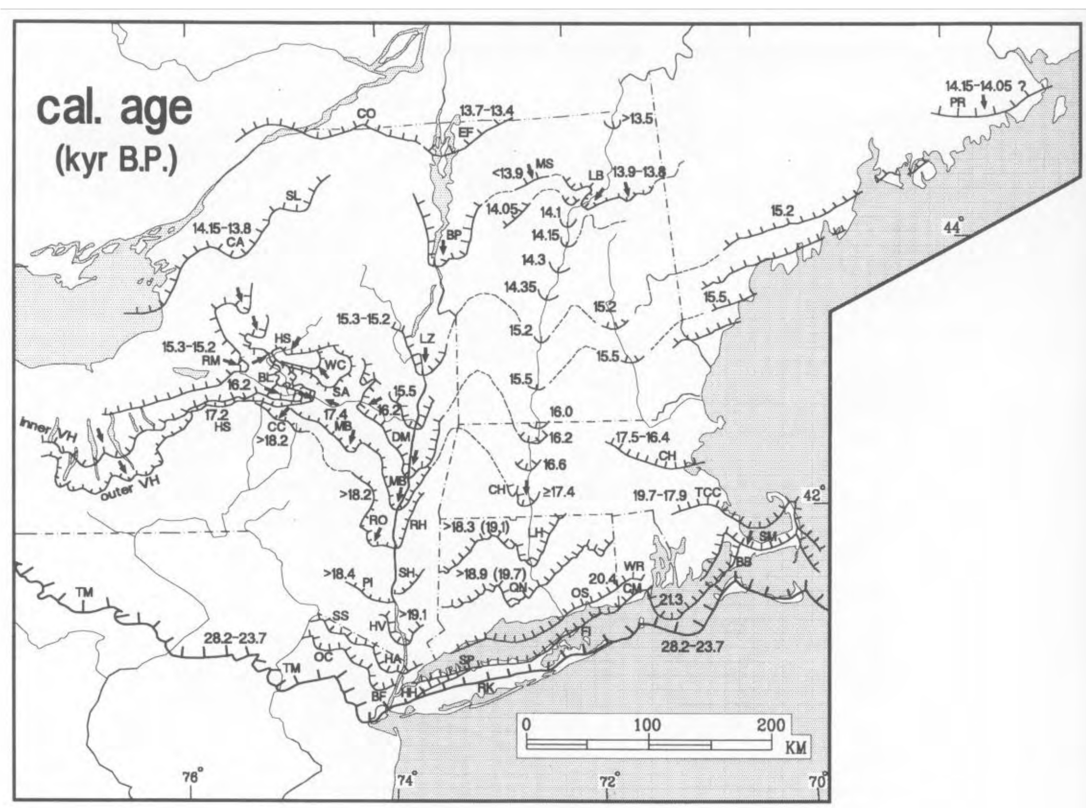


Figure 3.15: The location and ages of moraines left behind by the most recent ice sheet to impact the Northeast. Cal. Age kyr B.P. refers to calendar age in thousands of years before present. Dutchess County contains the Shenandoah (SH) and Red Hook (RH) moraines. (From Ridge, 2003)

Glacially streamlined rock knobs called drumlins are also mantled by glacial till. Examples of such hills include Spy Hill between Route 55 and Route 376 in the Town of Poughkeepsie and the College Hill park area in the City of Poughkeepsie.

Flat valley floors testify to the former presence of glacial lakes and outwash plains in the county (Map 3.3). These easily eroded sands and gravels provided a ready pathway along which post-glacial streams currently flow. Streams like the Wappinger Creek, Fishkill Creek, and Tenmile River flow through many of these deposits and have subsequently left their own in the form of channel floodplain sediments (white areas in Map 3.3).

Topographic Data Resources

Several sources of topographic data exist for Dutchess County. The United States Geological Survey (USGS) produces maps containing topographic information for all of the United States (http://topomaps.usgs.gov). The USGS maps of Dutchess County have an interval between contour lines of 10 feet and therefore cannot resolve features only a few feet high. Dutchess County has obtained more detailed topographic data using LIDAR, which was used to produce contour lines at 5 foot intervals. Using this data, contour maps, shaded relief maps, and maps of steep slopes can be created at a higher level of detail than previously. Examples of maps from these databases are shown in Figure 3.16.

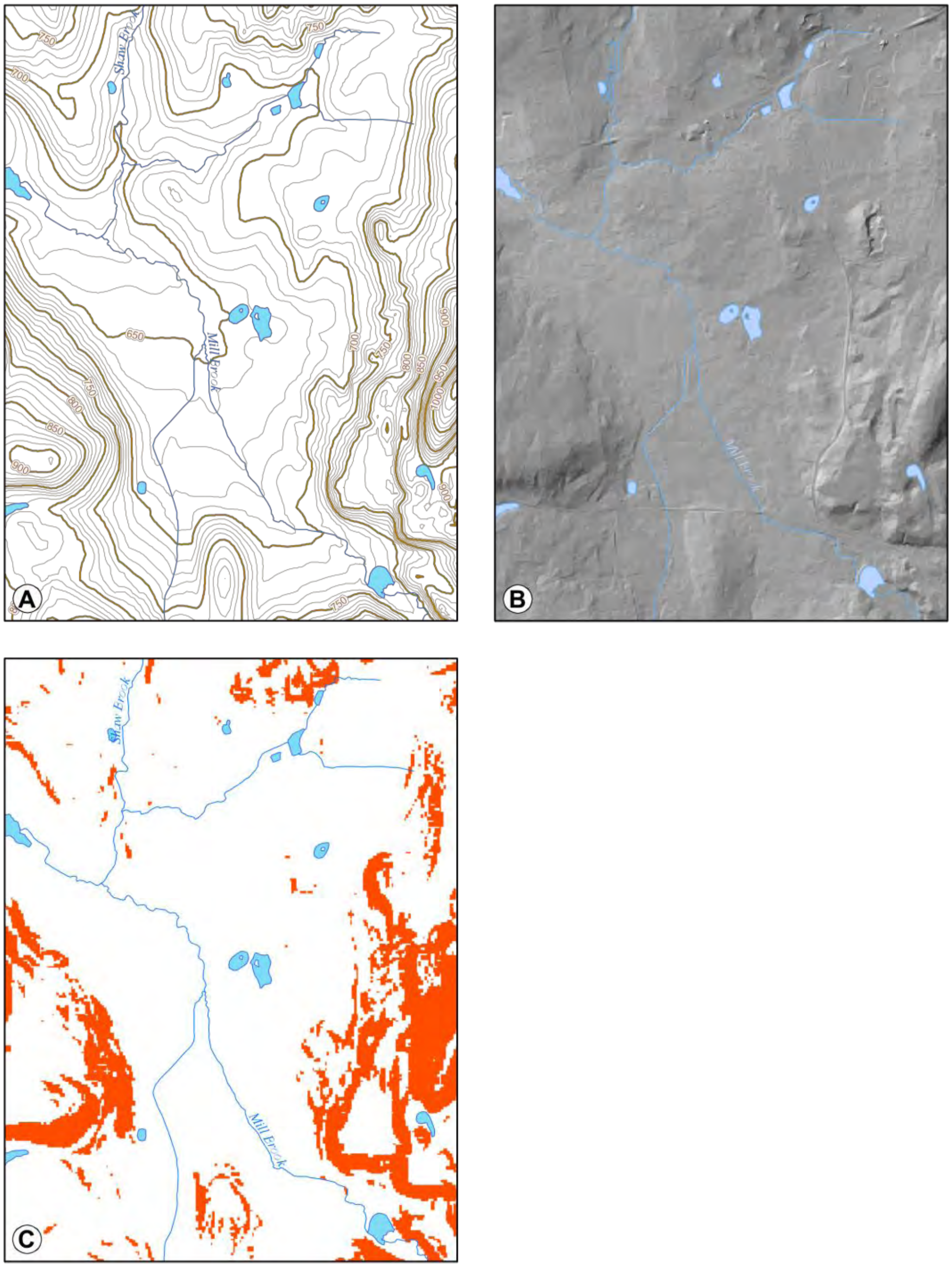


Figure 3.16: Different ways to express topographic information: a) topographic contours; b) shaded relief map; 3) steep slope map.

TRENDS AND CHANGES SEEN OVER TIME

Geologic processes typically proceed at a very slow rate within the interiors of tectonic plates. Consequently, the bedrock geology of Dutchess County has changed little since the current pattern of plate movements became established about 200 million years ago. The advance and subsequent retreat of the last ice sheet during the past 100,000 years shaped the topography created by millions of years of erosion. Uplands were eroded by the glacier and lowlands were filled with glacial debris.

The mines and quarries within Dutchess County have provided an adequate supply of high-quality aggregate for the needs of local residents and businesses since the start of European settlement. In contrast, resource-poor counties, west of the Hudson River, have had to rely largely on imported aggregate to supply their needs. Other geologic materials, such as cut stone, metals, and clay, are no longer supplied by local sources and must now be provided by mines outside of the region, and in some cases, outside of the country.

During historic times, minor changes in topography have occurred due to natural processes. Some streams have changed position a small amount through the natural processes of streambank erosion and sediment deposition. Some wind erosion has probably occurred in agricultural areas that are frequently plowed, but certainly not enough to be detected by the existing topographic data. Many small changes in topography have also occurred because of development, including changes in the drainage patterns of streams, removal of high points during mining operations, flattening areas to create parking lots, etc. The effects of these man-made changes in topography, and how each of them interacts with each other, are often not considered thoroughly when development is being planned. The result can be increased flooding in local streams, ponding of water on important roads and the filling of basements with water where this had never been a problem in the past.

Land-use conflicts have arisen during the last decades of the 20th century between mining and residential development. Glacial outwash deposits in the valleys are the sole sources of sand and gravel, as well as targets for suburban development. In addition, the visibility of mines has become equated with visual impacts. As a result, deposits that may have provided high-quality aggregate to supply new developments and infrastructure maintenance are either developed for residential housing, or new mines are opposed by residents.

IMPLICATIONS FOR DECISION-MAKING

Three aspects of Dutchess County geology and topography have important implications for decision making: availability of mineral resources, steep slopes, and viewsheds.

Mineral Resources

Mineral resources are finite in extent and are rapidly being lost to development. As a result, aggregate has to be trucked increasing distances to satisfy continuing demand within the county. Mining Overlay Districts have been established in some Dutchess County towns to restrict mining rather than encourage it.

Municipalities elsewhere in the nation have recognized the importance of an adequate supply of aggregate to society and have taken steps to preserve mineral resources from conflicting land uses. In Oroville, California, for example, mineral resource areas have been identified to indicate the significance of mineral deposits and to reduce the threat of encroachment by incompatible land uses.

Steep Slopes

Generally speaking lowlands were developed first in Dutchess County. Early development occurred along the Hudson River, along major streams and along major roads and railroads, which were built in lowland areas first. Development of level areas is often relatively easy and inexpensive. Today, much of the development occurs on moderate to steep slopes. Development in areas of steep slope (Map 3.4) is more expensive, more difficult, and is prone to serious environmental impacts. Care must be taken to ensure that development on slopes does not adversely affect pre-existing development in the lowlands. For this reason a few municipalities have passed steep slope ordinances in recent years. Development on steep slopes can lead to significantly increased soil erosion and greatly increased stormwater runoff which may lead to increased flooding in local streams and a variety of other problems. Local steep slope ordinances seek to reduce these problems.

Viewsheds

Dutchess County has long been known for its spectacular views. A **viewshed** is the area that can be seen from a particular spot, the viewpoint, and its size and shape are determined by the local topography. Important viewsheds can be damaged by development. For example, a building on top of a hill may have a wonderful view, but damage the view of everyone living in the nearby lowlands. The viewshed from a scenic overlook may be considered an important resource worthy of preservation by a community. Viewsheds along the Hudson River were deemed so important by many people that they formed an organization, Scenic Hudson, to protect them. Viewsheds along scenic highways, trails and parks may also be considered important to the public. Of course the view from an individual house is also important to the owner of that house. Scenic views in Dutchess County contribute to residents' sense of place and improve our quality of life. Fortunately, there are simple ways to build on high areas without damaging the community's scenic views, and at least one municipality in Dutchess County has passed a Ridge Protection Ordinance to protect a scenic ridgeline from being damaged by development.

RESOURCES FOR ADDITIONAL INFORMATION

- **U.S. Geological Survey (USGS):** As the Nation's largest water, earth, and biological science and civilian mapping agency, the U.S. Geological Survey (USGS) collects, monitors, analyzes, and provides scientific understanding about natural resource conditions, issues, and problems. See: http://www.usgs.gov/

REFERENCES

Cadwell, D.H., E.H. Muller and P.J. Fleisher. "Geomorphic history of New York state." In *Geoarcheology of landscapes in the glaciated Northeast*, edited by D.L. Cremeens and J.P. Hart. Albany, NY: New York State Museum Bulletin 497 (2003): 7-14.

Connally, G.G., and L. Sirkin. "Woodfordian ice margins, recessional events, and pollen stratigraphy of the mid-Hudson Valley." In *The Wisconsinan Stage of the First Geological District, Eastern New York* edited by D.H. Cadwell. Albany, NY: New York State Museum Bulletin 455(1986): 50-72.

Donnelly, J.P., N. Driscoll, E. Uchupi, L. Keigwin, W. Schwab, E.R. Thieler and S. Swift. Catastrophic meltwater discharge down the Hudson River Valley: a potential trigger for the Intra-Allerod cold period, *Geology* 33 (2005): 89-92.

Isachsen, Y.W., E. Landing, J.M. Lauber, L.V Rickard and W.B. Rogers. "Geology of New York, a Simplified Account." *New York State Museum/Geological Survey Educational Leaflet No. 28*. Albany, NY: New York State Museum, 1991

Knopf, E. B. Stratigraphy and Structure of the Stissing Mountain area, Dutchess County, N.Y. *Stanford University Publications in the Geological Sciences* 7, 1: 1962.

Murray, D.J. "Pleistocene history of the Millbrook, New York region." In New York State Geological Association Guidebook to Field Excursions edited by J. H. Johnsen, p. B-5-1 to B-5-10. 1976.

Oroville, California Municipal Code. "Chapter 23A, Surface Mining and Reclamation." Oroville, CA: 2008. http://oroweb.cityoforoville.org/citycode/_DATA/CHAPTER23A/23A_16_Mineral_resource_protec.html

Rayburn, J.A., P.L.K. Knuepfer and D.A. Franzi, D.A. A series of large, Late Wisconsinan meltwater floods through the Champlain and Hudson Valleys, New York State, USA. *Quaternary Science Reviews* 24 (2005): 2410-2419.

Ridge, J.C. "The last deglaciation of the northeastern United States: a combined varve, paleomagnetic, and calibrated ^{14}C chronology." In *Geoarcheology of landscapes in the glaciated Northeast* edited by Cremeens, D.L., and J.P. Hart. Albany, NY: New York State Museum Bulletin 497 (2003): 15-45.

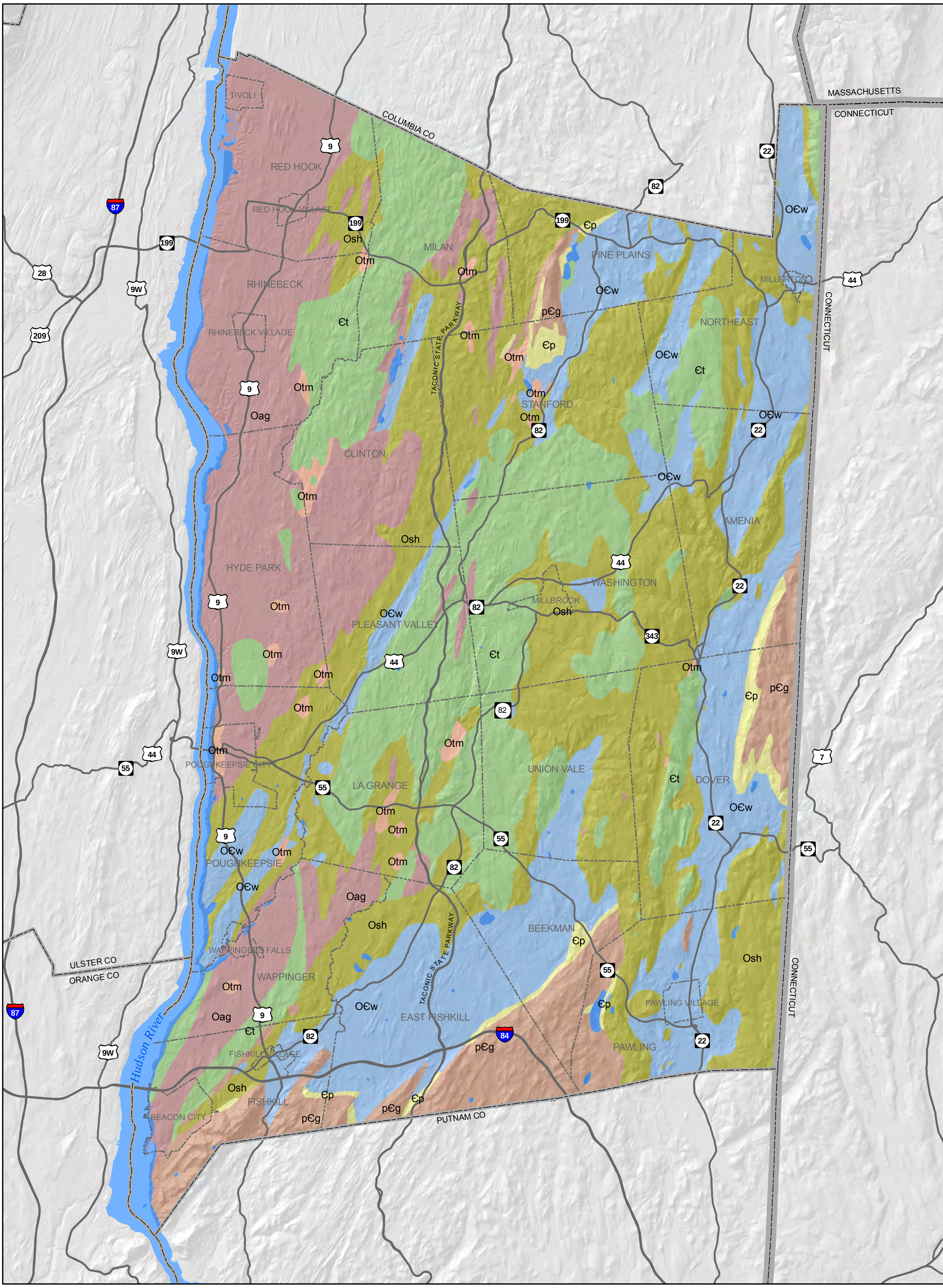
Ruddiman, W.F. Earth's Climate: Past and Future. New York: W.H. Freeman and Company, 2008.

Stanford, S.D. Onshore record of Hudson River drainage to the continental shelf from the late Miocene through the late Wisconsinan deglaciation, USA: synthesis and revision. *Boreas* 39(2009) 1-17.

Map 3.1: Bedrock Geology

Dutchess County, New York

Prepared by:
CCEDC GIS Lab, 2010



Geologic Formations

Oag	Austin Glen Formation
OЄw	Autochthonous limestone
Osh	Autochthonous shale
Єp	Poughquag Quartzite
pЄg	Precambrian granite and gneiss
Otm	Taconic Melange
Єt	Taconic sequence
h2o	Unknown

Miles
2 1 0 2

4 2 0 4
Kilometers

1:225,000

N

Map 3.2: Surficial Geology

Dutchess County, New York

Prepared by:
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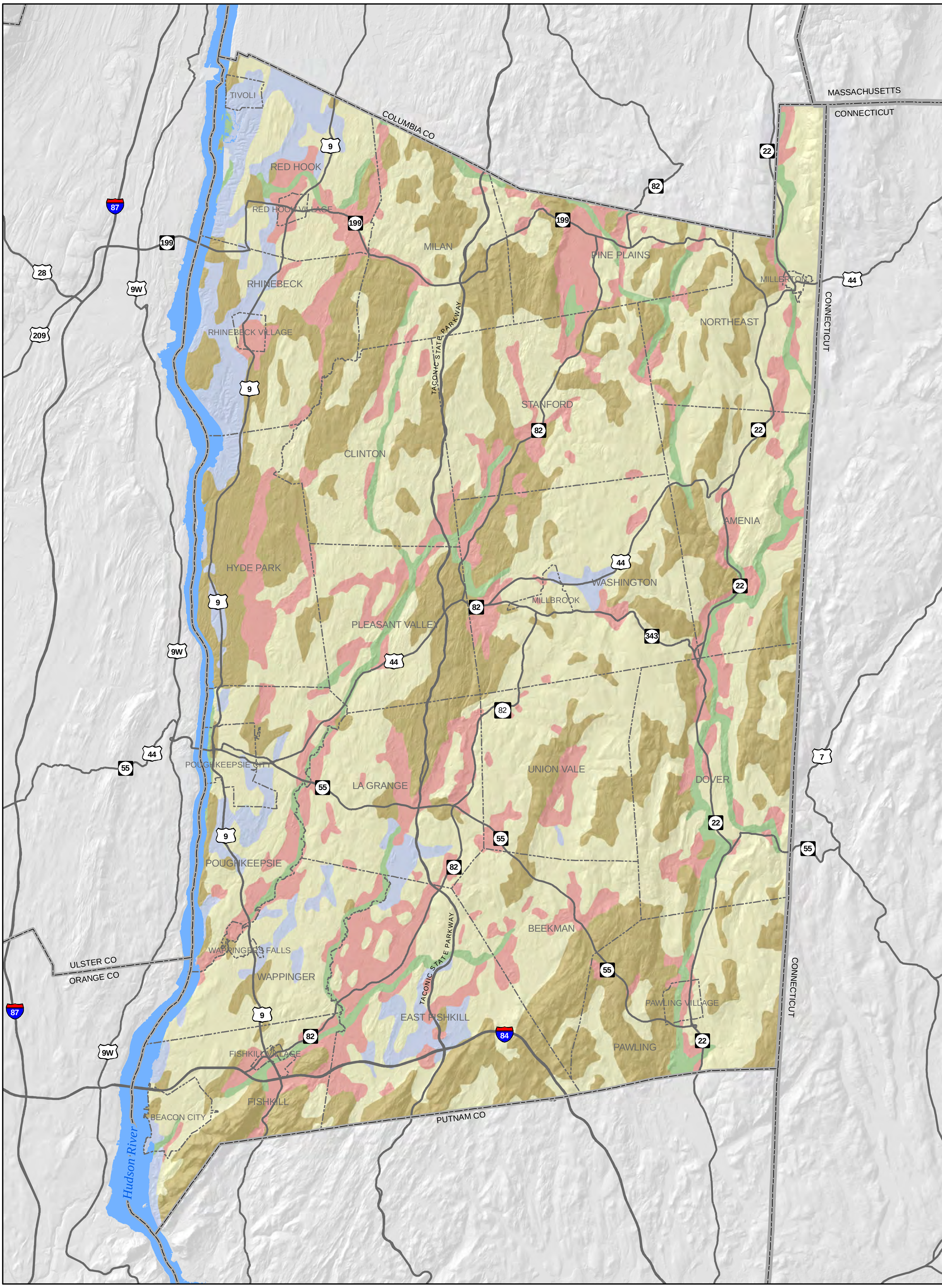

Surficial Geology

- Bedrock
- Glacial Outwash
- Lake Sediments
- Stream Sediments
- Till

Miles
2 1 0 2

4 2 0 4
Kilometers

1:225,000

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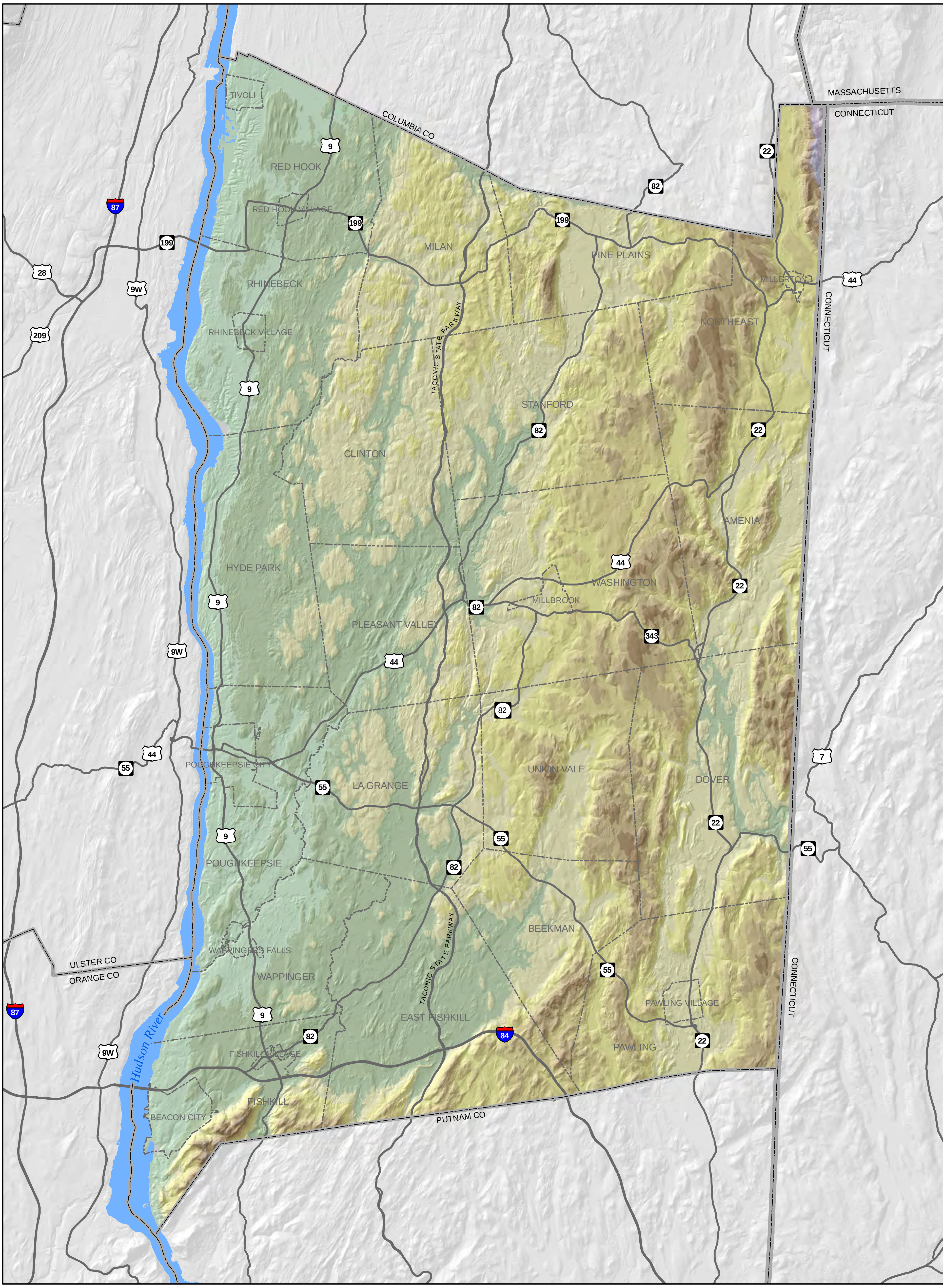
Map 3.3 Shaded Relief

Dutchess County, New York

Prepared by:
CCEDC GIS Lab, 2010



Elevation Range (ft)

0-200	1201-1400
201-400	1401-1600
401-600	1601-1800
601-800	1801-2000
801-1000	2001-2200
1001-1200	2201-2400

Miles
2 1 0 2

4 2 0 4
Kilometers

1:225,000

N

Map 3.4: Steep Slopes

Dutchess County, New York

Prepared by:
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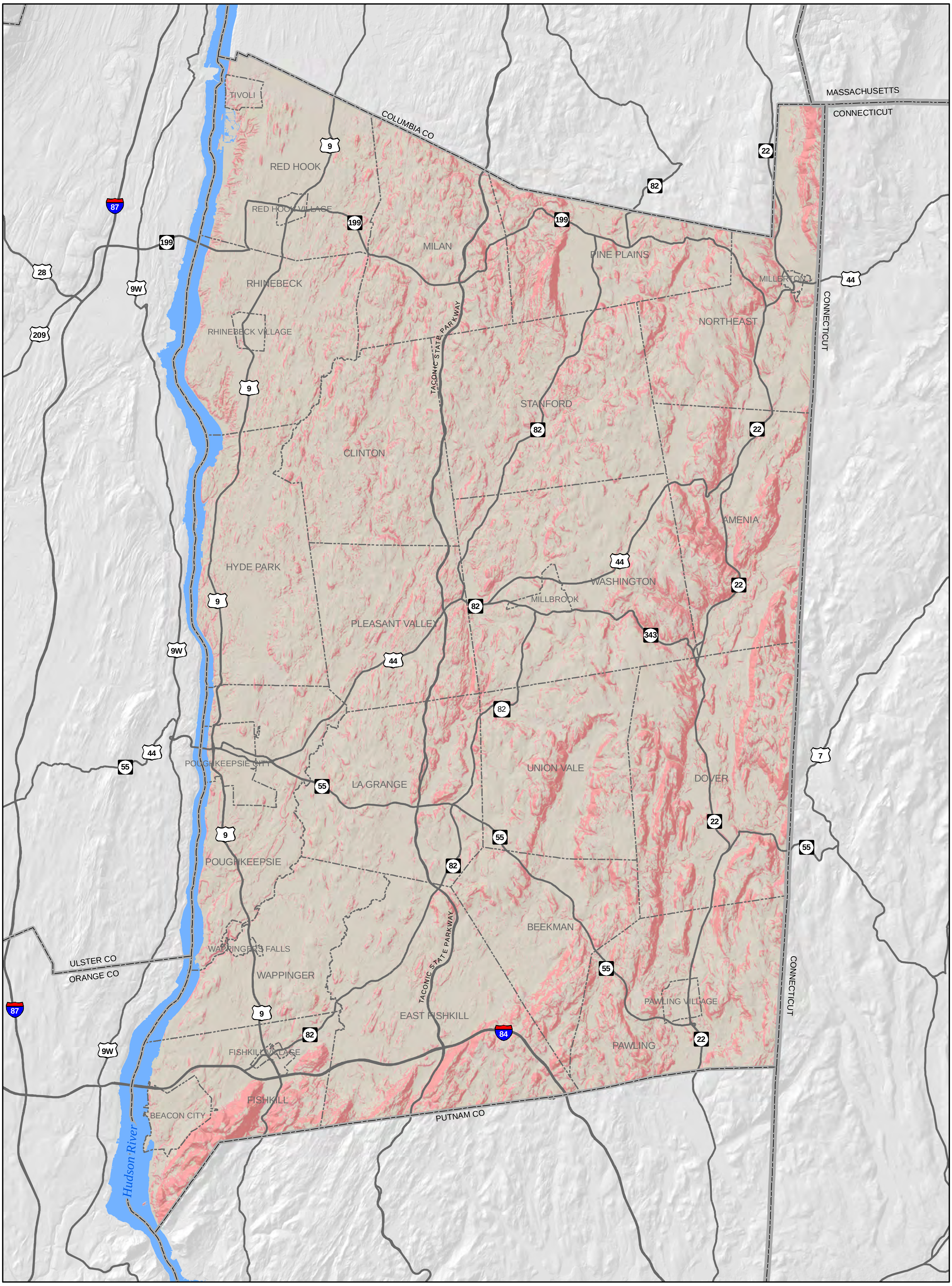


Slopes

	Slopes <= 20%
	Steep Slopes (> 20%)

Miles: 2 1 0 2

Kilometers: 4 2 0 4

1:225,000

N

Chapter 4:
The Soils of Dutchess County, NY

Jeff Walker, Ed Hoxsie, and Peter Groffman[1]
May 2010

INTRODUCTION TO SOILS

Chapter Contents

Soils are the unconsolidated weathered material that covers the surface of the earth. Soils act as a substrate for growing food crops. They also support building foundations, filter groundwater recharge, and sustain vegetation and wildlife habitats. An understanding of soil properties and limitations contributes to the intelligent use and preservation of those natural resources that depend upon the soil.

Soils can be classified according to any number of different parameters. For the purposes of this report, three classifications of soils will be emphasized: by map units based on their physical properties, by hydrologic properties, and by their appropriateness for agricultural activities.

[1] This chapter was written during 2009 and 2010 by Dr. Jeff Walker, (Department of Earth Science & Geography, Vassar College), with valuable input from Ed Hoxsie (Director of the Dutchess County Soil and Water Conservation District) and Dr. Peter M. Groffman (Microbial Ecologist, Cary Institute of Ecosystem Studies). It is an updated and expanded version of the soils chapter of the 1985 document *Natural Resources, Dutchess County, NY* (NRI).

Soil Physical Properties

Soils are made up of rock and mineral fragments, organic matter, and void spaces filled with air or water. The composition and proportions of the various different soil components vary from place to place, giving rise to differences in color, depth, texture, and the types of vegetation that a soil can support. In a county soil survey (such as the USDA 2005 Dutchess County survey), soils are classified on the basis of their texture, parent material, depth of soil development, and water-holding characteristics such as permeability and drainage. For a more thorough discussion of soil physical properties see http://soils.usda.gov/education/)

Texture

Texture is a physical characteristic that describes the distribution of different sizes of rock and mineral fragments in the body of the soil. The bulk of most soils is made up of grains that can be divided into three categories: **clay** (less that 0.002mm diameter), **silt** (0.002mm to 0.05mm in diameter), and **sand** (0.05 to 2mm in diameter). The percentages of these three grain sizes categories allow one to classify textures according to a triangular diagram as shown in Figure 4.1.

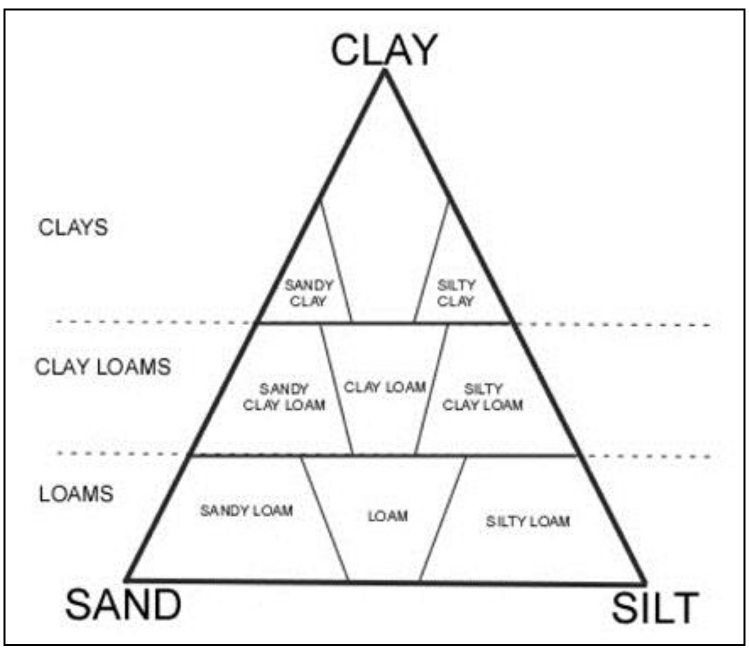


Figure 4.1: Soil texture triangle (Adapted from Thien & Graveel, 1997)

Dutchess County soil textures are dominated by silty loam and loam (25 percent clay and 75 percent a mixture of sand and silt in roughly equal proportions). Loam is the most desirable soil texture because it is well-aerated due to its high proportion of sand and silt particles, yet has a high enough proportion of clay-size particles to retain water without creating too dense a soil body. These clay-size grains are also important because they, along with organic substances such as humus, are the soil constituents that store and release plant nutrients.

In some soils, grains larger than 2mm (about the thickness of a dime) are present. Descriptors referring to these larger grains are used to modify the textural classification. For instance, **channery** loam, a soil containing thin, flat grains up to 6 inches in length known as "channers," is common in areas underlain by shale bedock which tends to break into fragments of this shape. Other loams are said to be "gravelly," meaning that they contain a significant number of roughly spherical fragments larger than 2mm in diameter.

Influence of Parent Material

The physical characteristics of a soil depend in large part on the nature of the parent material, and to a lesser extent, on the topography, the climate, the vegetation, and the amount of time the soil has to form. The most common parent materials for soils in Dutchess County (see NRI Chapter 3: Geology and Topography) are glacially-derived sediments including **glaciolacustrine** deposits (fine-grained sediments deposited in lakes), **glaciofluvial** deposits (coarser-grained sediments deposited by streams draining melting glaciers), and glacial **till** (mixed sediments deposited directly from a glacier). Glacial till may be either **lodgement till**, which is deposited by an advancing glacier and is very dense because it was compacted by the weight of overriding ice, or **ablation till** which is much less dense because it is simply the material left over after the ice melts. Lands in Dutchess County that do not have exposures of **bedrock**, and are not underlain by recently-deposited stream sediments (**alluvium**), are covered with glacial deposits making these deposits the principle parent materials for soils in the county. It is rare that the underlying bedrock contributes in a significant way to the parent material of Dutchess County soils, and there are no soils derived by direct weathering of bedrock. However, the bedrock can contribute grains to glacial sediments which eventually weather to become soils.

Influence of Topography

The topography of the county (see NRI Chapter 3: Geology and Topography) is dominated by northeast-southwest trending ridges of bedrock covered by a thin veneer of glacial till, separated by deep valleys filled with thick fluvial and lacustrine sediments, many of glacial origin. Slopes that do not have bedrock exposures are covered by thin glacial till deposits. The steepness of a slope determines the nature of soils formed on them: steeper slopes tend to have thinner, less well-developed soils because the parent material is transported downhill by gravity before soil can develop. Soils tend to be thicker at the toe of a slope where material moving downslope collects.

Influence of Climate and Vegetation

Climate is relatively consistent across the county (see NRI Chapter 2: Climate and Air Quality) except for microclimates developed on topographic irregularities. The climate is cool (mean annual soil temperature is about 50 degrees Fahrenheit) and moist, resulting in moderate weathering conditions. Similarly, the vegetative cover of the county has been relatively consistently forested since the last glaciation except during the past 400 years when agriculture combined with the demand for wood for fuel and charcoal resulted in widespread clearing of the primeval forests.

Influence of Time

In undisturbed locations in the county, the time available for soil to develop has been the same. However, disturbance by human interaction (such as agriculture, logging, and development), soil erosion, or mass wasting can destroy soil that took thousands of years to develop. The oldest soils of Dutchess County have only been forming since the most recent **glaciation** (approximately 12,000 years ago), which is a relatively short time in soil-formation terms. Short development times and moderate weathering rates result in immature soils. The soils of southern New York are classified by USDA as belonging to the "**inceptisol**" order, characterized by "weakly developed soils" (Kohnke and Franzmeier, 1995). The fact that Dutchess County inceptisols have developed only minimally in the past 12,000 years illustrates how slowly soils form (in this case, due to the low weathering rates), and dramatizes how fragile they are: once a soil is lost either to erosion or development, it will not recover in a human lifetime because the soil formation clock is reset to zero.

The combined effects of parent material, topography, climate, vegetation, and time determine the depth to which a soil will develop. Shallow soils are the result of one or more of the following conditions: dense parent material, steep slopes, incomplete vegetative cover, and/or short development time because of natural or artificial disturbance. Deep soils can be formed on even the densest parent material given conditions conducive to more extensive weathering such gentle slopes, stable vegetation, and/or long development times.

Over time, a soil develops a profile made of layers called **horizons**. A typical soil profile (Figure 4.2 below) contains four horizons which, from the surface down are called **organic matter** (decomposing organic material on the surface), **topsoil** (highly weathered parent material rich in organic matter from above), **subsoil** (weathered parent material with little accumulated organic material), and the unweathered **parent material**. The thickness and composition of the horizons vary with location, time, and disturbance.

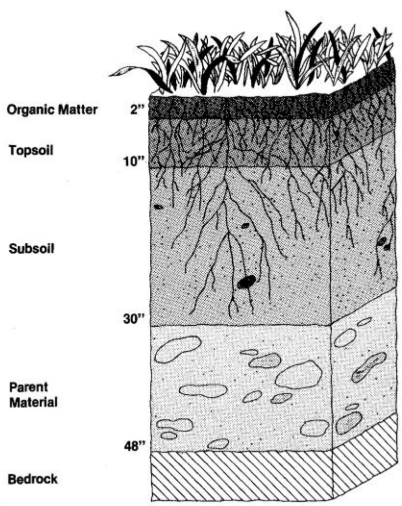


Figure 4.2: Typical Soil Profile (from 1985 Dutchess County NRI, Soils Chapter. Redrawn from the USDA Soil Conservation Service, "Conserving Soil")

SOIL SURVEY OF DUTCHESS COUNTY, NY

Once a **soil profile** is described, it is assigned to a **soil series**, which consists of all soil types whose profiles have nearly the same characteristics, thickness, and arrangement. A **soil survey** is an inventory that maps the soil series in a given geographical area.

The Soil Survey of Dutchess County was initially prepared in 1936 and updated in 1955 and 1972. A new survey, published in 2001, describes and maps 134 different soil series each with distinct characteristics and qualities. No single soil series covers more than three percent of the county. The 2001 survey mapped the county in 6 acres increments, instead of the 3 acre increment of previous surveys, and was one of the first digitized soil surveys in the nation. A web-based version of the Dutchess County soil survey is available at the National Resource Conservation Service (NRCS) Web Soil Survey.

Dutchess County soils vary greatly. Silty loam textures dominate, but textures vary from gravelly, sandy loam to fine, silty clay. Most of the soils that have been cultivated are moderately eroded, except in certain nearly level areas. More than 70 percent of county soils are well drained, but small areas of poorly- and very poorly-drained soils can be found, often in complex associations that may limit the use of the well-drained soils associated with them.

Soil Map Units on the Generalized Soils Map

The Generalized Soils Map presents an overview of soil types in Dutchess County. Each of the ten soil map units are groupings of dominant soil series. If a large area is dominated by two or three soil series that differ in detail (such as thickness, texture, drainage capacity) but are derived from the same type of parent material, the soil series are combined to form a map unit. Minor soil series are also present within these map units.

The map units used on the Generalized Soils Map are discussed in more detail in Appendix 1. It must be emphasized, however, that the Generalized Soils Map is not detailed enough to allow interpretations at the parcel or even township level. The map is strictly indicative of the general patterns of soil distribution in Dutchess County, and helps to organize the following discussion. The detailed Soil Survey of Dutchess County should be consulted for more details, but even using that (via the Web Soil Survey referenced above), one should remember that the smallest mapping unit is 6 acres, and detail at a finer scale is not possible. Dutchess County Soil and Water Conservation District should be consulted for assistance in interpreting information at smaller scales.

The map, therefore, is not suitable for planning the management of a farm or field or for selecting a site for a road or building or other structure. The soils in any one map unit differ from place to place in slope, depth, drainage, and other characteristics that affect management. In some areas along the borders of Dutchess County, the names of the general soil map units do not match those of adjoining counties. These discrepancies exist because of differences in the detail of mapping, changes in soil classification, and differences in the proportions of the same soil in adjoining counties.

Soil Hydrologic Properties

Soils play a very important role in ecosystems by filtering water, and by allowing infiltration and recharge of groundwater. The flow of water through a soil is governed by two different physical parameters, permeability and topography. **Permeability** is a measure of how well connected the pore spaces in a soil are. Permeability rates, which are usually given in inches per hour, measure the ease with which water flows through the soil layers. Values for permeability range from 0.06 inches of water per hour (very slow) to greater than 20 inches per hour (very rapid), and change according to the size of the soil particles and how closely they are packed. Soils dominated by very small (clay-sized) particles have low permeability rates simply because the grains are so small that surface tension limits the movement of water molecules through the pore spaces. Permeability combines with topography to determine the drainage characteristics of the soil. Drainage runs the gamut from a permeable soil located on a hillside that is said to be "excessively well drained" to a low permeability soil located in a depression with minimal external drainage that is said to be "poorly drained."

The information given here is strictly general. Design manuals are available and should be used for site specific work. Septic fields, farming, and other uses requiring good internal soil drainage may not function properly in soils with low permeability rates, placing severe restrictions on development densities in areas not served by central water and sewer systems.

Prime and Important Agricultural Soils

The best and potentially most productive soils are classified by the Natural Resources Conservation Service (NRCS) as **prime soils** (USDA Handbook part 622.04). They are considered prime because they are suited to a wide variety of farm crops with relatively few limitations, and represent an irreplaceable agricultural resource. Prime soils are well-drained, nearly-level, fertile, stable, and deep. These characteristics make them ideal for farming, but also easy to develop for residential and commercial uses.

"Prime" soils cover about 15 percent of Dutchess County. Significant concentrations occurred along the major stream valleys and throughout the towns of Red Hook and Rhinebeck, as well as major portions of Clinton and Pleasant Valley. High-quality soils also were abundant in the southwestern quarter of the county but many have since been built over.

"**Statewide Important**" (USDA handbook part 657.5(c)) soils support good crop fields, but unlike prime soils they have limitations that require special conservation measures and are suited to a smaller variety of crops. According to NRCS inventories, they cover about 32 percent of the county, and are usually found near prime agricultural soils. Smaller tracts of important soils are found in much of the county. Important and prime soils are noticeably absent from the Hudson Highlands, the ridges along the Harlem Valley, and other steeply sloping uplands where soils are characteristically shallow.

Erosion and Sedimentation

Soil erosion is an issue of concern in any area that is cultivated or otherwise cleared of vegetation for an appreciable portion of the year. By stripping topsoil, erosion robs the land of valuable natural nutrients, and washes soil, pesticides, and fertilizers into waterways. It also undermines soils and structures and chokes streams, lakes, rivers, and drainage systems with sediment.

The rate of soil loss varies dramatically with land use. Erosion rates from construction sites can be as much as 25 times higher than those from cropland, and as much as 75 times higher than those from pastures and woodlands. Proper conservation procedures can drastically reduce these rates.

Potential soil loss through erosion can be estimated using the Universal Soil Loss Equation, or USLE, which calculates the relative contribution of climatic, soil, and site specific management factors to potential soil erosion. The specific soil characteristic is the **erosion factor** (K) which is summarized in Table 4.2 for the various soil types included in the map units. Erosion factors quantify the susceptibility of soils to sheet and rill erosion by water. The estimates are based primarily on the percentage of silt, sand and organic matter, and on soil structure and permeability. Values for K range from 0.02 (very low susceptibility to erosion) to 0.69 (very susceptible), and in Dutchess County the values are between 0.1 and 0.64.

Table 4.1: Summary of Erosion Factors (K) for Dutchess County Soils (Soil Survey of Dutchess County, Natural Resource Conservation Service)

map unit	soil formations	average erosion factor
1	Hudson-Vergennes-Raynham	0.49
2	Hoosic-Wayland-Copake	0.28
3	Farmington-Galway-Stockbridge	0.28
4	Cardigan-Dutchess-Nassau	0.27
5	Bernardston-Pittstown	0.28
6	Charlton-Chatfield-Hollis	0.24
7	Stockbridge-Georgia	0.30
8	Taconic-rock outcrop-Macomber	0.24
9	Nassau-rock ourcrop-Cardigan	0.24
10	Hollis-Chatfield-rock outcrop	0.24

The figures given in Table 4.1 are approximate, but serve to illustrate that Dutchess County soils in general have moderate to moderately high susceptibility to erosion. Actual soil loss rates vary considerably from site to site, depending on slope, soil type, vegetation density, and rainfall.

Hydric Soils, Wetlands and Aquifers

Hydric soils are defined as those soils that form under conditions that are sufficiently wet to support anaerobic conditions in the upper part of the soil profile for a significant portion of the growing season. A list of hydric soils was created by the USDA NRCS National Technical Committee for Hydric Soils and is published in the National Soil Information System (NASIS) database. Hydric soil series in Dutchess County include Carlisle, Fredon, Halsey, Livingston, Palms, Raynham, Sun, and Wayland.

Hydric soils are critical to the formation and definition of wetlands as they support the presence of wetland (hydrophytic) vegetation. Many soils that were originally classified as hydric have been artificially drained to support agriculture and construction activities. These soils are still designated as hydric but they may no longer support hydrophytic vegetation and may not be considered wetlands. For a site to be considered a wetland it must have hydric soil, hydrophytic vegetation, and wetland hydrology as defined by local, state, or federal jurisdictions.

Wetlands are often directly connected to aquifers as either recharge or discharge areas. Hydric soils are therefore useful as a planning tool, indicating areas that should be evaluated carefully for aquifer protection.

Soils and Ecosystem Services

There are clear links between soils and all categories of ecosystem services in terms of production of food and fiber, as well as regulation of water quantity and quality through percolation, erosion, and hydric soil effects on aquifers. Recently, there has been a great increase in interest in the ability of soils to sequester carbon. Plants remove carbon dioxide from the atmosphere during photosynthesis and transfer some of this carbon to the soil when plant tissues die. Soil organic matter is the largest reservoir of carbon in most ecosystems and there is great interest in altering agriculture and forestry practices to increase soil carbon storage.

The role of soils in cultural services related to aesthetics and biodiversity are also important, and are largely driven by the effects of soils on vegetation. Distinctive vegetation communities, with specific aesthetic and biodiversity values, are associated with specific soil types. In general in Dutchess County, more fertile (high pH, high base cations) soil series are associated with maple forests, while more coarse-textured, low fertility soils are associated with oak forests. Suites of plants (such as spring ephemeral plants) and animals (such as salamanders and birds) are associated with these different soil-vegetation associations and can be used as a starting point for biodiversity, aesthetic, and recreational assessments. (For more information on vegetation communities and biodiversity, see NRI Chapter 6: Biological Resources and Biodiversity.)

Regulation of Soils

Except as the nature and limitations of different soil types might be included in local zoning ordinances, there is no county-wide regulation of activities based on particular soils. Prime and Important Agricultural Soils, for example, are not protected at the county level. In fact, their gentle topography and even-textures make them prime candidates for development. Development in wetland areas is restricted by state and local wetland ordinances enacted on a town-by-town basis; larger wetland development projects are regulated by US Army Corps of Engineers.

Soil erosion associated with clearing and grading is regulated by some municipalities as well as the NYS Department of Environmental Conservation, as is the practice of "soil mining" which removes unconsolidated glacial material for aggregate and bank-run fill material.

TRENDS AND CHANGES SEEN OVER TIME

Two trends seen over time are loss of prime and important agricultural soils and loss of hydric soils in wetland areas. In the last 40 years, Dutchess County has been an area of sustained development activity, and it is estimated that as much as 50 percent of the county's best soil acreage has been developed for residential, commercial, or industrial use. Similar losses have been experienced by hydric soils and wetlands.

Another change is soil pollution from toxic substances dumped on the surface of the land. Such a problem is more localized, and is probably more of an issue in terms of groundwater pollution because of its more far-reaching potential effects. However, soil pollution is an important issue because of the extremely slow migration rates of most pollutants through the soil. Once a soil is polluted, it is difficult to treat it short of removing it and/or incinerating it, which destroys the soil as a natural body.

The causes of these changes are related, either directly or indirectly, to development pressure. The population of the county increased from 222,295 in 1970, to 280,153 in 2000, to an estimated 293,562 in 2009, and along with that changing demographic came pressure to provide homes and services for the increasing population. Soil pollution is often related to businesses or industries that provide either employment for local residents, or goods and/or services for their consumption, creating a dilemma for local lawmakers.

IMPLICATIONS FOR DECISION-MAKING

Soil is a fundamental resource that is often taken for granted because of its abundance, low cash value, utilitarian functions, and lack of aesthetic charm. Soil makes it possible to use and live on the land. Without ample supplies of good, arable soil, food production would be vastly more difficult.

Soils have several characteristics, such as permeability, depth-to-bedrock, erodibility, and wetness, which limit the land uses they can support. All of these limiting characteristics should be considered during the land use decision-making process. Development proposals and local land use controls should be well-matched to soil features to ensure that the type, density, location, intensity, and design of all land uses are appropriate to the soils and other natural resources that must sustain them. No amount of mapping at the county-wide scale can substitute, however, for site-specific knowledge, so decisions about individual pieces of land should be made in consultation with soil-mapping professionals such as the Dutchess County Soil and Water Conservation District (DCSWCD). Specific policy considerations discussed below are primarily focused on the relationship of soils to development activities in terms of agriculture, permeability, thickness, and susceptibility to erosion.

Prime and Important Agricultural Soils

Much of Dutchess County's prime and important soil acreage has been developed for residential or commercial uses since the middle of the 20th century and is no longer available for agricultural or open space use. The best of these soils that remain undeveloped are located mainly outside the southwestern core area, and form a critical resource on which Dutchess County's current agricultural industry and future food-producing capability depend.

Agriculture is a significant and highly valued component of Dutchess County's economy, historic, and visual identity. Prime and important soils support active-farms throughout the northern and eastern communities, as well as a handful of farming operations within the urban area. Many of these farms are under intense development pressure, which threatens their continued viability. It is necessary, therefore, to devise ways to preserve the county's best soils even as farming activity declines.

If land uses that can function satisfactorily on less valuable soils are allowed to continue to consume the best soils in Dutchess County, the county's agricultural community will be further weakened, and its ability to respond to future changes in the nation's food production system will be severely impaired. The loss of agricultural open land also threatens one of the most traditional and aesthetically pleasing contributors to the county's high quality of life. Aggressive measures are needed to protect the soil resource. Communities must find equitable, effective ways to divert development to less valuable sites, to encourage open space preservation, to support agricultural activities, and to institute effective erosion control measures.

Permeability

Development densities and waste management practices should reflect the severely limited ability of impermeable soils to absorb and filter wastes. Otherwise, intensive development without central sewage treatment facilities will saturate soils with wastes, causing untreated wastes to spread into nearby surface waters and groundwater supplies. In areas where such contamination occurs, expensive construction of central sewage and water treatment facilities and pipelines may be the only remedy.

A report by Gerber (1982), updated by Chazen (2006), used the permeability characteristics of surficial materials (which are primarily soils) to calculate the maximum theoretical density of residential developments that are based on wells and septic systems. (See the Dutchess County Department of Planning & Development for copies of the Chazen report). The scale of mapping in the Chazen (2006) report is not sufficiently detailed for site specific work; it is intended to give an overview of infiltration issues in the county.

Highly permeable soils should also be used carefully, because of their ability to transmit hazardous materials into groundwater supplies. Landfills, petroleum storage tank farms, chemical manufacturers, and other facilities that handle such hazardous materials should not be located on top of the most permeable soils.

These considerations underscore the fact that soils are important filters of water as it makes its way from the surface to the water table to enter the aquifer. Whether that water is rain water, surface water flowing into, or out of, streams and lakes, or effluent from septic systems and/or sewage treatment facilities, making effective use of the biological and physical filtering capacity of soils is an important water resource protection strategy. (For more information, see NRI Chapter 5: Water Resources.)

Depth

Like permeability, depth-to-bedrock affects the development suitability of soils and should be considered when development proposals and land use policies are reviewed. Shallow soils limit the placement of wells, septic systems, foundations, agricultural uses, roads, and utilities. Expensive blasting is often needed for construction on shallow soils, and the likelihood of erosion and septic failures is much greater than in areas with deeper soil. At the same time, shallow soils with bedrock outcrops on steep slopes often offer spectacular views, making them tempting sites for recreational developments and homes. They are ideal sites for natural recreation areas such as hiking trails, forest preserves, and open space. Intensive development may be possible on shallow soils with thoughtful site planning, central sewage systems, and stringent erosion control measures.

Erosion and Sedimentation

Although federal and county soil conservation programs have helped reduce cropland erosion significantly since the mid-1970s, erosion continues to damage the county's soil and water resources. Erosion rates are especially severe on construction sites, road banks, and croplands that are not using erosion control practices. Soil erosion can be exacerbated by runoff from impervious surfaces such as parking lots or lawns where runoff gains momentum and erosive power before it flows off the surface onto the soil.

Soil eroded from improperly managed construction and agriculture can result in increased public expense when it chokes drainage culverts and sediment traps. During extreme weather events erosion causes deposition, which in turn can cause flooding. The agricultural community has embraced environmental practices resulting in significant reduction in per acre soil erosion. (For specific examples, see the Dutchess County Soil and Water Conservation District.)

RESOURCES FOR ADDITIONAL INFORMATION

- **Natural Resource Conservation Service – Soil Education:** For a more thorough discussion of soil physical properties see: http://soils.usda.gov/education/
- **Natural Resource Conservation Service – Web Soil Survey:** A web-based version of the Dutchess County soil survey is available at: http://websoilsurvey.nrcs.usda.gov/app/HomePage.htm
- **National Resource Conservation Service – National Hydric Soils List by State:** A list of hydric soils was created by the USDA NRCS National Technical Committee for Hydric Soils. See: http://soils.usda.gov/use/hydric/lists/state.html

REFERENCES

The Chazen Companies. "Dutchess County Aquifer Recharge Rates and Sustainable Septic System Density Recommendations, Groundwater Resources Report." Prepared for Dutchess County Water and Waste Water Authority. Poughkeepsie, NY: Chazen Co. 2006.

Daily, G.C., editor. *Nature's Services: Societal Dependence on Natural Ecosystems*. Washington, D.C.: Island Press, 1997.

Gerber, R. "Final Report: Water Resources Study for Dutchess County." Prepared for Dutchess County Department of Planning. 1982.

Kohnke, H. and D.P. Franzmuller. *Soil Science Simplified (4th edition)*. Long Grove. IL, Waveland Press, 1995.

Thien, S.J. and J.G. Graveel. *Laboratory Manual for Soil Science: Agricultural and Environmental Principles (7th edition)*. Boston, WCB McGraw-Hill, 1997.

APPENDIX 1. SOIL MAP UNIT DESCRIPTIONS

For detailed descriptions of all soil series, see "Soil Survey of Dutchess County, New York" 2001, available from: http://soils.usda.gov/survey/online_surveys/new_york/.

Hudson-Vergennes-Raynham (Map Unit 1)

USDA description: Dominantly nearly level to steep, very deep, moderately well drained and somewhat poorly drained, medium to moderately fine textured soils; on lowlands and dissected lake plains.

Hudson-Vergennes-Raynham soils form on glaciolacustrine deposits with a medium to high content of silt and clay. The unit underlies lands that are generally gently sloping although it is dissected in places by stream valleys. The unit contains about 25 percent Hudson, 25 percent Vergennes, 15 percent Raynham, and 35 percent minor soils. The soils are moderately well drained and very deep with a silt loam texture that has variable amounts of clay. Permeability is slow to very slow.

Most areas of this unit are used for cultivated crops, hay, or residential development. The steep areas are wooded and subject to active erosion. Some of the soils in this unit are highly erodible and require cross slope tillage, conservation tillage, careful crop rotations, and maintenance of permanent sod. Flatter areas used for farming need drainage.

Slow permeability, a seasonal high water table, clayey texture, slope, erodibility, and frost action are the main limitations if this unit is used for community development.

Hoosic-Wayland-Copake (Map Unit 2)

USDA description: Dominantly nearly level to steep, very deep, somewhat excessively drained and well drained medium textured soils and very deep, very poorly drained medium textured alluvial soils; on outwash plains, in lowlands and along streams.

Hoosic-Wayland-Copake soils form on glaciofluvial sediments in the large tributary valleys of the Hudson River, and on alluvial deposits adjacent to the major streams of the county. The unit is about 35 percent Hoosic soils, 15 percent Wayland soils, 15 percent Copake soils, and 35 percent minor soils. The soils are poorly to excessively drained and very deep with a gravelly to silty loam texture. Permeability is moderately rapid to rapid.

Most of the Hoosic and Copake areas of this unit are used as cropland, hayland, or residential development. Most of the Wayland areas of this unit are wooded or are in water-tolerant brush and sedges. The Hoosic and Copake soils are suitable for community development; however, installation of septic tank absorption fields is a problem because of the poor filtering capacity of these soils. Wayland soils are not suited to community development because of flooding.

Farmington-Galway-Stockbridge (Map Unit 3)

USDA description: Dominantly nearly level to very steep, shallow to very deep, somewhat excessively drained to moderately well drained medium textured soils formed in glacial till; on uplands.

Farmington-Galway-Stockbridge soils formed on thin glacial till deposits covering hills underlain by limestone bedrock. Outcrops of folded and tilted limestone and marble commonly occur. The unit is about 20 percent Farmington soils, 15 percent Galway soils, 15 percent Stockbridge soils, and 50 percent rock outcrop and minor soils. The soils are well drained and range from 10 to 60 inches deep to limestone bedrock. Thinner soils are found on slopes and thicker soils on flatter surfaces and at the toes of slopes. They have gravelly to silt loam textures. Permeability is moderate throughout.

Areas of this unit are used as woodland, pastureland, or residential development. Shallow depth to bedrock and steep slopes are the main limitations if this unit is used for community development.

Cardigan-Dutchess-Nassau (Map Unit 4)

USDA description: Dominantly nearly level to very steep, very deep to shallow, well drained and somewhat excessively drained, medium textured soils that formed in glacial till; on uplands.

Cardigan-Dutchess-Nassau soils form on glacial till on hills underlain by shale bedrock. Outcrops of folded and tilted shale bedrock are common, particularly in steep and very steep areas. The unit is about 25 percent Cardigan soils, 20 percent Dutchess soils, 10 percent Nassau soils, and 45 percent minor soils and rock outcrop. The soils are well drained and moderately deep with a silt loam to channery silt loam texture. Permeability is moderate.

Most areas of this unit are used as cropland, pastureland, woodland, or residential development. Slope, shallow depth to bedrock, and widespread rock outcrops are the main limitations in the areas used for community development.

Bernardston-Pittstown (Map Unit 5)

USDA description: Dominantly gently sloping to steep, very deep, well drained and moderately well drained, medium textured soils with a dense substratum; on uplands.

Bernardston-Pittstown soils form on glacial till on hilltops and hillsides underlain by shale and phyllite. The unit is about 50 percent Bernardston soils, 25 percent Pittstown soils, and 25 percent minor soils. The soils are well drained and very deep with a silt loam texture. Permeability is moderate, slowing with depth.

Some areas of this unit are used for growing cultivated crops and hay. Other areas are used as woodland or residential development. Drainage is commonly installed in farmed areas. Stripcropping and cross slope tillage help to reduce erosion on sloping areas. Erosion is a hazard in woodlots managed for timber. Slow percolation rates in the substratum, a seasonally high water table, and slope are the main limitations in the areas used for community development.

Charlton-Chatfield-Hollis (Map Unit 6)

USDA description: Dominantly gently sloping to very steep, very deep to shallow, well drained and somewhat excessively drained, medium and moderately coarse textured soils; on uplands.

Charlton-Chatfield-Hollis soils form on glacial till on hills underlain predominantly by folded and tilted granite, gneiss, and schist. Bedrock exposures are common with very steep to nearly vertical bedrock escarpments. The unit is about 25 percent Charlton soils, 25 percent Chatfield soils, 15 percent Hollis soils, and 35 percent minor soils and rock outcrop. The soils are well drained and vary in depth depending on their location in the topography. Textures range from loam to fine sandy loam, and permeability is moderate to moderately rapid throughout.

Most areas of this unit are wooded or are used for community development. A few areas are used for hay, pastures, and cultivated crops. Shallow depth to bedrock, scattered bedrock outcrops, and steep slopes are the main limitations in areas used for agriculture and community development.

Stockbridge-Georgia (Map Unit 7)

USDA description: Dominantly nearly level to steep, very deep, well drained and moderately well drained, medium textured soils; on uplands.

Stockbridge-Georgia soils form on hilltops and hillsides covered by glacial till with a moderate to large content of lime derived from local limestone bedrock. The unit is about 50 percent Stockbridge soils, 15 percent Georgia soils, and 35 percent minor soils. The soils are moderate to well drained and very deep with a silt loam texture. Permeability is moderate.

Most areas of this unit are used as cultivated cropland, hayland, or pastureland. Some areas are wooded or in residential development. Stripcropping and cross slope tillage help to reduce erosion in farmed areas. Georgia soils, and the wetter soils included in that classification, can be drained with tile. Slow percolation, moderate frost action, and slope are the main limitations in areas used for community development.

Taconic-Rock Outcrop-Macomber (Map Unit 8)

USDA description: Dominantly gently sloping to very steep, shallow and moderately deep, somewhat excessively drained and well drained, medium textured soils that formed in glacial till, and rock outcrop; on uplands.

Taconic-Rock Outcrop-Macomber soils form on bedrock controlled hillsides in the extreme northeastern part of the county. The unit is about 45 percent Taconic soils, 30 percent rock outcrop, 15 percent Macomber soils, and 10 percent minor soils. The soils are well drained and shallow to moderately shallow with a channery silt loam texture. Permeability is moderate to moderately rapid throughout. The rock outcrop consists of folded phyllite, schist, and quartz.

Many areas of this unit are wooded and, as part of the Taconic State Park, are used for recreation purposes. Most other areas of this unit are also wooded, although a small portion is in brushland.

These areas are also used for recreation. Slope and shallow depth to bedrock are the main limitations of this unit for community development.

Nassau-Rock Outcrop-Cardigan (Map Unit 9)

USDA description: Dominantly undulating to very steep, shallow and moderately deep, somewhat excessively drained and well drained, medium textured soils that formed in glacial till, and rock outcrop; on uplands.

Nassau-Rock Outcrop-Cardigan soils form on hills underlain by shale bedrock covered by glacial till. Bedrock exposures, with very steep to nearly vertical bedrock escarpments, are common. The unit is about 40 percent Nassau soils, 15 percent rock outcrop, 10 percent Cardigan soils, and 35 percent soils of minor extent. The soils are well drained and shallow to moderately shallow with a channery silt loam texture. Permeability is moderate throughout the soil. The rock outcrops consist of folded shale.

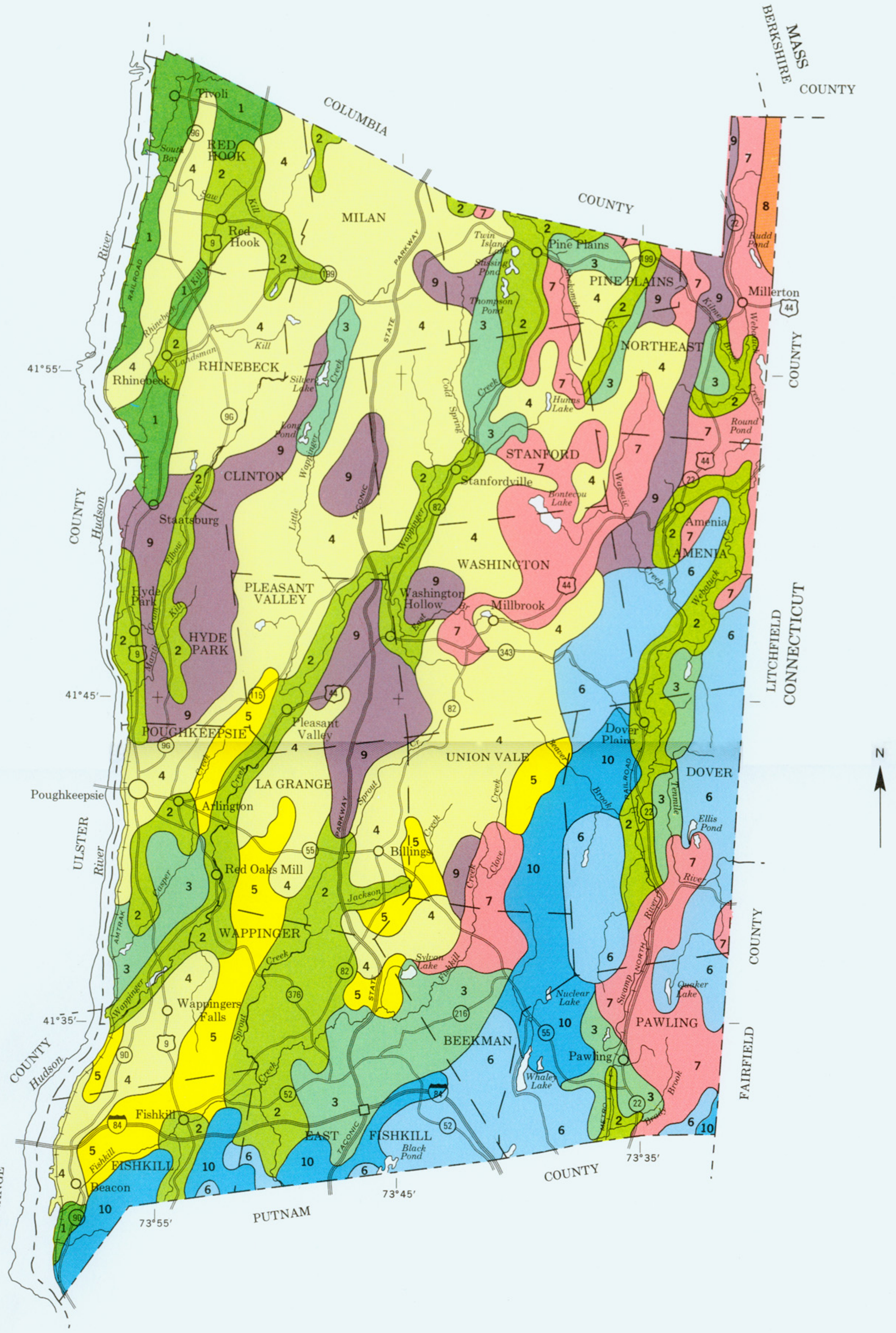
Most areas of this unit are wooded or used for community development. A few areas are used for pasture. Shallow depth to bedrock, scattered bedrock outcrops, and slope are the main limitations if this unit is used for agriculture and community development.

Hollis-Chatfield-Rock Outcrop (Map Unit 10)

USDA description: Dominantly undulating to very steep, shallow to moderately deep, well drained and somewhat excessively drained, medium and moderately coarse textured soils, and rock outcrop; on uplands.

Hollis-Chatfield-Rock Outcrop soils form on glacial till underlain by granite, gneiss, and schist bedrock in the southeastern part of the county. Bedrock exposures, with very steep to nearly vertical bedrock escarpments, are common. The unit is about 40 percent Hollis soils, 20 percent Chatfield soils, 20 percent rock outcrop, and 20 percent soils of minor extent. The soils are well drained to somewhat excessively drained and shallow to moderately deep depending on their placement on slopes. The soils have a loam to fine sandy loam texture. The rock outcrop consists of folded granite, schist, and gneiss.

Most areas of this unit are wooded or are used for community development. A few areas are used for pasture. Shallow depth to bedrock, scattered bedrock outcrops, and steep slopes are the main limitations in areas used for agriculture and community development.



SOIL LEGEND*

1	Hudson-Vergennes-Raynham
2	Hoosic-Wayland-Copake
3	Farmington-Galway-Stockbridge
4	Cardigan-Dutchess-Nassau
5	Bernardston-Pittstown
6	Charlton-Chatfield-Hollis
7	Stockbridge-Georgia
8	Taconic-Rock Outcrop-Macomber
9	Nassau-Rock Outcrop-Cardigan
10	Hollis-Chatfield-Rock Outcrop

*The units on this legend are described in the text under the heading "General Soil Map Units."

Compiled 1999

Each area outlined on this map consists of more than one kind of soil. The map is thus meant for general planning rather than a basis for decisions on the use of specific tracts.

UNITED STATES DEPARTMENT OF AGRICULTURE
NATURAL RESOURCES CONSERVATION SERVICE
CORNELL UNIVERSITY AGRICULTURAL EXPERIMENT STATION

GENERAL SOIL MAP

DUTCHESS COUNTY, NEW YORK

Scale 1:253,440

1 0 1 2 3 4 Miles

1 0 4 8 Km

Chapter 5:
Water Resources of Dutchess County, NY

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Chapter Contents

Water is a vital resource as drinking water and an essential component of habitat suitability for a wide array of aquatic organisms. In addition to these direct uses, the movement of water throughout the atmosphere, surface streams and lakes, and aquifers carries both necessary materials (such as dissolved oxygen and nutrients) and harmful materials (such as pollutants). The amount of water as well as quantity of material in transport will be affected by a host of natural factors including soils, vegetation, and underlying geology, along with numerous human activities such as direct discharge of wastes into surface waters and modification of land cover within watersheds. Water use must be balanced between amounts required to allow functioning of aquatic ecosystems and prudent use for drinking,

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manufacturing, and waste disposal. Setting this balance presumes a solid understanding of amounts of water available, how it moves through various flowpaths across and under the landscape, and the natural and societal requirements for water. (This chapter describes the surface water and groundwater resources of Dutchess County; for more information on atmospheric water see NRI Chapter: 2: Climate and Air Quality.)

THE HYDROLOGIC CYCLE

Water is a finite resource from a global perspective. Less than one percent of the total water on the planet is freshwater, with oceans and ice masses making up the vast majority. Water is continuously recycled through the hydrologic cycle (Figure 5.1). Within this cycle, water enters the atmosphere by evaporating from oceans and other large water bodies and by transpiration from plants. This water vapor condenses into clouds and eventually falls back to earth as precipitation in the form of rain, snow, sleet, or hail.

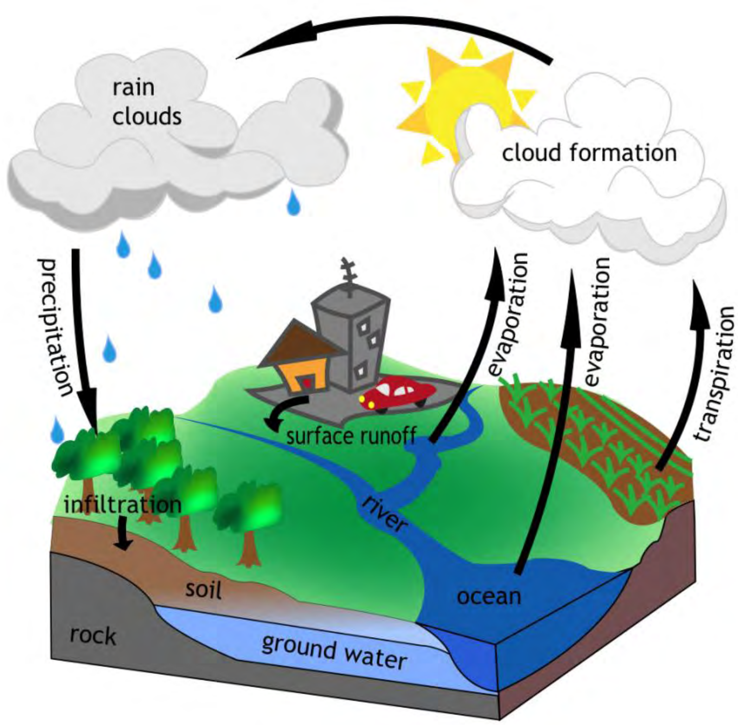


Figure 5.1: The hydrologic cycle (from Dutchess Watersheds)

Some of the water that falls on the land surface will evaporate or be transpired by plants. The rest will run off into streams and rivers or **infiltrate** into underground water storage areas, called **aquifers**, where it can be tapped for human use. Some may find its way into deep aquifers through cracks in the underlying bedrock, where it may be stored for centuries before working its way to the surface to evaporate, thus closing the cycle.

Human activity can have a profound impact on this natural cycle, and the largest scale effect has been our alteration of global climate which many predict will alter amounts of precipitation (see *Trends and Changes Over Time* section below), snowcover, and rates of evapotranspiration due to warmer temperatures in the northeastern United States. Once water falls on the land surface, the proportion that infiltrates versus runs off will be affected by the landcover, with the most dramatic effects due to conversion of vegetated areas to impervious cover such as roads, parking lots, and rooftops. Aside from affecting the quantity of water moving through various pathways, human activities can alter the substances carried in the water with some of the best studied examples including acid deposition and nutrient enrichment of surface and groundwaters.

DRAINAGE BASINS AND WATERCOURSES

Water drains from the land surface through drainage features ranging from rivulets in shopping center parking lots to large rivers like the Hudson. The entire area drained by a particular creek, stream, or river is called a **drainage basin** or **watershed**. The ridge that nearly encircles a drainage basin and separates one basin from another is called the **basin** or **watershed boundary**. These boundaries are based on surface topography, and it is easy to imagine how a drop of rainwater falling on one side or the other of a drainage boundary runs downhill to feed the streams of the respective basins. Subsurface flow (below the ground surface) generally follows the surface topography but large aquifers can extend across drainage basins and water may even move in directions different from surface flow (see *Groundwater Resources* section below). Surface basins are nested, with smaller streams contributing flow to the network. For example, each small tributary of the Little Wappinger Creek has its own drainage basin and is included in the 33.4 square mile watershed of the Little Wappinger Creek. This watershed is considered part of the 210 square mile

Wappinger Creek basin which, in turn, is included in the lower Hudson subdivision of the Hudson River watershed. Major watersheds of Dutchess County are shown in Map 5.1.

All of the surface water within a given watershed is part of the same hydrologic system. Watersheds, therefore, are the most appropriate geographic area for the study of surface water resources, the development of water resource management strategies, and the development of comprehensive waste treatment plans. Because all land uses both depend on and influence the quality and quantity of water supplies, watersheds are also the most logical physical units for natural resource management and land use planning.

Table 5.1: List of Major Drainage Basins in Dutchess County by size, including drainage areas, and flow attributes.

Basin	Area (sq. mi.)	10^{th} - 90^{th} Percentile Flow (cfs)
Fishkill@ Beacon	190	25 – 680
Wappinger near Wappinger Falls	181	21 – 600
Casperkill	11	NA
Falkill	19	NA
CrumElbow @ Hyde Park	19	1.9 – 60
Landsman Kill	11	NA
Saw Kill @ Red Hook	21	4.6 – 68
Stony Creek	22	NA
Ten Mile @ Wassaic	120	14.5 – 430

Sources, Ayer and Pauszek 1968; USGS; NA = not available

Most of the land in Dutchess County is within the Hudson River drainage basin, while a portion of the Harlem Valley drains into the Housatonic River in Connecticut (Map 5.1). Approximately 67 percent of the county's 807 square miles drain to the Hudson River through the Wappinger Creek, Fishkill Creek, and several smaller streams including the Casperkill, Fall Kill, Crum Elbow, Landsmankill, Saw Kill, and Stony Creek. The Tenmile River basin, part of the Housatonic River basin that ultimately drains to Long Island Sound, covers nearly 210 square miles or 26 percent of the county, including all of Dover and Amenia and most of North East and Pawling. The remaining 7 percent of the county is divided between two other watersheds: a small area in the southeastern corner drains into the Hudson River via the Croton River and a small portion in the North that drains to the Hudson via the Roeliff Jansen Kill.

Hudson River Basin

The Hudson River receives most of the surface runoff from Dutchess County streams and is also the water supply for the City of Poughkeepsie, surrounding areas, such as parts of Hyde Park, and some major industries such as IBM. The Hudson River is tidal, with about a 3 foot tidal range, therefore, currents reverse four times each day. Nutrient and suspended sediment concentrations are moderately high (Levinton & Waldman, 2006) and the primary drinking water issue is the occasional intrusion of salt water from downriver. Sea-level rise will eventually cause increases in upriver salt intrusions but the timing and magnitude are presently unknown.

The major water sources to the section of the Hudson along the Dutchess County shoreline are from the upper Hudson and the Mohawk River. Suspended sediments, contaminants, and wastewaters from upriver are delivered to the Dutchess County portion of the Hudson River but in general concentrations are not high enough to impede use as a drinking water supply.

Wappinger Creek Basin

The Wappinger Creek and its tributaries drain approximately 210 square miles, roughly one-fourth of Dutchess County. The drainage area extends about 30 miles southwest from the Town of Pine Plains toward New Hamburg at the southern tip of the Town of Poughkeepsie. There are three major branches of the Wappinger Creek: the Little Wappinger, the Main Branch, and the East Branch, and these converge near Salt Point in the town of Pleasant Valley. The Wappinger drainage basin includes large parts of the Towns of Pleasant Valley, Washington, Pine Plains, Milan, Stanford, and Clinton; the Villages of Millbrook and Wappingers Falls; and portions of the Towns of Wappinger, Poughkeepsie, LaGrange, and Fishkill. The Wappinger Creek basin is primarily forested, with some agriculture in the upper watershed and increasing residential, urban, and industrial areas moving downstream.

Fishkill Creek Basin

The Fishkill Creek basin covers approximately 194 square miles. Fishkill Creek, the basin's primary stream, begins in the center of the county in Union Vale and flows southwest, entering the Hudson River at Beacon. It drains large parts of Union Vale, Beekman, East Fishkill, and Fishkill, and a smaller portion of Wappinger. (The basin also includes the Towns of Philipstown and Kent in Putnam County.) Sprout Creek, Fishkill Creek's primary tributary, drains major sections of

LaGrange and Union Vale and small portions of Wappinger and East Fishkill. Like the adjacent Wappinger Creek basin, the landcover/use in the Fishkill basin grades from forest, agriculture and low-density residential in the upper basin to higher-density and urban nearer Beacon.

Tenmile River Basin

The Tenmile River drains 210 square miles in the eastern section of Dutchess County, from the Columbia County line south to the town of Pawling. The basin ranges from 5 to 8 miles wide, is 33 miles long, and has four principal watercourses: the Tenmile River itself, Swamp River, Webatuck Creek, and Wassaic Creek. The Tenmile River falls an average of 16 feet per mile as it travels its narrow path southward from the town of North East, through the Harlem Valley lowlands in Amenia and Dover, and enters Connecticut near Dogtail Corners. The Swamp River flows north from Pawling and joins the Tenmile River south of Dover Plains.

The Tenmile River and its tributaries wind through extensive floodplains and wetlands. During periods of increased runoff these areas retain flood waters, helping to minimize downstream flooding. Because the Tenmile River basin is not as developed as other drainage basins in the county, there are still many opportunities to preserve the functional and wildlife values of these wetlands and floodplains while accommodating agricultural activity and growth.

More detailed information on tributaries, landcover and water quality is available at the Dutchess Watersheds website.

SURFACE WATER QUANTITY

Eight-hundred miles of streams flow across the Dutchess County landscape. When managed properly, this high density of surface water provides residents with adequate water supplies and provides enough water to sustain our natural systems. In addition to the streams, there are 93 named lakes and ponds in Dutchess County and dozens that are unnamed. Many of the lakes and ponds, such as the largest Whaley Lake, were artificially created (Table 5.2).

Table 5.2: Lakes and ponds in Dutchess County larger than 25 acres

Name	Location	Approx. size in acres
Abel's Lake	Union Vale	59
Black Pond	East Fishkill	176
Bontecou Lake	Washington	115
Lake Carvel	Pine Plains	38
Cobalt Lake	Poughkeepsie	29
Crane Pond	Dover	38
DeFlora Bros. Lake	Hyde Park	43
Dieterich Pond	Millbrook	32
Lake Dutchess	Pawling	51
Ellis Pond	Dover	61
Green Mountain Lake	Pawling	35
Halcyon Lake	Pine Plains	26
Hillside Lake	East Fishkill	26
Hunns Lake	Stanford	68
Indian Lake	North East	194
Little Whaley Lake	Pawling	52
Long Pond	Clinton	66
Nuclear Lake	Pawling	55
Quaker Lake	Pawling	64
Round Pond	Amenia	49
Round Pond	Milan	40
Rudd Pond	North East	76
Sepasco Lake	Rhinebeck	26
Sharpe Reservation Pond	Fishkill	26
Shaw Pond	Washington	26
Silver Lake	Clinton	115
Spring Lake	Milan	26
Stissing Lake	Pine Plains	78
Swift Pond	Amenia	61
Sylvan Lake	Beekman	116
Thompson Pond	Pine Plains	68
Twin Island Lake	Pine Plains	62
Tyrrel Lake	Pleasant Valley	45
Upton Lake	Stanford	43
Lake Walton	East Fishkill	42
Wappingers Lake	Wappings Falls	122
Lake Weil	Dover	34
Whaley Lake	Pawling	287

Source: Dutchess County Department of Planning, 1985; *Natural Resources, Dutchess County, NY*, 1985

Surface Flow

Surface water in Dutchess County reflects the integrated effects of all watershed characteristics that influence the hydrologic cycle. Characteristics include climate of the drainage basin (type and distribution patterns of precipitation and temperature regime), geology, land use/cover (permeable or impermeable surfaces and materials and human-built drainage systems), and vegetation (uptake of water by plants, protection against erosion, and influence on infiltration rates). Combined, these factors determine the amount of water flowing through the streams at any given moment. For example, an urbanized watershed with impervious surfaces will have higher peak discharges following storms than a watershed that is predominantly forested and allows a higher percentage of rain water to slowly infiltrate before it reaches the stream. These stream flow patterns directly affect aquatic habitat, flood behavior, recreational use, and water supply and quality.

The literature has documented the deleterious effects impervious surfaces have on biota (Limburg and Schmidt, 1990; May et al., 2000; Wang et al., 2001; Roy et al., 2005), stream stability (Booth, 1990; CWP, 1998; White & Greer, 2005; Wohl, 2005), and in-stream water quality (Groffman et al., 2004 and Deacon et al., 2005). For example, impervious surfaces can raise the temperature of stormwater runoff, which in turn reduces the water's ability to hold dissolved oxygen and harms some game fish populations, while promoting excess algal growth. Field observation, research, and hydrologic modeling suggest a threshold of 10 percent impervious surface in a watershed, after which there is marked transition to degraded stream conditions (CWP, 1998 and Booth, 2000).

Between the 1960s and 1990s, the U.S. Geological Survey (USGS) participated in various studies at 84 stream sites in Dutchess County. Today, the USGS operates only three gage stations in Dutchess County: one on the Tenmile River near the Connecticut line, another on the Wappinger Creek near Wappingers Falls, and a third on the Hudson River near Poughkeepsie. The scarcity of up-to-date information about surface water flow rates makes it difficult to assess the hydrological impacts of recent land use changes on the county's watersheds.

Implications of Water Quantity

The rich hydrology of Dutchess County has historically provided adequate water to meet our needs. However, as human demands for water increase or groundwater recharge decreases, there is the potential for inadequate flow of water in streams during dry periods. Low flows can lead to high water temperatures, inadequate dissolved oxygen levels, and restrictions on movements of fish and other aquatic organisms. Efforts to establish minimal environmental flows have developed procedures to determine how much water must be left in a channel to ensure good habitat value and ecological functioning.

Flood dynamics play a large role in determining the shape, or **morphology**, of stream channels and the hazards associated with land uses on the banks and in the floodplain. For example, applications for stream disturbance permits (from New York State Department of Environmental Conservation (NYS DEC)) typically increase following floods as landowners and municipalities attempt to repair damage caused by flooding. For recommendations on dealing with flooding and floodplain issues in your community please visit: dutchess watersheds.org.

If we want to minimize flood impacts on property and infrastructure in an increasingly unpredictable climate, it is critical that we understand and plan for flooding behavior (see *Implications for Decision-Making* section below). Historically, this "planning" has emphasized attempts to constrain and control stream channels rather than planning to keep infrastructure, residences, etc. out of areas likely to flood (see *Floodplains* section below). The results are often costly and sometimes catastrophic, such as when berms or levees fail or bridges wash out. These "control" approaches typically result in ongoing maintenance costs that can draw valuable community resources away from other projects.

SURFACE WATER QUALITY

Several parameters are used to assess water quality and track human-induced impacts. Many of the data reported here are medians for selected water quality variables. The source of the majority of the data below is a study by the Dutchess County Environmental Management Council (Burns, 2006). Similar information, although spanning a different time period, is available for the Tenmile River at

Wassaic and there have been many studies at specific sites conducted by the Hudson River National Estuarine Research Reserve, The Cary Institute of Ecosystem Studies, and faculty at Vassar College.

Chloride

Chloride is the negatively charged portion of a variety of salts including sodium chloride (NaCl), calcium chloride ($CaCl_2$), and magnesium chloride ($MgCl_2$). Chloride enters surface water from several sources including geologic formations containing chloride, agricultural runoff, industrial wastewater, effluent from wastewater treatment plants, and a major contribution from salting of roads (Kelly et al., 2005). Excess chloride can contaminate freshwater streams and lakes, negatively affecting aquatic communities.

While there are no set standards for chloride in fresh surface waters, studies have shown impacts to aquatic communities at various concentrations. Chloride concentrations of approximately 140 mg/L should be protective of freshwater organisms for short-term exposure; concentrations less than 35 mg/L are likely protective during long-term exposures (Environment Canada, 2001). Approximately 5 percent of species would experience effects from chronic exposure to concentrations of chloride of 210 mg/L, while 10 percent of species would be affected at concentrations of 240 mg/L (Environment Canada, 2001). According to the United States Environmental Protection Agency, biota on average should not be affected if the four-day average concentration of chloride does not exceed 230 mg/L more than once every three years (USEPA, 2005a). Biotic impacts would be minimal if the one-hour average chloride concentration did not exceed 860 mg/L more than once every three years (USEPA, 2005a).

In a 2006 study of Dutchess County tributaries to the Hudson River (Burns, 2006), chloride concentrations were below levels set by the EPA for acute (860 mg/L) and chronic (230) exposure (Mullaney et al., 2009), but it is worth noting that Environment Canada recommends maintaining chronic chloride concentrations at or below 35 mg/L (Environment Canada, 2001). The annual median chloride concentration for Dutchess County streams ranged from less than 2 to 127 mg/L (Table 5.3). It is difficult to evaluate this chronic threshold because the data collected during this study were not collected frequently enough to develop chronic exposure recommendations. It is notable, however, that all the watershed median concentrations were higher than Environment

Canada's chronic threshold with the exception of the highly forested watersheds of Mount Beacon which fell well below 35 mg/L.

The highest median annual chloride concentrations were in the suburbanized watersheds of the Casperkill, and two streams designated HR 99 and HR 98. Although one would expect that the highest median concentrations would be in urban streams like the Fall Kill in Poughkeepsie and the Fishkill in Beacon, their annual median chloride concentrations were not nearly as high as in these suburban watersheds. The Fall Kill shows effects of road salting with extremely high chloride concentrations in January and much lower concentrations in the summer months. However, the Casperkill, HR 99, HR 98, and the Fishkill Creek contained high chloride concentrations throughout 2004. On average for all the watersheds, summer/fall chloride concentrations were higher than winter/spring concentrations. This could be an indication of a chronic source of chloride such as sewage, or perhaps road salt is being stored in the sediment and released throughout the year following rain events (Kincaid & Findlay, 2009).

Phosphorus

Phosphorus is a nutrient essential to plant growth. In aquatic ecosystems phosphorus occurs primarily in the form of organic phosphorus, which is bound in plant and animal tissue and unavailable for plant uptake. Plants are able to assimilate phosphorus in the form of phosphate (PO_4^{3-}) from the surrounding water and convert it to organic phosphorus. In freshwater ecosystems phosphate tends to be the least available nutrient, causing it to be the limiting factor for plant growth. Because of this, small additions of phosphate to surface waters can result in large amounts of plant growth and eutrophication.

The most likely sources of phosphate inputs include animal wastes, human wastes, fertilizer, detergents, disturbed land, road salts (anticaking agent), and stormwater runoff. In general, any concentration over 0.05 mg/L of phosphate will likely have an impact on surface waters (Behar, 1997). However, in many waterbodies, concentrations of phosphate as low as 0.01 mg/L can have a significant impact. In order to control eutrophication, the USEPA recommended limiting phosphate concentrations to 0.05 mg/L in waters that drain to lakes, ponds and reservoirs, and 0.1 mg/L in free flowing rivers and streams (USEPA, 1996).

The median phosphate concentration of Dutchess County's streams ranged from 0.01 mg/L in several streams to 0.09 mg/L in the Sawkill (Table 5.3).

In-stream median annual phosphate concentrations were similar to the threshold value in the literature of 0.010 mg/L for relatively undeveloped watersheds in the United States. Indian Kill, Crum Elbow Creek, Maritje Kill, Wappinger Creek, HR 98, and Wade's Brook all fell within this threshold. The three watersheds that stood out with high phosphate concentrations were Stony Creek, Saw Kill, and HR 99. In Stony Creek and the Saw Kill, concentrations were highest in July during the lowest flow period. This is an indication of a chronic source of phosphate that becomes more evident as water levels drop and the phosphate becomes more concentrated. The source may have been the wastewater treatment plants that were upstream of the sampling sites. However, HR 99 contained consistently high phosphate concentrations throughout the year. This could suggest another source such as failed septic systems or fertilizers, or be an indication that the stream is just too small to effectively dilute the wastewater effluents it receives.

Nitrogen

Nitrogen is found in various forms in ecosystems including organic forms such as proteins and amino acids, nitrate (NO_3^-), nitrite (NO_2^-), and ammonium (NH_4^+). The majority of nitrogen on earth is in its gas form (N_2), which makes up approximately 80 percent of our atmosphere. It is converted into organic forms by certain terrestrial plants (legumes), nitrogen-fixing bacteria, lightning, and microbes in the water and soil. Nitrate, the most mobile form of nitrogen, can be assimilated by vegetation to make protein, leached into groundwater or surface water, or converted to nitrogen gas in the process of denitrification (Welsch et al., 1995). Nitrite, ammonia, and ammonium are intermediate forms of nitrogen in aquatic systems and are quickly removed from the system by being converted to either nitrate or nitrogen gas (Behar, 1997). Ammonium is released into the system during decomposition or when animals excrete their wastes; through the process of nitrification, ammonium is oxidized to nitrate by bacteria.

Major sources of nitrate in streams include municipal and industrial wastewater discharges and agricultural and urban runoff. Atmospheric deposition of nitrogen from automobile exhaust, power plants, and industrial emissions is also a source (Smith et al., 1991).

Excess nitrate can accelerate eutrophication of surface waters and can present a human health concern in drinking water. Nitrate concentrations of 44 mg/L (equivalent to 10 mg/L nitrate-nitrogen for EPA and NYSDOH standards) or higher have the potential to cause methemoglobinemia, or "blue baby" disease in children (McCasland et al., 1998). High concentrations of nitrate in water can serve as an indicator of sewage, fertilizers, or other contaminants. Although the human health standard for nitrate consumption has little correlation with stream health, high levels of nitrate in both surface and ground water typically indicate widespread nonpoint source pollution.

Due to land uses and atmospheric deposition, concentrations of in-stream nitrate typical of undeveloped watersheds rarely occur in the Hudson Valley. The annual median nitrate concentration of Dutchess County's streams ranged from 0.02 (HR90) to 6.75 mg/L (Saw Kill) (Table 5.3). With the exception of Wades Brook and HR-90, median nitrate concentrations in Dutchess County streams were all above the threshold value of 0.087 mg/L for streams in the United States in relatively undeveloped watersheds (Clark et al., 2000). Gordon's Brook, Wade's Brook, and HR 90 all contained relatively low concentrations of nitrate, chloride, and phosphate because their watersheds mostly drain the heavily forested Mount Beacon. These watersheds could be considered as a reference baseline for comparison with other local watersheds.

In northern Dutchess County, nitrate concentrations were highest in Stony Creek and the Saw Kill in July 2004. These high concentrations occurred during periods of low-flow, indicating a chronic source of nitrate that becomes diluted during higher flows. The source could be treated sewage effluent, since both sampling sites were downstream of wastewater treatment plants, and/or septic system effluent. Watersheds in the Poughkeepsie-Fishkill region had the highest median annual nitrate concentrations, and the highest individual reading was in the Fishkill Creek in July 2004. The Fall Kill, located in one of the most urbanized areas of Dutchess County (City of Poughkeepsie), contained relatively low nitrate concentrations, likely because a majority of the watershed above the sampling site was sewered and several ponds and wetlands located upstream of the sewered section trap pollutants.

Conductivity

Conductivity measures the ability of water to carry an electric current and is determined by bedrock geology and addition of salts from several human activities. Studies of inland fresh waters indicated that streams supporting good mixed fisheries had a conductivity range of 150 to 500 µmhos/cm (USEPA, 1997). Annual median conductivity for Dutchess County streams ranged from near 50 µmhos/cm (at HR90 and Wade's Brook) to nearly 1000 µmhos/cm (at HR 99, Table 5.3).

Table 5.3: Annual median nitrate, phosphate, chloride and conductivity summary for 2004 (collected January through November, bimonthly) and the water quality impact criteria from literature values (expanded upon in introduction).

Watershed	Nitrate (mg/L)	Phosphate (mg/L)	Chloride (mg/L)	Conductivity (µmhos/cm)
Stony Creek	3.08	0.05	34.85	396.5
Saw Kill	6.75	0.09	38.84	357.5
Muddler Kill	1.09	0.02	76.55	476
Landsman Kill	3.95	0.06	42.99	376.5
Fallsburg Creek	1.16	0.02	47.4	352
Indian Kill	1.64	0.01	44.56	434
Crum Elbow Creek	2.42	0.01	40.14	346
Maritje Kill	3.19	0.01	62.26	531
Fall Kill	1.21	0.02	76.89	501.5
Casper Kill	5.19	0.03	127.34	740.5
Wappinger Creek	2.25	0.01	46.59	393
HR 99	4.96	0.32	126.34	977.5
HR 98	2.36	0.012	119.25	689
Fishkill Creek	8.87	0.04	78.3	611.5
Gordons Brook	0.17	0.02	4.51	69.15
Wades Brook	0.06	0.01	1.57	51
HR 90	0.02	0.02	1.59	55.8
Literature Concentration for Non-impacted Streams	0.087 (Clark et al., 2000)	0.010 (Clark et al., 2000)	230 (4-day average) (USEPA, 2005a)	500 (USEPA, 1997)

Table 5.4: Annual mean nitrate, chloride and phosphate concentrations and standard deviation from the mean for small (0.5 to 5.0 square miles), medium (19 to 28 square miles) and large (193 to 210 square miles) watersheds of Dutchess County.

Watershed Size	Mean Nitrate Concentration mg/L	Mean Chloride Concentration mg/L	Mean Phosphate Concentration mg/L
Small (9)	1.86 ± 1.94 (N=51)	58.12 ± 48.25 (N=51)	0.06 ± 0.17 (N=51)
Medium (6)	4.10 ± 2.23 (N=36)	64.30 ± 47.96 (N=36)	0.08 ± 0.21 (N=36)
Large (2)	6.60 ± 5.64 (N=12)	64.54 ± 22.57 (N=12)	0.04 ± 0.04 (N=12)

Other Chemical and Physical Parameters

Dissolved oxygen refers to oxygen gas (O_2) molecules in the water. The molecules are naturally consumed and produced in aquatic systems and are necessary for almost all aquatic organisms. If dissolved oxygen levels fall below a certain threshold, biologic integrity will be compromised. For example, on a scale of 0 to 14 mg/L, a concentration of 7 mg/L to 11 mg/L is ideal for most stream fish (Behar, 1997). Dissolved oxygen can be measured as the concentration of milligrams O_2 per liter (mg/L) or as percent saturation of O_2. Percent saturation is the amount of oxygen in a liter of water relative to the total amount of oxygen the water can hold at a given temperature. In cold water systems, a percent saturation of 60 percent to 79 percent is acceptable for most stream animals (Behar, 1997). The lowest values in a stream will typically occur near dawn under low flow, warm conditions. High frequency sampling required to detect sporadic low oxygen conditions have not been conducted for many sites across the county, but spot sampling showed a July 2004 median of 7.2 mg/L in 16 Hudson River tributaries, with the lowest value of 1.3 mg/L in Fallsburg Creek in Rhinebeck.

The **pH** of water is important to monitor because most species of aquatic organisms require a pH in the range of 6.5 to 8.0; variance outside of this range can stress or kill organisms. Due to the acidity of rainfall in the northeastern United States, maintaining this range is of concern. According to the NYSDEC (2004a), average pH of rainfall in New York ranges from 4.0 to 4.5. Dutchess County contains large amounts of calcium carbonate bedrock, which provides a buffer for acidic inputs and acts to raise the alkalinity and hardness of water. However, this buffering capacity can diminish over time with geologic weathering.

Sulfate (SO_4^{2-}) can occur naturally as a result of decomposition of organic matter, water passing through rock or soil containing gypsum and other common minerals, or atmospheric deposition. It can be also be found in municipal sewer treatment plant discharges, fertilized agricultural runoff, or industrial discharges. The combustion of fossil fuels releases large amounts of sulfur to the atmosphere, where it is oxidized to sulfate and may fall in precipitation or be deposited as gas. Sulfate is highly mobile and often ends up in streams and lakes; therefore, monitoring levels of sulfate in surface waters may provide a means of tracking impacts of fossil fuel combustion. The median concentration of sulfate across all streams in the 2006 Hudson River tributaries study was 17.3 mg/L; the highest concentration was found in the lower Fishkill at 52.2 mg/L. Several streams with long-term water quality monitoring have shown declines in SO_4 concentrations almost certainly due to lowered sulfur emissions following the Clean Air Act Amendments.

Turbidity is an optical measurement of the light-scattering at 90° caused by particles suspended in water. Turbidity is measured in arbitrary "nephelometric turbidity units" (NTUs) by a "nephelometer." The higher the NTU value, the lower the water clarity and the murkier the appearance. **Total suspended solids** are a measure of suspended solids concentration, expressed as a mass per volume (mg/L) obtained by physically separating the liquid and solid phases by filtration. There is no single, fixed relationship between turbidity and total suspended solids. Turbidity can be influenced not only by the amount of particles in suspension, but also by the shape and size of the particles. Increased turbidity can be caused by soil erosion, waste discharge, urban runoff, bottom feeders such as carp, and algal growth. Turbid waters become warmer as suspended particles absorb heat from sunlight, causing oxygen levels to fall. Photosynthesis also decreases with less light, resulting in even lower oxygen levels. Finally, the suspended material in turbid water can clog fish gills, reduce growth rates, decrease resistance to disease, and prevent egg and larval development. In general, turbidity tends to be low in Dutchess County streams although high-frequency sampling that would detect turbidity spikes related to storm events has generally not been carried out.

Water temperature is one of the most important variables in aquatic ecology. Temperature affects movement of molecules, fluid dynamics, and metabolic rates of organisms as well as a host of other processes. In addition to having its own potential "toxic" effect (such as when temperature is too high), temperature affects the solubility and toxicity of other parameters. Generally the solubility of solids increases with increasing temperature, while solubility of gases (including dissolved oxygen) decreases with higher temperatures.

In densely wooded areas where the majority of the streambed is shaded, heat transferred from air and groundwater inputs drives in-stream temperature dynamics. However, in areas that aren't shaded, the water temperatures can rise much more quickly due to the direct exposure to the sun's radiation. Water temperatures exceeding 77 degrees Fahrenheit cannot be tolerated by brook trout; they prefer water temperatures less than 68 degrees Fahrenheit (TU, 2006).

Determining whether a stream has good or bad water quality depends largely upon the end user. Water quality in Dutchess County can vary from stream-to-stream and mile-to-mile within the same stream. However, as indicated by the "snapshot" offered above, water quality in Dutchess County tends to be good, with a few exceptions. Degradation tends to not come from a direct point, but result from slower changes that occur over time with land use changes that increase impervious surface cover and decrease the amount of water that infiltrates into the ground. The impacts of these activities on our water resources reverberate throughout the system. They are most obvious during flood events that cause the loss of property and infrastructure, but effects are also evident during low flow periods when the stream is over-wide and shallow, unable to support a vibrant coldwater fishery in affected segments.

WATER QUALITY STANDARDS

The federal and New York State governments have developed water quality and purity standards to monitor and protect waterbodies. The Federal Water Pollution Control Act of 1972, as amended (and subsequently called the Clean Water Act), imposes strict standards on water quality and pollutant levels. Part 701 of the 1974 New York Environmental Conservation Laws (6 NYCRR) outlines the water quality and priority classifications and standards for New York State waterbodies.

NYSDEC Stream Classification and Impaired Water Body List

All waters in New York State are given a class and standard designation based on present quality and best usage for that water body (NYSDEC, 2004). In the case of streams and rivers, the classifications are assigned to specific segments of a watercourse. The New York State DEC stream classification system includes the following designations:

Stream Classifications

Class	Best Use
AA	Drinking (after disinfection), Bathing and Fishing
A	Drinking (after disinfection and approved treatment), Bathing and Fishing
B	Bathing and Fishing
C	Fishing – Propagation and Survival
D	Fishing - Survival

New York Codes, Rules, and Regulations ("NYCRR"), Title 6, Section 701.

Additional designations of "T" or "TS" can be added to Class A, B, or C stream if a water body has sufficient amounts of dissolved oxygen to support trout (T) and/or trout spawning (TS). Water bodies that are designated as "C (T)" or higher (e.g., "C (TS)", "B", or "A") are collectively referred to as "protected streams," and are subject to additional regulations and require a State permit for disturbance of the bed or banks.

The New York State DEC also applies standards that correspond to these classifications when reviewing stream disturbance or pollutant discharge permit applications. This is to prevent the existing water quality from deteriorating. Some of these standards are described in numerical form whereas others are in narrative form. The details of these standards can be found in New York Codes, Rules, and Regulations, Title 6, Department of Environmental Conservation, Chapter X, Division of Water, Part 703, Surface Water and Groundwater Quality Standards and Groundwater Effluent Limitations at http://www.dec.ny.gov/regs/4590.html.

Most of the streams, rivers, lakes, and ponds within Dutchess County are Class B, C, or D. Some of the more significant AA and A streams and lakes are listed below:

- Clove Creek - at Fishkill water supply
- Crum Elbow Creek and tributaries - upstream of Hyde Park Fire and Water District intake
- Ellis Pond
- Fishkill Creek - at Beacon water supply
- Gardiner Hollow Brook - at Green Haven State Prison water supply
- Green Mountain Lake
- Hiller Brook and tributaries - at Pawling Village water supply.
- Indian Kill - at Staatsburg water supply
- Long-Pond
- Pawling Reservoir
- Silver Lake
- Swamp River - at Harlem Valley Hospital water supply
- Ten Mile River, wells, stream, and tributaries - at Dover Plains auxiliary water supply
- Tributaries of Cargill Reservoir

A complete list of the classifications for Dutchess County waterbodies and stream segments can be found at Department of Environmental Conservation Regulations, Chapter X, Part 857 for the Wappinger Creek Basin and at Part 862 for the other drainages entering the Hudson River. The corresponding websites are: www.dec.ny.gov/regs/4557.html for the Wappinger Creek Basin and www.dec.ny.gov/regs/4552.html#16995 for the other drainages.

Waterbody classifications affect, but do not totally restrict, land uses and discharges along waterways. If wastes are treated to satisfy the appropriate standards, they can be discharged under permit (see below). The standards protect the rights and property values of landowners along water courses by protecting them from water pollution. Stream classifications are periodically revised by the New York State Department of Environmental Conservation. Public hearings are an integral part of the reclassification process.

Periodically, the DEC publishes the Priority Waterbodies List (PWL), which includes a list of water bodies that do not meet their designated "best use" classification. A data sheet that describes the conditions, causes, and sources of water quality degradation for each of the respective listings is included in the PWL. The PWL is used by the DEC and other agencies as a primary resource for water resources management and funding. You can access the classification of your stream at the following website: http://www.dec.ny.gov/permits/6042.html (go to the environmental resource mapper). Additionally, the 2008 NYSDEC 305b report reporting the state of New York's impaired water bodies is available here: http://www.dec.ny.gov/chemical/23837.html and information on the 305d report of impaired water bodies can be found at this site: http://www.dec.ny.gov/chemical/37129.html. The most recent version of the WI/PWL for the Lower Hudson River Basin was released in August 2008 and can be found in its entirety at www.dec.ny.gov/chemical/36740.html.

The PWL is included within the Waterbody Inventory (WI), a comprehensive inventory of all the waterbodies in New York State that is maintained by the DEC. The purpose of the WI/PWL is to characterize the extent to which designated water uses are being supported, to identify waterbodies that have been impaired, and to track efforts to restore impaired waterbodies to their designated uses. The WI is part of an overall program known at the Comprehensive Assessment Strategy (CAS) conducted through an ongoing series of rotating basin surveys. The DEC has assigned all of the waterbodies in NYS to one of 17 designated drainage basins. The waterbodies of Dutchess County, including those that drain to the Housatonic River, are part of the Lower Hudson River Basin.

Each year two to three of the drainage basins are reassessed, allowing all 17 to be reevaluated every five years. The reassessments are conducted over a two year period and involve an examination of data on biomonitoring, water and sediment chemistry, and sediment toxicity as well as any data generated by site- or problem-specific monitoring activities. The primary question that is addressed in each review is whether the waterbodies support their designated uses such as public bathing, drinking water, support of aquatic life, etc. Based on the data review by DEC staff and personnel from other cooperating agencies, the waterbodies (or segments thereof) are classified into one of six categories: impaired waters, waters with minor impacts, threatened waterbodies, waterbodies with impacts needing verification, waterbodies with no known impacts, and unassessed waterbodies. Waterbodies that are classified in one of the first three categories are assigned to the Priority Waterbodies List (PWL).

According to the 2008 Final Draft Lower Hudson River Basin WI/PWL Report, most waterbodies in Dutchess County have not been assessed. For those waterbodies that were assessed, impairment was documented at Hillside Lake, Wappingers Lake, and segments of the Fall Kill and its tributaries. Minor impacts were observed at lower Fishkill Creek, Sylvan Lake, and segments of the Casperkill Creek, the Landsman Kill, the Rhinebeck Kill, and their respective tributaries.

Discharges of stormwater and wastewater are regulated in New York State under the State Pollutant Discharge Elimination System (SPDES). The original intent of this legislation was to control **point sources** of pollution such as industrial outfalls and discharges from publically owned wastewater treatment plants. Operators of these facilities are required to obtain permits that specify the maximum quantity of wastewater to be discharged into waters of New York State. The law also imposes upper limits for specific categories of pollutants. When the federal CWA was amended in 1987, a set of mandated requirements known as Phase I was added to address discharges from additional types of industrial activities, medium and large Municipal Separate Storm Sewer Systems (MS4s) and construction activity disturbing more than five acres of soil. These sources were also required to obtain SPDES permits.

Under the more recent Phase II of the CWA, efforts were intensified to reduce pollutant loading from constructions sites of one acre or larger and from municipal stormwater conveyance systems. Municipalities that met certain criteria of population size (>50,000) and population density (>1000 people per square mile) were automatically designated as MS4s. As of January 2010, these communities are required to develop and fully implement a Stormwater Pollution Prevention Plan in order to receive a general permit allowing them to discharge stormwater into the waters of New York State. The communities in Dutchess county that were automatically designated as MS4s are listed as follows: Beacon (C), Beekman (T), East Fishkill (T), Fishkill (V) and (T), Hyde Park (T), LaGrange (T), Pleasant Valley (T), Poughkeepsie (C) and (T), Union Vale (T), Wappinger (T), Wappingers Falls (V), where T, C, and V refer to town, city, and village respectively. Because they have lands that fall within the New York City Department of Environmental Protection East of Hudson watershed, additional parts of Pawling (T) and (V), Beekman (T), and East Fishkill (T) are also required to comply with the Phase II regulations for MS4s.

GROUNDWATER RESOURCES

Groundwater in the Hydrologic Cycle

Groundwater encompasses the water flow in the hydrologic cycle which moves beneath the earth's surface. Groundwater recharge occurs when local precipitation enters soil and rock horizons and infiltrates down to subsurface depths where the sediment porosity or bedrock fractures are already saturated from prior precipitation events. The boundary between unsaturated and saturated geologic materials is called the **watertable**. Below the watertable, any geologic formation containing useful quantities of groundwater is recognized as an **aquifer**. Aquifers can consist of sand and gravel formations or fractured bedrock. Since residential wells providing useful quantities of water have been drilled in every bedrock formation in the county, all of Dutchess County's bedrock formations are recognized as aquifers, although some are lower yielding than others. Sand, gravel, and even some silt deposits in Dutchess County's valleys have long been utilized for the installation of water wells, so these formations are also recognized as aquifers. Approximately 381 million gallons of replenishable groundwater recharge county aquifers each day, equivalent to roughly 1,300 gallons daily per capita based on the 2008 census populations for Dutchess County.

Rates of groundwater recharge into aquifers are primarily limited by the general **porosity** (amount of void volume within a volume of soil or fractured bedrock) of Dutchess County's soils, with higher recharge rates possible in areas with sandy soils and lower recharge rates occurring in areas with silty or clayey soils. The Soil Conservation Service assigns all soils into one of four major Hydrologic Soil Groups (HSG). HSG A soils are generally our sandiest soils, HSG B soils consist of mixed silt and sand, HSG C soils are silty, and HSG D soils are clay rich soils. Figure 5.2 identifies average annual recharge rates identified for each Hydrologic Soil Group in the county's major watershed areas. The highest recharge rates occur in areas with sandy soils and higher precipitation rates; the lowest recharge rates occur in areas with low precipitation rates and clayey soils. The recharge rates identified on Figure 5.2 were calibrated to stream flows of the Wappinger Creek, Tenmile River, and the Fishkill Creek. The distribution of Hydrologic Soil Groups in Dutchess County is discussed in NRI Chapter 4: Soils. A majority of soils in Dutchess County fall in Hydrologic Soil Groups B and C.

Once recharge from precipitation reaches the watertable, it no longer flows directly downward since all available pore spaces are already occupied by prior water. Groundwater then migrates downhill (downgradient) through the openings in granular soils or through networks of interconnected fractures in otherwise solid rock formations, flowing toward lower-elevation areas in the watershed, where it eventually exits the subsurface in springs or by emerging in the beds of streams, rivers, or wetlands. It is helpful to think of groundwater flow as "subsurface runoff," with the slope of the watertable generally mirroring the topography of the landscape in a muted way. Rates of subsurface runoff are far slower than surface water runoff because groundwater flow is obstructed by the complexity and constriction necessitated by flow though fractures and pores. Groundwater flow is therefore usually measured at rates less than one foot per day.

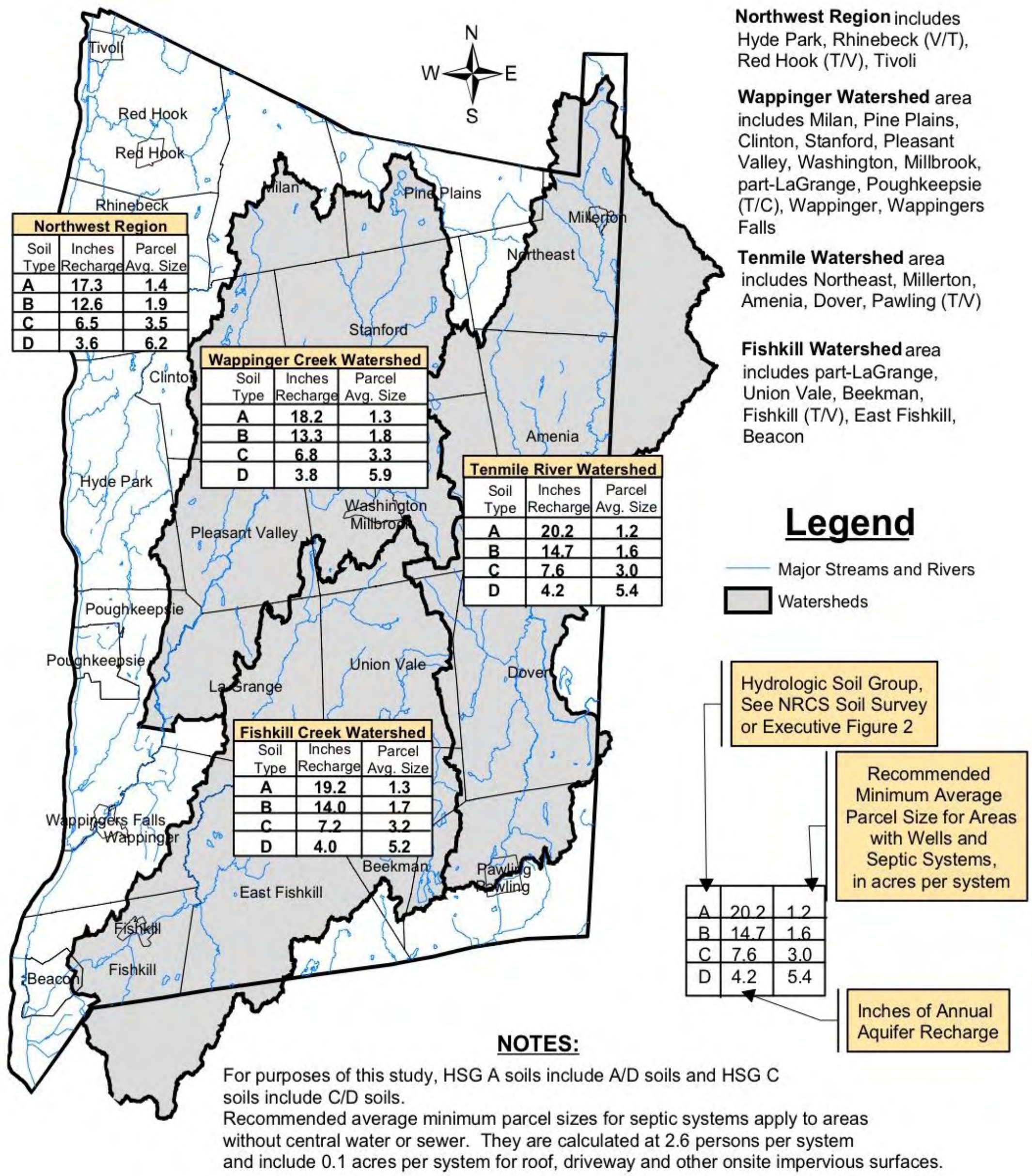


Figure 5.2: Soil types and aquifer properties for major basins in Dutchess County (provided by The Chazen Companies).

The emergence of groundwater in surfacewater bodies and wetlands is recognized as **base flow**, available as an important component of streamflow year round and particularly critical to wetland vegetation and stream flows during extended dry periods.

In most hillside and upland areas in Dutchess County, the watertable lies between 20 and 30 feet below the land surface. Perennial streams, rivers, lakes, and wetlands exist where the land surface and the watertable converge.

People sometimes think groundwater is "stored" in aquifers, but it is more accurate to see groundwater as being "in transit," continuously migrating slowly through aquifers. This slowly migrating water can be accessed using wells drilled to intersect the fractures containing slowly moving groundwater, or using wells with screens positioned in sand and gravel containing groundwater moving slowly towards streams. The travel period between when precipitation first enters an aquifer to when it exits in a stream or riparian wetland may be measured in weeks to months, and sometimes even years. It is important to recognize that groundwater is not permanently stored – rather it is simply delayed drainage available to support a host of uses. These uses include human uses where wells are drilled into aquifers, and a host of natural uses including vegetative use by plants with deep root systems, shallow vegetative uses by wetland vegetation, and aquatic uses where groundwater exits aquifers to move into our streams. Groundwater resource management includes allocation decisions among competing uses for this water.

AQUIFERS AND GROUNDWATER QUANTITY

Although groundwater is sometimes locally scarce due to low-yield geologic formations or overpumping, there appears to be sufficient groundwater in Dutchess County, limited only by withdrawal techniques and distribution system limitations. Compared with many parts of the United States and indeed the world, our precipitation rates and average recharge rates are generous and offer us development and quality-of-life advantages unavailable to many communities. More than half of the county's population relies on community wells or individual wells. Wells also serve as back-up or auxiliary supplies for another significant percentage of county residents.

Aquifers most capable of supporting high yielding wells generally consist of sand and gravel. These deposits lie along some of the county's major stream and river valleys, a result of glaciers leaving behind deposits after the latest glacial period. In some places these glacial outwash deposits overlie limestone or marble (carbonates) bedrock formations. Some bedrock formations in Dutchess County consist of carbonates (limestone, marble or dolomite); these formations tend to be more fractured than other bedrock formations, so they can support high-capacity wells capable of withdrawing hundreds of gallons per minute. Map 5.2 shows areas in Dutchess County where carbonate bedrock aquifers are covered by glacial outwash sediments which include sand and gravel areas. These areas offer some of the most promising lands for installing high-yield test wells, found in the Harlem Valley along the Tenmile and Swamp Rivers, along the Wappinger Creek, and along the Fishkill Creek. Extensive sand and gravel deposits not necessarily overlying limestone formation also exist along the Sprout Creek in East Fishkill and LaGrange, the east branch of the Wappinger Creek in Washington, and the Saw Kill Creek in Red Hook. (For more information on surficial and bedrock geology in Dutchess County, see NRI Chapter 3: Geology and Topography.)

Well yields will tend to be highest in areas where the sediment or fractured rock geologic formations have high hydraulic conductivity tendencies and where these areas lie low in their respective watersheds so groundwater flows toward them from large upwatershed area. The water-bearing characteristics of unconsolidated deposits vary widely because of differences in porosity and hydraulic conductivity (also often referred to as permeability). **Hydraulic conductivity** is a measure of the ability of a material to transmit water. In unconsolidated deposits, **permeability** depends on the size of the pores between the particles of sand, gravel, silt, or clay. In bedrock, permeability depends on the degree of fracturing and how well the rock fractures, crevices, and cavities interconnect. The higher the permeability of a material, the greater the potential immediate yield, again, providing there is adequate recharge to replenish the withdrawal. Porosity influences the volume of water that will be present below the watertable in a particular geologic formation. Where there is more porosity, more water can be present in transit within the aquifer as groundwater is moving toward streams and wetlands.

Sand and gravel are especially valuable aquifer materials because they are highly porous and permeable. The pores in sand and gravel deposits are large enough to hold considerable volumes of water, while allowing water to flow easily toward wells, springs, and other discharge points. Known yields from sand and gravel aquifers in Dutchess County range from 2 to 1,400 gallons per minute (gpm). Clay, on the other hand, is extremely impermeable, so few wells other than some early hand-dug wells are completed in clay deposits. Detailed analysis of wells installed in Putnam County indicates that in general, wells are being drilled deeper each decade as drilling techniques become less costly and as higher levels of yield reliability are required by regulators. There is no evidence that aquifers are being depleted or becoming plugged. A network of wells monitored by Dutchess County from 2002 to 2009 has consistently shown water levels less than 20 feet below ground level.

As described in NRI Chapter 3: Geology and Topography, much of Dutchess County's bedrock is composed of shales and slates. These all have low porosity and low permeability. The bedding planes and fractures in these rocks allow slow movement of groundwater. Studies by the United States Geological Survey show that yields from drilled wells in these average 16 gpm, with hilltop wells yielding 14 gpm and valley wells yielding 17 gpm.

The more mountainous parts of Dutchess County are underlain by crystalline types of bedrock such as Hudson Highlands Gneiss and Poughquag Quartzite, where there are fewer openings for water infiltration. Well yields are relatively low, averaging 11 gpm for the gneiss and 10 gpm for the quartzite. Unproductive wells have been drilled in all these formations, the result of drilling that has the misfortune to miss any water-bearing fractures. The natural quality of groundwater withdrawn from Dutchess County's geologic formations reflects the mineral composition of each formation as a result of the contact time between the natural water with the geologic materials.

Dutchess County's aquifer monitoring program and the simple overall water budget calculation indicate that no broad reductions in aquifer water capacity or watertable levels are occurring. However, stream flow analyses conducted by the former Dutchess County Environmental Management Council, The Chazen Companies, and Horsley Witten have nonetheless identified some areas where stream flows have been or can be modified by groundwater withdrawals. Such stream flow reductions are likely related to groundwater withdrawals without adequate off-setting return flows. Specific examples of likely direct influences of water use on stream flows include:

- Heavy pumping of wells used by the Millerton community can affect flow of the nearby Webatuck Creek.
- Flow of the Sprout Creek may be reduced as it flows through the Town of Wappinger as a result of well withdrawals.
- A segment of the Wappinger Creek north of the hamlet of Pleasant Valley has been documented to lose flow (less water in the stream) due to unexplored factors.
- Under low flow conditions, daily flow fluctuations symptomatic of well withdrawals are documented by flow variations recorded by the USGS stream gauging site at Red Oaks Mill on the Wappinger Creek.

Groundwater Quality

Groundwater quality can be impacted by a wide range of contaminant sources. Most contaminant point sources are well known and carefully managed (such as industrial contaminant spills, gas stations, dry cleaners, and injection wells). Others are diffuse and wide-spread (such as road salt, fertilizers and pesticides, and septic systems). Some are "emerging," meaning that insufficient research has been completed to know either the prevalence of the impact or the significance of the impact to human or ecosystem health (such as pharmaceutical and personal care chemical releases from wastewater plants, septic systems, and stormwater recharge features).

Results from the 250 well water samples collected from active domestic wells in Dutchess County during 2008 and 2009 are presented separated into wells minimally impacted by residential presence (Table 5.5) versus the complete data set including all wells (Table 5.6). Only well samples minimally impacted by nitrate, sodium and chloride were included in Table 5.5, as these conditions best reflect what would be expected in areas of low impact land uses. The following outlines the water quality data of the wells of this subsample, according to Dutchess County's three major geological formational categories. (For the complete water quality testing results, see the Appendix to this chapter.)

Table 5.5: Data from Dutchess County wells "minimally impacted by residential presence" sampled in 2008 and 2009.

			Sample Parameters [2]								
			Alkalinity	Chloride	Hardness	Iron	Lead	Nitrate	pH	Sodium	Sulfate
Major Geologic Formations	# of wells	MCL[3]	[4]	250.00	[4]	0.30	0.02	10.00	6.5-8.5	[4]	250.00
		Percentile [5]									
Carbonates: Wappinger Group (Dolomitic Limestones), Stockbridge Marble	n=36	Min	52.0	0.0	15.10	0.000	0.000	0.00	6.50	1.14	9.00
		10	111.0	0.0	116.50	0.000	0.000	0.00	6.90	2.14	10.50
		25	170.8	2.0	187.00	0.006	0.000	0.00	7.00	3.115	13.75
		Median	**208.5**	**6.0**	**211.00**	**0.017**	**0.000**	**0.25**	**7.30**	**9.285**	**18.50**
		75	264.8	42.5	288.75	0.136	0.000	0.99	7.63	21.975	27.25
		90	323.5	58.5	347.50	0.877	0.003	1.715	7.85	31.15	38.50
		Max	368.0	93.0	418.00	2.610	0.009	1.89	9.40	43.0	56.00
Crystalline: (Precambrian Gneiss)	n=9	Min	0.0	0.000	0.000	0.000	0.000	0.00	5.20	0.000	0.00
		10	9.6	2.4	19.76	0.000	0.000	0.00	5.97	1.992	8.80
		25	25.0	5.0	40.50	0.000	0.000	0.00	6.68	4.05	11.00
		Median	**56.0**	**11.0**	**72.20**	**0.000**	**0.000**	**0.27**	**7.05**	**6.23**	**15.00**
		75	69.0	25.0	94.20	0.005	0.005	1.10	7.43	12.0	17.00
		90	76.6	41.6	110.00	0.033	0.033	1.504	7.53	14.96	18.20
		Max	79.0	56.0	126.00	0.060	0.060	1.92	7.60	18.8	23.00
Shales, Slates, and Metasediments [6]	n=96	Min	32.0	0.0	0.00	0.000	0.000	0.00	5.90	1.92	3.00
		10	58.0	1.0	73.30	0.000	0.000	0.00	6.70	3.41	13.00
		25	98.5	5.75	110.75	0.000	0.000	0.00	7.00	6.195	16.00
		Median	**151.5**	**18.5**	**180.50**	**0.000**	**0.000**	**0.00**	**7.40**	**13.25**	**24.50**
		75	196.3	46.25	230.50	0.001	0.001	0.40	7.60	22.4	31.25
		90	230.5	82.5	268.00	0.002	0.002	1.27	7.85	35.1	41.50
		Max	308.0	98.0	392.00	0.198	0.198	1.82	9.40	47.5	72.00

(1) To assess groundwater quality most reflective of geologic regions and least affected by septic systems, softeners or road de-icing, only samples that met all of the following conditions were included in this table: nitrate concentrations below 2 mg/L, chloride concentrations below 100 mg/L, and sodium concentrations below 50 mg/L. 141 of 250 available domestic water samples met all of these conditions. Nitrate, chloride and sodium data were then excluded from the table since they are not naturally occurring compounds in Dutchess County.

(2) In addition to the parameters shown above, all samples were analyzed for Antimony, Beryllium, Cadmium, Cyanide, Mercury, Selenium & Thallium, but nearly all samples results were at concentrations below laboratory minimum detection limits and are therefore not listed on this table for purposes of clarity.
(3) MCL = Maximum contaminated limit per NYSDOH Subpart 5-1 tables where applicable.
(4) Alkalinity, Hardness, and Sodium do not have an MCL, but are typically considered elevated at concentrations exceeding 200 mg/l, 200 mg/l and 20 mg/l respectively.
(5) Percentage values express the frequency that a constituent was encountered at a specific concentration. For example, if the 75th percentile value was 110 mg/l, this means that 75% of samples contained less than or equal to 110 mg/l and 25% contained more than 110 mg/l.
(6) Included in the Shales, Slates and Metasediments are: Elizaville Formation (slate), Germantown formation (shale), Mt. Merino Formation (shale), Nassau Formation (shale), Normanskill Shale, Stuyvesant Falls Formation (shale), Walloomsac Formation (shale) and the Everett Schist (schist).
Note: Values of 0.0000 in the data table are used to represent the minimum laboratory detection limit for each parameter.

Data source: Dutchess County Department of Health website; http://www.co.dutchess.ny.us/CountyGov/Departments/Health/14361.htm

In areas with limestone, dolostone or marble bedrock (primarily in the valleys of the Fishkill Creek watershed, Tenmile/Webutuck/Swamp watershed, and the Wappinger Creek watershed), groundwater is moderately alkaline and hard. Iron may exceed the standard of 0.3 mg/L in more than 25 percent of samples. All sampled parameters are reasonable, low, and pH is slightly basic.

In areas with crystalline bedrock (primarily in southern portions of East Fishkill and Union Vale, and western portions of Pawling), groundwater is generally soft. Approximately 10 percent of samples may contain lead in concentrations exceeding the drinking water standard of 0.02 mg/L, approximately 25 percent of samples contain sodium in concentrations exceeding the lowest guidance value of 20 mg/L, and sulfate values are lower than levels identified in the limestone and shale terrains. All other sampled parameters are reasonable, low, and pH is neutral.

In areas where wells are installed in shale, slate and schist (most hillsides and uplands of Dutchess County, except crystalline uplands identified previously), groundwater is moderately hard. Iron and manganese may exceed the drinking water standard in approximately 10 percent of water samples, and chloride concentrations exceed the drinking water standard in more than 10 percent of samples. All other sampled parameters are reasonable, low, and pH is slightly basic.

Table 5.6 summarizes all 250 samples, including many samples collected within residential areas with moderately compact parcel sizes and all using septic systems. Some modifications in water quality were noted and are likely to be typical of the variability of water quality in both rural and suburban non-sewered areas.

In general, point sources of pollution are adequately managed and spills, although unfortunate, are managed in prescribed ways. Contaminant plumes occur and their locations are generally known and remediation efforts are usually under way. Legal mechanisms require reporting and correction for new spills.

Non-point source contaminant sources pose a new challenge to communities and regulators. Where wells and septic systems are in use, well water quality can suffer if not buffered by adequate recharge. The recharge rates presented in Figure 5.3 have been used to recommend minimum average parcel sizes for homes using individual wells and septic systems. Analysis of the 250 domestic well water samples discussed above suggest that nitrate concentrations detected in groundwater wells show a greater incidence of higher levels when near clusters of septic systems.

Table 5.6: Data from all Dutchess County wells sampled in 2008 and 2009.

Major Geologic Formations	# of wells	MCL (2) / Percentile (4)	Alkalinity	Chloride	Hardness	Iron	Lead	Nitrate	pH	Sodium	Sulfate
			Sample Parameters (1)								
		MCL (2)	(3)	250.00	(3)	0.30	0.02	10.00	6.5-8.5	(3)	250.00
Carbonates: Wappinger Group (Dolomitic Limestones), Stockbridge Marble	n=66	Min	34.0	0.00	5.56	0.000	0.000	0.000	6.50	1.14	5.00
		10	121.6	0.80	109.80	0.000	0.000	0.000	6.90	2.94	12.00
		25	183.0	5.00	190.00	0.000	0.000	0.000	7.00	6.48	16.00
		Median	**238.0**	**40.00**	**256.00**	**0.014**	**0.000**	**0.960**	**7.20**	**21.00**	**21.00**
		75	314.0	110.00	326.00	0.056	0.001	2.470	7.60	61.00	33.00
		90	376.6	186.00	417.60	0.537	0.004	3.822	7.77	125.20	45.00
		Max	453.0	250.00	521.00	2.610	0.042	9.860	9.40	347.00	61.00
Crystalline: (Precambrian Gneiss)	n=34	Min	0.0	0.00	0.00	0.000	0.000	0.000	5.20	0.00	0.00
		10	59.2	1.60	52.10	0.000	0.000	0.000	6.80	3.12	11.00
		25	47.0	12.25	56.68	0.005	0.000	0.285	6.80	6.80	12.75
		Median	**73.5**	**47.00**	**100.10**	**0.016**	**0.001**	**1.475**	**7.00**	**16.40**	**17.00**
		75	135.0	108.00	235.50	0.099	0.007	2.915	7.30	25.93	22.75
		90	230.4	318.00	334.40	0.221	0.036	3.446	7.54	172.80	25.10
		Max	452.0	370.00	516.00	0.392	0.140	5.210	7.70	240.00	49.00
Shales, Slates, and Metasediments (5)	n=150	Min	32.0	0.00	0.00	0.000	0.000	0.000	5.90	1.92	0.00
		10	66.8	3.00	77.80	0.000	0.000	0.000	6.60	4.55	14.00
		25	106.0	11.50	125.00	0.006	0.000	0.000	6.80	8.48	19.00
		Median	**166.0**	**55.50**	**213.50**	**0.030**	**0.000**	**0.000**	**7.30**	**25.60**	**28.00**
		75	204.0	140.00	278.75	0.149	0.001	1.193	7.60	60.25	36.00
		90	256.3	260.00	347.90	0.537	0.003	2.892	7.80	129.00	44.30
		Max	317.0	620.00	550.00	4.550	0.198	15.100	9.40	308.00	116.00

(1) In addition to the parameters shown above, all samples were analyzed for Antimony, Beryllium, Cadmium, Cyanide, Mercury, Selenium & Thallium, but nearly all samples results were at concentrations below laboratory minimum detection limits and are therefore not listed on this table for purposes of clarity.
(2) MCL = Maximum contaminated limit per NYSDOH Subpart 5-1 tables where applicable.
(3) Alkalinity, Hardness, and Sodium do not have an MCL, but are typically considered elevated at concentrations exceeding 200 mg/l, 200 mg/l and 20 mg/l respectively.

(4) Percentage values express the frequency that a constituent was encountered at a specific concentration. For example, if the 75th percentile value was 110 mg/l, this means that 75% of samples contained less than or equal to 110 mg/l and 25% contained more than 110 mg/l.
(5) Included in the Shales, Slates and Metasediments are: Elizaville Formation (slate), Germantown formation (shale), Mt. Merino Formation (shale), Nassau Formation (shale), Normanskill Shale, Stuyvesant Falls Formation (shale), Walloomsac Formation (shale) and the Everett Schist (schist).
Note: Values of 0.0000 in the data table are used to represent the minimum laboratory detection limit for each parameter.

Data source: Dutchess County Department of Health website;
http://www.co.dutchess.ny.us/CountyGov/Departments/Health/14361.htm

Sodium and chloride concentrations recorded in the 250 domestic well samples also can be higher more often; mostly likely due to the proximity of the parcels to roads. USGS analysis of sewered and unsewered watersheds in Putnam and Westchester Counties verified that there were few differences in sodium chloride concentrations in groundwater between watersheds with or without septic systems, suggesting that road salt rather than water softener discharges to septic systems are the dominant source of salt in groundwater.

Dutchess County's aquifers are vulnerable to contamination from sources other than septic systems and roads, including a host of regulated and some remaining unregulated land-use practices. Traditional sources of recognized groundwater contamination such as landfills, leaking petroleum or chemical storage tanks, both accidental and intentional illegal discharges, and heavy uses of fertilizers continue to contribute to the risk of aquifer contamination.

Other sanitary waste components such as pharmaceutical residues and personal care chemicals may also be present in groundwater near septic systems. Recommended parcel sizes, based on hydrologic soil group and aquifer recharge (see Figure 5.3), ensure a greater measure of dilution of such discharges from surrounding unimpacted groundwater but desirable contaminant dilution ratios have not been developed since no human health or aquatic health standards are available.

Many cases of groundwater pollution have appeared in recent years. The most common pollutants fall into distinct categories:

- road deicing salts (sodium chloride) particularly at bottoms of hills or ends of cul-de-sacs where salt residues can accumulate as a result of heavy application or plowing or within settlement areas where road networks are particularly dense

- organic solvents (trichloroethylene, perchloroethylene, or carbon tetrachloride) from illegal dump sites, industrial sites, and sometimes from household products
- fertilizers
- petroleum products (gasoline and heating fuel) from spills, leaking tanks, and pavement runoff
- septic system discharges

Drinking Water

The 1980 census indicates that 60 percent of the county's total population of 245,055 is served by community surface or groundwater systems; the remaining 40 percent relies on private domestic wells.

The Hudson River is by far the county's largest supplier of drinking water, providing more than 11.7 million gallons per day (mgd) to approximately 70,000 residents in the city and town of Poughkeepsie, Hyde Park, Hopewell Junction (Maybrook water line), and the Village of Rhinebeck. New York City has also established a Hudson River tap and pumping station at Chelsea, in the Town of Wappinger as a precaution against water shortages in its upstate system.

The **salt front** of the Hudson River (defined as concentrations of chloride greater than 100 mg/L) shifts regularly and predictably along the southwestern border of the county. It moves with the balance between the downstream inflow of freshwater and the upstream forces of the ocean tides. Under average flow conditions the salt front is typically well south of Beacon. However, in drought years the salt front can move close to the Poughkeepsie water intake, particularly at low tide. Water containing about 100 mg/L of chloride requires notification to those using it for drinking water, and under those conditions precautions need to be taken to limit the amount of Hudson River water consumed by individuals on sodium restricted diets.

In addition to the Hudson, many public well fields tap aquifers adjacent to the county's major interior waterways, providing 10.4 mgd to county residents. At present, no public water supplies are drawn directly from these larger streams and rivers, but the close proximity between the wells and streams does provide for an interaction. Several smaller streams or reservoirs, however, do provide water for community systems in Beacon, Hyde Park, and the Village of Pawling as well as for large institutions in Dover, Beekman, and Red Hook.

FLOODPLAINS

Floodplains are low-lying areas, normally adjacent to streams, which are inundated in times of heavy rains or severe snow melts. They act as shock absorbers in a drainage system by providing space for the storage and absorption of excess runoff. Left undisturbed, floodplains can also serve as recharge areas for groundwater supplies due to the heterogeneous texture of their alluvial soils.

Floodplains that have a one percent annual chance of being inundated are commonly referred to as 100-year floodplains. In a similar manner, land areas that have a 0.2 percent annual chance of being flooded are 500 year floodplains. Another way of stating this concept is that floods of these magnitudes would have a return interval averaging 100 years and 500 years respectively. Such floodplains line the rivers and streams of Dutchess County (Map 5.3). Detailed maps (in draft form) of the 100-year floodplains in all of the municipalities of Dutchess County have been developed by the Federal Emergency Management Agency (FEMA) in support of the National Flood Insurance Program. These maps are used to determine low-cost federal flood insurance rates and to develop local land use controls that comply with FEMA's requirements. Two copies of the newer maps have been sent to each municipality in the county. The maps and a draft of the Flood Insurance Study for Dutchess County can also be viewed at http://www.rampp-team.com/ny.htm.

In reviewing floodplain maps, it is important to note that the locations of floodplain boundaries are not static. Floodplain boundaries are altered as a result of changes in land use, the amount of impervious surface, placement of obstructing structures in floodways, changes in precipitation and runoff patterns, improvements in technology for measuring topographic features, and utilization of different hydrologic modeling techniques.

Table 5.7: 100-year floodplain acreages for Dutchess County municipalities

Municipality	Approx. Floodplain Acreage	Percentage of Municipality
CITIES		
Beacon	463	14.5
Poughkeepsie	147	4.4
TOWNS		
Amenia	981	3.5
Beekman	944	4.8
Clinton	1,227	4.9
Dover	2,549	7.1
East Fishkill	5,436	14.8
Fishkill	1,862	10.9
Hyde Park	1,440	6.1
LaGrange	4,779	19.2
Milan	345	1.5
North East	1,102	4.0
Pawling	2,086	7.6
Pine Plains	955	4.8
Pleasant Valley	3,930	18.5
Poughkeepsie	2,260	12.1
Red Hook	1,051	4.8
Rhinebeck	760	3.4
Stanford	977	3.0
Union Vale	492	2.1
Wappinger	3,563	21.0
Washington	393	1.1
VILLAGES		
Fishkill	96	18.1
Millbrook	121	10.3
Millerton	121	10.3
Pawling	224	17.4
Red Hook	Not available	Not available
Rhinebeck	70	7.3
Tivoli	44	4.5
Wappingers Falls	110	14.1
COUNTY TOTAL	38,444	7.5

From Dutchess County Department of Planning, 1985

Flood-prone areas are currently referred to by FEMA as Special Flood Hazard Areas that encompass by definition lands that occur within the 100 year floodplain. Table 5.7 indicates that 7.5 percent (38,444 acres) of Dutchess County is flood-prone. The floodplain acreages listed in the table, which are based on 1985 data from the Dutchess County Department of Planning, range from a low of 1.1 percent in the Town of Washington to a high of approximately 21 percent in the Town of Wappinger. The extent to which these numbers might change will remain unknown until such time as the newer draft maps are accepted as final.

As previously discussed, a floodplain's ability to carry flood flows safely depends both on the types of development within the floodplain and on the land use characteristics of the surrounding watershed. The amount of runoff within a watershed increases with the amount of developed area because development generally brings an increase in the percentage of impervious surface area. Precipitation on or snowmelt from these impervious surfaces is rapidly directed into nearby channels, thereby increasing the volume of water the channel is expected to carry. All of the runoff from a given watershed eventually funnels through a series of channels to the major stream or river at the watershed mouth. The floodplains along these channels become inundated more frequently and with greater volumes of water as upstream development intensifies.

As described in NRI Chapter 2: Climate and Air Quality, several significant floods have occurred in Dutchess County. Flooding frequently occurs in the early spring when melting snow cannot be absorbed by the still-frozen or saturated ground. Serious floods also occur as a result of hurricanes or coastal storms such as those that occurred in 1938, 1955, and 2007.

Floodplain soils in the county consist of sand and silt mixtures with some gravel. The floodplains are usually fertile and flat, and are often deceptively attractive development sites. The floodplains most susceptible to serious flood damage are along the lower Wappinger and Fishkill Creeks where development has already occurred. In the Harlem Valley, extensive flooding has occurred along the Webatuck Creek, the Swamp River, and the Tenmile River.

WETLANDS

Wetlands are found where the watertable is at or near the surface of the land for a significant portion of the year. Plant communities are dominated by species either tolerant of or actually requiring wet soils. In NYS, the legal demarcation of wetlands is based on vegetation but other states may use soil indicators or evidence of prior flooding. Different kinds of wetlands can exist depending upon location, topography, geology, and hydrology.

Freshwater wetlands cover 6.4 percent of Dutchess County, or approximately 33,000 acres (Map 5.4). Many of the wetlands in the county are small and scattered about the county without any discernible pattern. There are concentrations, however, along many of the major waterways, including the Swamp River in the Towns of Pawling and Dover, the Tenmile River in Amenia and North East, and the Fishkill Creek in East Fishkill. The Great Swamp, which extends along the Tenmile and Swamp Rivers from Dover well into Putnam County, is one of the largest and most diverse wetlands in the state. Several large tidal wetlands border the Hudson River.

Historically, wetlands have been regarded as waste lands, useful only if they could be filled or drained for development or agricultural purposes. Because of this attitude, at least half of the wetlands in the lower 48 United States have been destroyed since colonial time (Mitsch & Gosselink, 1993). Wetlands are now recognized for the many benefits they provide, including storage of floodwaters, removal of many pollutants, and breeding areas for amphibians and many other animals and plants.

Wetlands are unique resources at the interface between water and land. Hydrogeologic studies have shown that wetlands are often important regulators and purifiers of surface water and groundwater supplies. Flooded wetlands can, in turn, recharge groundwater supplies or surface waters. Water stored in wetlands helps maintain continuous stream flows during droughts.

In addition to these valuable water management functions, wetlands provide food, cover, and breeding grounds for waterfowl and other wildlife. They support unusual plant life and diverse ecological communities, and provide recreational, educational, and aesthetic benefits.

(For more information on wetland habitats, see NRI Chapter 6: Biological Resources and Biodiversity.)

As development pressures increase, corresponding pressures to fill, drain, or build in wetlands also increase. Wetlands are not suitable locations for landfills, basements, septic systems, or other structures and uses that function poorly in wet soils or destroy natural wetland functions.

Concern about the destruction of wetland resources led to the passage of the New York State Freshwater Wetlands Act in 1975. This act requires permits for all non-agricultural activities that could change the quality of wetlands 12.4 acres or larger and smaller wetlands of unusual local importance. It also requires the State Department of Environmental Conservation to inventory and evaluate the wetlands of the state. The act applies to 4.4 percent of Dutchess County and approximately 70 percent of the county's total wetland acreage.

TRENDS AND CHANGES OVER TIME

Global Climate Change Effects on the Watershed

Global warming will impact the county in coming years. Greenhouse gases are trapping energy in our atmosphere that would normally be lost to space and causing global temperatures to rise. This warming is a natural phenomenon that provides enough heat to allow humans to thrive on earth, but the burning of fossil fuels and the atmospheric concentration of other gases, such as methane, have dramatically increased the rate of warming (Figure 5.3). Based on local data collected between 1952 and 2005, researchers have concluded that a broad general pattern of warming air temperatures, increased precipitation, increased stream runoff, and increased potential evapotranspiration has occurred in the Catskills region (Burns et al., 2007). In coming years, there is no doubt that the effects of global warming will impact management decisions in the Dutchess County.

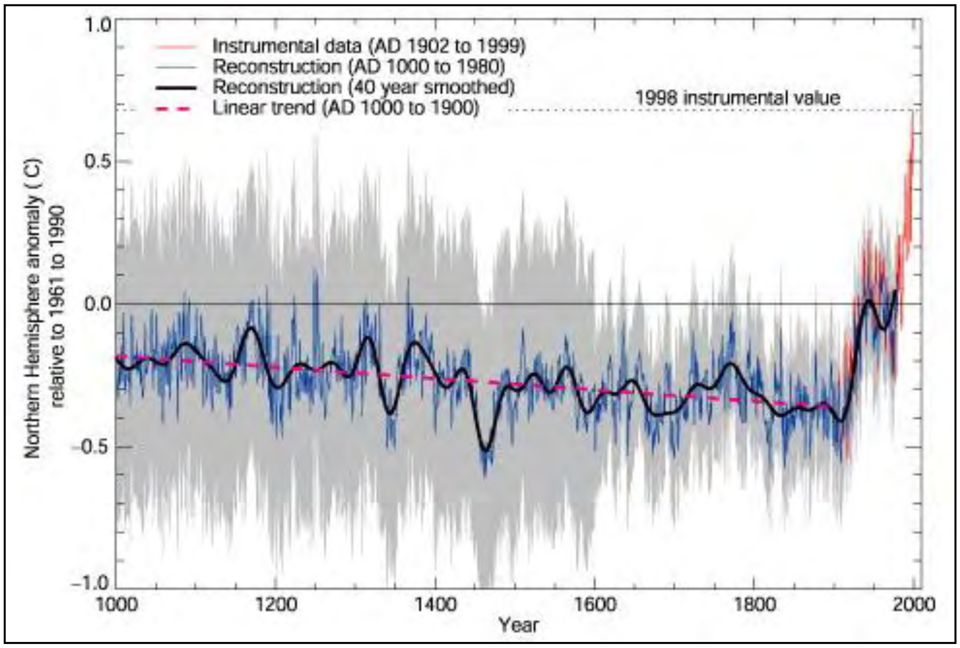
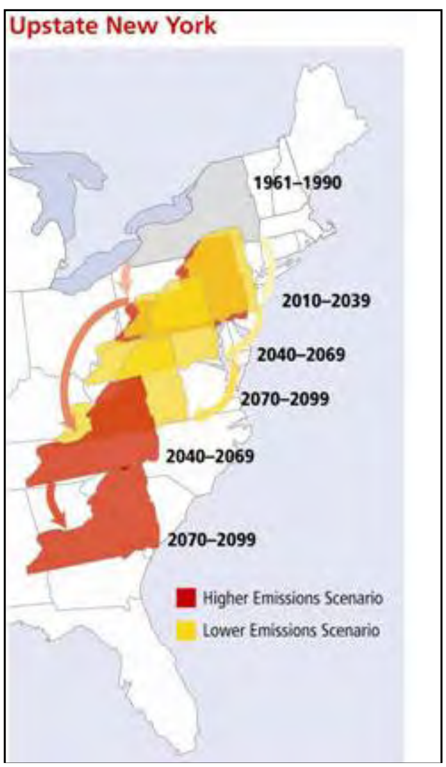


Figure 5.3: Millennial northern hemisphere temperature reconstruction, based on ice core data, relative to actual temperatures recorded from 1902 through 1999. Despite large variation, the recent trend of rapid heating in the industrial era is apparent (National Climatic Data Center adapted from Mann et al., 1999).



Temperature increases will have effects on food production, plants, wildlife, invasive species, flooding, drought, snowfall, and the economy. Based upon current climatic trends, our climate may migrate to the extent that by the end of the century, summers in upstate New York may feel like Virginia (Figure 5.4) (Frumhoff et al., 2006). This climatic migration will have deleterious effects on plant and animal life, allowing new warmer climate species to thrive at the expense of our traditional plants and animals. The number of snow-covered days across the Northeast has already decreased, as less precipitation falls as snow and more as rain, and as warmer temperatures melt the snow more quickly. By the end of the century, the southern and western parts of the Northeast

Figure 5.4: Projected climate "migrations" for Upstate, NY based on average summer heat index, under the lower- (yellow) and higher-emissions (rust) scenarios. Based on the average of the GFDL, HadCM3 and PCM model projections (Frumhoff et al., 2006).

could experience as few as 5 to 10 snow-covered days in winter, compared with 10 to 45 days historically (Frumhoff et al., 2006). Decreased snowfall and increased rainfall would have negative effects on stream flows and the economy of the county.

With the lack of snowfall, streams and groundwater will not receive a slow sustaining release of water through the winter and spring. Instead, there will be more intense storms that will sporadically dump large quantities of water into the system potentially causing damaging flooding (Figure 5.5). However, streams will return to base flow relatively quickly once the rain stops. Modeling predictions indicate that in the next century we will see more extreme stream flows that will cause streams to flow higher in winter, likely increasing flood risk, and lower in summer, exacerbating drought (Frumhoff et al., 2006).

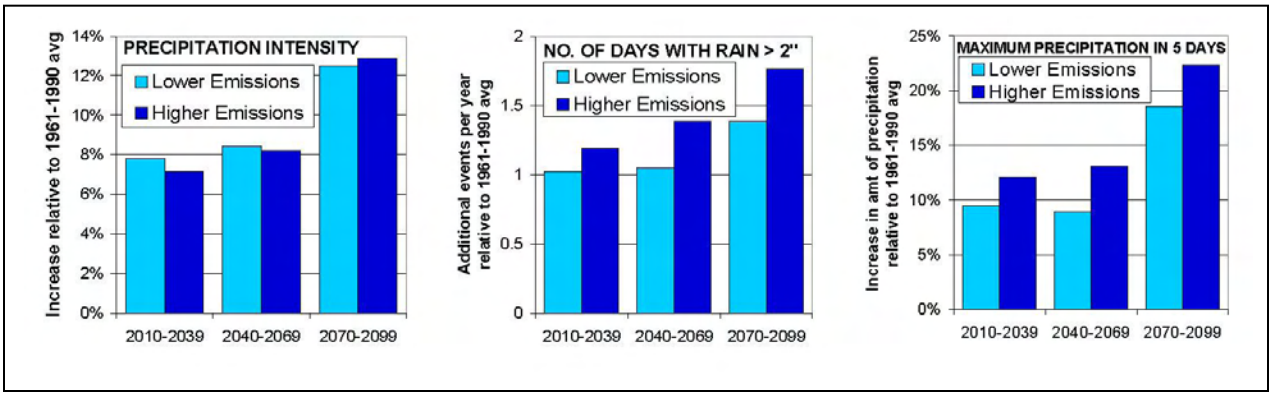


Figure 5.5: Projected increases in three indices of extreme precipitation: (1) precipitation intensity, (2) number of days per year with more than two inches of rain, and (3) maximum amount of precipitation to fall during a five day period each year (Frumhoff et al., 2006).

Since we do not have a clear understanding of all of the potential impacts of climate change, resource managers need to employ the "**no-regrets policy**" with regard to their current management actions and policies. The no-regrets policy is the recognition that lack of certainty regarding a threat or risk should not be used as an excuse for not taking action to avert that threat. Delaying action until there is compelling evidence of harm will often mean that it is then too costly or impossible to avert the threat. Stream managers – including streamside landowners – will need a basic understanding of how streams are formed and evolve to effectively adapt to coming changes. They will need to compare the potential consequences of different management options and act conservatively: oversizing culverts and bridge spans, leaving larger buffers of undisturbed streamside vegetation, and considering limiting new development of infrastructure or personal property in areas where conditions indicate a high risk of the stream channel shifting across the floodplain. The humid continental climate has been an unquestionable asset to the historical development of Dutchess County and its many occupants and uses. With proper planning and implementation of the no-regrets policy, undoubtedly, the climate will continue its important role in Dutchess County life.

Through a better understanding of stream process and proper planning we can better protect the residents, infrastructure and wildlife of Dutchess County from flooding and drought. To this end, it is critical the County maintain the agency support necessary to coordinate the vast array of resources available through local colleges, universities, government agencies and nonprofits, and focus efforts on planning for the future of the County's water resources.

IMPLICATIONS FOR DECISION-MAKING

Dutchess County's surface water and groundwater supplies support a large human population and sustain a diverse natural resource base. The abundance of water in the county has made it easy to take these resources for granted, and to treat land and water use as if they were unrelated. In recent years, however, the interdependence of land use, water quality, and water quantity has become obvious as reports of water shortages, groundwater contamination, and drainage problems have multiplied. It is now clear that allowing water supplies to be damaged by overuse and pollution can threaten the county's environmental, social, and economic well-being. Well-integrated land and water management plans are needed to restore water supplies that are showing signs of misuse, and to prevent further damage from occurring.

Watershed landowners have direct influence over land uses in the watershed and directly benefit by assisting in the protection and restoration of their water resources. There are also local benefits to be derived from implementation of watershed protections measures. For example, protecting and enhancing the fishery could also benefit the economy and aesthetic values of the region. Proper watershed management can also assist in protecting infrastructure, reducing flood damages, and developing a stream stewardship ethic. Wherever you live in the watershed, what you do at your home and its surroundings can have a direct impact on your neighbor's water resources.

Future development in the stream corridor, with a resulting increase in impervious surface, may increase runoff and impair water quality. Therefore, management efforts should be focused on preventing further human-induced degradation through implementation of best management practices designed to reduce or minimize impacts. These efforts should be both direct measures such as remediating failing septic systems and upgrading sewer treatment plants (point sources of pollution), and indirect measures, such as reducing stormwater inputs, properly installing new infrastructure, and planting riparian buffers. In areas where existing infrastructure is acting to destabilize the stream or is threatened by erosion, stabilization techniques incorporating natural channel design should be employed. Reforesting the banks of Dutchess County streams, coupled with the protection of cold groundwater seeps, may help to lower summer water temperatures and enhance the fishery.

Groundwater

A range of water resource capacity planning tools can help protect groundwater resources.

- Pumping tests for new higher-capacity wells must evaluate potential impacts to streams and wetlands. Minimum flow needs of groundwater to streams and riparian wetlands should be understood and preserved by controlled pumping rates or by strategic return of treated wastewater flows.

- Stream gauging has been completed at municipal boundaries in the Harlem Valley to identify approximate stream flow growth from the aquifers in each individual town. Such gauging is needed in the Fishkill Creek and Wappinger Creek watersheds. Once available, relative shares of water contributing to stream flow by each municipality can be assigned to manage allocation for future development projects and collectively assure preserved water quantity.

- Pumping tests for new higher-capacity wells should be conducted at higher flow rates if conducted during wet periods. For example, if a test is conducted during a period with 10 percent more precipitation than normal, a 10 percent flow premium should be applied to the test as a measure to identify likely affects or reliability of the proposed well during drier periods.

- In general, higher capacity wells will be more successful if installed lower in a watershed where the well can benefit from groundwater flowing toward the well from a larger upper portion of a watershed.

- All reasonable measures should be taken to enhance recharge on sites. Stormwater measures should prioritize groundwater recharge to maximize groundwater replenishment, although no enhanced recharge should be authorized without proper pre-treatment.

- Efforts should be made to limit coverage of higher-permeability soils (Hydrologic Soil Group A B, and C where possible) and limit connections and hard stormwater conveyances between necessary impervious surfaces. Careful design considerations are needed especially where sites exceed 30 percent of connected impervious surfaces, which is the approximate limit at which groundwater recharge losses begin to reduce stream flows during dry periods.

- Disconnecting impervious surfaces and the provision of infiltration devices (with proper pre-treatment) can be mitigating strategies in such areas. Limiting areas with highly impervious surfaces is consistent with land use policy recommendations restricting the size of hamlet and town center areas to walkable distances.

Efforts should generally be made to minimize interbasin transfers, returning treated wastewater to the same aquifer system or local watershed system from which water was withdrawn. (An exception to the general guidance against interbasin transfers relates to transfers of Hudson River water into the interior of Dutchess County. It appears that relatively massive volumes of water can be transported inland from the Hudson River for a multiple of uses with little to no significant impact to the salt front.)

Climate change predictions suggest that the northeastern seaboard of the United States, including the Hudson Valley, will receive more precipitation in the future. Depending on how it is delivered, groundwater resources may remain robust water resources into the plannable future. Current aquifer status recording stations across Dutchess County show that aquifers today remain in flush condition during all but periodic drought spates.

Drought management planning remains a critical obligation for communities reliant on groundwater supplies. Our aquifers, although robust and reliably recharged, can temporarily lose capacity during extended rainless periods. When this occurs, measures to limit consumption are advised and interconnections or water delivery arrangements are warranted.

A range of water resource groundwater quality planning tools is recommended:

- Where uses of individual wells and septic systems are expected into the foreseeable future, zoning should be adapted to ensure that average parcel sizes do not fall below those recommended, at least for soils in hydrogeologic soil group B, and preferably for hydrologic soils group C. This will help ensure availability of potable water along with the sustainable use of time-proven septic system designs.

- Adopt water protection ordinances to provide water resource quality protections where there are gaps in State or Federal regulations. Dutchess County has funded drafting of a model aquifer protection ordinance (available at the Dutchess County Planning and Development website).

- Lay out cluster subdivisions so that undersized parcels do not inadvertently position wells and septic systems closer than those recommended above. Cluster subdivision platting layout advice is included in the model ordinance noted in the previous entry.

- Fund research and outreach on waste management programs to reduce environmental discharges of pharmaceuticals, caffeine, and personal chemical residues.

- Continue periodic regional well sampling initiatives focused on traditional and perhaps emerging contaminants of concern. Funding can be engaged efficiently by focusing on specific compounds of concern rather than sampling entire lists of constituents seldom found in groundwater samples.

De-icing activities should be refined to minimize application rates, using methods that result in minimum undissolved salt residues. Drainage improvements or snow aprons may be necessary at ends of cul-de-sacs or near the bottom of heavily salted hills. Unless proper treatment for de-icing compounds can be provided, road runoff should never be directly infiltrated into groundwater using drywells or other injection devices. This has been a standard NYS stormwater position for some time but some design firms overlook it in the interest of other water management priorities. Ongoing sampling should evaluate efficacy of such programs.

Wetlands

Municipalities have the authority under State Law to enact local wetland protection so long as these laws are at least as protective as the State Law. Several local towns (East Fishkill, Clinton, and Pawling) have passed such regulations usually with a lower size limit of an acre or less. One of the major decisions in choosing a local wetlands law to protect smaller wetlands is deciding the lower size limit that would be covered by the Law. Figure 5.6 is a size frequency diagram showing the number of small wetlands (<12 acres) falling in several size classes and the total area made up by each size class. For example, if a municipality chooses to exclude wetlands smaller than 0.5 acres from a local law they will be excluding about 7,000 individual wetlands with a total area of 1,221 acres from protection. If a municipality chose a 3 acre minimum size they would exclude 5,773 acres out of a total of 12,084 (48 percent). The size patterns probably differ from one part of the county to another but this figure provides some guidance of what wetlands would fall under protection given a certain choice of minimum size.

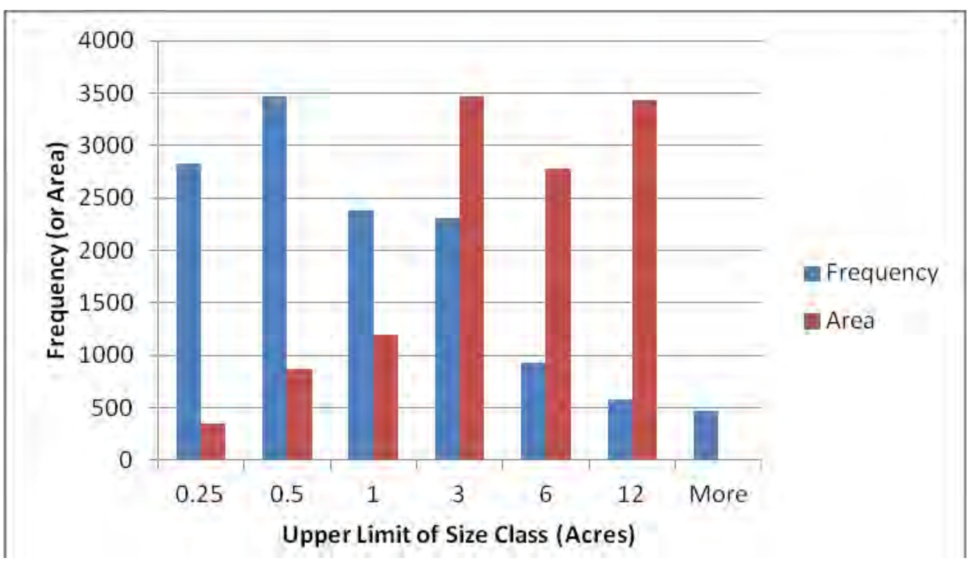


Figure 5.6: Size frequency (or area) distribution of wetlands in Dutchess County derived from the National Wetland Inventory. Blue bars show the number of wetlands occurring in each size class. Red bars show the total area of wetlands in each size class. Wetlands greater than 12 acres were not included since they fall under DEC jurisdiction.

RESOURCES FOR ADDITIONAL INFORMATION

- **Dutchess Watersheds website:** www.dutchesswatersheds.org
- **Dutchess County Watershed Management Plans:** http://www.dutchesswatersheds.org/watershed-organizations
  - Casperkill Assessment Document: http://www.townofpoughkeepsie.com/planning/stormwater/2009/Health_of_the_Casperkill.pdf
  - Fall Kill Watershed Management Plan: http://www.dutchesswatersheds.org/images/dwp/fallkill/fallkill_management_plan.pdf
  - Fishkill Creek Management Plan: http://www.dutchesswatersheds.org/images/dwp/fishkill/fishkillcreekmgtplan.pdf
  - Hudson River Estuary Program Action Agenda: http://www.dec.ny.gov/docs/remediation_hudson_pdf/hreaa2010draft.pdf
  - Wappinger Creek Watershed Management Plan: http://www.hudsonwatershed.org/plans09/wappinger.pdf
- **Dutchess County Planning and Development Department:** http://www.co.dutchess.ny.us/CountyGov/Departments/Planning/PLIndex.htm
- **NYS DEC Regulations, Chapter X, Part 857 for the Wappinger Creek Basin**: www.dec.ny.gov/regs/4557.html

  A complete list of the classifications for Dutchess County waterbodies and stream segments in the Wappinger Creek Basin.
- **NYS DEC Regulations, Chapter X, Part 862 for the other drainages in Dutchess entering the Hudson River:** www.dec.ny.gov/regs/4552.html#16995

  A complete list of the classifications for Dutchess County waterbodies and stream segments of the other drainages entering the Hudson River.
- **NYS DEC, Stream Classifications:** http://www.dec.ny.gov/permits/6042.html
- **NYS DEC, Chapter X, Division of Water, Part 703, Surface Water and Groundwater Quality Standards and Groundwater Effluent Limitations:** http://www.dec.ny.gov/regs/4590.html.

  The New York State DEC applies standards that correspond to these classifications when reviewing stream disturbance or pollutant discharge permit applications. This is to prevent the existing water quality from deteriorating. Some of these standards are described in numerical form whereas others are in narrative form.

- **NYS Department of Environmental Conservation (DEC) New York State Water Quality 305b Report**: http://www.dec.ny.gov/chemical/23837.html Reporting the state of New York's impaired water bodies.
- **NYS Department of Environmental Conservation (DEC) Waterbody Inventory/Priority Waterbodies List for the Lower Hudson River Basin**: www.dec.ny.gov/chemical/36740.html.
- **FEMA Preliminary Floodplain Maps and Flood Insurance Study for Dutchess County:** http://www.rampp-team.com/ny.htm.

REFERENCES

Ayer, G.R. and F.H. Pauszek. **"**Streams in Dutchess County, New York: Their Flow Characteristics and Water Quality in Relation to Water Problems." *State of New York Water Resources Commission Bulletin 63*. New York (State): Water Resources Commission, 1968.

Behar, Sharon. *Testing the Waters Chemical and Physical Vital Signs of a River.* Montpelier, VT: River Watch Network, 1997.

Booth, D.B. "Stream Channel Incision Following Drainage Basin Urbanization." *Water Resources Bulletin* 26 (1990): 407-417.

Booth, D. "Forest Cover, Impervious Surface Area, and the Mitigation of Urbanization Impacts in King County, Washington." Seattle, WA.: Center for Urban Water Resources Management, University of Washington, 2000.

Burns, David. 2006. "Assessment of In-Stream Water Quality of Hudson River Tributaries in the Rural to Urban Landscapes of Dutchess County, NY." Millbrook, NY: Dutchess County Environmental Management Council, 2006.

Burns, D.A., Klaus, J. and M.R. McHale. Recent Climate Trends and Implications for Water Resources in the Catskill Mountain Region, New York, USA. *Journal of Hydrology* 336, 1-2 (2007): 155-170.

Clark, G.M., D.K. Mueller and M.A. Mast. Nutrient Concentrations and Yields in Undeveloped Stream Basins of the United States. *Journal of the American Water Resource Association,* 36, 4 (2000): 849-860.

CWP. *Rapid Watershed Planning Handbook: A Comprehensive Guide for Managing Urbanizing Watersheds.* Ellicot City, Maryland: Center for Watershed Protection, 1998.

Deacon, J.R., S.A. Soule and T.E. Smith. "Effects of Urbanization on Stream Quality at Selected Sites in the Seacoast Region in New Hampshire, 2001-03." *United States Geological Survey Investigations Report 2005-510.* Reston, VA: USGS, 2005.

Environment Canada. "Road Salt." Priority Substances List Assessment Report. Canadian Minister of Public Works and Service, 2001

Frumhoff, P., J. McCarthy, J. Melillo, S. Moser, and D. Wuebbles. "Climate Change in the U.S. Northeast." A Report of the Northeast Climate Impacts Assessment. Cambridge, MA: Union of Concerned Scientists, 2006.

Groffman, P.M., N. L. Law, K.T. Belt, L.E. Band and G.T. Fisher. Nitrogen Fluxes and Retention in Urban Watershed Ecosystems. *Ecosystems* 7 (2004): 393-403.

Kincaid, D.W. and S.E.G. Findlay. Sources of Elevated Chloride in Local Streams: Groundwater and Soils as Potential Reservoirs. *Water Air Soil Poll.* 203 (2009): 335-342.

Levinton, J.S. and J.R. Waldman. *The Hudson River Estuary.* Cambridge, MA: Cambridge University Press., 2006.

Limburg, K.E. and R.E. Schmidt. Patterns of Fish Spawning in Hudson River Tributaries: Response to an Urban Gradient?. *Ecology* 71, 4 (1990): 1238 – 1245.

May, C.W., R.R. Horner, J. R. Karr, B.W. Mar and E.B. Welch. Effects of Urbanization on Small Streams in the Puget Sound Ecoregion. *Watershed Protection Techniques* 2, 4 (2000): 483-494.

McCasland, M., N.M. Trautmann, R. J. Wagenet and K.S. Porter. Nitrate: Health Effects in Drinking Water. Cornell University Cooperative Extension Department of Natural Resources Fact Sheet. Ithaca, NY: Cornell Cooperative Extension, 1998.

Mitsch, J.G. and J.G. Gosselink. 1993. *Wetlands*. New York: Van Nostrand Reinhold, 1993.

Mullaney, J.R., D. L. Lorenz, A.D. Arntson, A.D. Chloride in Groundwater and Surface Water in Areas Underlain by the Glacial Aquifer System, Northern United States. *U.S. Geological Survey Scientific Investigations Report 2009–508*. Reston, VA: USGS, 2009.

NYSDEC. New York State Water Quality Section 305b Report (2004). Albany, NY: New York State Department of Environmental Conservation, Bureau of Watershed Assessment and Management, Division of Water. NYSDEC, 2004.

NYSDEC a. "Some Questions and Answers on Acid Rain." New York State Department of Environmental Conservation, accessed October 8, 2004, http://www.dec.state.ny.us/website/dar/ood/acidrain.html .

Roy, A. H., M.C. Freeman, B. J. Freeman, S.J. Wenger, W.E. Ensign and J.L. Meyer. Investigating Hydrologic Alteration as a Mechanism of Fish Assemblage Shifts in Urbanizing Streams. *Journal of the North American Benthological* Society 24, (2005): 656-678.

Smith, R.A., R.B. Alexander and K. J. Lanfear. "Stream Water Quality in the Continuous United States -- Status and Trends of Selected Indicators During the 1980's." *National Water Summary 1990-91 -- Stream Water Quality, U.S. Geological Survey Water-Supply Paper 2400*. Reston, VA.: U.S. Geological Survey, 1991.

TU. "Eastern Brook Trout: Status and Threats. Trout Unlimited Report." Arlington, VA: Trout Umlimited, 2006.

USEPA. "Environmental Indicators of Water Quality in the United States." *United States EPA Report # EPA 841-R-96-002*. Washington, D.C.: United States Environmental Protection Agency Office of Water, 1996.

USEPA. "Volunteer Stream Monitoring: A Methods Manual." *EPA 841-B-97-003*. Washington, DC.: United States Environmental Protection Agency Office of Water, 1997.

USEPA. "Current National Water Quality Criteria" http://www.epa.gov/waterscience/criteria/wqcriteria.html#G2 (Accessed June 3, 2005).

Wang, L., J. Lyons, P. Kanehl and Bannerman, R. Impacts of Urbanization on Stream Habitat and Fish Across Multiple Spatial Scales. *Environmental Management* 28, 2 (2001): 255-266.

Welsch, David J., David L. Smart, James N. Boyer, Paul Minkin, Howard C. Smith, and Tamara L. McCandless. "Forested Wetlands: Functions, Benefits, and the Use of Best Management Practices." Radnor, PA: United States Department of Agriculture Forest Service, 1995.

White, M.D. and K.A Greer. The effects of watershed urbanization on the stream hydrology and riparian vegetation of Los Peñasquitos Creek, California. *Landscape and Urban Planning*. 74, 2 (2005): 125-138.

Wohl, E. Compromised Rivers: Understanding Historical Human Impacts on Rivers in the Context of Restoration. *Ecology and Society* 10, 2 (2005): Article 2.

APPENDIX

Full data set from Dutchess County groundwater wells that are "minimally impacted by residential presence" sampled in 2008 and 2009.

			Sample Parameters (2)															
			Alkalinity	Arsenic	Barium	Chromium	Chloride	Hardness	Iron	Lead	Manganese	Nickel	Nitrite	Nitrate	pH	Sodium	Sulfate	Turbidity
Major Geologic Formations	# of wells	MCL(3)	(4)	0.05	2.00	0.10	250.00	(4)	0.30	0.02	0.30	0.10	1.00	10.00	6.5-8.5	(4)	250.00	5.00
		Percentile (5)																
Carbonates: Wappinger Group (Dolomitic Limestones), Stockbridge Marble	n=36	Min	52.0	0.000	0.000	0.000	0.0	15.10	0.000	0.000	0.000	0.000	0.00	0.00	6.50	1.14	9.00	0.00
		10	111.0	0.000	0.006	0.000	0.0	116.50	0.000	0.000	0.000	0.000	0.00	0.00	6.90	2.14	10.50	0.04
		25	170.8	0.000	0.011	0.000	2.0	187.00	0.006	0.000	0.000	0.000	0.00	0.00	7.00	3.115	13.75	0.10
		Median	**208.5**	**0.000**	**0.015**	**0.000**	**6.0**	**211.00**	**0.017**	**0.000**	**0.003**	**0.000**	**0.00**	**0.25**	**7.30**	**9.285**	**18.50**	**0.20**
		75	264.8	0.000	0.036	0.000	42.5	288.75	0.136	0.000	0.020	0.000	0.00	0.99	7.63	21.975	27.25	1.23
		90	323.5	0.000	0.053	0.000	58.5	347.50	0.877	0.003	0.127	0.002	0.00	1.715	7.85	31.15	38.50	5.80
		Max	368.0	0.000	0.088	0.000	93.0	418.00	2.610	0.009	1.000	0.004	0.02	1.89	9.40	43.0	56.00	21.00
Crystalline: (Precambrian Gneiss)	n=9	Min	0.0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.00	0.00	5.20	0.000	0.00	0.00
		10	9.6	0.000	0.002	0.000	2.4	19.76	0.000	0.000	0.000	0.000	0.00	0.00	5.97	1.992	8.80	0.04
		25	25.0	0.000	0.012	0.000	5.0	40.50	0.006	0.000	0.000	0.000	0.00	0.00	6.68	4.05	11.00	0.15
		Median	**56.0**	**0.000**	**0.026**	**0.000**	**11.0**	**72.20**	**0.017**	**0.000**	**0.000**	**0.000**	**0.00**	**0.27**	**7.05**	**6.23**	**15.00**	**0.20**
		75	69.0	0.000	0.029	0.000	25.0	94.20	0.158	0.005	0.015	0.000	0.00	1.10	7.43	12.0	17.00	0.60
		90	76.6	0.000	0.038	0.000	41.6	110.00	0.275	0.033	0.260	0.000	0.00	1.504	7.53	14.96	18.20	0.76
		Max	79.0	0.000	0.065	0.000	56.0	126.00	0.392	0.060	1.220	0.000	0.00	1.92	7.60	18.8	23.00	1.20
Shales, Slates, and Metasediments (6)	n=96	Min	32.0	0.000	0.000	0.000	0.0	0.00	0.000	0.000	0.000	0.000	0.00	0.00	5.90	1.92	3.00	0.00
		10	58.0	0.000	0.004	0.000	1.0	73.30	0.000	0.000	0.000	0.000	0.00	0.00	6.70	3.41	13.00	0.05
		25	98.5	0.000	0.010	0.000	5.75	110.75	0.009	0.000	0.000	0.000	0.00	0.00	7.00	6.195	16.00	0.10
		Median	**151.5**	**0.000**	**0.052**	**0.000**	**18.5**	**180.50**	**0.022**	**0.000**	**0.020**	**0.000**	**0.00**	**0.00**	**7.40**	**13.25**	**24.50**	**0.35**
		75	196.3	0.000	0.114	0.000	46.25	230.50	0.184	0.001	0.121	0.000	0.00	0.40	7.60	22.4	31.25	0.86
		90	230.5	0.000	0.173	0.000	82.5	268.00	0.616	0.002	0.253	0.004	0.00	1.27	7.85	35.1	41.50	2.85
		Max	308.0	0.012	1.040	0.002	98.0	392.00	4.550	0.198	1.130	0.008	0.23	1.82	9.40	47.5	72.00	40.00

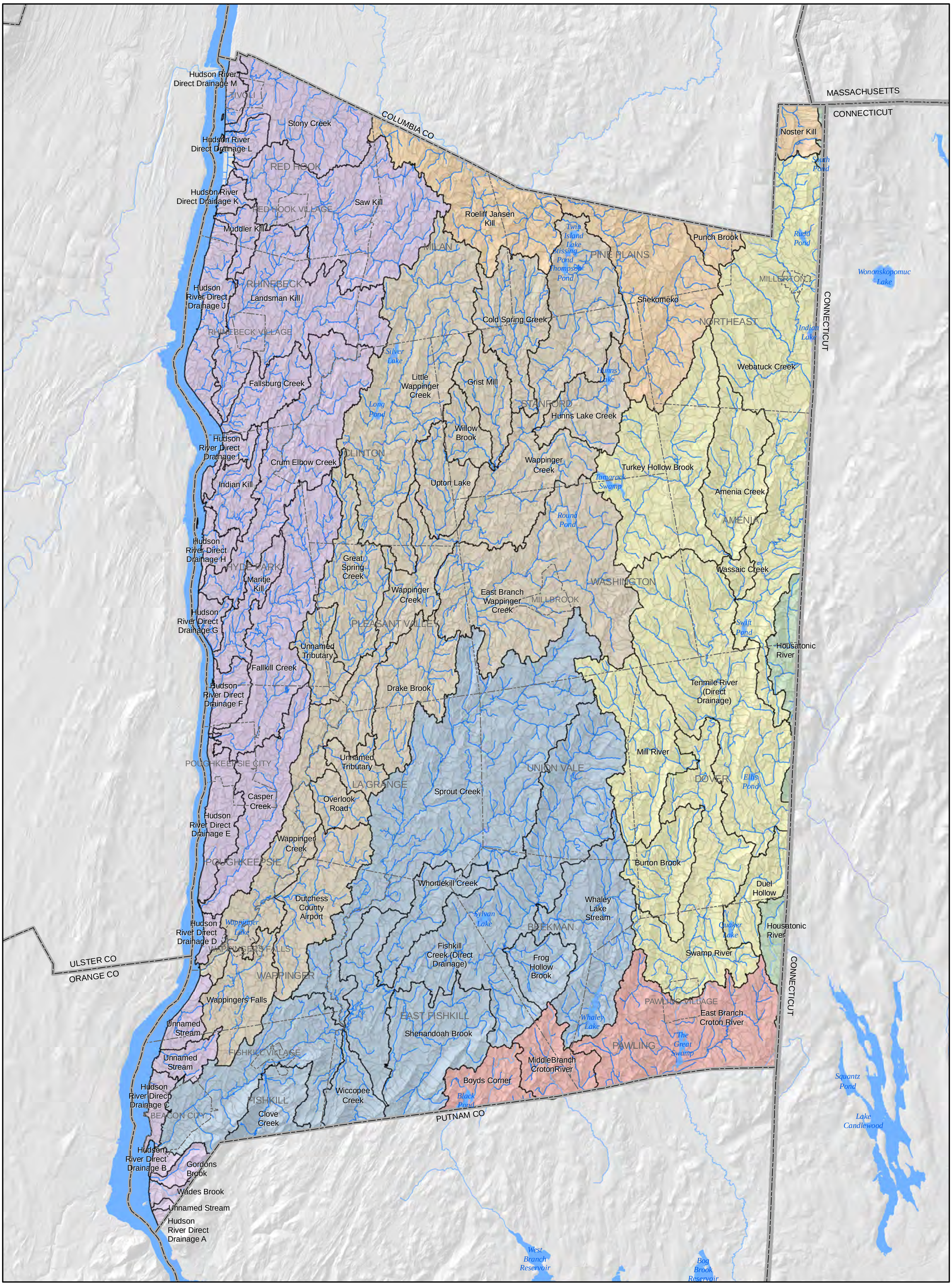
(1) To assess groundwater quality most reflective of geologic regions and least affected by septic systems, softeners or road de-icing, only samples that met all of the following conditions were included in this table: nitrate concentrations below 2 mg/L, chloride concentrations below 100 mg/L, and sodium concentrations below 50 mg/L. 141 of 250 available domestic water samples met all of these conditions. Nitrate, chloride and sodium data were then excluded from the table since they are not naturally occurring compounds in Dutchess County.
(2) In addition to the parameters shown above, all samples were analyzed for Antimony, Beryllium, Cadmium, Cyanide, Mercury, Selenium & Thallium, but nearly all samples results were at concentrations below laboratory minimum detection limits and are therefore not listed on this table for purposes of clarity.
(3) MCL = Maximum contaminated limit per NYSDOH Subpart 5-1 tables where applicable.
(4) Alkalinity, Hardness, and Sodium do not have an MCL, but are typically considered elevated at concentrations exceeding 200 mg/l, 200 mg/l and 20 mg/l respectively.
(5) Percentage values express the frequency that a constituent was encountered at a specific concentration. For example, if the 75th percentile value was 110 mg/l, this means that 75% of samples contained less than or equal to 110 mg/l and 25% contained more than 110 mg/l.
(6) Included in the Shales, Slates and Metasediments are: Elizaville Formation (slate), Germantown formation (shale), Mt. Merino Formation (shale), Nassau Formation (shale), Normanskill Shale, Stuyvesant Falls Formation (shale), Walloomsac Formation (shale) and the Everett Schist (schist).
Note: Values of 0.0000 in the data table are used to represent the minimum laboratory detection limit for each parameter.

Data source: Dutchess County Department of Health website; http://www.co.dutchess.ny.us/CountyGov/Departments/Health/14361.htm

Map 5.1: Watersheds

Dutchess County, New York

Prepared by:
CCEDC GIS Lab, 2010



Watersheds (Sub-basins)

- Croton River
- Fishkill Creek
- Housatonic River (Direct Drainage)
- Hudson River (Direct Drainage)
- Roeliff Jansen Kill
- Tenmile River
- Wappinger Creek

Miles: 2 1 0 2

Kilometers: 4 2 0 4

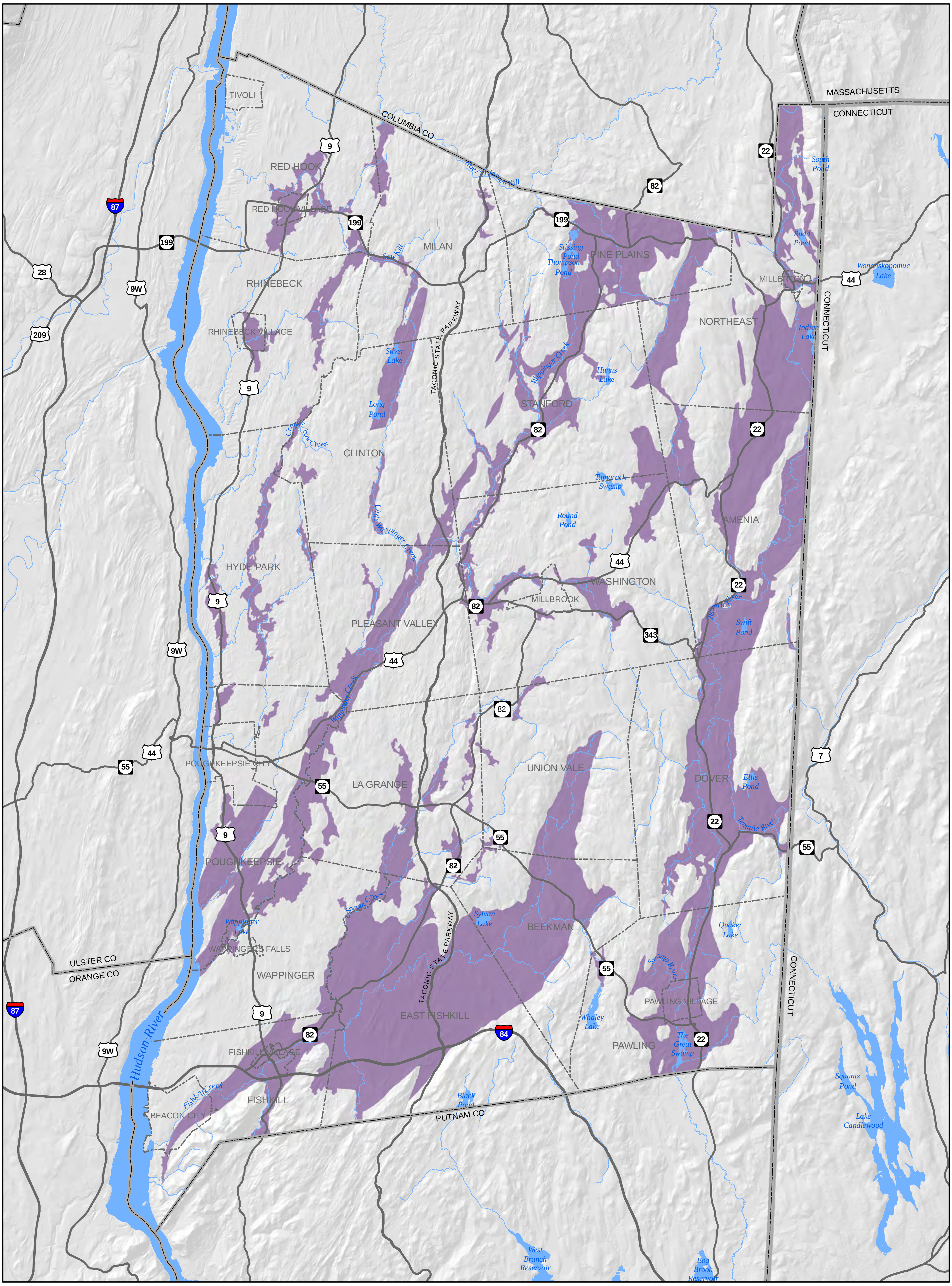
1:225,000

N

Map 5.2: Aquifers

Dutchess County, New York

Prepared by:
CCEDC GIS Lab, 2010



Aquifers

higher yield bedrock and overburden aquifers

Miles
2 1 0 2

4 2 0 4
Kilometers

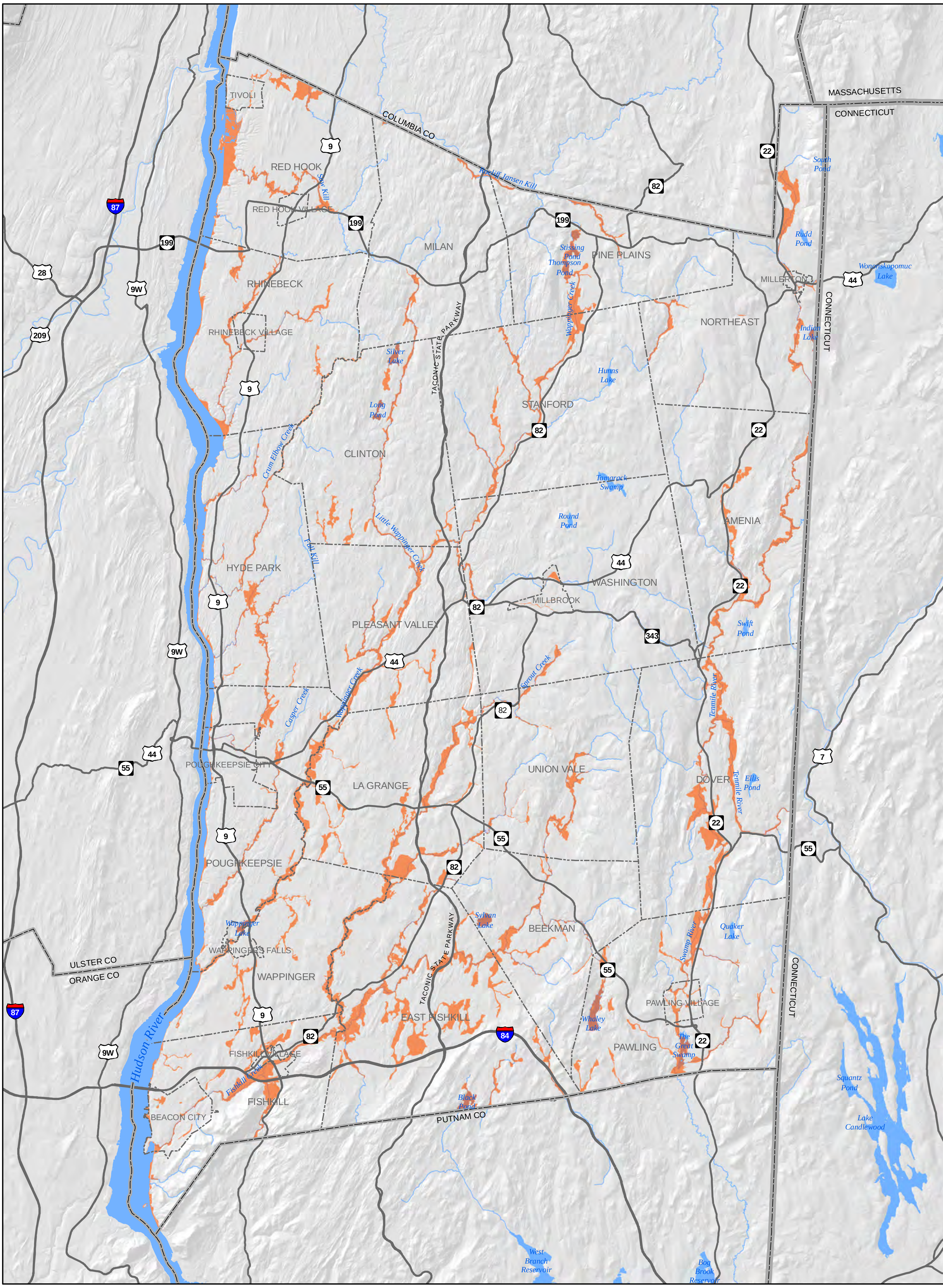
1:225,000

N

Map 5.3: Floodplains

Dutchess County, New York

Prepared by:
CCEDC GIS Lab, 2010



Floodplains

Special Flood Hazard Areas (100-year floodplain)

Miles: 2 1 0 2

Kilometers: 4 2 0 4

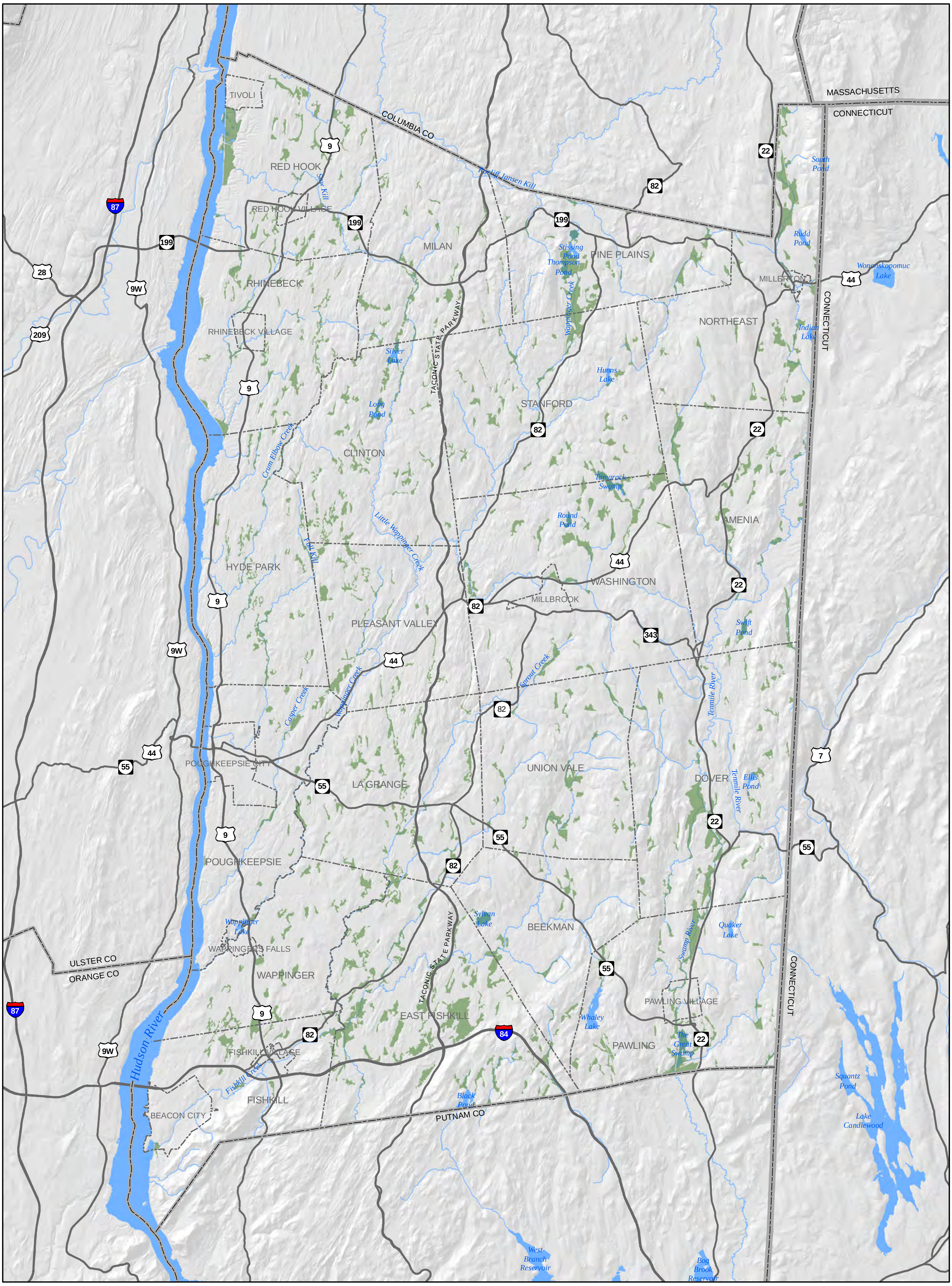
1:225,000

N

Map 5.4: Wetlands

Dutchess County, New York

Prepared by:
CCEDC GIS Lab, 2010



Wetlands

NYS Regulated Wetlands

Miles
2 1 0 2

4 2 0 4
Kilometers

1:225,000

N

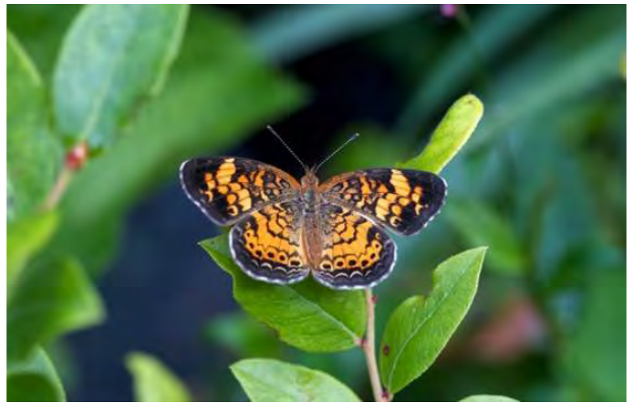


Photo credit: Tom Finkle

Chapter 6:
Biological Resources and Biodiversity of Dutchess County, NY

Mary Ann Cunningham, Neil Curri, and Robert Wills[1]
October 2010

BIODIVERSITY IN OUR AREA

Chapter Contents

Situated in the mid-Hudson River Valley, at a biological crossroads between species and habitats of the surrounding regions, Dutchess County contains a rich diversity of habitats (Strong, 2008, Map 6.1[2]). These habitats support species that are rare in more densely settled regions, from river otters and black bear to pileated woodpeckers, woodland warblers, and specialized wetland orchids and sedges. The county supports federally listed threatened species, such as the Blanding's turtle and the Indiana bat. Many residents might be surprised to learn about the level of diversity that persists in what we often consider a suburban county. In this chapter we review the

[1] This chapter was written in 2010 by Dr. Mary Ann Cunningham (Vassar College), Neil Curri (Cornell Cooperative Extension Dutchess County), and Robert Wills (Dutchess County Department of Planning & Development), with assistance from the NRI Committee. It is an updated and expanded version of the vegetation and wildlife chapters of the 1985 document *Natural Resources, Dutchess County, NY* (NRI).
[2] Maps are located at the end of this chapter.

county's key habitat types, distribution of ecological regions, and factors that influence the biological diversity of our area.

The Dutchess County Legislature identified the importance of the county's biological diversity when it established an Environmental Management Council in 1972. The EMC was established to help protect "the biologic integrity of the natural environment, on which man is dependent for survival, and the natural and functional beauty of our surroundings which condition the quality of our life," (Dutchess County Legislature, 1972). The concept of **biodiversity** can be defined as the entire diversity of genetic variety, species, and ecosystems in a given region (U.N. Convention on Biological Diversity, 1992). Biodiversity includes plants, animals, fungi, and microorganisms, although we give most attention to the larger plants and animals. Conserving these organisms and the systems they occupy requires some familiarity with the current state of the resources, both rare and common.

Biodiversity conservation in Dutchess County requires collaboration of private land-owners and local decision makers. Over 90 percent of the county is privately owned, and many important habitat areas in the county occur on private lands. For example, most known locations of the Northern cricket frog (a state listed endangered species) in the county are on privately owned land (NY Natural Heritage Program). Populations such as these have often been viewed as obstacles to development, but protecting them can also help protect the landscapes and habitats that make our area distinctive.

Conservation is most effective when communities can identify important biological resources and develop conservation priorities before target species become threatened. Planning ahead can help communities save time and money in land use disputes, in debates between land developers and planning and zoning boards, or even in legal action over conservation of legally protected species and their habitats.

The goals of this chapter are: 1) to guide municipal officials and residents toward identifying biodiversity resources in their communities, and 2) to provide resources to aid local governments, land owners, and communities in identifying priorities for biodiversity conservation.

Benefits of Habitat Conservation

Habitat conservation can entail protecting key spots of special value, or it can mean maintaining open space with minimal development or clustered development. "Green space" is another term often used for vegetated open space. Both green space and open space may be actively used, for example, in farming, pasture, or forestry, and often these actively managed areas can provide useful habitat for a variety of flora and fauna. Thus the ideas of "open space" and "habitat" can overlap considerably. Certainly habitat conservation is generally impossible *without* open space conservation.

Why Should I Care about Natural Areas and Wildlife?

Diverse natural ecological systems provide a number of beneficial services to human health and our communities.

- Forests, wetlands, and stream corridors work together to keep our water supply clean and abundant.
- Natural areas and open spaces can provide economic benefit through increased tourism and reduced cost of town services.
- Nature keeps your family healthy—by cleaning the air and water, lowering stress, and lessening the risk of disease.
- Plants and animals and the intact natural areas that support them are important parts of community character and local quality of life.
- Protected natural areas and associated wildlife provide vital recreational opportunities.

Source: Strong, 2008
http://www.dec.ny.gov/lands/5096.html

Conserving open space can provide a variety of economic benefits. Protecting open space, as outlined in Dutchess County's "centers and green spaces" plans, can support the local farm economy while conserving woodlands and open fields. Wetland and floodplain conservation can help reduce the impact of flooding and also protect groundwater resources. The aesthetic amenity of open space enhances property values, and biodiversity contributes to regional income from recreation and tourism. These and other benefits have been outlined by the Hudson River Valley Greenway Compact.

Conserving open space and biodiversity also helps communities safeguard essential ecological services on which we depend, such as water purification (performed as soil microbes consume nutrients from septic effluent), soil development, and climate regulation. (For more information on ecosystem services, see NRI Chapter 1: Introduction.) Healthy ecosystems can minimize erosion and sediment accumulation in streams, maintain groundwater resources by protecting aquifer recharge zones, and reduce flooding and low stream flow associated with denuded or impervious landscapes (see Natural Capital project.org; NRI Chapter 5: Water Resources.)

Open space and biodiversity conservation don't mean stopping all development. Land development and conservation can work together if development is done thoughtfully. Strategic site design can allow smart development that preserves water quality; conserves soil, vegetation, and biodiversity; and maintains aesthetic values (http://www.sustainablesites.org/report/). Smart development strategies also have economic benefits, as they can reduce a community's liability for things such as road building and maintenance, sewer and water, fire and police (http://smartgrowth.org; Dutchess County Planning).

Conservation priorities for the Hudson Valley region

This document reviews main points for communities to consider for understanding and conserving biodiversity. Further details are available from a wealth of publications and organizations that provide data on biodiversity in our region, particularly the New York Department of Environmental Conservation (DEC), the New York Natural Heritage Program (NYNHP) and Hudsonia Ltd. These organizations document species and their habitats, and provide conservation guides and fact sheets about individual species' needs. Karen Strong (2008), in cooperation with the DEC and Cornell Cooperative Extension, has provided many of the arguments and justifications for understanding how to plan for biodiversity conservation in the Hudson River Valley.

A first step toward identifying areas of importance for conserving biodiversity is to identify target habitats, or habitats likely to be of value in the Hudson Valley region (Table 6.1). In addition to these general environments, specific habitats, such as acid bogs, talus slopes, or tidal marshes can shelter rare species. Examples of these habitats (and threatened or vulnerable species that may occur) include fens and calcareous wet meadows (Bog Turtle, *Glyptemys muhlenbergii*), kettle shrub pools (Blanding's turtles, *Emydoidea blandingii*), and cliff habitats (Ram's head ladyslipper, *Cypripedium arietinum*). Characteristics of these habitat types have been documented by the NY Natural Heritage Program and by Kiviat and Stevens (2001).

Familiarity with regional species and habitats of concern will aid in identifying priority areas in your community. Maps (including those in this Natural Resource Inventory) can aid in identifying local resources. A key resource is the DEC's New York Natural Heritage Program (NYNHP), which has mapped biologically important areas for the region. Biologists at NYNHP can aid communities in prioritizing species and areas for conservation. Communities can also consult with other municipalities in the area that have completed biodiversity conservation plans. To identify these municipalities, local groups should consult with Dutchess County Planning and NYNHP. Findings and decision criteria should then be documented for later reference.

Table 6.1: Target habitats with special value for conservation (Strong et al., 2008)

Habitat	Examples of species needing this habitat
Shoreline corridors*	river otter, wood turtle, cerulean warbler, wading birds, trout, stream salamanders and Hudson River water nymph
Unbroken forests	scarlet tanager, warblers, wide-ranging mammals, hawks, owls, box turtles, and plants like fringed polygala flower
Grasslands and shrublands	northern harrier, bobolink, eastern meadowlark, golden-winged warbler, short-eared owl and uncommon butterflies
Wetlands	American bittern, marsh wren, Blanding's turtle, northern leopard frog and a rich diversity of flora like pitcher plant
Seasonal woodland pools	Northeast including Jefferson, marbled, and spotted salamanders, wood frog, spotted turtle, fairy shrimp and others declining throughout the Northeast
Caves and cliff habitats	bats, peregrine falcon, overwintering snakes, migrating hawks, and rare cliff plants like purple cliffbrake and prickly pear
Unique natural areas	at-risk plants and animals

* Includes Hudson River shoreline, streams, intermittent streams

KEY CONCEPTS

Keeping in mind some general principles will aid in identifying priority areas and understanding why some areas are especially valuable for maintaining biodiversity. In this section we define some of these key concepts.

Biodiversity (or "biological diversity") refers to the variety of different kinds of living organisms in an area. Maintaining high diversity of species implies that populations of rare species, as well as common species, are protected. Ecologists often describe biodiversity in terms of **species richness** (the total number of species in an area) and **species evenness**, or the relatively high abundance of many different species, rather than the dominance of just a few. For example, a pine plantation is dominated by one tree species; in contrast, a well-established Hudson Valley deciduous forest might contain smaller numbers of a dozen or more maple, oak, hickory, and other species. There is greater species evenness in the latter community. In general, a more diverse forest is likely to support a greater variety of other animal and plant species than a low-diversity community.

Endangered and threatened species that are legally designated, or listed, have stronger legal protections than other species. **Endangered species**, as defined by the US Endangered Species Act (ESA), are species in danger of extinction throughout all or a significant portion of its range (excepting insect pests). **Threatened species** are those likely to become endangered in the foreseeable future. New York State also lists endangered species that are (1) native species in imminent danger of extirpation or extinction in New York and (2) listed by the ESA for all or part of its range. In addition, **species of special concern** are those that warrant attention and consideration, but for which there is insufficient information yet for listing as endangered or threatened. A list of New York designated endangered, threatened, and special concern species can be found here.

Habitat is the area and the resources that support species. In the Hudson Valley, the dominant natural habitat is eastern deciduous forest, but many additional habitats are critical, including wetlands, seasonal woodland pools, tidal environments, and others. Some organisms occupy only one specific type of habitat; some can make use of many different types. Urban environments also provide habitat; for example, cities provide habitat for a variety of birds as well as urbanized mammals (such as skunks, deer, and coyotes). Stream corridors within cities can also be high in biodiversity. Most often we pay attention to habitat types that are uncommon and thus need special protection. Maintaining overall abundance of common habitat is also important, however, for "keeping common species common."

Ecosystems are interacting communities of living things and the non-living resources on which they depend. For example, a lake can be described as an ecosystem that contains aquatic plants, insects, fish, fish-eating birds, and so on. Living organisms depend on nutrients and other resources from the lake, and they contribute to the organic matter accumulated on the lake bed, the chemical characteristics of the water, and so on. (For more information on ecosystems, see NRI Chapter 1: Introduction.)

Fragmentation is the division of once-expansive habitats or ecosystems into smaller or more isolated parts. For example, before European settlement, the Hudson Valley contained expansive areas of deciduous forest, which have been reduced to smaller and more isolated areas of forest since the introduction of agriculture. In recent decades, deciduous forests have expanded again, and the principal cause of habitat fragmentation at present is expansion of residential land uses (see *Historic Changes and Current Threats to Biodiversity* section below).

Interior habitat (or core habitat) and **edge habitat** are often considered ecologically distinct because some species avoid edges—such as the edge of a wooded area or the edge of a grassland area—while other species prefer to occupy edges. In general, our current land use patterns include roads, residential neighborhoods, and commercial developments, which tend to increase abundance of edges and decrease availability of interior habitat. Consequently, preserving expansive undeveloped areas that contain abundant interior habitat is often a concern in biodiversity planning.

Connectivity is a general term for connectedness among habitat areas. Species may be less vulnerable to population declines when they are able to move safely among different habitat areas. Connectivity can give access to more resources, increase the amount of core habitat, and also minimize inbreeding that can happen in isolated populations. **Corridors** are areas that connect larger units of habitat. For example, bobcats and black bears can travel safely along wooded corridors to move from one wooded area to another. Maintaining connectedness among habitat areas is usually a priority in conservation planning. Wetland complexes can also be considered connected, for example salamanders can travel safely among a cluster of wetlands when the complex is not fragmented by roads or other development.

Disturbance is any process that interrupts an ecosystem, such as fire, development, drought, floods, or other disruptive processes. Systems may show resilience to disturbance or an ability to recover to pre-disturbance conditions.

An **ecological region** is an area roughly defined by general similarity of habitat types, topography, underlying geology, or other factors that help shape the biological community. Identifying ecological regions can help communities place their plans in a context of more generally defined biological areas. Ecological region boundaries have been mapped, but it should be remembered that in reality boundaries are rarely clear or sharp, and there are usually gradual transition zones between ecological regions.

Ecosystem services are resources or functions provided by natural systems, such as water filtration by soils, air purification by plants, or temperature regulation by water and forests. Usually the benefits of these services is diffuse and the value hard to calculate, but they contribute to environmental health and quality of life (see the Natural Capital Project and The Economic Evaluation of Biodiversity (TEEB) project). (For more information on ecosystem services, see NRI Chapter 1: Introduction.)

Terms for general classes of organisms help us describe the general groups of species that may share particular habitat types or general ecological roles. **Herpetofauna** include amphibians (frogs, toads, salamanders, newts) and reptiles (snakes, turtles, and lizards), many of which require wetlands or undisturbed rocky environments. **Invertebrate** is a general term for organisms that lack a backbone, including insects, spiders, crayfish, worms, and other groups.

CURRENT STATE OF BIOLOGICAL RESOURCES

The Hudson Valley has some of the greatest biodiversity in New York, owing to the combination of woodlands, wetlands, river, and mountain environments. Mature deciduous forests support an abundance of bird species as well as mammals, including black bear and bobcat. Streams and wetlands support fauna as diverse as river otter, native clams, and threatened and endangered turtles. Localized and uncommon habitats such as sedge meadows or rocky summits support rare species adapted to extreme conditions.

In this section, we review the major habitat types in Dutchess County and identify several notable species of concern or of interest for each. The maps and discussion here may be used as starting points for identifying key habitat areas and species in areas that interest individual communities in the county. For a detailed inventory of habitat types and their associated flora and fauna, see the 1985 Natural Resources Inventory (http://dutchessemc.org/projects/dutchess-county-nri/1985-nri/) and the Hudsonia Biodiversity Manual (Kiviat & Stevens, 2001).

Areas of greatest biodiversity are frequently those least disturbed by development. Often these remnant undisturbed environments are too steep, wet, or remote for easy access or building. Environments with minimal human activity tend to occur in large blocks of habitat unfragmented by roads or built structures. A "biodiversity block" approach thus can be used to map unbuilt habitats—including forest, open fields, wetlands, and so on—which are especially likely to have high conservation values (Wills, 2010; Map 6.2). Another way to identify areas of biodiversity value is to locate *concentrations* of a *target* habitat type. In Dutchess County, where forest is the dominant habitat type and most species occupy forest cover, it is also useful to identify areas of concentrated forest, which are most likely to contain abundant core habitat and minimal amounts of anthropogenically modified edge (Map 6.3). Wetlands also are frequently areas of high biodiversity: having abundant moisture and sunshine, they can have high biological productivity and can support specialized or rare species. Conservation of these areas of key biodiversity value is one of the important strategies for maintaining overall diversity in our area.

Wildlife Communities

In reflection of the wide range of habitats in Dutchess County, our area supports a diversity of plant and animal communities. We have a rich diversity of birds, dragonflies, butterflies, amphibians, and other groups. Larger mammals include white-tailed deer, black bear and coyote, as well as rarer species such as red fox and river otter. The widespread and relatively common animal species have value for wildlife viewing and for maintaining ecosystem structure in general. Most legal protections, however, focus on less common species. The New York Natural Heritage Program (http://www.acris.nynhp.org/), a collaboration of scientists from the DEC and the Nature Conservancy, provides online guides to aid land managers, planners, and others in understanding rare, threatened, and endangered species in New York. NYNHP provides online guides to the rare or threatened animals, plants, and habitats known to occur in each county in New York (Appendix 1).

DUTCHESS COUNTY HABITATS

Identifying habitat types in an area is a first step toward understanding the species that are present. New York's habitat types have been defined by the DEC's Ecological Communities of New York State (Edinger et al., 2002). Habitat types within Dutchess County specifically have been defined by Kiviat and Stevens (2001) and by the 1985 Dutchess County NRI.

Aquatic Habitats

Tidal shorelines and wetlands

Tidal shorelines and wetlands are distinctive because of daily cycles of flooding and drying, and plants must tolerate these daily changes. Tidal environments in Dutchess County generally are freshwater systems because the dense, deep salt water moving north from the ocean normally reaches no farther than New Hamburg, although brackish water can reach Poughkeepsie during droughts (USGS, 2008). Tidal environments are distinguished by variations in depth: **subtidal** areas remain below the waterline at low tide; the **intertidal** zone is the range between high and low tide lines, so that it is flooded at high tide and exposed at low tide. **Supratidal** areas are above the high tide line and are not generally flooded. Tidal zones are also distinguished by the composition of the substrate—generally muddy, sandy, or rocky.

Tidal shorelines occur along the Hudson River and at the mouths of tributary streams, such as at Tivoli Bay, Norrie Point, and New Hamburg. Mud flats may be exposed at low water. Below the low tide line, submerged aquatic vegetation roots in the river bottom, with leaves floating on the surface. In the intertidal zone (which experience both flooded and exposed conditions) vegetation includes cattail, pickerelweed, and other herbaceous plants. Tidal environments support plants and invertebrates that tolerate varying degrees of salinity (where water is brackish), as well as animals and birds that forage in exposed mudflats. A wide range of plants; waterfowl, wading birds, and songbirds feed in the shallow water and low vegetation. Species of conservation concern include the American Bittern, Wood turtle, and Northern leopard frog (Kiviat & Stevens, 2001).

Non-tidal Wetlands

Non-tidal wetlands are widely distributed across Dutchess County, including lowland and level areas, floodplains, and rocky ridge tops. Isolated wetlands are also important, however, as they support specialized groups of amphibians, turtles, dragonflies, and other fauna. Wetlands are often hot spots of biodiversity. They provide high-productivity environments that support specialized plants and a high diversity of fish, amphibians, turtles, birds, mammals, and invertebrates.

Wetlands are differentiated according to length of saturated seasons, vegetation types (wooded, emergent herbaceous, floating vegetation), substrate type (muddy, sandy, or organic beds) and other factors (Cowardin et al. 1979).

Many of the region's wetlands were drained for agriculture or development decades ago. Most that remain are protected by laws put in place since the 1970s, which protect wetlands larger than 12.4 acres, as well as a 100-foot buffer surrounding protected wetlands. Many extant wetlands are also too expansive or too wet for cost-effective drainage. Because of their biological importance, and because of their function in mitigating flooding and maintaining water supplies, there are federal, state, and local ordinances that protect them from draining, filling, or other destruction (see Implications for Decision-making, below). Upland areas that drain into wetlands, however, are not necessarily addressed by most wetland protection laws, and development of these areas can alter the depth, water quality, and vegetative community of wetlands.

Unlike forests, wetlands have great biological importance when they are small and isolated. Where isolated wetlands lack stream outlets, they are generally inaccessible to fish that would prey on the eggs and young of frogs and salamanders. Thus isolated and seasonal wetlands provide safe reproductive habitat for amphibians. This type of wetland is often referred to as seasonal wooded wetlands because they typically occur in wooded areas in our region. They may also be called *vernal pools*, because they are most evident in spring. These wetlands can be easy to overlook: they are usually too small to appear on maps, they may be dry in late summer or fall, and their extent varies from year to year. In addition, wetland complexes can consist of scattered water bodies that appear isolated from above but are hydrologically connected below ground. Modification of part of such a complex can lead to unforeseen effects on other parts of the complex.

Riparian Habitat

In-stream and river environments provide critical biological resources including fish, eels, invertebrates, and plants that contribute to on-shore ecosystems and even to human food supplies. Riparian habitats are distinguished by substrate conditions, size of stream, and abiotic conditions such as oxygen levels and temperature, which influence the biotic community in the stream.

Terrestrial Habitats

Major plant communities of Dutchess County are documented by the 1985 NRI and by the Hudsonia Biodiversity Manual. We follow these in the discussion below. The relative abundance of different land cover gives an indication of the availability of general habitat types in the county (Table 6.2).

Table 6.2: Distribution of habitat types in Dutchess County

Land Use	Area (1,000 acres)	Percentage of county
Forests	2941	56%
Agriculture, grasslands	1233	23%
Developed	472	9%
Wetland	237	4%
Shrublands	225	4%
Open water	149	3%
Unclassified	18	0%

Source: NOAA Coastal Change Analysis Program (C-CAP) Land Cover Data, NOAA Ocean Service, Coastal Services Center (CSC), 2006.

Forests

Forests are wooded areas in which trees are the dominant vegetation type. In this chapter, wooded areas are considered forested if their trees at least five meters tall occupy more than 20 percent of the land area (NOAACSC, 2007). Dutchess County forests are mostly deciduous, but there are also some significant areas of coniferous and mixed forest.

Deciduous Forest

Deciduous forests (dominated by maples, hickory, oak, ash, birch) occur throughout the county and are the dominant forest type. The 1985 NRI differentiated lower slope, mid-slope, and upper slope deciduous forest. All have forest canopies dominated by the tree families noted above, although proportions vary. Understory vegetation also varies: at low elevations, common species include spice bush, honeysuckle, dogwood, grape, and Virginia creeper; at higher elevations common species include mountain laurel and blueberry.

Deciduous forests grow over much of the county, but notable areas of expansive, unfragmented forest include the Hudson Highlands, the Taconic Highlands, and the Wappinger Creek headwaters area of north-central Dutchess County. Among these forests, wooded wetlands can have particular value for birds, mammals, invertebrates, and specialized plants, as noted above. Much of this forest is second-growth, and 75 years after agriculture it may still retain an understory, soil, and herbaceous characteristics that are still developing toward mature old-growth conditions. Mature deciduous forest may contain a greater richness of spring ephemeral flowers as well as a richer soil microbial community, mushrooms, and other characteristic woodland flora and fauna.

Species of interest for conservation include a variety of spring ephemeral flowers (Figure 6.1), eastern box turtle, wood frogs, salamanders, woodland warblers, woodpeckers, American turkey, and Indiana bat http://www.sustainablesites.org/report/). Sugar maple, a traditional dominant, is a species of concern because it is widely being displaced by the similar-looking Norway maple. Less common but notable species include the Cooper's hawk, barred owl, pileated woodpecker, black bear, bobcat, and southern flying squirrel.

Figure 6.1. Spring ephemeral flowers such as this Dutchman's Britches (*Dicentra cucullaria*) grow mainly in undisturbed deciduous forest with a healthy understory.

Photo credit: Tom Finkle

Coniferous and Mixed Forest

Dutchess County contains some conifer plantations as well as scattered naturally occurring coniferous stands. Plantations consist of more uniform stands of Scotch pine, red pine, European larch, and Norway spruce, while natural stands include eastern hemlock, white pine, and eastern red cedar. Coniferous forests provide important habitat for a variety of mammals, including winter shelter for white-tailed deer. Some species of owls and hawks utilize coniferous forests for roosting and nesting, because the dense foliage provides secure cover year round. Many songbirds also nest in coniferous forests.

Mixed forests comprise a combination of deciduous and coniferous tree species, where neither type is dominant (NOAACSC, 2007). White pine, red cedar, and hemlock are common conifers in mixed forest stands, as well as maple, oak, hickory, and other deciduous trees.

Grasslands and Shrublands[3]

Open habitats in Dutchess County are dominated by grasses and by herbaceous plants (goldenrod, asters), shrubs (blackberry, multiflora rose, juniper, sumac), and scattered early successional trees (red cedar, gray birch, white pine, quaking aspen). These open areas are less abundant than in previous decades, owing to the regrowth of tree cover noted above. These habitats generally include plant types that readily occupy disturbed environments, since many remain open beause of haying or grazing. Although grasslands and shrublands are often considered temporary or transitional in our region, they can be of great ecological interest as they support birds, butterflies, fireflies, distinctive grassland plants, and other flora and fauna of interest.

Grasslands

This category includes areas dominated by grassland and other herbaceous species, including hayfields, pasture, and croplands. Habitat values in these areas vary by the type of vegetation present and the type of disturbance to which they are subjected. Infrequently mowed hayfields, for example, may support grassland breeding birds while cultivated croplands may have little habitat value. However, when left undisturbed, pastures, hayfields, and croplands tend to develop similar characteristics as diverse species of grasses, forbs, and shrubs colonize and create habitat for a variety of wildlife species, including invertebrates, reptiles, mammals, and birds.

Shrublands

Shrublands are upland areas dominated by woody vegetation less than 5 meters in height (NOAACSC, 2007). Shrublands represent an intermediate stage of ecological succession, or transition from abandoned fields, pasture, or cropland to forest. Forest is considered the climax

[3] The primary source of this information can be found in Hudsonia's "Biodiversity Assessment Manual for the Hudson River Estuary Corridor" by Kiviat and Stenvens (2010).

ecological community in this region of the country, since open areas left undisturbed will eventually develop into mature forests. Typical shrubland plant species include goldenrod, aster, orchard grass, gray dogwood, multiflora rose, black raspberry and many other shrubby species. Some bird species, such as northern mockingbird and American robin, nest in shrublands. Several state and federal-listed birds can be found utilizing shrublands, including northern harrier, golden-winged warbler, and grasshopper sparrow. Many butterflies may be present as well.

ECOLOGICAL REGIONS[4]

Ecological regions denote areas of general similarity in ecosystems and in the type, quality, and quantity of environmental resources (Bryce et al., 2010). Dutchess County is comprised of six ecological regions: Hudson Valley, Taconic Foothills, New England Marble Valleys, Hudson Highlands, and Berkshire Transition (Map 6.3). Each ecological region has unique characteristics that structure the ecosystems they contain. Local officials can use ecological regions to help determine which of the habitats described in the previous section may be found in their community, identify priority habitats for conservation, become aware of their important or unique characteristics (such as the presence of rare or threatened species), and develop appropriate conservation and management strategies.

The remainder of this section includes a brief description of each ecological region in Dutchess County, with suggested priority habitats for conservation.

Hudson Valley

The Hudson Valley ecological region in Dutchess County extends along the entire western boundary of the county, encompassing all or most of the area of each municipality along the Hudson River, including the county's two urban centers, the Cities of Poughkeepsie and Beacon (Map 6.1). One of the county's main transportation corridors and its most developed urban corridor, U.S. Route 9, runs north and south through this ecological region.

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[4] The primary source of this information can be found in the references section of this chapter, "Ecoregions of New York" by Bryce et al. (2010).

The Hudson Valley consists of plains broken by hills and terraces, with a narrow floodplain along the Hudson River. Low elevations and the moderate climate of the Hudson Valley allow Appalachian oak-hickory forest, with black and white oak and pignut, mockernut, and shagbark hickories, to penetrate northward. Some of the Appalachian species are at the northern extent of their distribution, but as the climate warms they are expected to expand their range into areas now dominated by northern hardwoods. Common land uses include pasture and cropland, deciduous forest, mixed deciduous and evergreen forest, major urban, suburban, and rural residential land.

Freshwater tidal marshes and mudflats occur along the river, with Tivoli Bays just south of the Village of Tivoli being the largest and most ecologically significant in Dutchess County (Map 6.1). Estuarine species include shortnose sturgeon, American eel, and American shad.

Priority habitats: tidal aquatic communities, streams, wetlands, contiguous forest, open grasslands.

Taconic Foothills

The Taconic Foothills form a transition zone between the Hudson Valley and the Hudson Highlands to the south, and the Western New England Marble Valleys, the Berkshire Transition, and Taconic Mountains to the east and northeast. It extends northward into Columbia County and along the eastern boundary of the Hudson Valley ecological region. The foothills therefore have a more rounded and rolling profile than the upended Taconic Mountains, but also contain narrow valleys with steep slopes, which are drained by moderate gradient bedrock, boulder, and cobble-bottomed trout streams. Some natural lakes and ponds occur throughout the region, but many have been created by small dams.

Appalachian oak-hickory forest dominates this ecological region in Dutchess County, with some northern hardwoods (maple-beech-birch). Hemlock forests can be found on northern slopes and in narrow valleys with steep slopes. Stands of red maple, eastern white pine, and sugar maple are often found colonizing abandoned farm fields. The land use mosaic in the Taconic Foothills consists of woodland, pasture, minor areas of cropland, and rural residential development. In Dutchess County, the southern portion of this ecological region is significantly more developed than the northern area, which contains more forested and agricultural lands (Map 6.1: CCAP habitat data map).

Priority habitats: Contiguous Forest, Seasonal Woodland Pools, Grasslands (including pasture), Streams and Intermittent Streams

Hudson Highlands

This ecological region extends from the southwest corner of Dutchess County, through the southern portions of Fishkill, East Fishkill, and extending north along the boundaries of Beekman and Pawling, Union Vale, and Dover.

The Hudson Highlands ecological region is a low portion of the Appalachian Mountains between the mid-Appalachians and the Berkshires and Green Mountains in New England. It is comprised of hills and low mountains, with steep narrow valleys and lakes, some containing fish or functioning as drinking water reservoirs. Streams have moderate gradients with boulder and cobble-bottom substrates, containing trout or cool enough to support trout. Naturally acidic runoff plus acid deposition from upwind industrial sources put the Hudson Highlands' lakes at risk for future harm to aquatic life from acidification.

Bedrock outcrops are common. Soils are shallow, rocky and highly acidic. As a result, the Hudson Highlands region is mostly forested with Appalachian oak-hickory on drier sites and northern hardwoods and hemlock on north slopes and moist sites. Transition hardwood forests of sugar maple, American beech, black birch, tulip tree, oaks (red, white, and chestnut oak) and hickories (shagbark and pignut hickory) are dominant.

The forested highlands provide an important natural buffer zone and an outer boundary for the New York City megalopolis. These lands have long been recognized by conservation groups as important for wildlife habitat, tourism, and recreation. While there is some rural residential development in the Hudson Highlands, most of the region in and outside of Dutchess County is forested; much of it is protected in state parks or privately-owned conservation land. A 16-mile stretch of the Appalachian Trail passes through the Hudson Highlands region.

Priority habitats: Contiguous Forest, Cliff Habitats, Streams and Intermittent Streams

Western New England Marble Valleys

Portions of the Western New England Marble Valleys exist in two separate areas of Dutchess County. From the north, this ecological region covers much of Pine Plains and part of Stanford in northern Dutchess County. The other part of this region lies in the Harlem Valley, which extends through the towns on the county's eastern boarder with Connecticut and Massachusetts (Map 6.4).

Steep-sided valleys with floodplains, terraces, and rolling to hilly terrain characterize this region. Streams have low to moderate gradients with bedrock, boulder, cobble, and sandy substrates. Springs, seeps, and wetlands are common, with few lakes and reservoirs.

Wetland habitats in the Western New England Marble Valleys are common, and include diverse swamps, floodplains, and calcareous fens. One of the largest wetlands in the Hudson Valley, the Great Swamp, covers an area of almost 2,000 acres in the Town and Village of Pawling as well as southern Dover (NYS Dept. of Environmental Conservation, 2007). Another critical wetland habitat in this ecological region is Thompson Pond in Pine Plains, a rare example of a circumneutral bog lake. These spring-fed water bodies support vegetation typical of both acidic bogs and calcareous marshes, and contain habitat for a variety of rare and uncommon species (Kiviat and Stevens 2001).

Woodland habitats in the Western New England Marble Valley consist of northern hardwoods (maple-beech-birch) and species-rich transition hardwoods (maple-beech-birch, Appalachian oak-hickory forest). Hardwood species include sugar maple, white ash, basswood, bitternut hickory, hophornbeam, and alternate-leaved dogwood. Calcareous rock outcrops contain eastern red cedar, purple clematis, and roundleaf shadbush.

Land use in the Western New England Marble Valley is a mosaic of pasture and cropland, mixed and deciduous forest, urban, suburban, and rural residential development and rock quarries.

Priority habitats: Contiguous Forest, Grassland, Swamps, Calcareous Fens, Calcareous Rock Outcrops, Floodplains, Streams and Intermittent Streams

Berkshire Transition

A small portion of this ecological region lies within New York near the border with Connecticut. The Berkshire transition is comprised of low mountains and narrow valleys, with some steep slopes. Its streams have moderate gradients, with bedrock, boulder, or cobble substrate. There are some natural lakes and ponds, and a few larger reservoirs.

Forest types resemble those in the Hudson Highlands. Northern hardwoods (maple-beech-birch), hemlock, and white pine are mixed with a species-rich Appalachian oak-hickory forest in warmer microclimates. Northern hardwoods and hemlock-white pine forest occur on dry to mesic – mostly north-facing – slopes and ravines. Red oak-sugar maple transition forests are found on mesic mid-slopes with northern red oak, sugar maple, beech, black birch, and some white pine and hemlock. Oak-hemlock-white pine forests include white oak, chestnut oak, northern red oak, and black birch. Some ridgetop habitats with pitch pine-scrub oak woodland can be found. On steep slopes and terraces, red maple, silver maple, American elm, basswood, sugar maple, shagbark hickory, and black cherry occur.

Land uses include a mix of forestry, hay/pasture, rural residential, tourism, recreation, and some urban land as well as some public state forest and state park lands.

Priority habitats: Contiguous Forest, Streams and Intermittent Streams, Seasonal Woodland Pools

Taconic Mountains

On the eastern border of New York, the highest ridges of the Taconics gradually descend to the more gently rolling Taconic Foothills (58x) and Hudson Valley (59i) ecological regions (Map 6.4). The Taconics consist of low mountains and high hills, gently rounded to steep slopes, and narrow valleys. Streams have moderate to high gradients, with bedrock, boulder, and cobble-bottomed substrates. Wild rainbow trout inhabit many streams. There are some springs and caves, and few to no lakes.

Forest vegetation consists of northern hardwoods (maple-beech-birch), with small areas of spruce-fir at higher elevations. Oak and hickory predominate throughout in the south and on south-facing slopes and at lower elevations in the north. Population centers are limited by the prevalence of steep slopes and incised valleys that are typically too narrow for profitable agriculture.

Land uses include deciduous forest, mixed deciduous and evergreen forest – for forestry, recreation, and hunting – as well as some minor pasture and cropland in narrow valleys.

Priority habitats: Contiguous Forest, Streams and Intermittent Streams, Seasonal Woodland Pools

HISTORIC CHANGES AND CURRENT THREATS TO BIODIVERSITY

The dominant trends in biological resources in the past century have to do with economic shifts, primarily the growth and decline of farming, followed by regrowth of forests on old fields, then expansion of suburban land uses into former farm fields, orchards, and woodlands. In this section we highlight some details and results of these changes.

Historic Changes in Population and Land Use

Dutchess County's population has grown steadily since European settlement, with notable increases in the 1950s and 1960s (Figure 6.2). This change has resulted in clearing for farmland, followed by substantial field abandonment in the 1940s. These changes can be observed in historic photographs, some of which have been made available by Dutchess County Office of Computer Information Systems. These photos capture the county during the decline of agriculture in the 1920s and before the post-war housing boom of the 1950s (Figure 6.3). Preliminary analysis of these photos has shown that tree cover in the county as a whole has increased by approximately 140 percent from 1936 to now**.** (Table 6.

An important recent trend in land use have been dominated by expanding developed land, in particular housing, commercial, and transportation activities. These land uses increasingly occur in away from urban centers, as residents increasingly want, and can afford, large lot sizes, larger houses, and longer commutes to work. In the past 10-15 years, roughly one-third of new houses have been built on lots 2 acres or larger—a dramatic transition from the 1960s and 1970s (Figure 6.4). The implications of this change for biodiversity in the county include (but are not limited to) greater fragmentation of habitat, road hazards to wildlife, increasing opportunities to invasive species to colonize new areas.

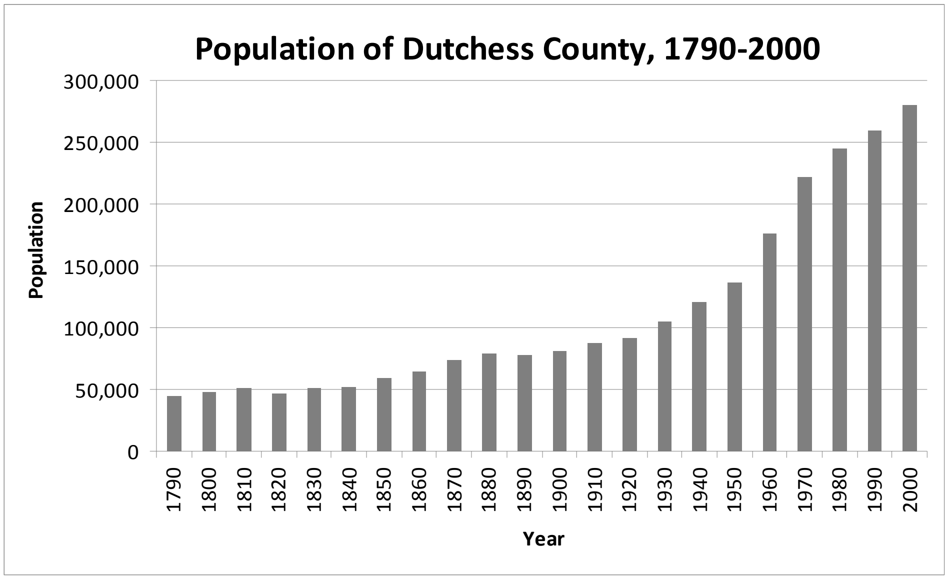


Figure 6.2: Population Growth in Dutchess County from 1790-2008. (from U.S. Census)

Figure 6.3. Land use changes in Dutchess County, 1936 and 2009. Table 6.3 provides as summary of key changes.

Table 6.3: Changes in forest cover and orchards, and roads from 1936 to 2000.

Land use class	1936	2000	Percentage change
Forest	75,410 ha	116,300 ha[1]	+54%
Orchards	5120 ha	1202 ha[2]	-77%
Roads	2,867 km	4,609 km[3]	+61%

Sources: Unpub. data, M.A. Cunningham; GIS data from Dutchess County Planning, Dutchess County Office of Computing and Information Services

[1] (2000 aerials)

[2] (EMC LUNR 1998)

[3] (DC Road Centerline – 2004)

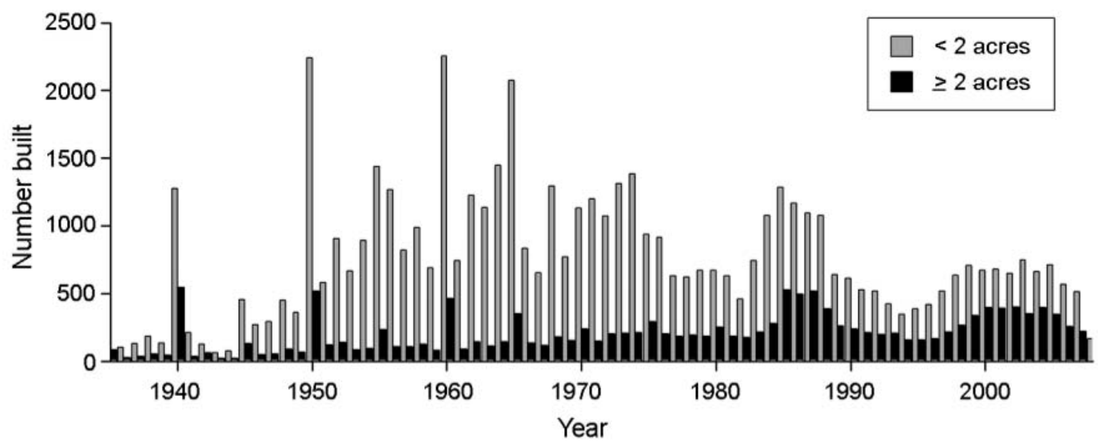


Figure 6.4: Number of houses built in a year, on small lots and large rural lots, from RPS4 data, 2008. Peaks at decades (e.g. 1940, 1950) include records for which build dates were rounded or estimated. (RPS4 2008 data; Cunningham et al. 2009.)

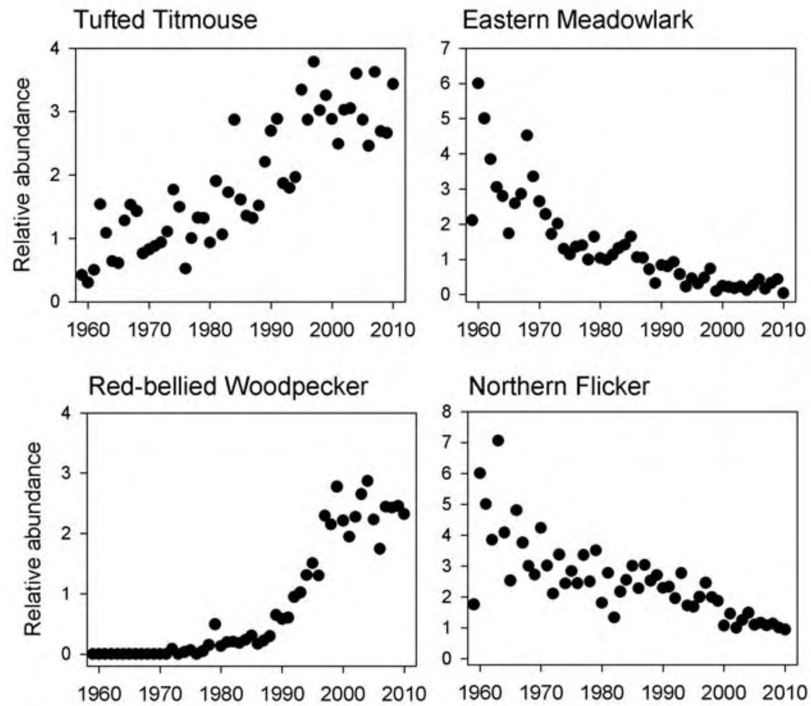
Changes in Biodiversity

Historic shifts in biodiversity have occurred in response to a variety of factors, chief among them: changing land use, human settlement, and climate change. Systematic long-term records are available for few taxonomic groups. One exception is bird populations, which have long been monitored by skilled volunteer birders. For Dutchess County, these records have been kept by the Waterman Bird Club (http://www.watermanbirdclub.org/). Plots of the group's May census data produce several distinctive trends. Many woodland and yard birds have increased as woodland habitat and suburban environments have expanded (for example the tufted titmouse, Figure 6.5). Another evident trend seems to be an increase in populations of southern species, such as northern cardinal, Carolina wren, and red-bellied woodpecker. Populations of many open country birds, such as grasshopper sparrow and eastern meadowlark, have declined in recent decades, reflecting a decline in grassland habitat availability. However, some open country birds have remained relatively stable, possibly those that can tolerate relatively small fragments of open country (bobolink, savannah sparrow).

Mammal population shifts parallel those in the Hudson Valley as a whole. These shifts have included declines in habitat specialists, including amphibian species and turtles, and declines in many invertebrates, including some migratory species such as monarch butterflies. Trends have also included increasing populations of white-tailed deer, which thrive on wooded edges and in suburbs, as well as raccoons and opossums and coyotes, which adapt readily to suburban and urban conditions.

Amphibian populations are of concern because they are known to be declining globally and nationally. Causes of declines generally include habitat loss, chemical contamination (for example, from agricultural pesticides), introduced pathogens, road mortality, predation, and possibly other factors. The North American Amphibian Monitoring Initiative, founded in 2000, has been collaborating with the DEC to assess and monitor Hudson Valley amphibians since 2008. Thus little local information is available, but reasons for concern for amphibians are well established.

Figure 6.5: Relative species abundance, 1959-2010. Trends in woodland bird populations are consistent expansion of tree cover in Dutchess County, as well as increases in suburban yard birds (e.g., Tufted Titmouse, Red-bellied Woodpecker). Open grassland, farmlands, and hayfields have declined, as have open-country birds (e.g., Western Meadowlark, Northern Flicker).[5]



Current Threats to Biodiversity

Habitat Loss

Habitat loss is perhaps the most important cause of lost biodiversity globally. In Dutchess County, the nature of habitat loss is primarily the loss of unfragmented forest, resulting from expansion of suburbs, and decline of open hay fields and pastures. Fragmentation of expansive habitat areas is a special case of habitat loss: some species are understood to survive most readily within core areas of large woodlands or grasslands. For these species, expansive woodland provides suitable habitat; for those that don't require habitat, unfragmented habitat also supports larger populations and promotes genetic diversity, compared to isolated and fragmented populations.

Invasive and Exotic Species

The spread of invasive plant species, especially vine types, is also a dramatic trend in recent years. In particular there is mile-a-minute, porcelain berry, Asiatic bittersweet, Japanese knotweed, and

[5] Graphs from May census data, http://watermanbirdclub.org. To estimate relative abundance over time, it was necessary to adjust for increasing detection rates (more birds counted per observer) over time. Thus Y axes show species counts divided by the third quartile of all species counts in a year, not actual counts. The third quartile was used to normalize counts because the mean is weighted by large outliers, while the median varies little over time, owing to large numbers of 0 counts each year. Graphs created from R.T.Waterman Bird Club data by M.A. Cunningham, 2010.

Japanese stiltgrass. Many previous invaders, such as ailanthus (tree of heaven), purple loosestrife, and leafy spurge, have become established as part of the local community. Invasive species include animals and pathogens, as well. European starlings, house sparrows, rock pigeons, and house finches are common, introduced urban birds. Pathogens are important invaders, as well. Lyme disease is a pathogen that has spread through the region in the recent decades, and tree pathogens such as Dutch elm disease and beech blight have dramatically altered the composition of Dutchess County forests. New invertebrate invaders, including the Asian long-horned beetle and the emerald ash borer, may cause the next round of ecological transitions in our region. At the time of writing, the emerald ash borer is present in western NY and Ulster County but has not yet been recorded in Dutchess County. How this and others will modify forest conditions remains to be seen.

Biotic Impacts

Impacts of predation, herbivory, and competition among resident species can alter habitats and biological communities. Predation by "subsidized predators," or predators aided by human settlement, including house cats, raccoons, skunks, or coyotes, can impact survival of birds, turtles, amphibians, and other animals. White-tail deer might be called subsidized browsers, as they thrive on forest edges, lawns, and gardens of suburban areas. Impacts of deer browsing on the forest community include dramatic reduction of understory habitat and groundcover, which provides essential nesting cover for many birds. Deer also alter forest tree composition, as they selectively browse the most palatable seedlings, such as sugar maple and yellow birch, and leave behind less palatable species, such as Norway maple and American beech. Many subsidized predators and herbivores are aided not only by their ready adaptation to human settlement but also by removal of natural predators, such as wolves.

Wetland loss

Destruction of wetlands is legally restricted for those greater than 12.4 acres (5 hectares), and a 100 foot buffer around these wetlands, but smaller wetlands remain vulnerable to development and drainage. These are a particular concern for seasonal woodland pools, which may be invisible to the eye for much of the year. Often these wetlands occur as wetland complexes with extensive underground interconnections. Development of nearby upland areas can interfere with subterranean flow, increase the rate of runoff, or introduce contaminants to these wetland complexes.

Damage to riparian zones

Loss of stream-side (riparian) zones can alter in-stream habitats by increasing sediment, chemical, and salt inputs into streams. Riparian zones are critical environments for upland species, such as birds that nest and forage in stream-side shrubs, as well as for in-stream organisms such as turtles, frogs and invertebrates. Riparian habitat is especially important in urban areas, where water and undisturbed shrub environments are otherwise uncommon. Normally the riparian zone is protected from new development in local master plans or comprehensive plans. But the width of the riparian zone is defined differently by different localities (see NRI Chapter 5: Water Resources). Minimum standards are frequently 25 feet, but a buffer of 100 feet or more is of value for stream health and for habitat provision in the riparian corridor. Runoff of nutrients, sediment, and other contaminants is affected by amounts of development within 300 feet or more (Cunningham et al., 2010). Loss and degradation of these habitats remains an important consideration in biodiversity conservation beyond the stream corridor itself.

Water contamination

Water quality affects the health, biodiversity, and composition of in-stream biotic community, even in relatively undeveloped areas. Principal contaminants in surface waters in Dutchess County include road salt, excess nutrients (which increase algae populations), and sediment, and high temperatures. Road salt has widespread impacts because roads are widely distributed across the county. In general, salt levels in streams increase proportionally as the area of roads and other impervious surfaces increase (Cunningham et al., 2009), so that urbanized areas have high salt levels and rural areas have low to moderate salt levels. Salinity affects the survival of invertebrates and other instream organisms that require clear, fresh water. Nutrients from waste treatment plants, fertilizers, septic systems, and leaking sewer systems, can reduce in-stream biodiversity by causing excessive growth of algae in streams and ponds. Sediment, such as sand or silt, derives from exposed soil or from pavement, and constant sediment influx can smother rocky habitat in the substrate and maintains an unstable stream bed. In-stream biotic diversity is also degraded by warm temperatures, which result from extensive pavement and from turbidity in water that absorbs solar heat. Reduced riparian vegetation also exposes streams to solar heating and raises temperatures. (For further discussion on water quality, see NRI Chapter 5: Water Resources.)

Climate Change

Warming winters, longer summers, and possibly deeper droughts in summer are already having important impacts on biological communties in our area, although at present many of the observations are anecdotal. Impacts on biodiversity are likely to involve northward shifts in populations of vegetation, animals, and diseases or parasites that affect wildlife or plants, as well as increased prevalence of invasive species. In many areas of New York, including Dutchess County, cold winters previously prevented the survival of many invasive species, which can cause dramatic shifts in habitat and biotic communities. Examples include deer ticks and tick-borne diseases, or the wooly adelgid, a minute aphid-like insect that has depleted hemlock stands in warm climates. Forest composition is expected to change considerably as a consequence of climate change. For further details, see NRI Chapter 2: Climate and Air Quality.

IMPLICATIONS FOR DECISION-MAKING

Communities can use the ideas outlined above to identify priority habitats or species, contiguous habitat areas, or other important areas that are biologically important. Communities should then prepare to work with landowners in developing plans for clustered development, for low-impact design, or other strategies that can support biological diversity on private lands.

Communities can also work within the various policy frameworks that protect biodiversity. Biological resources are protected by laws at the federal and state level, as well as by policies outlined in local comprehensive plans. In this section we identify some of the legal frameworks and policies that can be useful for decision making when planning for biodiversity conservation.

Developing policy for biodiversity conservation

While laws to protect biodiversity have been enacted at the federal and state level, New York is a home-rule state, which means that local municipalities hold considerable power to set land use policies, to outline plans for biodiversity protection, and to regulate land use. Thus local areas are legally empowered to make decisions, but they also have responsibility for policy making through zoning and local planning processes. Citizens can wield considerable influence by attending local planning meetings, municipal council meetings, and zoning board meetings.

Municipal and county comprehensive plans outline the general intent regarding development and land use. Development plans can then be evaluated on whether or not they are consistent with an accepted plan. Examples of master plans, with statements of intent for open space and biodiversity conservation, can be found on line, such as those from the Town of Clinton, the Town of Beekman, or the Town of Poughkeepsie. In principle, plans are to be revised approximately every decade, and these revision processes are points at which local residents can weigh in on priorities they would like to see established in the town plan.

While a master plan, or comprehensive plan, lays out the intent of a community, the zoning code identifies legally enforceable rules for land use. Zoning codes are usually available online for each town in Dutchess County. Exceptions and appeals to zoning rules are frequently discussed by town Zoning Boards, and these board meetings can provide important opportunities for citizens to learn about or influence local land use decisions.

In addition to these policy settings, there are many additional opportunities for municipalities to influence biodiversity protection or to seek aid in projects that can support local biodiversity. These include policies and organizations such as the Hudson River Greenway Compact, the Hudson River Watershed Alliance, the Open Space and Farmland Protection Plan, and many others.

In addition to these policies and legal structures, habitat conservation strategies include conservation easements and transfer of development rights. Conservation easements are clauses attached to deeds that restrict future development. Transfer (or purchase) of development rights involves payment to landowners today to control development rights in the future. Alternatively, development rights can be exchanged from one property to another. As with conservation easements, a non-profit organization normally purchase or holds development rights. A review of these options has been provided by Hudsonia, Inc.

Legal protections

The principal legal mechanism for environmental review in New York is the State Environmental Quality Review (SEQR). Like the federal government's Environmental Impact Statement, a SEQR study identifies probable environmental impacts and outlines how a project will address those impacts. State, county, and local governments can act to enforce the SEQR process. In addition, since 2005, all environmental impact statements must be posted online for public access. Thus citizens have access to examine the contents of review findings.

The importance of biodiversity for its own sake has been acknowledged in the formation of legal codes that protect species and their habitat. There are legal protections for rare, threatened, and endangered, and migratory species, in efforts to minimize threats to biodiversity. Agencies that administer these regulations usually also provide assistance to landowners. Because landowner participation is so important in conservation in the New York, the US Fish and Wildlife Service and other agencies are charged with helping landowners design conservation plans, devise plans for development that maximize habitat conservation, and provide grants for assistance in habitat conservation.

Biodiversity is protected most specifically at the federal level by the Endangered Species Act of 1973, which defines and lists rare, threatened, vulnerable, and endangered species both nationally and regionally. The ESA also provides assistance in planning for habitat conservation, and it provides a framework for enforcing species protection laws if necessary. The Migratory Bird Treaty Act of 1918 is one of our earlier landmark species protection laws that allows for protection of wild birds. These and other federal policies can provide the most general policy protection for biodiversity in our area, if local polices prove insufficient.

RESOURCES FOR ADDITONAL INFORMATION

A wealth of resources are available for understanding biodiversity in our region, including (but not limited to) documents from the New York DEC (http://www.dec.ny.gov/lands/5094.html), the New York Natural Heritage Program (http://www.dec.ny.gov/animals/29338.html), and education programs from Hudsonia Ltd. (http://hudsonia.org/education). The New York Natural Heritage Program in particular documents species and their habitats, as well as providing conservation guides and fact sheets about individual species' needs. Strong (2008), in cooperation with the DEC and Cornell Cooperative Extension, has provided many of the arguments and justifications for understanding how to plan for biodiversity conservation in the Hudson River Valley.

Educational institutions and community organizations are also resources for understanding local biodiversity. The Cary Institute of Ecosystem Studies, Cornell Cooperative Extension Dutchess County, the New York DEC (field station at Norrie Point, Stony Kill Farm), and local colleges are among the many institutions in our area that offer public talks, ecology walks, and training sessions. Citizen groups such as the Ralph T. Waterman Bird Club (http://watermanbirdclub.org) and local watershed groups (http://dutchesswatersheds.org) hold educational events and nature walks that attract people from within the county and beyond it.

- **NYS DEC Species Conservation overview**: http://www.dec.ny.gov/animals/279.html
- **Dutchess County Greenway Guides:** http://www.co.dutchess.ny.us/CountyGov/Departments/Planning/17329.htm
- **Dutchess County Planning and Development:** http://www.co.dutchess.ny.us/CountyGov/Departments/Planning/PLIndex.htm
- **New York Natural Heritage Conservation Guides:** http://www.acris.nynhp.org/
Conservation guides are comprehensive fact sheets about individual rare species and natural community types that are designed to help land managers, decision-makers, planners, scientists, consultants, students, and the interested public better understand the biodiversity that characterizes New York. Conservation Guides include information on biology, identification, habitat, distribution, conservation, and management. Guides are completed for many of New York's rare species and natural community types, and more are continually being added to the Guides website.
- **NYS DEC Ecological Community Information:** http://www.dec.ny.gov/animals/29338.html
Ecology staff assess and delineate New York's natural communities which are variable assemblages of interacting plant and animal populations that share a common environment.
- **Northern Wallkill Biodiversity Plan:** http://www.ecostudies.org/mca/13_Northern_Wallkill_Biodiversity_Plan.pdf
LaBruna, D. T., and M. W. Klemens. Northern Wallkill Biodiversity Plan: Balancing Development and Environmental Stewardship in the Hudson River Estuary Watershed. Bronx, NY: MCA Technical Paper No. 13. Metropolitan Conservation Alliance, Wildlife Conservation Society, 2007.

- **Hudsonia Ltd.:** (http://hudsonia.org/education).

REFERENCES

Bell, Kristen, C. Dickert, J. Tollefson and G. Stevens. Significant habitats in the Town of Stanford, Dutchess County, New York. Annandale, NY: Hudsonia Ltd., 2005.

Bryce, S.A., G.E. Griffith, J.M. Omernik, G. Edinger, S. Indrick, O. Vargas and D. Carlson. *Ecological regions of New York* [color poster with map, descriptive text, summary tables, and photographs]. 1:1,250,000. Reston, Virginia: U.S. Geological Survey, 2010.

Cowardin, L. M., V. Carter, F. C. Golet, E. T. LaRoe. "Classification of wetlands and deepwater habitats of the United States." *Northern Prairie Publication 0421*. U.S. Department of the Interior, Fish and Wildlife Service, Washington, D.C. Jamestown, ND: Northern Prairie Wildlife Research Center, 1979. http://www.npwrc.usgs.gov/resource/wetlands/classwet/index.htm (Version 04DEC1998).

Cunningham, M.A., C. M. O'Reilly, K.M. Menking, K.M., D.P. Gillikin, K.C. Smith, C.M. Foley, S.L. Belli, A.M. Pregnall, M.A. Schlessman and P. Batur.. The suburban stream syndrome: Evaluating land use and stream impairments in the suburbs. *Physical Geography* 30, 3 (2009): 269–284.

Cunningham, M.A., K.M. Menking, D.P. Gillikin, K.C. Smith, C.P. Freimuth, S.L. Belli, A.M. Pregnall, M.A. Schlessman and P. Batur. Influence of open space on water quality in an urban stream. *Physical Geography* 31, 4 (2010):336–356.

Dutchess County Legislature. "A Local Law to Establish a County Environmental Management Council." Resolution No. 58. Poughkeepsie, NY: Dutchess County Legislature, 1972.

Edinger, G.J., D.J. Evans, S. Gebauer, T.G. Howard, D.M. Hunt, and A.M. Olivero, editors. "Ecological Communities of New York State, 2nd ed." A revised and expanded edition of Carol Reschke's *Ecological Communities of New York State*. (Draft for review). Albany, NY: New York Natural Heritage Program, New York State Department of Environmental Conservation, 2002. http://www.dec.ny.gov/animals/29392.html

Kiviat, E. and G. Stevens. *Biodiversity Assessment Manual for the Hudson River Estuary Corridor*. Red Hook, NY: Hudsonia Inc., 2001.

National Oceanic and Atmospheric Administration Coastal Services Center (NOAACSC). C-CAP zone 64 2006-Era Land Cover Metadata. Charleston, SC.: 2007.

NYS Dept. of Environmental Conservation. *Critical Environmental Areas* (vector digital data): Albany, NY: 2007.

Strong, K. *Conserving Natural Areas and Wildlife in Your Community: Smart Growth Strategies for Protecting the Biological Diversity of New York's Hudson River Valley*. Ithaca, NY: New York Cooperative Fish and Wildlife Research Unit, Cornell University, and New York State Department of Environmental Conservation, Hudson River Estuary Program, 2008.

United Nations Convention on Biological Diversity. Rio de Janeiro, Argentina: 1992. http://www.cbd.int/

US Geological Survey. "Resource Management Evaluation and Study of Saltwater Movement Within the Transition Zone of the Hudson River Estuary, New York (NY 88-175)." USGS, last modified April 25, 2003, http://ny.water.usgs.gov/projects/dialer_plots/hsfmis.html

Wills, Robert. "Biodiversity Blocks: A Sensible, Science-Based Way to Define Greenspaces." *Plan On It: Dutchess County Planning Federation eNewsletter*. Poughkeepsie, NY: Dutchess County Planning Federation, September 2010. http://www.co.dutchess.ny.us/CountyGov/Departments/Planning/planonit092010.pdf

Appendix 1. Animal, plant, and habitat guides listed for Dutchess County by the NY Natural Heritage Program. Species are not distinguished here by status designations (such as rare, threatened, or vulnerable). See guides linked below or the NYNHP website for further details. Source: NYNHP http://www.acris.nynhp.org/search.php.

Animal Guides
Sort by: -Common Name- -Scientific Name-

A Noctuid Moth *Fagitana littera*	**Alewife Floater** *Anodonta implicata*	**Atlantic Needlefish** *Strongylura marina*
Atlantic Sturgeon *Acipenser oxyrinchus*	**Bald Eagle** *Haliaeetus leucocephalus*	**Barn Owl** *Tyto alba*
Blanding's Turtle *Emydoidea blandingii*	**Bog Turtle** *Glyptemys muhlenbergii*	**Common Loon** *Gavia immer*
Dwarf Wedgemussel *Alasmidonta heterodon*	**Eastern Pondmussel** *Ligumia nasuta*	**Eastern Spadefoot** *Scaphiopus holbrookii*
Fence Lizard *Sceloporus undulatus*	**Golden Eagle** *Aquila chrysaetos*	**Great Blue Heron** *Ardea herodias*
Indiana Bat *Myotis sodalis*	**Kentucky Warbler** *Oporornis formosus*	**King Rail** *Rallus elegans*
Least Bittern *Ixobrychus exilis*	**Mocha Emerald** *Somatochlora linearis*	**New England Cottontail** *Sylvilagus transitionalis*
Northern Cricket Frog *Acris crepitans*	**Northern Harrier** *Circus cyaneus*	**Northern Metalmark** *Calephelis borealis*
Peregrine Falcon *Falco peregrinus*	**Pied-billed Grebe** *Podilymbus podiceps*	**Russet-tipped Clubtail** *Stylurus plagiatus*
Sedge Wren *Cistothorus platensis*	**Shortnose Sturgeon** *Acipenser brevirostrum*	**Southern Leopard Frog** *Rana sphenocephala*
Spatterdock Darner *Rhionaeschna mutata*	**Tawny Emperor** *Asterocampa clyton*	**Timber Rattlesnake** *Crotalus horridus*
Upland Sandpiper *Bartramia longicauda*	**Worm Snake** *Carphophis amoenus*	**Yellow Lampmussel** *Lampsilis cariosa*

Plant Guides

Sort by: -Common Name- -Scientific Name-

American Waterwort *Elatine americana*	**Back's Sedge** *Carex backii*	**Basil Mountain-mint** *Pycnanthemum clinopodioides*
Black Sedge *Carex nigra*	**Brown Bog Sedge** *Carex buxbaumii*	**Button-bush Dodder** *Cuscuta cephalanthi*
Carey's Smartweed *Persicaria careyi*	**Carolina Whitlow-grass** *Draba reptans*	**Cat-tail Sedge** *Carex typhina*
Clustered Sedge *Carex cumulata*	**Davis' Sedge** *Carex davisii*	**Delmarva Beggar-ticks** *Bidens bidentoides*
Dragon's Mouth Orchid *Arethusa bulbosa*	**Drummond's Rock-cress** *Boechera stricta*	**Dwarf Bulrush** *Lipocarpha micrantha*
Estuary Beggar-ticks *Bidens hyperborea* var. *hyperborea*	**Fairy Wand** *Chamaelirium luteum*	**Fernald's Sedge** *Carex merritt-fernaldii*
Glaucous Sedge *Carex glaucodea*	**Golden Club** *Orontium aquaticum*	**Golden Corydalis** *Corydalis aurea*
Golden-seal *Hydrastis canadensis*	**Green Milkweed** *Asclepias viridiflora*	**Gypsy-wort** *Lycopus rubellus*
Handsome Sedge *Carex formosa*	**Heartleaf Plantain** *Plantago cordata*	**Hill's Pondweed** *Potamogeton hillii*
Hooker's Orchid *Platanthera hookeri*	**Hudson River Water-nymph** *Najas guadalupensis* ssp. *muenscheri*	**Knotted Spikerush** *Eleocharis equisetoides*
Large Twayblade *Liparis liliifolia*	**Marsh Horsetail** *Equisetum palustre*	**Marsh Valerian** *Valeriana uliginosa*
Meadow Horsetail *Equisetum pratense*	**Mock-pennyroyal** *Hedeoma hispida*	**Mountain Spleenwort** *Asplenium montanum*
Narrow-leaved Sedge *Carex amphibola*	**Northern Blazing-star** *Liatris scariosa* var. *novae-angliae*	**Northern Bog Aster** *Symphyotrichum boreale*

 **Northern Reedgrass** *Calamagrostis stricta*

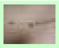
 **Ogden's Pondweed** *Potamogeton ogdenii*

 **Ovate Spikerush** *Eleocharis ovata*

 **Pod Grass** *Scheuchzeria palustris*

 **Purple Milkweed** *Asclepias purpurascens*

 **Rattlebox** *Crotalaria sagittalis*

 **Reflexed Sedge** *Carex retroflexa*

 **Riverbank Quillwort** *Isoetes riparia*

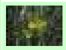
 **Rough Avens** *Geum virginianum*

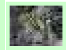
 **Scarlet Indian-paintbrush** *Castilleja coccinea*

 **Schweinitz's Sedge** *Carex schweinitzii*

 **Shining Bedstraw** *Galium concinnum*

 **Side-oats Grama** *Bouteloua curtipendula* var. *curtipendula*

 **Smooth Bur-marigold** *Bidens laevis*

 **Smooth Cliff Brake** *Pellaea glabella* ssp. *glabella*

 **Southern Yellow Flax** *Linum medium* var. *texanum*

 **Spongy Arrowhead** *Sagittaria montevidensis* var. *spongiosa*

 **Spotted Pondweed** *Potamogeton pulcher*

 **Stiff-leaf Goldenrod** *Oligoneuron rigidum* var. *rigidum*

 **Straw Sedge** *Carex straminea*

 **Swamp Birch** *Betula pumila*

 **Swamp Cottonwood** *Populus heterophylla*

 **Swamp Lousewort** *Pedicularis lanceolata*

 Tinged Sedge *Carex tincta*

 **Torrey's Mountain-mint** *Pycnanthemum torrei*

 **Two-ranked moss** *Pseudotaxiphyllum distichaceum*

 **Violet Wood-sorrel** *Oxalis violacea*

 **Virginia False Gromwell** *Onosmodium virginianum*

 **Woodland Agrimony** *Agrimonia rostellata*

 **Woolly Lip-fern** *Cheilanthes lanosa*

 **Yellow Giant-hyssop** *Agastache nepetoides*

Community Guides

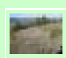
 **Acidic Talus Slope Woodland**

 **Appalachian Oak-Hickory Forest**

 **Brackish Intertidal Mudflats**

 **Brackish Tidal Marsh**

 **Calcareous Cliff Community**

 **Calcareous Red Cedar Barrens**

 Chestnut Oak Forest

 Deep Emergent Marsh

 Dwarf Shrub Bog

 Floodplain Forest

 Freshwater Intertidal Mudflats

 Freshwater Intertidal Shore

 Freshwater Tidal Marsh

 Freshwater Tidal Swamp

 Hemlock-Northern Hardwood Forest

 Limestone Woodland

 Maple-Basswood Rich Mesic Forest

 Medium Fen

 Oak-Tulip Tree Forest

 Pitch Pine-Oak-Heath Rocky Summit

 Post Oak-Blackjack Oak Barrens

 Red Cedar Rocky Summit

 Red Maple-Hardwood Swamp

 Rich Graminoid Fen

 Rich Shrub Fen

 Rich Sloping Fen

 Rocky Summit Grassland

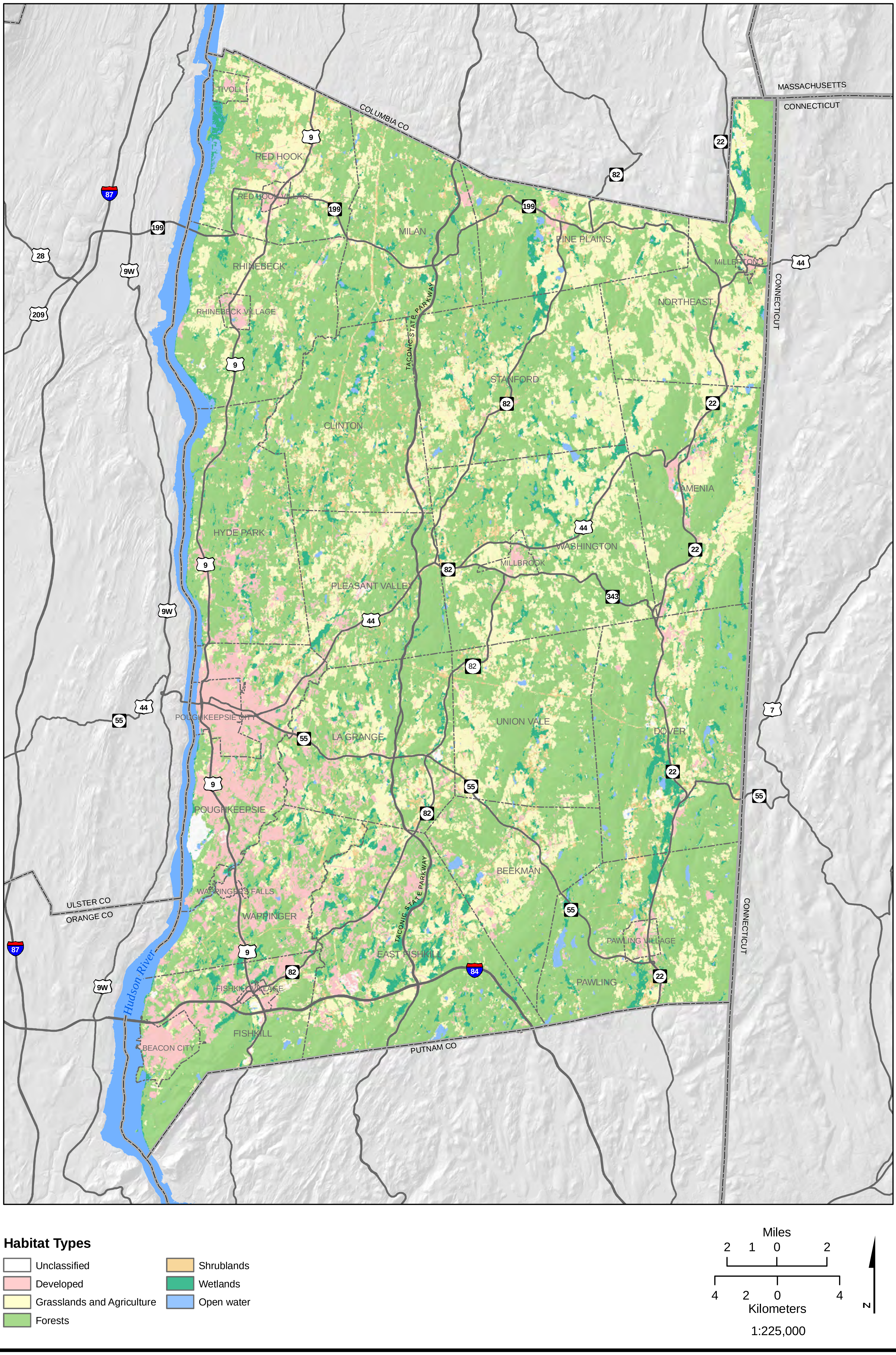
 Sedge Meadow

 Tidal River

Map 6.1: Habitat Types

Dutchess County, New York

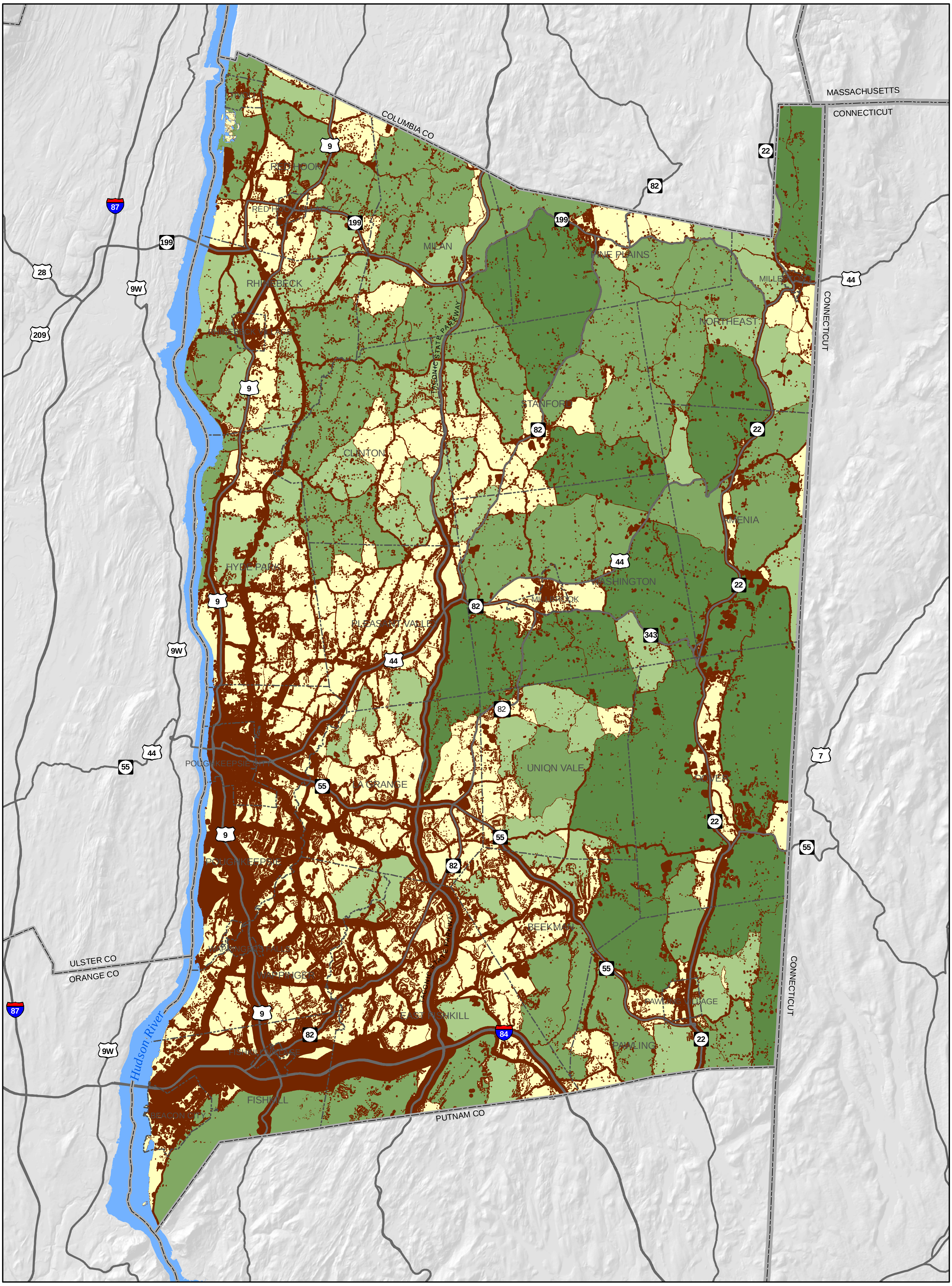
Prepared by:
CCEDC GIS Lab, 2010



Map 6.2: Biodiversity Blocks

Dutchess County, New York

Prepared by:
CCEDC GIS Lab, 2010



Biodiversity Blocks (acres)

- > 0 - 1000
- > 1000 - 2000
- > 2000 - 6000
- > 6000
- Human Activity Buffers

Miles
2 1 0 2

4 2 0 4
Kilometers

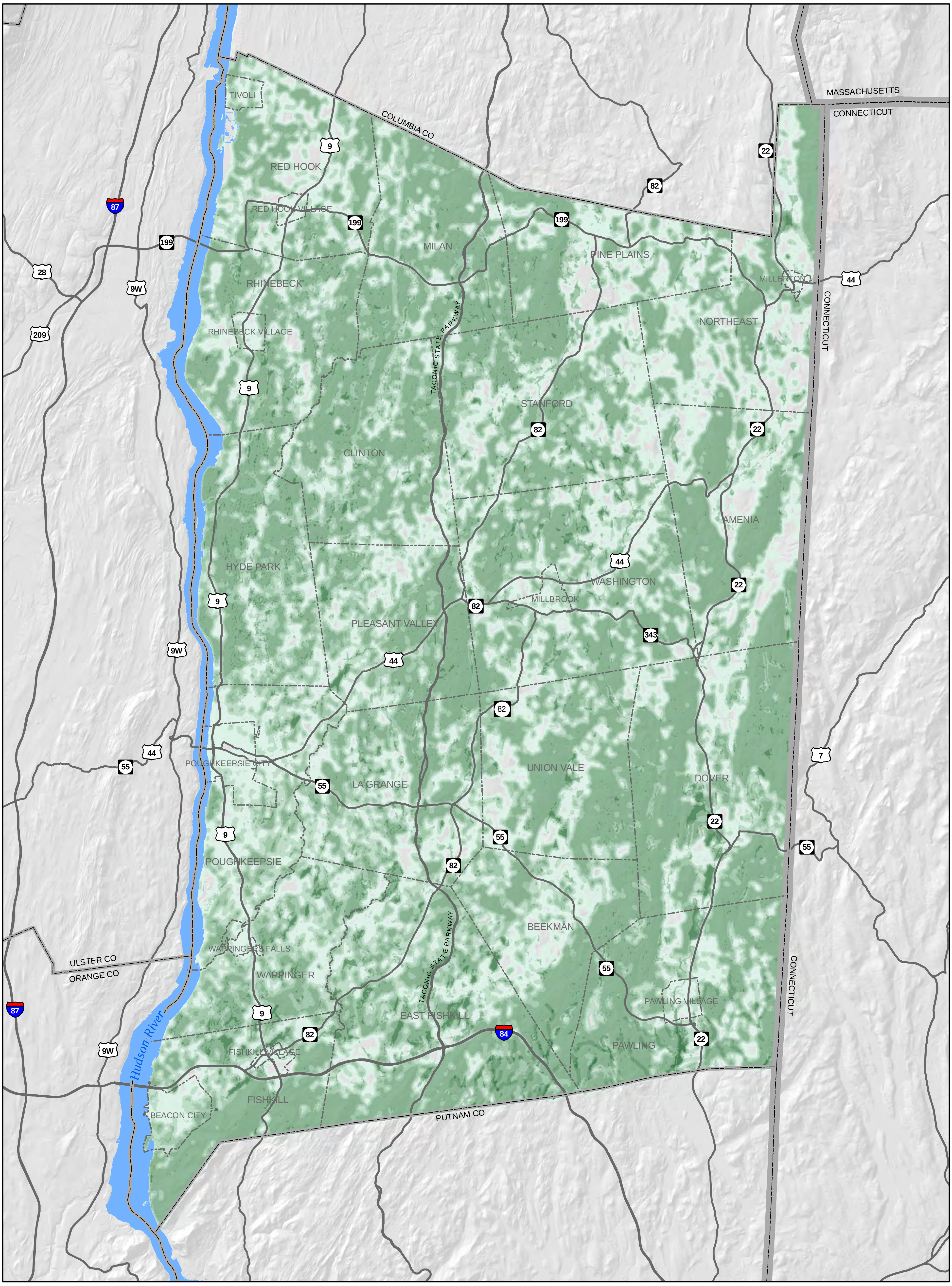
1:225,000

N

Map 6.3: Habitat Index

Dutchess County, New York

Prepared by:
CCEDC GIS Lab, 2010



Habitat Index*

- 1
- 2
- 3
- 4
- 5
- 6
- 7

* Habitat index values represent the sum of key habitat attributes identified by Strong et al., 2008 (Table 6.1): amount of forest cover, wetlands, stream corridors, and seasonal wetlands. Dark areas represent areas of core and high value habitats, while lighter areas show edge and lower value habitats.

Miles
2 1 0 2

4 2 0 4
Kilometers

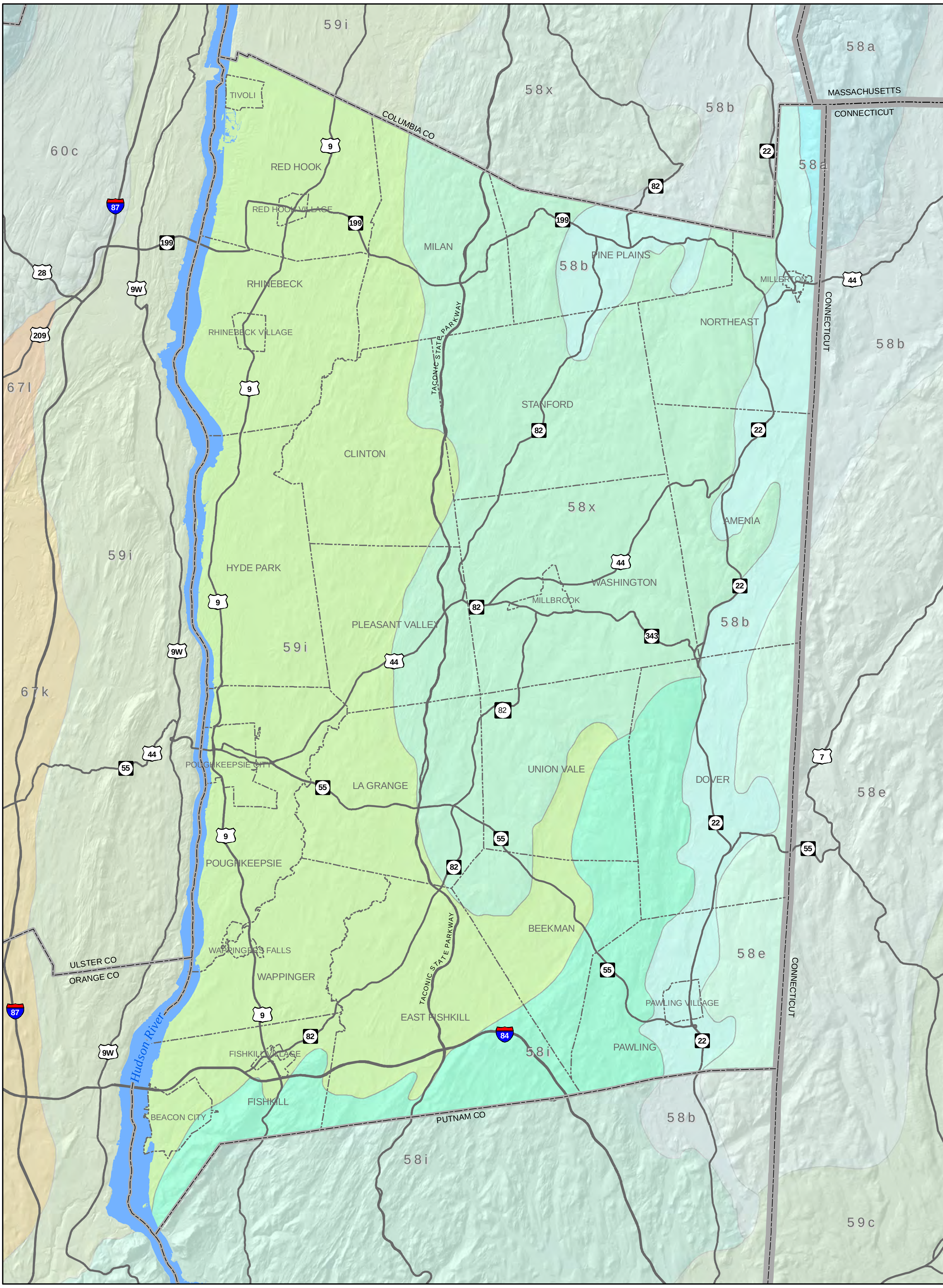
1:225,000

N

Map 6.4: Ecological Regions

Dutchess County, New York

Prepared by:
CCEDC GIS Lab, 2010



Ecological Regions of Dutchess County

- 58a Taconic Mountains
- 58b Western New England Marble Valleys
- 58e Berkshire Transition
- 58i Glaciated Reading Prong/Hudson Highlands
- 58x Taconic Foothills
- 59i Hudson Valley

Miles: 2 1 0 2
Kilometers: 4 2 0 4

1:225,000

N

Chapter 8:

Geospatial Resources of Dutchess County, NY

Robert Wills and Neil Curri[1]
October 2010

INTRODUCTION

Chapter Contents

The Natural Resource Inventory of Dutchess County, NY gives our communities and the public a detailed look at our rich and varied natural environment, while describing the natural and man-made forces affecting it and its health. It is a living document that will be updated periodically, so the public, in their private and civic actions, can consider the consequences of their actions on nature, and temper or alter them as appropriate to minimize any negative effect.

The inventory of natural resources for the county was first published in 1985. Although similar in format to the original, the 2010 version makes great

[1] This chapter was written during 2010 by Robert Wills (Dutchess County Department of Planning and Development) and Neil Curri (Cornell Cooperative Extension Dutchess County Environment & Energy Program). The document was reviewed by Dr. Phil Thibault (Dutchess County Office of Computer Information Systems).

use of digital technology in the form of **Geographic Information Systems** (www.gis.com) to create, store, and analyze the accurate digital representations of environmental features, and through the internet to communicate concepts and policies through maps. This chapter will provide an explanation of how this data was developed, and how it can be used in support of environmentally responsible land use decisions.

Making a map has been the traditional method of documenting a natural resource. For example, in one of the first maps of a section of the original Nine Partners Patent, a subjective delineation of features found on the ground was recorded on paper (Figure 8.1).

Figure 8.1: Janet Livingston Map of Rhinebeck, circa 1803

In the first Dutchess County Soils maps published in 1939, field survey and paper maps were the tool and communication device to record and disseminate this information. With the invention and wide-spread use of the Global Positioning System (GPS) and Geographic Information Systems (GIS), natural resource data can now be collected and mapped on a more regular basis and with much greater accuracy than in the past.

All of the natural resource information in the county is now in electronic form and available to municipalities and the public, either for their use within a GIS or as customized maps.

Throughout the Natural Resource Inventory, data are used to illustrate the relationships we have with the elements of our environment and the consequences our actions have on nature. Much of this data describes a place – whether a bird's nest or stream bank, back yard or municipality, it is geographic in nature, and has a location as part of its definition. Location is the unifying element of the data: given a place (like an address), inferences can be made about the conditions present at that location.

Figure 8.2: Creed Ankony Farm in the Town of Rhinebeck

We rely on **geographic analysis** to help us understand the complicated relationships between the things we see in our landscapes. "What caused a wetland to form at that spot?" "Why is that plant community present at the base of that hill?" For example, one layer of polygons might represent areas of fertile soils; another, areas of gentle slope. A third layer might focus on only those hillsides facing directly south into strong sunshine. One can imagine each type of data drawn on separate layers of tracing paper. When all the layers are stacked up, one soon sees where characteristics overlay and where they don't. If we assign a value from most suitable to least suitable, based on the quantity of superimposed characteristics, we can begin to make a decision based on a place. Adding up all the occurrences of overlap gives us a high score. What we may have found in this example is a good location for a vegetable garden. This is what GIS does for us electronically, with any of our locally produced data layers, or with those which can be found on the internet (Figure 8.3).

Figure 8.3: Example of GIS data layers

The Natural Resource Inventory is a similar, but comprehensive, collection of layers of geographic information representing ecosystems and natural features. By design, each of the layers overlays one another, registered to coordinates common to all -- the boundaries of the county. Further, this collection overlays all other county geographic data, including temporal data (such as tax parcel boundaries) and physical features (such as structures and roads). Because of this connection, powerful analysis can occur, giving us a rich and dynamic look at the characteristics of a place.

The concept of overlaying layers of environmental information as a foundation for understanding people's relationship to nature was pioneered by the planner and philosopher, Ian McHarg. In his landmark book published in 1969, "Design with Nature", McHarg lays out a framework for using environmental information in land planning exactly like the previous example about our vegetable garden. In an ecological approach, humans come to understand the specialness and limitations of nature, designing their habitats *with* nature in mind, not in opposition or ignorance to it. GIS and the overlay of data about natural systems help us see this relationship clearly.

Figure 8.4: Overlay Mapping, a precursor to modern GIS analysis

"It's not a stretch to say that the development of GIS technology and the entire industry around it was profoundly influenced by the work of McHarg. He popularized the overlay concept and laid the groundwork for what was to become GIS, thus taking a number of budding young landscape architects and geographers and changing their lives forever."

- Jack Dangermond, Environmental Systems Research Institute President, in ArcNews Online Summer 2009

Dutchess County has invested considerable amounts in not only the creation of the data behind the Natural Resource Inventory, but in its dissemination to the public through our website: www.co.dutchess.ny.us/CountyGov/Mapping.htm Please visit often.

GIS HISTORY IN DUTCHESS COUNTY

Understanding the history of GIS development in the county is integral to understanding how the data supporting the Natural Resource Inventory can be correctly used. GIS data in the county was created by many organizations, using many different methods, over a twenty-five year period. Inherent in each method is a level of accuracy that likely will vary substantially from another method. As the position of features will be affected, any analysis that uses methods which superimpose one layer on another must be designed to account for these imprecisions.

Geographic Information Systems were developed in the late-1960s by the Government of Canada. The first commercially available GIS was developed in the 1970s by the Environmental Systems Research Institute (ESRI). In the mid-1980s, the first use of GIS in Dutchess County was a joint effort between The Rockefeller University Field Station and the Environmental Management Council (EMC). Through this partnership, many base environmental layers were developed and used in the first edition of the Natural Resource Inventory in 1985. In 1986, Dutchess County Government organized the GIS Executive Committee to coordinate the GIS efforts of any interested county entity. Besides county departments, the EMC, Central Hudson, Dutchess Community College, and several municipalities participated. Interestingly, it was 1988 when IBM submitted the first proposal for a unified, county-wide GIS, to the tune of over $2 million dollars ($3,750,000 in today's dollars), a proposal that was not funded by the Dutchess County Legislature.

During the subsequent decade, while the EMC's GIS Lab flourished, a number of independent initiatives began in Dutchess County. GIS courses were developed and taught at Dutchess Community College, Marist, Vassar, and SUNY New Paltz. The Office of Emergency Response funded the development of Enhanced 911, which included the delineation and addressing of road centerlines. The New York City Department of Environmental Protection awarded the County Real Property Tax Service Agency a $50,000 grant to develop digital real property tax parcel lines for all properties within the NYC watershed boundary. The county purchased the first set of digital aerial photography, based on scans of the US Department of Agriculture's National Air Photo Program for 1995. It was with these layers that departmental initiatives and analysis began in earnest.

In 1999, a study was completed which looked at the current state of GIS operations in the county and presented a vision for the future. The ongoing arrangement, where individual departmental staff exercised their specialized knowledge to create subject-specific geographic information, was respected. However, the need to establish a common base map to which all other data can be referenced, in concert with standards for data creation, was deemed critical to growth and future operations, because it would allow sharing data. It was only within this organizing framework of data and standards that sharing data and analysis among all county departments and municipalities could take place. In this way GIS could grow in an organized fashion. This vision was implemented by the GIS Executive Committee, funded by County Government, and established over subsequent years (Koehler, 1999).

Currently, many county departments and agencies create geographic information, specific to their missions, just as at the turn of the century. Each layer, however, is registered to the common base map or core data layers as we now call them. Data standards allow any municipality, department, or interested party the ability to create new data and share it with other users. Everyone then has the comfort of knowing that layers will overlay and accuracy standards are respected. This framework has also allowed a number of local communities and Conservation Advisory Committees to create their own GIS data, and analyze it along with NRI data and other base data layers like tax parcels. The City of Poughkeepsie, Clinton, Dover, East Fishkill, LaGrange, and Pleasant Valley have been among the leaders in this effort.

Dutchess County has a robust system to put this GIS data investment into the hands of our residents, through on-line applications available to the public and to municipalities. Beginning in 2004, ParcelAccess made possible viewing of Real Property Tax information on all county parcels, and GeoAccess provides a portal to much municipal data. In addition, Dutchess County Office of Computer Information Systems (OCIS) has designed three tools specifically for viewing and analyzing data layers, to answer questions about planning and environmental protection. The ACCESS and Local Data Explorer (LDE) tools, now obsolete, and the current tool, ArcStudio, allow viewing of most county GIS data and queries of the associated data, buffering of features, markups, measuring, and creation of mailing lists. ArcStudio is accessible to municipalities, county employees, and the general public through a Dutchess County GIS workstation. All applications and others continue to evolve with the latest advances in internet and GIS technology. Cooperatively, the Cornell Cooperative Extension (CCEDC) Environment & Energy Program GIS Lab also continues a long history of providing GIS outreach and data access to residents and municipal Conservation Advisory Committees.

Individual GIS data distribution and mapping assistance is available to municipalities, consultants, and individuals both through individual Dutchess County Departments and CCEDC. At this time, there are over 100 published datasets available by request. For a comprehensive list, inquire with departmental GIS contacts listed at the following web page, http://www.co.dutchess.ny.us/CountyGov/14461.htm#Contacts, or log onto a public GIS workstation available at many town government offices, where you can also access the ArcStudio application.

DUTCHESS COUNTY DATA DEVELOPMENT

Over time, Dutchess County has taken steps to standardize data creation methods and quality control procedures. These, along with the use of reference data layers like digital orthophotography to derive new data, has vastly improved the accuracy of newly created data. However, some of this early data is still available and being used right along with data produced more recently. Before embarking on a GIS analysis, one must be aware of these differences.

The accuracy and accessibility of environmental data that we have today was unimaginable when the first NRI was compiled in 1985. Methods of data capture have changed, as have the methods for creating the documentation of the capture, our interpretive maps. Throughout the past twenty-five years, environmental data and maps compiled for the NRI have been either created or acquired by many county departments, and reflect the non-centralized organization of GIS in the county. Improvements in computer technology and remote sensing (acquiring information about an object without being in contact with it) have meant great improvements in data accuracy, and more intuitive and accessible means of analysis and display. Clearly, older geographic data is likely to be less accurate than newly captured data. Caution is warranted when overlaying geographic data of different production dates.

RASTER DATA

Raster data represents features through a continuous matrix of cells, otherwise known as a GRID, as opposed to drawn borders demarcating object A from object B. Although raster data can represent discrete features, it is most suited to continuous data themes such as terrain elevation, temperature, or population (shown in Figure 8.5). Digital photographs are raster data representing variations in color, whereas a digital elevation model (DEM) represents variation in the elevation of terrain.

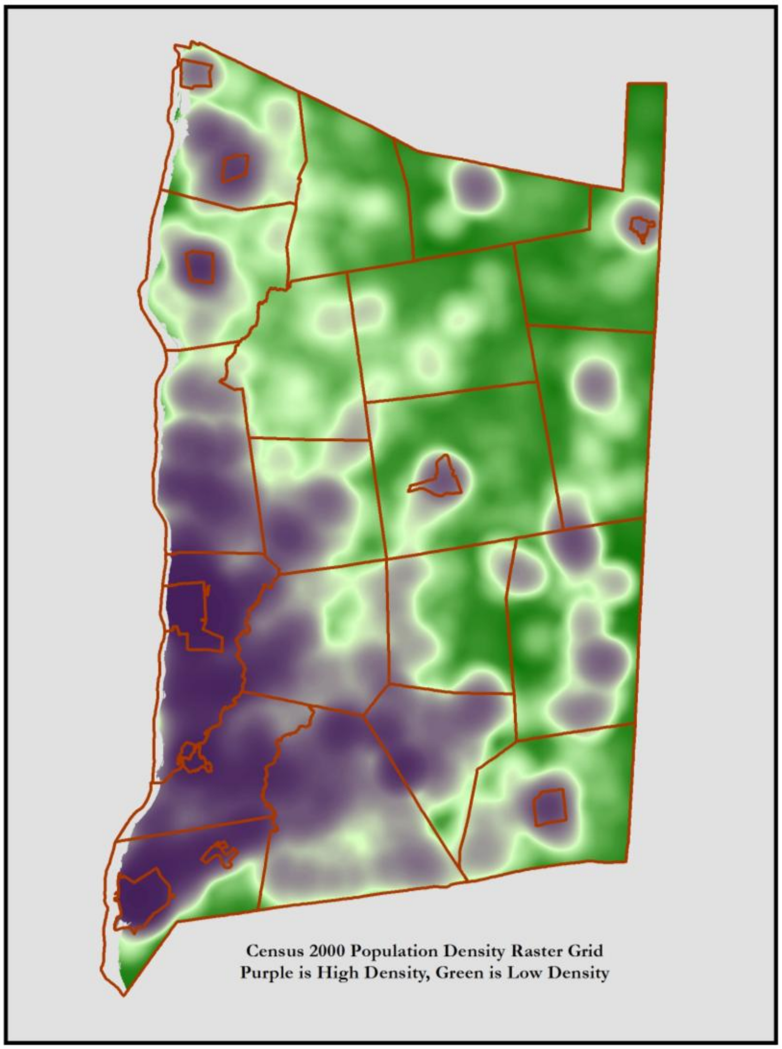


Figure 8.5: Density raster grid of Dutchess County population, from 2000 Census

Raster data can be created either by converting photographs or maps to digital form with an optical scanner, or collected from objects in the environment using remote sensing devices such as aerial cameras, space vehicles, or temperature sensors. Similar to vector data, conversion procedures had to take into account error inherent in the source material, dependant on the quality of the original pictures or in the media upon which it was reproduced. Remote sensing methods also must account for and correct error. In the case of aerial photography, deviations in elevation of the terrain and the position of the camera mounted in the aircraft, as well as the stability of the aircraft, had to be measured and corrected to achieve a high accuracy result. Even the shape of the camera lens affected which portion of the resulting image was within accuracy standards. For example, the 1990 edition of county aerial photography could only be referred to as simple "pictures," as it was not corrected for many of these artifacts. Radial distortion caused by the shape of the camera lens caused an elongation of objects the further they were from the center of the exposure. Nor were the photographs orthorectified, or tied through sophisticated measurement to true ground location. Our current 2009 edition of digital orthophotography has a horizontal accuracy of plus/minus five feet, meaning that the coordinates of 98 percent of objects visible in the photos can be at most five feet from their true ground location.

Current technology has eliminated the need to use film in aerial cameras. Direct-digital imaging is used as the source for orthophotography. All manipulation of the original image to correct for errors introduced by camera lens, etc. is now done directly through computer programs. This eliminates all of the errors introduced in conversion from film to digital media, and can correct some of the aforementioned problems. In addition, the flight vehicle carries Global Positioning System (GPS) equipment that records, with sub-centimeter accuracy, the exact position of the camera at the time each of the photos was taken, which additionally eliminates another source of inaccuracy.

Resolution, or the size of the smallest cell of information capable of being captured, was a factor in what could be seen in the digital file. Obviously, very small features would be lost if the resolution was larger than these features. The storage capacity and speed of computers also dictated how detailed (and therefore how large) a file could be before it was rendered unusable. Because the resolution of space-based remote sensing devices have been so coarse (the latest LANDSAT-7 sensors collect 15-, 30-, and 60-meter resolution) Dutchess County has utilized aircraft-based cameras instead. The 2009 digital orthophotography has a resolution of six inches, making objects as small as one foot across clearly visible. Because of its accuracy and resolution, the 2009 digital orthophotography is the reference layer for all other layers. In fact, **orthophotography** (aerial photography registered to the earth's surface) has long been used as the basis for developing other GIS data comprised of points, lines and polygons (vector data). The American Society for Photogrammetry and Remote Sensing first developed standards for extracting useful information from aerial photography in 1937. Dutchess County Tax Parcel Maps were first created in 1972 using the 1970 edition of orthophotography as a reference.

Figure 8.6: A farmer leading cows from one corral to another, Town of Washington, from the 2009 edition of Dutchess County digital orthophotography

A different type of airplane-mounted sensor is used to collect elevations from our landforms, to develop contour lines and terrain maps. In this technique, called **LiDAR (Light Detection and Ranging)**, a laser transmitter and receiver, similar to that used in highway speed enforcement, shoots laser pulses at the ground at the rate of 10,000 bursts of light per second. The reflected light is captured, with the time interval between projection and reception recorded. From this, distance between the aircraft and ground is calculated. As the height of the aircraft is known, the elevation of the terrain can be derived. This is illustrated as a continuous surface, or GRID (shown in Figure 8.7).

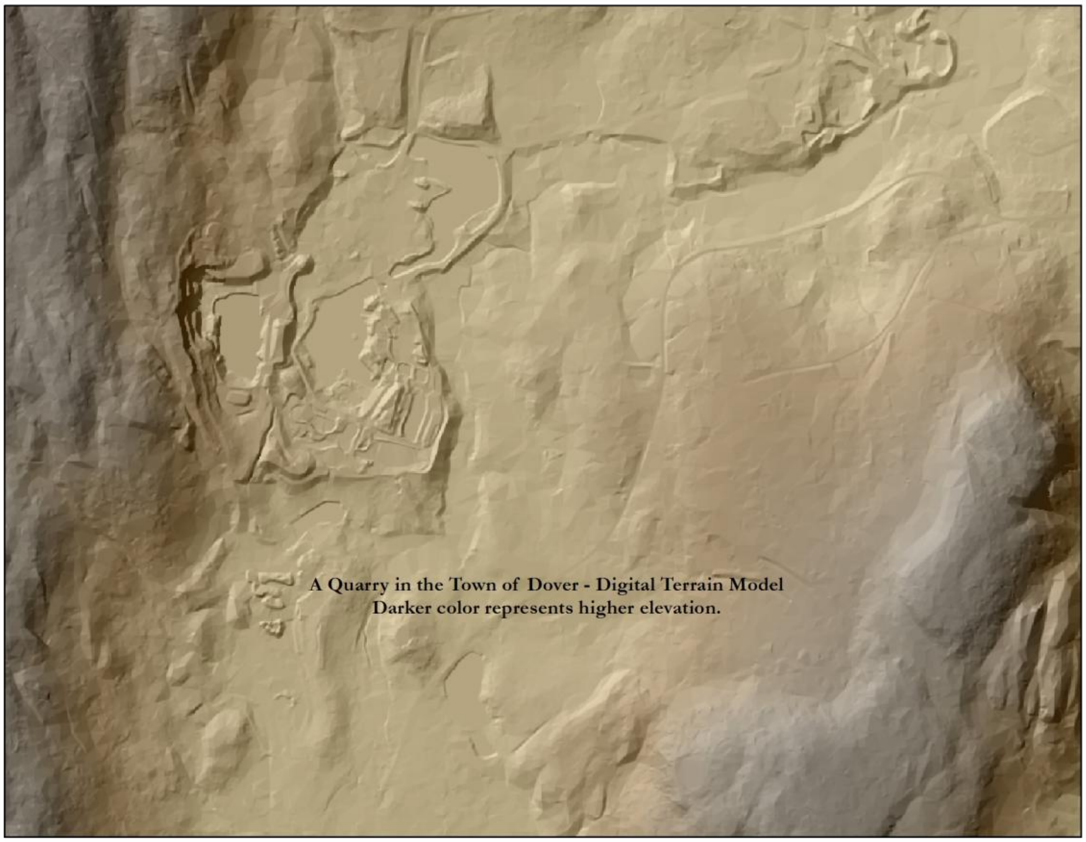


Figure 8.7: Digital terrain model showing a quarry in the Town of Dover

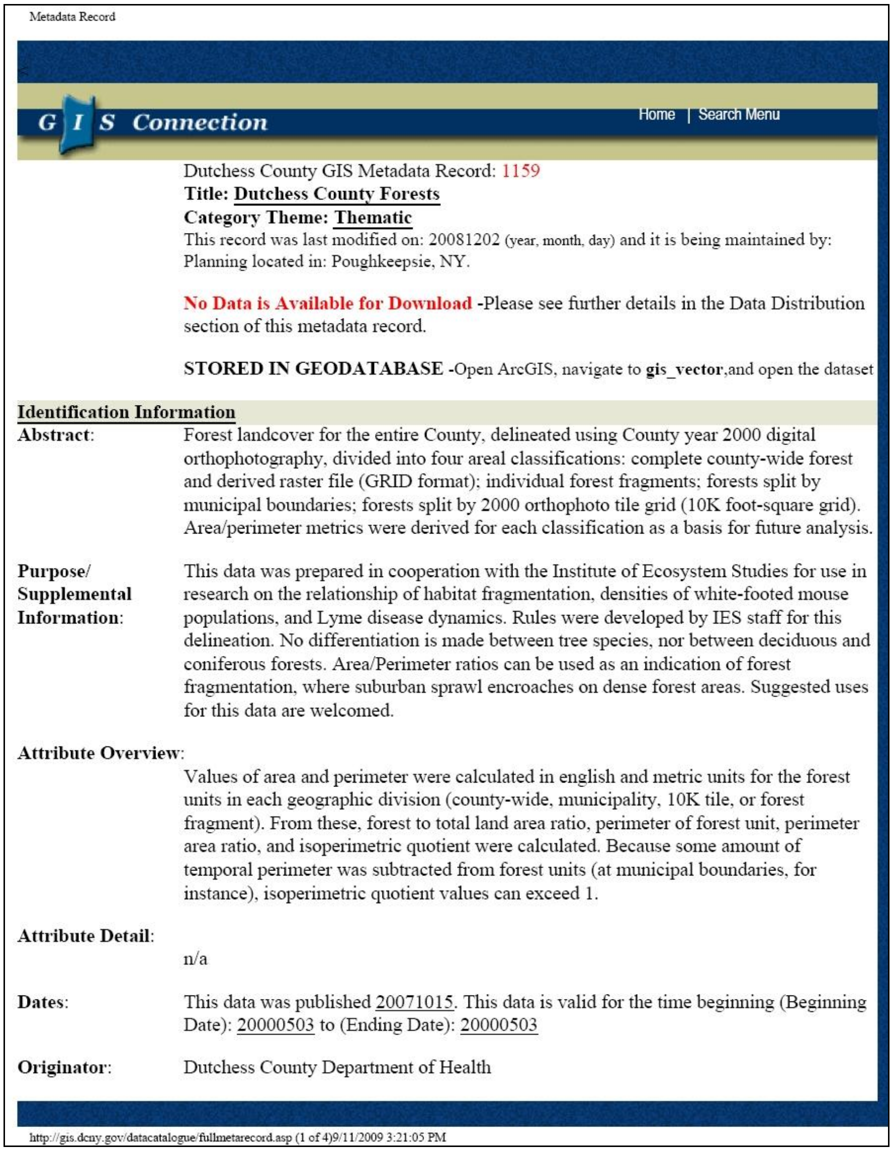
VECTOR DATA

It is only recently that new GIS data has been developed from existing highly accurate digital representations of geographic features. Most GIS data did not start out in digital form, but as a map of the features of the earth, usually on paper, which required conversion to use on the computer. Features which appeared on a map were traced, using a device called a digitizer, which generated an electronic version of the points, lines and polygons that existed on paper or other media. This data is called **vector data**, and is comprised of discrete features, each of which can be associated with different characteristics. The accuracy of the resultant computer version relied not only on the operator's skill at tracing accurately, but on the accuracy of the source map. Inherently, the source map had errors based on many factors, including the scale and accuracy of the source from which *it* was created, delineator's error, the number of times and methods used in its reproduction, its scale, and even the media upon which it was created (paper changes size based on the relative humidity). Further, accuracy is degraded when misinformation is placed in the layer's database.

Vector data is captured and drawn with many new techniques and technology. For example, **Global Positioning Systems** utilizes satellites in earth orbit to derive the location of devices capable of receiving signals from the satellites that include their locations and the time of the transmission. These hand-held devices, or GPS receivers, which can be carried over the ground by a person, are used to locate objects in the environment, or trace the path of a trail or area like a farm field. While tracing the path or area, data about the feature can be logged into the device. This field-collected data can then be brought directly into a geographic information system and analyzed or displayed as a map.

GUIDELINES FOR USING DATA

A GIS analysis does not simply start by throwing data layers together and seeing what overlaps. Whether using Dutchess County data or that acquired elsewhere, one must understand how the data was made. And the first source for an explanation is the **metadata** (Figure 8.8). Metadata is the "data about the data", the "who, what, where, when, why" of its creation, and the "how much and how good" it is in objective terms. What this leads you to is an idea of how the data can be used. Dutchess County has a format for metadata that is based on the Federal Geographic Data Committee standard for metadata. It includes all necessary information about how the data was created and its accuracy. From it, one can determine why it was made, what its age and accuracy are, what it can be appropriately used for, and what source documents were used in its creation. (Source documents refer to those maps or images which, through electronic means, were converted into digital form.)



Metadata Record

G I S Connection   Home | Search Menu

Dutchess County GIS Metadata Record: 1159
Title: Dutchess County Forests
Category Theme: Thematic
This record was last modified on: 20081202 (year, month, day) and it is being maintained by: Planning located in: Poughkeepsie, NY.

No Data is Available for Download -Please see further details in the Data Distribution section of this metadata record.

STORED IN GEODATABASE -Open ArcGIS, navigate to **gis_vector**,and open the dataset

Identification Information

Abstract: Forest landcover for the entire County, delineated using County year 2000 digital orthophotography, divided into four areal classifications: complete county-wide forest and derived raster file (GRID format); individual forest fragments; forests split by municipal boundaries; forests split by 2000 orthophoto tile grid (10K foot-square grid). Area/perimeter metrics were derived for each classification as a basis for future analysis.

Purpose/ Supplemental Information: This data was prepared in cooperation with the Institute of Ecosystem Studies for use in research on the relationship of habitat fragmentation, densities of white-footed mouse populations, and Lyme disease dynamics. Rules were developed by IES staff for this delineation. No differentiation is made between tree species, nor between deciduous and coniferous forests. Area/Perimeter ratios can be used as an indication of forest fragmentation, where suburban sprawl encroaches on dense forest areas. Suggested uses for this data are welcomed.

Attribute Overview:
Values of area and perimeter were calculated in english and metric units for the forest units in each geographic division (county-wide, municipality, 10K tile, or forest fragment). From these, forest to total land area ratio, perimeter of forest unit, perimeter area ratio, and isoperimetric quotient were calculated. Because some amount of temporal perimeter was subtracted from forest units (at municipal boundaries, for instance), isoperimetric quotient values can exceed 1.

Attribute Detail:
n/a

Dates: This data was published 20071015. This data is valid for the time beginning (Beginning Date): 20000503 to (Ending Date): 20000503

Originator: Dutchess County Department of Health

http://gis.dcny.gov/datacatalogue/fullmetarecord.asp (1 of 4)9/11/2009 3:21:05 PM

Figure 8.8: Dutchess County GIS Metadata for Dutchess County Forests

Some of the data characteristics listed in a metadata record will be related to **scale**. Is this data set really good enough to tell me something about: my back yard? …my neighborhood? …my town? There is a reason why the disclaimer "not for site specific use" appears on maps…it is because the minimum mapping unit, or **resolution**, of the data, is larger than the proposed analysis unit. For instance, the Dutchess County Soil Survey is an approximation of soil types in a location. It cannot be the sole source for locating a septic distribution field on a property. A field investigation utilizing excavation is the supplement for acquiring "site specific" data at the "back yard" level. The same is true for GIS datasets, and knowledge of their resolution is necessary for an appropriate analysis.

Scale of the original source map adds another kind of error. The contour layer first used in the County's GIS was created by the US Geological Survey. The contour lines were digitized from 1:24,000 quad maps for which 90 percent of the features were positioned to within fifty feet of their ground location (see National Map Accuracy Standards). Compare this to our current five-foot contours, which are based on our digital terrain model (Figure 8.9). Using this much more accurate source, 98 percent of the features are within five feet of their true ground location, an improvement of over ten times!

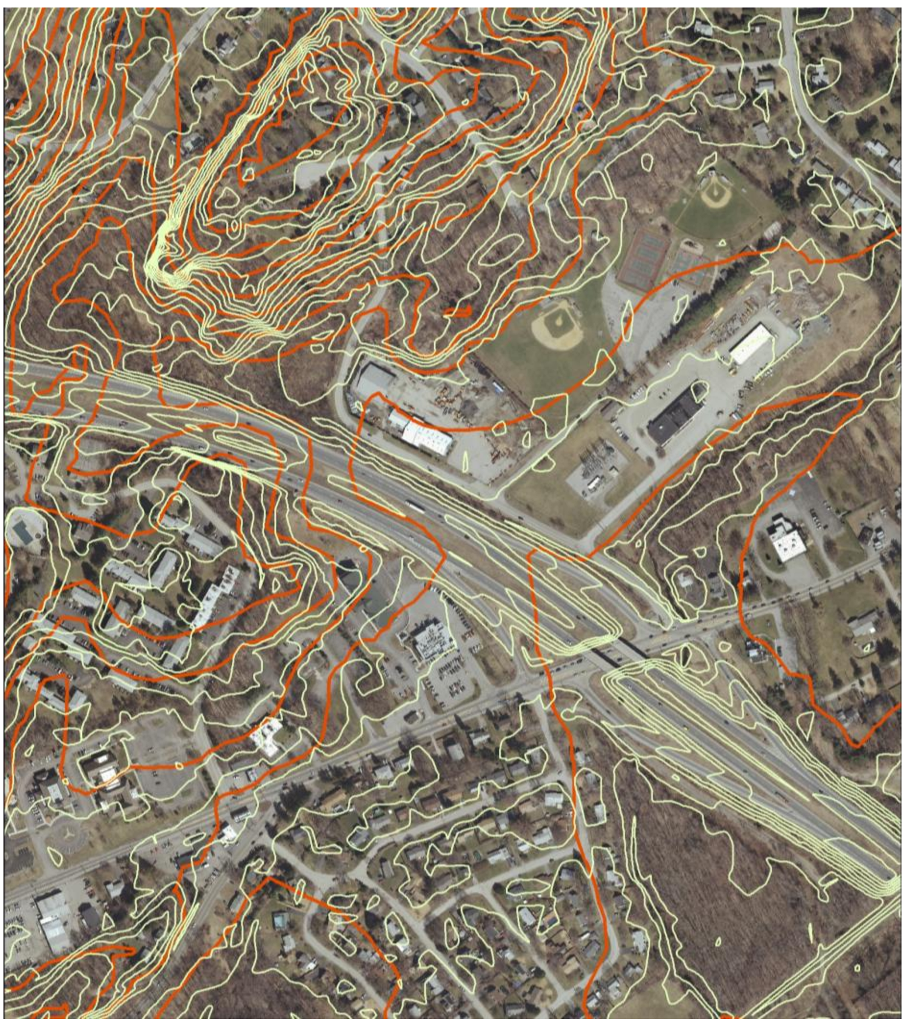


Figure 8.9: Map of US Interstate 84 in Fishkill. Yellow lines represent current five-foot contours; orange lines represent USGS ten-foot contours.

Location is one dimension of geographic data; time is another. In many instances, time is a characteristic not to be ignored, as important as location in understanding a complex natural phenomenon. "When did that happen?" "How quickly did that change?" These are two questions that knowledge of when an observation was made can help to answer. For example, the amount and extent of changes to land use becomes readily apparent when comparing two (or more) editions of aerial photography (Figure 8.10)

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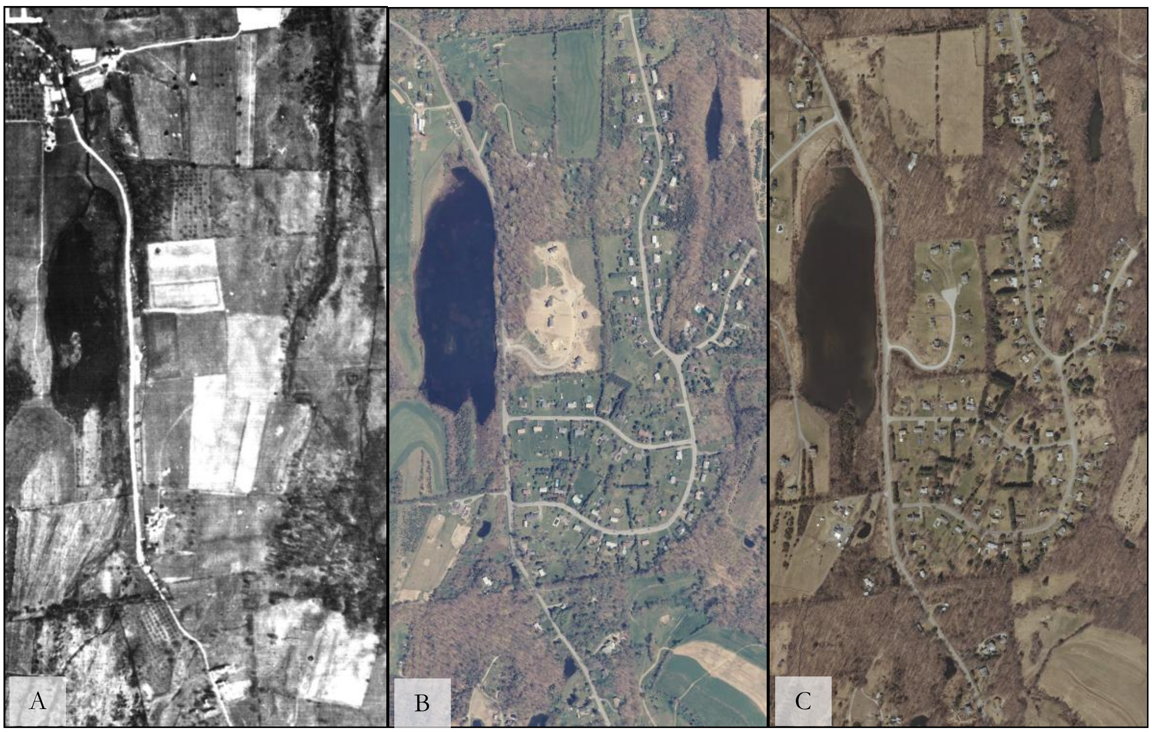


Figure 8.10: Aerial imagery of the Town of LaGrange from A) 1936 Aerial Photography, B) 2000 Digital Orthoimagery, C) 2009 Digital Orthoimagery

Equally important is knowledge of the age of the data. "How current is it?" With fast-paced changes in technology come improvements in the accuracy, completeness, and comprehensiveness of data. One needs to know these characteristics, described in the metadata, before valid analysis can take place. For example, many residential structures had been built between the time of the 2004 and 2009 digital orthophoto acquisitions. Conducting an analysis on 2004 data could therefore lead one astray.

DATA

Following is a list of geographic information data resources for the county, organized by NRI Chapter: Climate; Geology and Topography; Soils; Hydrological Resources; Biological Resources and Biodiversity; and Designated Significant and Protected Areas. From a public GIS workstation available at municipal offices or Cornell Cooperative Extension, one can access a complete list of all GIS data for Dutchess County at http://gis.dcny.gov/datacatalogue/topicsearchresults.asp. This is not a World Wide Web address, but a link to Dutchess County's intranet, and is only available from a computer linked to the county network. Note that each dataset has a person to contact for more information about the resource and instructions on how to obtain it.

For each dataset there is a Technical Contact and Interpretive Contact. The Interpretive Contact verifies that the GIS data is correct, maintains the metadata record, and coordinates the distribution of the data layer to those requesting it. The Technical Contact is the person within the department who can be contacted for technical issues like database construction, and who physically updates the GIS data.

The data layers, categorized by NRI chapter:

Climate

- Meteorological data (current and historic) from the Cary Institute of Ecosystem Studies
- GIS and meteorological data from the National Weather Service

Geology and Topography

- Bedrock and Surficial Deposits
- Contours: five-, ten-, and twenty-foot
- Terrain, Hillshade, and Elevation Models: two-, ten-, and thirty-meter resolution

Soils

- Hydrologic Soil Groups
- Soil Survey (SSURGO)
- Steep Slopes: 15%, 20%, and 25%.
- Prime and Secondary Agricultural Soils

Hydrology

- Aquifers
- NYC DEP East of Hudson Drainage
- FIRM Maps FEMA Q3 Flood data
- Minor Streams
- National Hydrological Dataset
- Linear and Areal Hydrology (planimetric)
- SPDES Storm Discharge Points
- Detailed Watersheds
- Well Completion Reports
- Wellhead Protection Areas
- Wells/Public Water Supplies

Biological Resources

- Municipal Biodiversity Assessments (Hudsonia)
- New York State:
    - NYS DEC Biodiversity Outreach Program
    - NY Natural Heritage Rare Animal Status List
    - NYS Biodiversity http://www.dec.ny.gov/lands/5094.html
- Cary Institute of Ecosystem Studies
- Cornell Cooperative Extension Dutchess County Environment & Energy Program
- http://www.dutchesswatersheds.org
- Dutchess County Planning & Development:
    - Biodiversity Blocks
    - Centers and Greenspaces Plan
- Local municipalities: Conservation Advisory Committees; watershed groups

Protected and Significant Areas

- Critical Environmental Areas
- Municipal Open Space Plans, Habitat Maps
- Land protected by Conservation Easement or Government-owned
- Forested lands

Core Data Layers

- Tax Parcel Maps and Real Property Tax database
- Digital Orthophotography (true-color and false-color infrared)
- Planimetric data layers (pavement, structure footprints, large parking lots)
- Road centerline file

CORE DATA LAYERS

Critical in most GIS analyses are the core data layers that describe ownership and our built environment. The county's 2009 digital orthophotography represents the reference standard for all visible features on the ground, with an accuracy of about five feet horizontal and six-inch pixels. It will be used as the reference for updating all planimetric features. The county digital elevation model also has an accuracy of about five feet horizontal, and is the reference for all elevation information including contours, terrain, and watersheds. The Real Property Tax Parcel Maps present a representation of the limits of ownership with a core database input by local assessors of key property and structure descriptors reflecting what improvements have been made to any property. Planimetric features, or those drawn directly from the orthophotography, represent areas of impervious surfaces found in roads, structures and parking lots. Along with ownership information and appropriate environmental layers, the core data layers are essential to include in any environmental GIS analysis.

COMMUNITY-BASED LANDSCAPE ANALYSIS

One of the most frequent ways communities implement land use policy is through the review of development proposals brought before their Planning Boards. Instead of being ecology-centered, this process often pits the landowner against the community in an expensive adversarial relationship in which ecosystems can be the losers. Traditionally, a land owner interested in developing will retain the advice of an engineer, who develops a plan that maximizes the profit potential of the property before understanding the visions and aspirations of the community, and the ecological systems within which their client's property sits. This elaborate plan, which undoubtedly reflects a substantial investment, is presented at the beginning of a lengthy, confrontational process. Following is an example of how the Natural Resource Inventory data is being used in land use decisions.

Dutchess County Planning & Development has proposed an alternative that is being implemented in a number of our communities. In a process that begins with an initial meeting focused on a site map and Resource Analysis, the landowner and Planning Board discuss the assets and constraints of the site (Figure 8.11A, B, and C). This is the start of a conversation where everyone knows what is important to the community, what features are important to save, and what the reviewing body would like to see on the site. With minimal expense, the applicant learns up front where the "buildable" areas are on the site. The applicant will also know what to expect in the State Environmental Quality Review (SEQR) process, as possible environmental impacts will already have been discussed. This can be done with an 11x17 map of ecological systems, physical constraints such as soils and slope water bodies and streams, a checklist, a site walk, and a discussion. The potential for months of "back and forth" between the applicant and the Board has now been avoided. The engineering consultants can use their talents to satisfy both the needs of the applicant and the municipality (Carille and Akeley, 2007).

FORM A: RESOURCE ANALYSIS ASSESSMENT Date filled in:________

(To be initially reviewed and completed by applicant in preparation for review and completion by Planning Board)

Name of subdivision: ____

Address:____

Specific Site Considerations

	Yes	No	Not Sure
1. Are there streams, wetlands, water bodies or watercourses that might require protective buffer areas? Refer to Hudsonia guidelines.	___	___	___
2. Is this parcel adjacent to the Harlem Valley Rail Trail or a public recreational area?	___	___	___
3. Is there active or inactive farmland on the parcel(s)?	___	___	___
4. Will the farmland be preserved?	___	___	___
5. Is there active farmland on adjacent parcel(s)?	___	___	___
6. Is this an Agricultural Exempt parcel(s)?	___	___	___
7. Can land contiguous to the adjacent farmland be preserved?	___	___	___
8. Is this parcel within an aquifer resource area?	___	___	___
9. Are there ridgelines and mountaintops that the Town desires to be kept clear of development?	___	___	___
10. Are there stone walls or rock outcrops on the site? If yes, indicate walls on land use sketch.	___	___	___
11. Could development significantly alter the viewshed from public lands?	___	___	___
12. Could development alter the quality of public viewsheds?	___	___	___
13. Is the parcel adjacent or within an officially designated historic site or district?	___	___	___
14. Are there special cultural and historic features that should be preserved?	___	___	___
15. Are there high-quality trees and significant groups of trees that should be preserved?	___	___	___
16. Are there, or is there the potential for significant wildlife habitats or wildlife migration areas? Refer to the Hudsonia study.	___	___	___
17. Do any of these significant natural areas (forests, wildlife habitats, etc) extend into abutting properties?	___	___	___
18. Can the development be connected to a public water supply?	___	___	___
19. Are there prime soils or soils of statewide importance located on the property?	___	___	___

Figure 8.11A: Resource Analysis Form

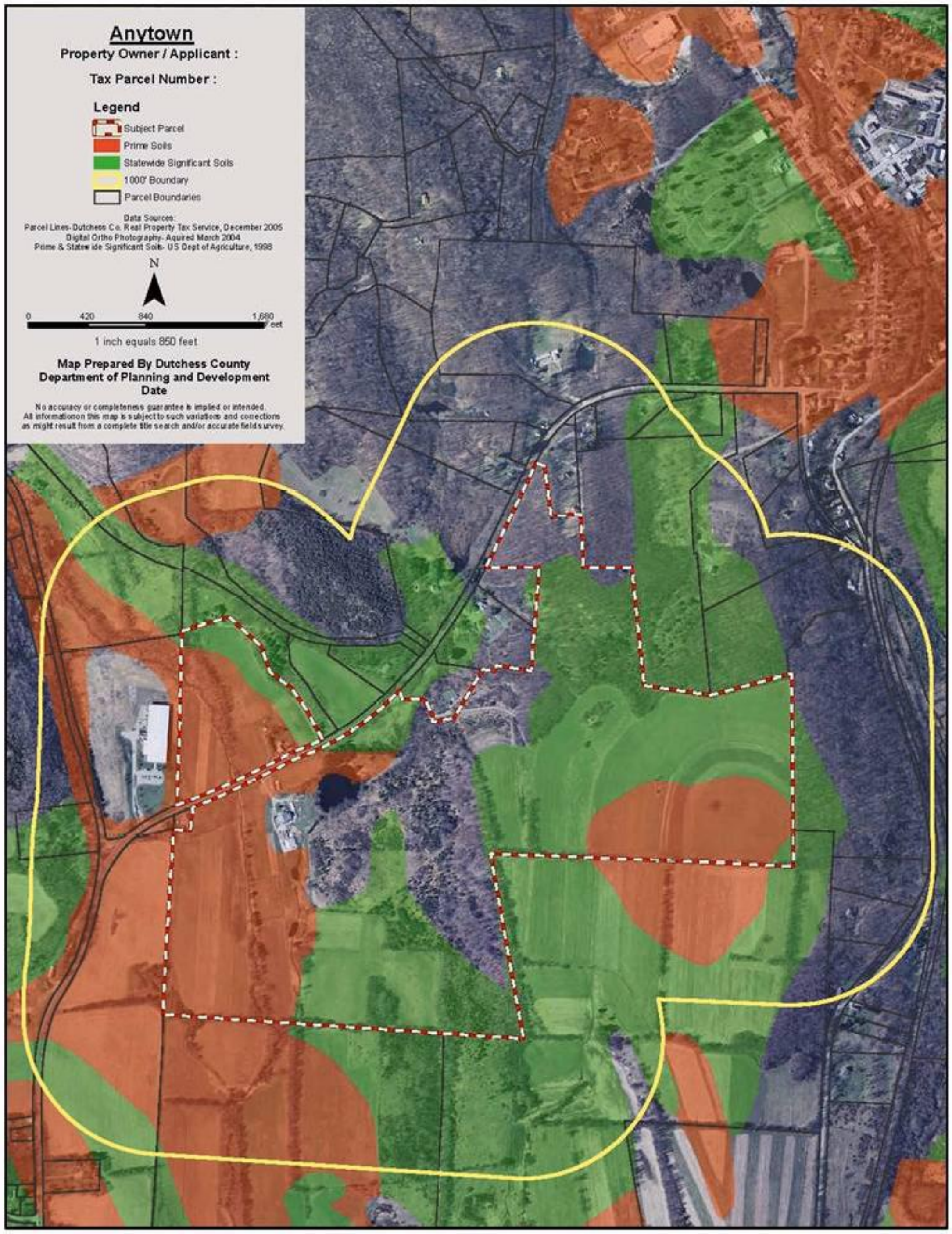


Figure 8.11B: Soils Map

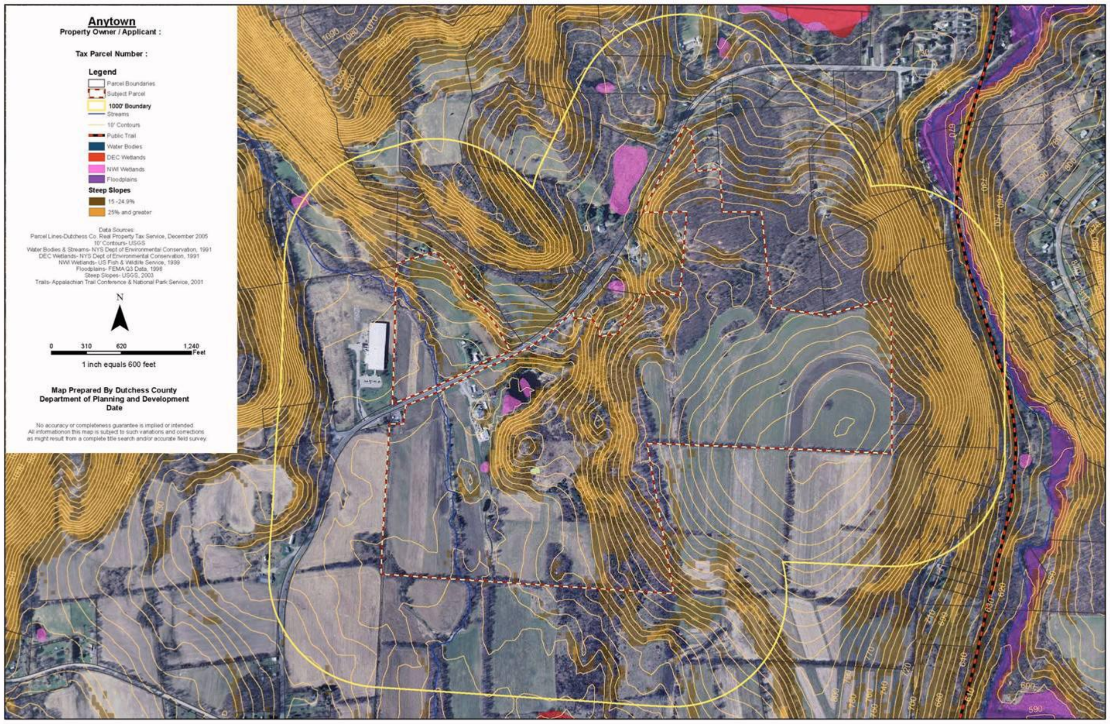


Figure 8.11C: Resource Analysis Map

SUMMARY

It is comparatively easy to recognize that traditional forms of human habitation like villages and hamlets can exist in harmony with natural ecosystems, while suburban sprawl, progressively using ever increasing amounts of land per household, fragments sensitive habitat and agricultural lands, and renders them unusable for their previous residents. Taking civic actions to lessen these negative impacts requires an accurate portrayal of the natural conditions and development context.

Sound land use policy necessarily relies on sound environmental data, scrutinized with sound analysis. This sturdy three-legged support, crafted with the vision and aspirations of a community, can then allow the ecological expectations to match the realities of the built environment. The Natural Resource Inventory provides policymakers and the public with the interpretation and accurate data necessary to conduct the legitimate analyses necessary to make sound policy. This chapter has described the data behind the NRI and hopefully conveyed some insight into responsibly using the data, in an effort to make a compelling argument for protecting both nature and humanity.

RESOURCES FOR ADDITIONAL INFORMATION

- **GIS in Dutchess County:**
  - http://www.co.dutchess.ny.us/CountyGov/14456.htm
  - http://www.co.dutchess.ny.us/CountyGov/14461.htm
  - http://www.co.dutchess.ny.us/CountyGov/GISStandards.htm
  - http://ccedutchess.org/environmentenergy/geographic-information-systems-gis
- **The NRI:** www.co.dutchess.ny.us/CountyGov/Mapping.htm
- **NRI Data:** http://gis.dcny.gov/datacatalogue/topicsearchresults.asp
- **Raster Imagery:**
  - http://www.satimagingcorp.com/satellite-sensors/landsat.html
  - http://landsat.gsfc.nasa.gov/data/where.html
  - http://glcf.umiacs.umd.edu/data/landsat/
- **Metadata:**
  - http://www.fgdc.gov/metadata
  - http://www.co.dutchess.ny.us/CountyGov/GIS.htm
  - http://www.nysgis.state.ny.us/coordinationprogram/workgroups/wg_1/related/standards/index.html
- **Remote sensing data:**
  - http://www.satimagingcorp.com/satellite-sensors/landsat.html
  - http://landsat.gsfc.nasa.gov/data/where.html
  - http://glcf.umiacs.umd.edu/data/landsat/
- **National Map Accuracy Standards:** http://egsc.usgs.gov/isb/pubs/factsheets/fs17199.html#US%20National
- **Model Subdivision Regulations:** http://www.co.dutchess.ny.us/CountyGov/Departments/Planning/subdivisionofland.pdf

REFERENCES

Carille, Lindsay & Roger Akeley. "Model Subdivision Regulations." Poughkeepsie, NY: Dutchess County Department of Planning and Development, January 2007.

Koehler, David. *GIS Needs Assessment for Dutchess County*. PlanGraphics, Inc. July 29, 1999.

Chapter 9:
Ecological Implications for Local Decision-Making

John Clarke, Mark Doyle, Robert Wills and Allison Chatrchyan[1]
June 2011

Chapter Contents:

The Natural Resource Inventory of Dutchess County, NY presents a comprehensive evaluation of all the major natural elements of the county's ecosystems, documenting many facts and details, but the true beauty is in the big picture. Perhaps it may be more accurate to refer to the NRI as "*The Ecology of Dutchess County*." Ecology is the study of the interactions among organisms and their environment (Forman, 1995: 19). It stresses systems or network thinking, reciprocal relationships, and a combined understanding of seemingly separate activities within the context of a larger whole. This concluding chapter concentrates on how to make successful decisions and designs for the future within the

[1] This chapter was written by John Clarke (Dutchess County Department of Planning and Development), Mark Doyle (Town of Amenia, NY Conservation Advisory Council; independent farm consultant; and CCEDC Board), Robert Wills (Dutchess County Department of Planning and Development), and Allison Chatrchyan (Cornell Cooperative Extension Dutchess County (CCEDC).

concept of a broader natural network, looking at nature and human activities as interconnected ecosystems, not competing camps.

Every natural species is distinctive and valuable in its own way, but humans have evolved with several key distinguishing characteristics. We routinely override our basic instincts with independent decision-making, are adaptable to almost every environment on Earth, and are capable of sophisticated language, abstract reasoning, and technological achievements. We can even consciously and creatively accelerate the multi-generational process of natural evolution with dramatic cultural and physical changes. Most importantly in this context, humans can envision an ideal and then produce imaginative plans and the means to make it happen. To a large degree, we are distinctive through our designs, especially in the redesigning of our own human habitats.

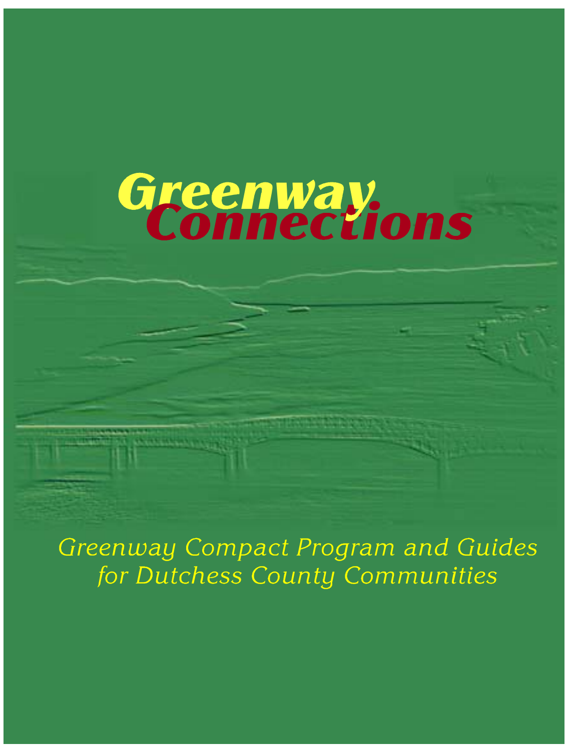
Figure 9.1. Two contrasting development models: single-use, auto-dependent commercial strip displaces nature along Route 9, or a mixed-use, walkable center embedded in nature, like the City of Beacon.

However, many of our past development practices have attempted to dominate and displace the natural world, and we have degraded much of it in the process. Pollution, invasive species, and landscape fragmentation caused by sprawling development patterns destroy sensitive species and threaten wider natural systems throughout the region. In some ways sprawl acts like an invasive species. Given the unsustainable level of land consumption over the last 60 years and the broader urgency imposed by global energy and climate concerns, it seems time now to acknowledge our deep interdependence with nature, find a green way to live with the land, and repair our common home.

> We abuse land because we regard it as a commodity belonging to us.
> When we see land as a community to which we belong,
> we may begin to use it with love and respect…
> That land is a community is the basic concept of ecology,
> but that land is to be loved and respected is an extension of ethics.
> - Aldo Leopold, *A Sand County Almanac*, 1949: xviii

THE GREENWAY COMPACT

The Hudson Valley Greenway Act of 1991 created a process for voluntary regional cooperation among 324 communities within 13 counties that border the Hudson River. Dutchess County developed the first Greenway Compact plan in 2000, designed to be a model for Greenway planning throughout the region. *Greenway Connections: Greenway Compact Program and Guides for Dutchess County Communities* has been adopted by 29 out of 30 municipalities and by Dutchess County as a voluntary set of regional planning principles, practical guidelines, and incentives to promote intermunicipal cooperation. It has translated into numerous intermunicipal partnerships and projects and served as a guide for the coordination of state, county, and local government priorities.



The Greenway Compact:
- is entirely voluntary;
- respects home rule; and
- relies on incentives and guidelines, not any state or county requirements.

Figure 9.2

Greenway Connections **guidebook**

A basic Greenway premise is that environmental enhancement improves economic development opportunities. Major regional income generators, including tourism, agriculture, main street and waterfront revitalization, and urban and industrial redevelopment projects, benefit from improved environmental surroundings. A higher quality of life is also a proven way to attract investment and creative talent. *Greenway Connections* provides both smart growth and natural protection principles and a wide range of illustrated Greenway Guides, from saving farmland and connected habitats to priority growth areas and commercial strip redevelopment, all in an easy-to-use format for local officials.

This primary Greenway goal to merge economic and environmental priorities builds on the following conceptual framework for our relationship with nature (*Greenway Connections*, 2000: 14):

Nature is too-often categorized:

- as somehow outside, even the opposite of the human community and the places we live and work;
- as separated resources (e.g. wetlands, floodplains, steep slopes, prime aquifers), and;
- as focused on natural constraints, negative impacts, and protective regulations.

As a beginning Greenway step, municipalities are asked to appreciate nature as:

- an essential part of our everyday environment in both cities and the countryside;
- integrated systems that flow through landscapes like river valleys or mountain ranges, creating continuous wildlife corridors and potential trail connections; and
- positive features and surrounding greenbelts that enhance and shape the places we build.

Greenway principles first recognize that human communities are not separate from nature as automatic alien elements. We are instead immersed in natural relationships, from the atmosphere we breathe and the daily weather patterns to local food sources and the substantial benefits of surrounding natural features, such as cleaner air and water sources, moderated temperatures, reduced flood potential, recreational uses, and all the other ecological cycles and services. Designers that combine creativity with a conservation ethic have begun to construct buildings and imagine cities and villages that emulate the deep structure of nature, so "[b]uildings, systems, neighborhoods and even whole cities can be entwined with surrounding ecosystems in ways that are mutually enriching"

(McDonough and Braungart, 2002: 87; see also Alexander, 2003: 3). Greenways are defined as paths (in the broadest sense of the term) where the natural and the human landscapes coincide. Physically, they link large continuous greenspaces, countryside trails, and parkways with, boulevards, sidewalk systems, tree-lined main streets, and central parks.

A second key point is that fragmented landscapes are a direct result of fragmented thinking. As examples, "[l]and is partitioned into zoning districts that strictly separate housing from stores and job sites, the environment is segmented into various natural constraints (wetlands, floodplains, steep slopes) with different rules and regulating agencies, while layers of government create additional fragmented jurisdictions" (Greenway Connections, 2000: 21). Thinking in a green way, by comparison, expands the perspective to mixed-use neighborhoods, connected landscape patterns, and regional cooperation, rather than focusing on piecemeal or parcel-by-parcel analyses.

> Each pattern can exist in the world, only to the extent that it is supported by other patterns…when you build a thing you cannot merely build that thing in isolation, but must also repair the world around it, and within it, so that the larger world at that one place becomes more coherent, and more whole; and the thing which you make takes its place in the web of nature, as you make it.
>
> - Christopher Alexander, *A Pattern Language*, 1977: xiii.

Finally, advocates for development, agriculture, or the environment far too often get locked in reactive land use battles where confrontational tactics and half-measure compromises usually leave everyone dissatisfied. Arguments are framed in defensive terms; the wonders of nature are classified as natural constraints, while development is primarily judged by a compilation of negative impacts. If, however, potential developers follow the Greenway Guides up front and place new development in priority locations identified in local plans, projects can be welcomed as positive contributions to the community. Since so much of recent suburban development remains spread across the landscape in inefficient patterns for transportation, infrastructure connections, and ongoing local maintenance costs, it is not enough to merely focus on preventing future sprawl. Public support for well-designed regenerative development in smart growth locations is needed to reverse the trends, restore existing centers, help heal the rural countryside, and reestablish healthy natural biodiversity (Johnson and Klemens, 2005: 355). Smart growth plans, supplemented by the best practices illustrated in the Greenway Guides, offer opportunities to give growth back its good name.

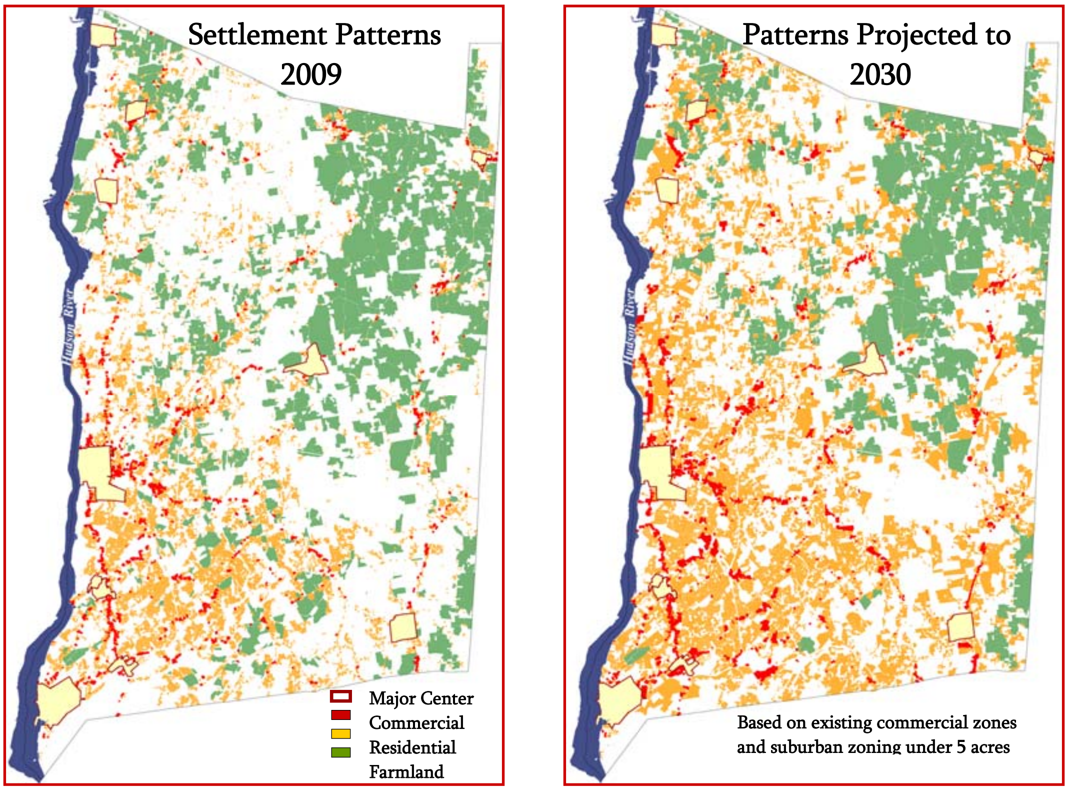


Figure 9.3. Spreading strip-and-sprawl patterns or the Hudson Valley Greenway

CENTERS AND GREENSPACES

A proposed new Centers and Greenspaces guide for Dutchess County provides a way for local communities to define smart growth and counter the current commercial strip and scattered residential sprawl patterns that are fragmenting both communities and nature (Dutchess County Planning Federation, January/February 2010). This new approach integrates traditional land use, transportation, and ecological planning precedents to re-center most new development into walkable, mixed-use forms, protect our natural and agricultural heritage, end wasteful land, energy, and pollution practices, and provide a wider range of transportation choices. The Centers and Greenspaces regional pattern guide will also be linked to an interactive website, featuring the most up-to-date digital mapping layers and our best local planning examples where centers have been designed to save greenspaces.

Build close-knit, connected centers...

- **Reinforce existing centers and main streets;**
- **Mix uses to promote walking;**
- **Integrate major centers with transit services;**
- **Locally identify <u>priority growth areas</u> for close-in expansion and conversion of strip districts or subdivisions into new centers.**

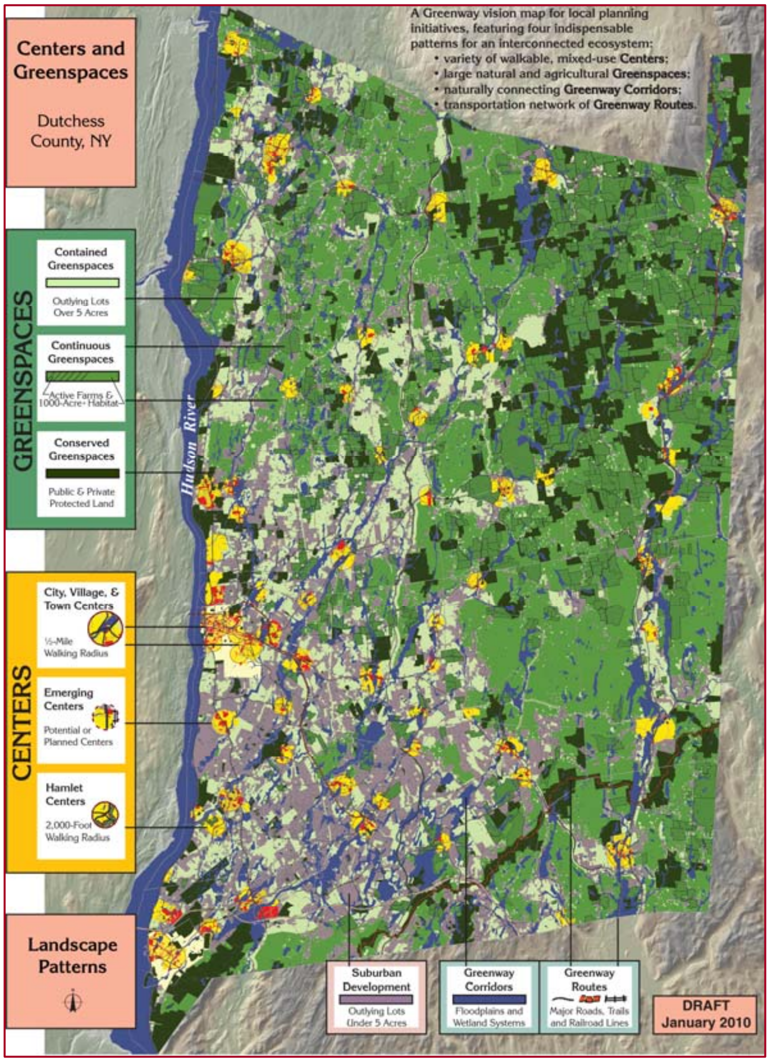
To protect our landscape legacy.

- **Employ a range of protection measures for farmland and natural wildlife areas;**
- **Adopt rural and agricultural zoning;**
- **Plan for continuous greenspace systems;**
- **Locally identify <u>priority greenspaces</u> for future public or private conservation.**

Figure 9.4. Centers and Greenspaces comprehensive planning.

The goal is to encourage municipalities to create plans that identify natural and agricultural greenspaces for possible protection measures and priority growth centers with positive development potential. Using a build-from-the-bottom-up Greenway approach, the guide and maps are based on initial Centers and Greenspaces plans for seven Dutchess County communities, including two villages and two rural towns, two more suburban communities, and a central city. The featured case study is the Red Hook Centers and Greenspaces Plan, produced by an Intermunicipal Task Force from the town and two villages working together to protect their rural character and save farms through a new Agricultural Business District, while reinforcing the traditional village centers and promoting economic development. The plan and proposed zoning not only locally designate greenspaces and growth centers, they also illustrate what new close-in development might look like to ensure compatibility with existing neighborhoods and to provide design guidance for future proposals.

Instead of negative reactions to random development locations, the plan offers a positive community statement for where growth can be beneficial, acting as an advertisement for new economic investment and streamlining the review process for projects consistent with community plans.



Centers and Greenspaces Guide
linked to County website, featuring:

- **full range of digital map layers;**
- **county, town, and center levels; and**
- **exemplary local plans and projects.**

Figure 9.5. Dutchess County Centers and Greenspaces map

The draft Centers and Greenspaces map is based on underlying conditions in Dutchess County, but acts as a Greenway vision map for future local planning initiatives, featuring four indispensible patterns for interconnected natural and human ecosystems:

- **Centers:** priority locations for mixed-use growth, including cities, villages, hamlets, and emerging centers, organized within a ¼- to ½-mile convenient walking radius;
- **Greenspaces:** priority areas for conservation, combining active farmland and continuous natural areas into large "biodiversity blocks" over 1,000 acres for area-sensitive species;
- **Greenway Corridors:** waterway systems, connecting natural patches, and other critical linkages between greenspaces for water quality protection and wildlife movement; and
- **Greenway Routes:** transportation linkages between centers, connecting trails to sidewalk systems and regional rail lines and parkways to central tree-lined main streets.

Both centered and connected, these essential landscape patterns demonstrate how the traditional, time-tested ways of constructing compact communities are complemented by the most productive large block forms for surrounding plant and wildlife communities. And just as large continuous greenspaces of woods, wetlands, and mixed agricultural areas generate the greatest diversity of natural species, mixed-use centers create the highest levels of diversity in population characteristics, commerce, and culture. Broader ranges of biodiversity are a sign of healthy and more resilient living systems at all levels and locations.

What is remarkable about the Centers and Greenspaces mapping is that, despite decades of primarily auto-dependent strip-and-sprawl development, the framework for a smart growth future that preserves our county's natural and rural heritage is still visible. There is available space for new infill development, close-in extensions around our historic centers, and for retrofitting existing commercial strips and subdivisions into mixed-use emerging centers, without spreading out into the remaining countryside. Connected greenspaces, initially defined by habitat studies as over 1,000 acres and undivided by roads over 25 vehicles per hour, still prevail in large sections of the county. Communities can use these general mapping thresholds as starting points for more detailed greenspaces protection plans that include a variety of locally identified factors, such as agricultural soils, important habitats or natural features, open views, gateway locations, settings for historic structures, or potential for public access. The NRI, supplemented by town-wide biodiversity mapping or other place-specific studies, should be part of the process for designating significant local and intermunicipal greenspaces.

LAND CONSERVATION AND DEVELOPMENT TOOLS

The following sections introduce a few of the land conservation measures and incentives for compact development that can be used to support Greenway and smart growth principles. This is not intended as a catalog of complete information on land use laws, but as a discussion of implications for planning and recent trends. For more information and for specific legal issues, questions should be directed to the New York State Department of State.

Local Plans and Zoning

As a home rule state, New York provides very broad authority to its municipalities to address local land use and environmental issues at the local level (Nolon, 2003). Under the New York State Municipal Home Rule Law, localities are given the authority to adopt laws relating to their property, affairs, or government, to the protection and enhancement of the physical and visual environment and to matters delegated to them under the statute of local governments (Article 2, Section 10). The New York State Statute on Local Governments (Article 10, Sections 6 and 7) also delegates the power to adopt, amend, and repeal zoning regulations, and perform comprehensive or other planning work to local governments. Thus, although subject to specific state health, transportation, and environmental permits and regulations, development in New York is primarily controlled at the municipal level through zoning, subdivision, and other local laws.

Zoning is intended to protect the health, safety, morals, and general welfare of a community and, according to state statute, should be based on a well-considered or comprehensive plan. Plans need to incorporate a broad public participation process and most end up containing lists of commendable goals and long-term recommendations. However, to be effective, comprehensive plans should move beyond vague goals to include designated priority greenspaces and growth centers, as well as illustrative plans for specific project areas. Overly general long-term plans generate little lasting inspiration and too soon become out of date, while specific, shorter-term plans with committed visions tend to maintain public momentum. The Town of LaGrange, for example, supplemented its plan with an illustrative sketch for a new Town Center, complete with proposed improvements for Route 55, a village green, commercial main street, and mix of housing types that attracted immediate developer interest. The Town of Red Hook followed the adoption of its Open Space Plan with a successful public bonding referendum to fund a purchase of development rights program for important farmlands.

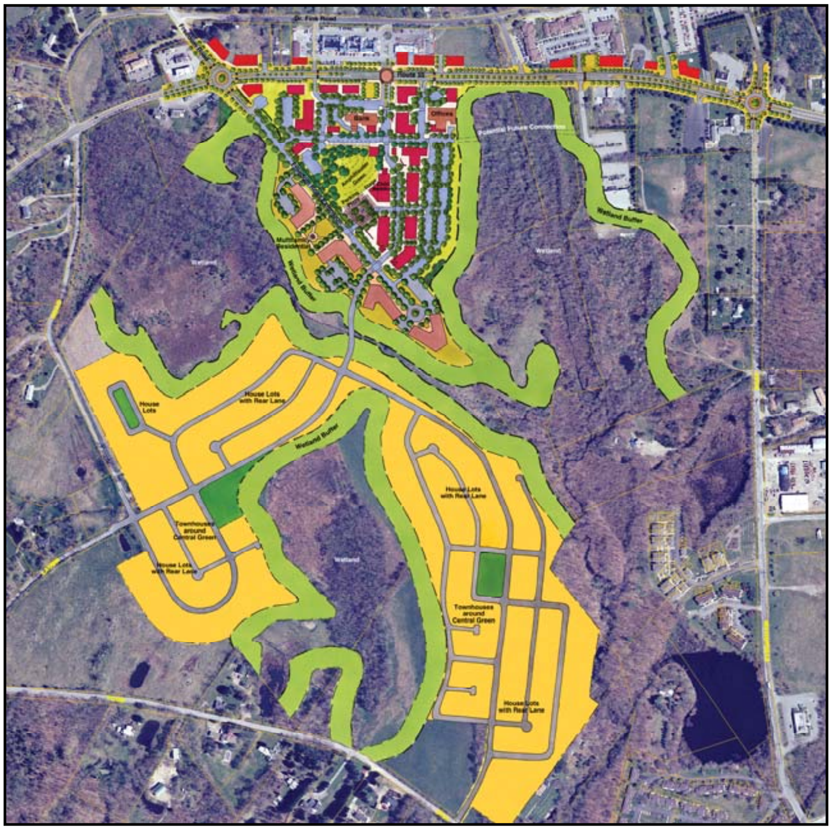


Figure 9.6. LaGrange Town Center Illustrative Plan was adopted into the Comprehensive Plan in 2003 as a model for subsequent rezoning and private development proposals.

Too often well-intentioned comprehensive plans flounder or are soon forgotten once the subsequent zoning code is adopted. This is an indication that the plan did not have enough creative substance or detail to be self-sustaining. Zoning laws provide purpose statements, procedures, specific standards, and regulatory districts, but are not intended to offer an overall vision or inspire ongoing public action. Codes mostly contain lists of what uses can and cannot happen in certain districts, not descriptions or illustrations of what the community would like to see. To address this problem and to bridge the gap between plans and zoning, some municipalities are adopting form-based zoning codes that incorporate illustrations and emphasize positive design guidance, rather than primarily restrictions.

Modern zoning techniques have also been justifiably criticized for stressing the segregation of uses into widely separated residential, retail, office, and industrial districts, larger-than-necessary housing lots, and high minimum parking standards. The resulting spread-out development patterns require automobile trips for every major movement and allow excessive paving to dominate most site plans. Recent trends in local land regulations are moving away from the separated, single-use districts and from suburban-scale residential zoning that carves up former fields and forests into small repetitive pieces. Too many strip commercial zones still remain, but many communities are encouraging more flexible development options with mixed-use hamlet districts and multi-family housing encouraged around and above central business buildings. Site plan priorities can shift toward pedestrians, biking, and transit-oriented development to balance automobile access. Minimum parking mandates can be turned into maximum parking standards with lower space requirements and strong landscaping provisions to convert sterile lots into shaded parking groves.

Consistent with the information in the Natural Resource Inventory, local governments can also add supplemental sections to protect important natural features, such as prime agricultural soils, steep slopes, ridgelines, local wetlands and watercourses, aquifers, and even local climate change provisions. Model zoning and subdivision regulations and GIS mapping are available for a variety of issues and areas. Rather than zoning as if sprawling residential development was inevitable in outlying areas, rural and agricultural zoning districts should be established with lot sizes and other standards to discourage scattered subdivisions. Suburban zoning is generally considered to be in the 1/2-acre to five-acre lot range, too large to be cost efficient for transportation connections and central utilities, while too small to allow farming or maintain the previous rural character. Larger acreage zoning combined with conservation development requirements creates a more effective strategy for rural land protection. The Greenway Guides also offer practical solutions for fitting development into the rural landscape, preventing strip residential subdivisions, and creating farm conservation plans.

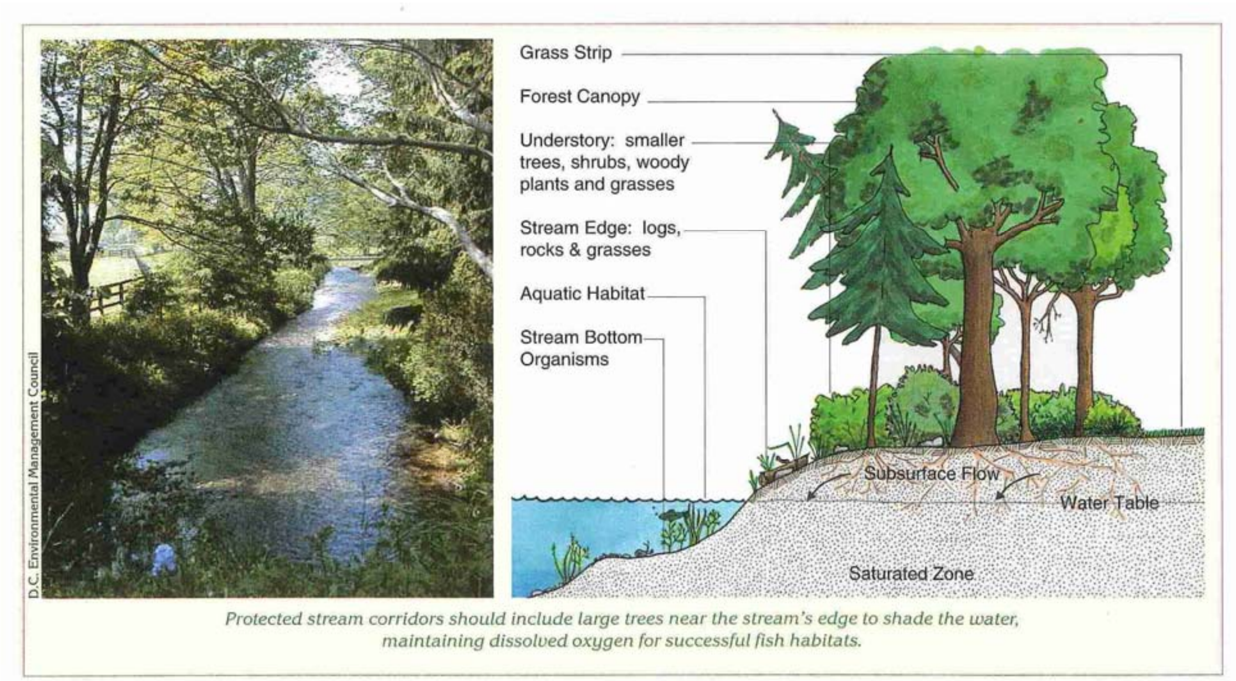


Figure 9.7. From the Greenway Guide on Stream Corridor Protection.

Conservation Development

Conservation subdivisions allow development in rural locations, but save substantial percentages of natural areas or farmland by clustering development on smaller lots than the designated minimum lot sizes. Each site has unique circumstances, but conservation design can be described in three simple steps. First, map all the area's significant natural and cultural features, especially natural systems that continue on surrounding properties, as well as potential development pockets that fit well within that natural framework and also might create linkages to adjacent development sites or possible street networks. Second, determine the maximum lot count by sketching a standard subdivision that complies with all zoning and health regulations. Under this conventional layout the important features of the site would likely be fragmented into various back yards. Finally, arrange the same number of allowable lots in the best development pocket for conserving the maximum amount of sensitive land and making external connections.

Ideal designs permanently preserve well over half the land in a conservation easement, while reducing the developer's costs for roads and other utilities and providing new residents with direct access to open land and excellent countryside views. Larger minimum lot sizes facilitate the conservation design process and create better opportunities for substantial greenspace protection. For example, it is almost impossible to reduce development pockets in one-acre residential districts without access to central utilities because of separation distances for wells and septic systems. In five-acre or larger districts, however, clustering down to smaller legal lots can result in 80 percent protected landscapes.

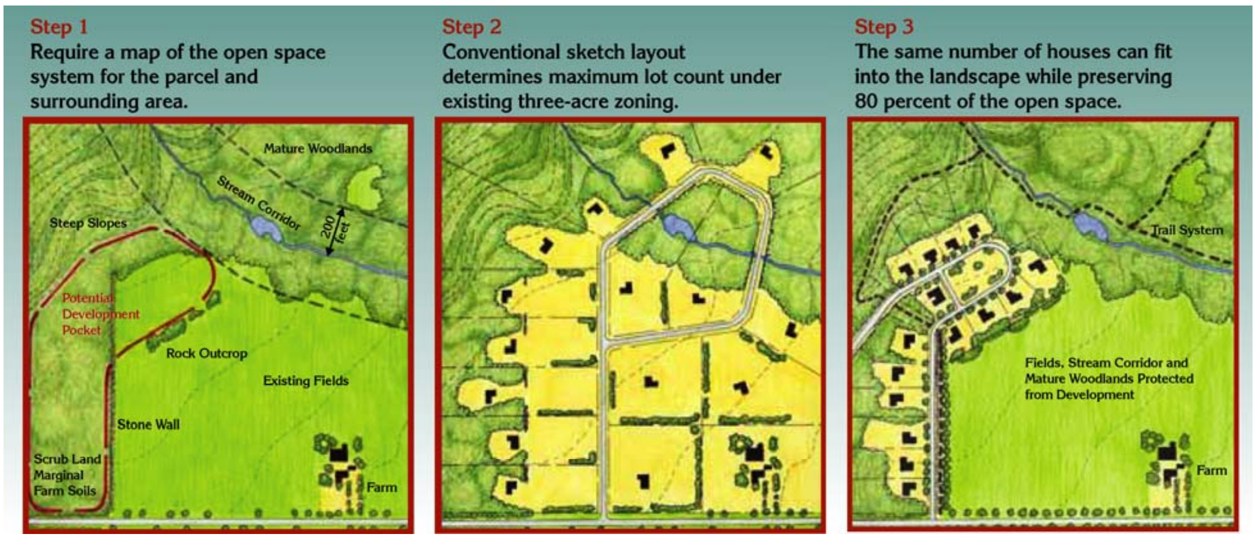


Figure 9.8. Model conservation subdivision process for fitting into the rural landscape.

However, conservation subdivisions are not necessarily the best way to preserve rural character. They still lead to pockets of scattered development that are entirely dependent on long automobile trips, can induce residential conflicts with adjacent farming activities, and partially fragment large natural biodiversity blocks. Boards overseeing conservation design should, as much as possible, gather lots and buildings together in compact groupings, close to existing adjacent development or road connections, rather than allowing strung-out cul-de-sacs through the buildable portions of the property to fragment natural landscapes. Some subdividers try to take advantage of the process to squeeze in more lots, while only protecting land that is already unbuildable because of floodplains, designated wetlands, or slopes over 20 percent. To avoid this, communities have begun deducting truly unbuildable land before establishing the base unit count. Other conservation techniques may provide more comprehensive protection.

Conservation Easements

A Conservation Easement is a tool for conserving private land. It is a legal agreement between a landowner and a land trust or government entity that permanently limits uses of the land in order to protect its conservation values. It allows landowners to continue to own and use their land; the property remains on the tax rolls and can be sold or passed on to heirs. Conservation easements do not generally require public access to privately owned, protected parcels. Establishing a conservation easement is initiated by a landowner and is not a governmental taking.

When owners sell or donate a conservation easement to a land trust, they give up some of the rights associated with the land. For example, a landowner might give up the right to build additional structures, while retaining the right to grow crops. Future owners also will be bound by the easement's terms. A conservation easement should be administered by either the municipality or a qualified local land trust to ensure its permanent status and to oversee any necessary maintenance. The land trust is responsible for making sure the easement's terms are followed. This is managed through "stewardship" by the land trust (Land Trust Alliance, 2010). Homeowners associations representing multiple private owners are not always reliable partners for maintaining the easement property, paying any necessary taxes, or avoiding encroachments.

A municipality may use conservation easements to secure areas of critical importance to its residents. In an Open Space Plan, a community, after identifying areas of natural or cultural value, can rely on a number of strategies including easements to protect significant areas. Although the cost of outright purchase of all sensitive land is usually far too expensive for a community to undertake, an easement between a landowner and land trust might be suggested at a fraction of the cost. Areas where this is especially effective may be near other areas of land already preserved by a community.

Purchase or Transfer of Development Rights

Perhaps the most straightforward way to permanently preserve land is to simply buy it. Purchase of development rights (PDR) is even better than that because it only buys the rights to further develop, so the property can maintain its original use and stay on the tax rolls. PDR costs less than outright purchase, but it is still very expensive unless the area is zoned for very limited development.

Beekman, LaGrange, and Red Hook have funded local PDR programs and Dutchess County has committed approximately $6 million through the *Partnership for Manageable Growth and Open Space and Farmland Protection Matching Grant Program*, contributing to the protection of almost 2,500 acres as of 2010. But to buy all the development rights in a prime agricultural valley or thousands of continuous acres of forest reserves is a difficult proposition. Thus, PDR is usually used when the most important individual parcels become available, resulting in a patchwork approach to land conservation.

Figure 9.9. Properties funded by the Dutchess County PDR program include the 228-acre Steiner Farm in Red Hook and the 58-acre Stone Church natural and historic site in Dover.

A less costly but more complicated way to preserve land is to use transfer of development rights (TDR). Municipalities setting up TDR programs designate sending districts that they want to protect and receiving districts where development is promoted. Property owners are encouraged to transfer allowable housing units from sending to receiving areas. Conservation easements are then placed on the sending parcels. In active markets this can be sometimes be negotiated between private property owners and substantial land can be preserved without any public expenditures. In areas with softer market demand governments may need to intervene, either by helping to negotiate the transfer or by setting up TDR banks to purchase and resell development rights. TDR often requires considerable administrative effort to promote the program, match buyers and sellers, and accurately assess the changing values of development rights. The Town of Amenia recently adopted a one-page TDR zoning provision, so simple TDR rules are possible, but successful programs usually involve substantial staff time.

State Environmental Quality Review Act

New York State adopted the State Environmental Quality Review Act (SEQR) in 1978 as a process to evaluate the potential environmental, social, and economic effects of private and government actions. Reviewing bodies are required to take a hard look at activities that meet certain thresholds as prescribed in the law, coordinate with other involved and interested agencies, and invite public comments. Environmental assessment forms provide lead agencies with the basic information to determine whether the impacts on a variety of environmental factors are significant enough to warrant closer review. Major projects with significant impacts require a complete environmental impact statement (EIS), which can involve thousands of pages in multiple volumes. SEQR is an invaluable tool to provide all the necessary facts to make informed decisions, but it has also been mis-used to simply stall or stop controversial proposals.

The SEQR process, as generally practiced, can generate legitimate complaints, not only for the sometimes slow time frames, but also because of its limited track record in creating much better projects. Projects are routinely judged in terms of minimizing negative impacts, in other words making them less bad, instead of insisting on positive solutions that contribute to the places they change. Required project alternatives in environmental impact statements are also not often treated seriously. The applicants do not want to change their preferred proposal and the reviewing agencies are timid in challenging them to provide legitimate alternatives that might mean re-engineering the project. As an example of what is possible under SEQR, the Town of Dover required an applicant to not only provide credible alternatives to an unacceptable EIS proposal, but also hire a different design consultant with experience in the desired type of mixed-use, transit-oriented development. One of the resulting alternatives pleased both the Town and the applicant, who adopted it as the new preferred option. A primary objective of the SEQR process should be producing positive alternatives, not filling out checklists or creating pounds of paperwork.

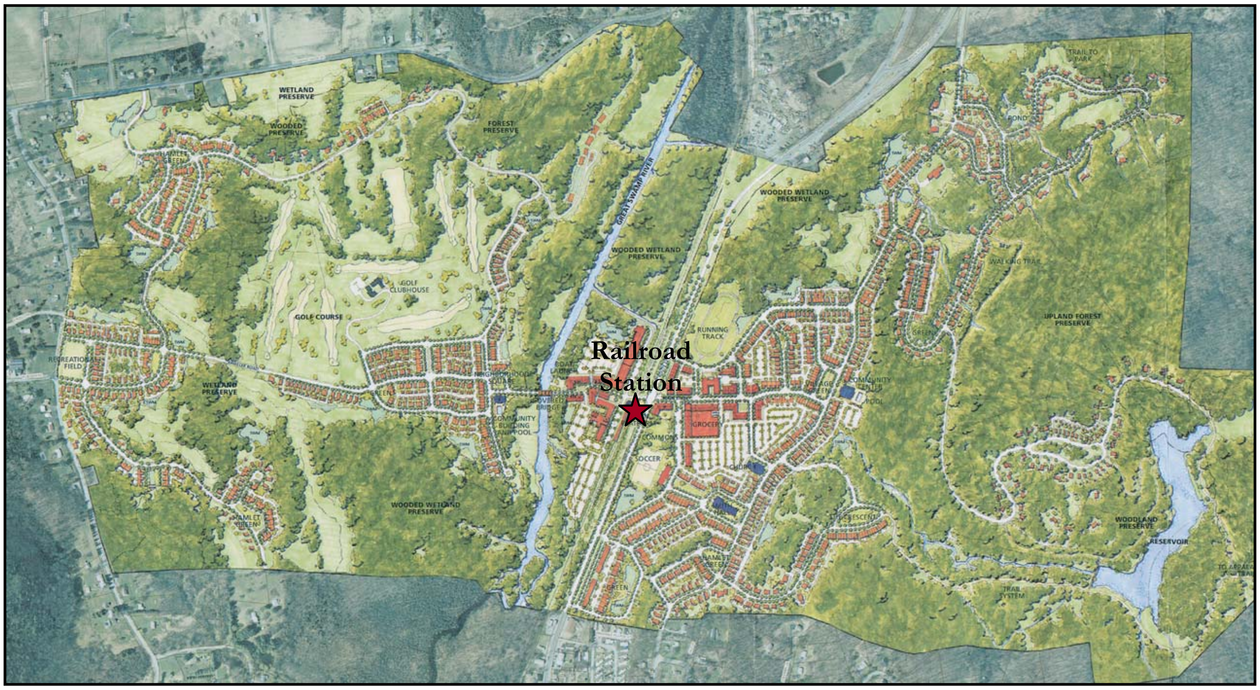


Figure 9.10. The Knolls of Dover is a transit-oriented development project on a former state institution site, proposing 1,376 housing units, most within walking distance of the rail station, and a new main street center with a supermarket anchor.

Strategies for successful SEQRA reviews on significant projects include:

- Meet with the applicants very early in the process to evaluate the site and discuss development options before they get locked into a proposal and spend too much money on consultants;
- As lead agency, take charge of the process by making sure that the documents are accurate and edited for clarity and completeness, rather than just accepting drafts from the applicants;
- Set a schedule for the various steps, avoid stalling tactics, and keep the process moving;
- Go beyond the checklists, requiring complete Part 3 analyses on long assessment forms, whenever appropriate;
- Use an EIS scoping session to get early comments and ideas from the public and to clarify specific project alternatives;
- Focus the scoping outline on critical issues, rather than just adding every possible category and loading up documents with boilerplate text and unnecessary information;
- Emphasize quality of information, not quantity of pages, with each major section having a clearly written concluding summary for easier public review; and
- Concentrate on meaningful design alternatives, carefully outlining expectations in the scope, and making sure that the alternatives are not merely designed to justify the preferred proposal or present options that are deliberately not feasible.

CASE STUDY OF AMENIA, NY

Incorporating Natural Resource Data into the Town of Amenia Comprehensive Plan and Zoning Law of 2007

Beginning in 2003, the Comprehensive Plan Committee of Town of Amenia, NY set about updating the outdated Comprehensive Plan and Zoning Ordinance. The most frequent observation during numerous public input sessions was that the natural resources and scenic beauty of Amenia is what sets it apart and is the key to future prosperity. To this end, a primary policy statement in the updated Comprehensive Plan is: "… this Comprehensive Plan Update is essentially about making Amenia more sustainable: that is, enabling Amenia to grow and prosper without depleting or destroying the environmental, historic, and visual resources that form the basis of that prosperity."[2]

The implementation of such a policy assured much discussion and the conclusion was to create both: an overall pattern for future development, via the use of zoning district and overlay maps that reflect the underlying resources and the desire to concentrate development in the appropriate locations; and a development permit, application and planning process that requires, as a first step in the process, the documentation of a site's natural resources and a thorough review of the proposed impacts.

Starting at the level of a building or zoning permit application, applications are required to include a map, survey or scaled plot plan indicating not only the detailed construction and landscaping plan, but also wetlands, watercourses, slopes in excess of 15 percent, and biodiversity mapping.

A "conservation analysis" is required as part of any "Sketch Plan" submission for a major subdivision and may be required by the Planning Board for a minor subdivision. As detailed in Town of Amenia Zoning Law, the analysis shall show lands with a conservation value on the parcel and within 200 feet of the boundary of the parcel, including but not limited to the following:

- Wetlands, watercourses, slopes 15 percent to 30 percent and slopes over 30 percent;
- Prime and statewide important farmland soils, land in active agricultural use, trail corridors, scenic viewsheds, public water supply wellheads, park and recreation land, un-fragmented forestland, wildlife corridors and habitats, vernal pools, and historic and archaeological sites,

[2] Town of Amenia Zoning Law, Town of Amenia, NY Adopted July 19, 2007. Art VII, Sect. 121-54. C. 6.a. p.89 and 90.

if such areas are specifically identified in the Comprehensive Plan, in the Hudsonia Report, in the New York Natural Heritage Program, in biodiversity maps prepared for the Town by an environmental consulting organization, or in any adopted open space or farmland protection plan;

- Designated overlay zones for stream corridors, aquifers, scenic protection, and floodplains;
- Buffer areas necessary for screening new development from adjoining parcels;
- Stone walls and individual trees or forested areas containing trees that are 18" diameter at breast height (dbh) or larger;
- Land that has been disturbed or altered in the past and therefore may be more suitable for development (this does not include land disturbed by an applicant prior to applying for a development approval); and
- If identified by the Planning Board or the Town's planning consultant in the course of the pre-application discussions, other land exhibiting present or potential future recreational, historic, ecological, agricultural, water resource, scenic or other natural resource value.[3]

In the course of pre-application conferences, the analysis should result in a determination of the most important conservation aspects, including ecological connections to adjacent parcels. The instruction to the Planning Board is to: "take into account the purposes of this Chapter and of the various overlay districts, the recommendations in the Amenia Comprehensive Plan, and the Town's goal of protecting biodiversity."[4]

Although the list may initially appear dauntingly complex and seem to require the services of experts for even the smallest application, this is not the case. Mapping resources are freely available on-line, both from the county's Natural Resource Inventory web pages, and access to the ArcStudio GIS application available on Dutchess County's intranet, through the Town's public access computer. More resources are available through the Town's website, including all zoning maps and the maps created in 2006 by Hudsonia, Ltd., the *Significant Habitats of the Town of Amenia*. Furthermore, the Town advises applicants to consult with the Dutchess County Soil and Water Conservation District, Dutchess Land Conservancy and Cornell Cooperative Extension Dutchess County. These resources should enable any property owner to assemble the required information. Larger projects, requiring SEQR review, are now well informed at the beginning of the process, obviating much of the contentiousness that often accompanies applications in which a considerable, up-front investment in

[3] Town of Amenia Zoning Law, Town of Amenia, NY Adopted July 19, 2007. Art.V, Sect. 121-20. A. 1. p.40.
[4] Town of Amenia Zoning Law, Town of Amenia, NY Adopted July 19, 2007. Art. V. Sect. 1221-20. A.2. p.40-41.

planning is made.

In order to assure that the standards of the Zoning Code are followed equitably, the Town of Amenia Planning Board retains environmental consultants for large projects and requests comments from the Conservation Advisory Council (CAC) as appropriate. The town planning process has gone from one of contentiousness to collaboration, largely due to the active and prolonged input from the community. The strong emphasis on good planning has become a source of great pride to the community.

POLICY IMPLICATIONS FROM EACH NRI CHAPTER

Chapter 2: Climate and Air Quality

Businesses and municipal leaders need to start planning for climate adaptation, or planning for the changes to the climate that will occur, taking into account future risks. Changes to the type of crops grown and tree species that may predominate with higher temperatures will affect agriculture; hotter and more violent swings in weather will affect risk management, emergency response planning, and the insurance industry, and individual residents planning for disruptions to utility service and transportation systems.

- Adopt a local climate change action plan that describes the policies and measures that the municipality will enact to reduce greenhouse gas emissions and adapt to climate change. One example is a program through the New York State Department of Environmental Conservation, for communities to adopt the New York State Climate Smart Communities Pledge;
- Work on long-term infrastructure planning that takes into account changing climate models for precipitation, sea level rise and rising temperatures and their possible impacts on drinking water supplies and water treatment plants, roads and bridges, and energy supplies;
- Establish and enhance riparian buffers and protect wetlands and open space in order to prepare for possible increased high-intensity storm events;
- Work with private forest owners to protect and sustainably manage forested areas;
- Include protection of open space, biodiversity, and wetlands/watercourses in comprehensive plans, zoning and local ordinances, and incorporate smart growth and low impact development principles into planning decisions;

- For more adaptation strategies, see the NYS Open Space Conservation Plan, Climate Change Adaptation Recommendations, see: http://www.dec.ny.gov/docs/lands_forests_pdf/osp09chapter3a.pdf.

Ozone and particulates are two of the leading causes of air pollution in Dutchess County. They are predominantly caused by fossil-fueled vehicles and the burning of fossil fuels. Policies that encourage a reduction in the number of vehicle miles driven and discourage burning will help to better our air quality. Some examples include:

- Establish zoning and land use planning that discourage suburban sprawl and promote mixed use development in walkable, compact Priority Growth Areas of a half-mile in radius, and greenway linkages between destinations that can be walked or bicycled;
- Restrict emissions from and reduce usage of outdoor wood burning furnaces, which can produce high concentrations of particulates;
- Require sealing mechanisms on gas pumps to reduce the escape of Volatile Organic Compounds, a precursor to greenhouse gases, when pumping fuel;
- Promote efficiency in home heating systems and maximize insulation in new and existing homes to reduce consumption of fossil fuels.

Chapter 3: Geology and Topography

Knowledge of a community's geology and environment is a critical component in formulating a community vision as expressed in planning efforts.

- Identify the location of limited or pristine resources, such as mineral resources, in order to protect their finite quantities;
- Limit development on steep slopes, which have a grade of greater than twenty percent, due to the potential impact on pre-existing development in the lowlands as well as drive up the cost of development;
- Protect viewsheds – which are determined by the local topography - as cultural resources that can be damaged by inappropriate development. Enact Ridgeline Protection Zones or Scenic Overlay Zones to direct new development away from highly visible areas to those that are more concealed;

Chapter 4: Soils

Soil is a fundamental resource that makes it possible for us to use and live on the land. Knowledge of soil's unique and varying characteristics can lead to appropriate choices about where to locate activities that capitalize on and do not squander this resource.

- Avoid soil depletion at all costs, since soils take thousands of years to form and once depleted or destroyed, it will take a very long time to replace them;

- Protect prime and statewide important agricultural soils, whose characteristics allow the highest yields when planted with crops. Due to the limited availability of these soils, development should be diverted to less valuable sites, to allow continued farming in areas with agriculturally important soils;
- Understand the implications of soil permeability for site development and groundwater protection. Soil impermeability is a key factor for effective residential septic disposal system operation. Too much development in an area of low permeability can lead to water pollution and health threats. By mapping areas of soil impermeability, the most appropriate development densities for each soil type can be specified;
- The construction and agriculture industries can adopt environmental practices for excavation that reduce erosion of soils.

Chapter 5: Water Resources

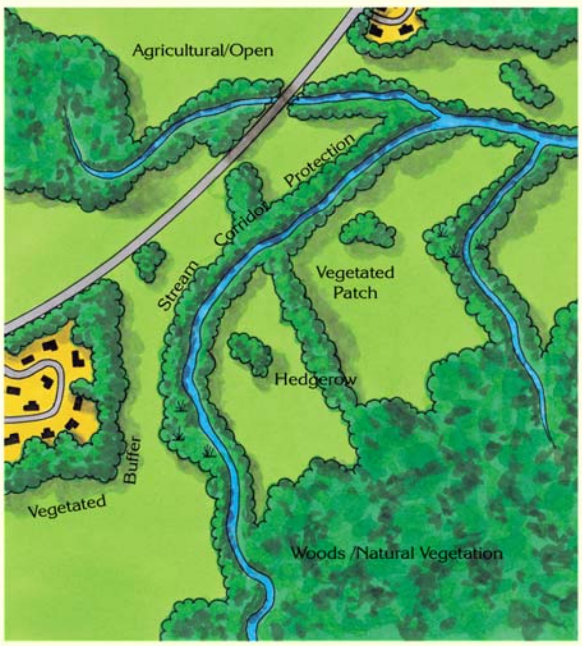
Although our surface water and ground water resources are abundant, well-integrated land and water management plans are necessary to protect this resource vital to our existence. Proper watershed management can assist in protecting infrastructure, reducing flood damage, and developing a stream stewardship ethic. In doing so, our resource will not be squandered nor destroyed through pollution.

- Municipalities should measure water resources through continued monitoring of stream gauges and testing of wells;
- Municipalities should minimize inter-basin water transfer (where water from an aquifer in one watershed is transferred to another, limiting water recharge) through well-designed on-site and sewage treatment plans;
- Zoning should consider soil permeability when the establishing limits on the density of development, so that all parcels have access to clean drinking water in the future;
- Municipalities should review and adjust their use of de-icing chemicals to minimize undissolved salt residues in surface and groundwater;
- Municipalities may want to consider establishing wetland protection ordinances for those significant wetlands that are not currently regulated by State or Federal law.

Chapter 6: Biological Resources & Biodiversity

Protecting biodiversity does not happen simply by protecting one or two rare or endangered species in a community. All nature is interrelated, and the first steps a community can take to protect their flora and fauna is to identify areas where the threats to nature are few. From this very general starting point, areas of habitat significant for its uniqueness, or for its ability to support rare or endangered species can be identified and mapped. When combined with identification of significant cultural resources like agricultural and recreational lands, and a set of conservation priorities and protection strategies, a community can develop an Open Space Plan, which is one of the foundation components for a Zoning Law.

- Municipalities may want to undertake a Biodiversity Assessment to identify significant flora and fauna, and work through community discussions to prioritize those natural resources and environments most important to the community;
- Municipalities may want to set conservation strategies for the identified resources, which may include zoning restrictions, recommendation of properties for conservation easement or purchase, or community-wide Transfer of Development or Purchase of Development Rights programs;
- Municipalities may want to minimize landscape fragmentation through zoning ordinance and subdivision review, since it is important to protect large, unbroken areas of significantly biodiverse habitats;
- Municipalities can participate fully in programs that provide assistance for biodiversity protection, including through the Open Space and Farmland Protection Program, Hudson River Greenway Compact, and Hudson River Watershed Alliance.



Habitat Protection Goals

- Map and maintain a system of stream bank protection areas, hedgerows, road and trail corridors, wetlands, development buffer areas, small and medium sized forest patches, and woodland reservations.
- Strive for connectivity (vegetated corridors) and proximity (stepping stones) among the vegetated open space tracts.
- Limit development on large, consolidated open space tracts.
- Allow smaller wildlife areas (patches) of 20 acres or more to be liberally scattered throughout the town.
- Work to establish soft feathered edges along woodland boundaries.
- Allow fingers of wild land to connect with suburban and urban districts.
- Encourage use of native species in landscaping.

Figure 9.11. From the Greenway Guide on Connected Habitats.

Chapter 7: Designated Significant and Protected Areas

- Municipalities may want to undertake local biodiversity assessment/habitat mapping to better understand the significant areas in their communities;

- Many municipalities have adopted local ordinances to protect sensitive habitats – others may want to consider using these tools;
- Municipalities can incorporate protection into comprehensive plans, open space plans, and farmland protection plans;
- Communities may want to identify additional Critical Environmental Areas (CEAs) in their municipality, and submit them to the NYS DEC for official designation. According to the DEC, following this designation, "the potential impact of any Type I or Unlisted Action on the environmental characteristics of the CEA is a relevant area of environmental concern and must be evaluated in the determination of significance prepared pursuant to Section 617.7 of SEQR" (DEC, 2010).

CONCLUSIONS

This chapter connects the NRI to the larger plan for sustainable regional planning in Dutchess County based on the county's Greenway Compact program, *Greenway Connections*, the proposed Centers and Greenspaces guide, and local planning tools and regulations. Building on the Case Study of Local Land Use Planning in Amenia, communities can begin to use the NRI as a decision-making tool by considering the following steps:

- Based on the information in the NRI and locally-relevant natural resource data, develop a set of goals and strategies for the conservation of significant natural features, landscapes, and habitats;
- Communities should also assess existing and proposed land use conditions, including priority growth areas for future development and priority greenspaces;

Separated Sprawl or Connected Centers

Separated subdivision on outlying land makes residents completely reliant on cars.

Same number of homes integrated into an existing walkable center, saving farmland and supporting village businesses.

Figure 9.12. Focusing development in priority growth centers.

- Use the NRI and other referenced sources as a baseline of information to assess the environmental impacts of proposed activities;
- Use the NRI and local natural resource data to identify critical areas for protection, such as wetlands, floodplains, or prime aquifer recharge areas;
- Identify threats to natural resources and plan for conservation and mitigation;
- Develop comprehensive plans that incorporate the concepts and information provided in the natural resource inventory; and
- Consider whether local natural resource conservation policies, such as planning and zoning board procedures, zoning laws, and other regulations, need to be revised and/or adopted.

The authors of the NRI chapters and agencies involved in developing the NRI sincerely hope that this document will provide municipal officials with the necessary information and tools needed to make successful decisions, respecting natural and human ecosystems.

RESOURCES FOR ADDITIONAL INFORMATION

- American Farmland Trust: Guide to Local Planning for Agriculture in New York: http://www.farmland.org/resources/publications/default2.asp.
- Cary Institute of Ecosystem Studies: http://www.caryinstitute.org/.
- Congress for the New Urbanism: http://www.cnu.org/.
- Cornell Cooperative Extension Dutchess County (CCEDC): http://ccedutchess.org (Environment and Energy Program) and CCE, Ithaca, NY http://cce.cornell.edu (information on environment and natural resources and community and economic vitality).
- Dutchess County Department of Planning & Development website: http://www.co.dutchess.ny.us/CountyGov/Departments/Planning/16138.htm
- Dutchess Land Conservancy: http://www.dutchessland.org/.
- Hudsonia, Ltd.: http://hudsonia.org/. Hudsonia conducted environmental research, education, training and technical assistance to protect the natural heritage of the Hudson Valley and neighboring regions.
- Land Trust Alliance: http://www.landtrustalliance.org/conservation/landowners/conservation-easements.
- Minnesota Department of Natural Resources, 2001, Natural Resource Guide: A guide to Using Natural Resource Information in Local Planning: http://files.dnr.state.mn.us/assistance/nrplanning/community/nrig/fullguide/overview.html (accessed November 2010).
- New York State Department of Environmental Conservation (DEC): 2009 Open Space Conservation Plan: http://www.dec.ny.gov/lands/47990.html.
- New York State Department of Environmental Conservation (DEC): State Environmental Quality Review Act: http://www.dec.ny.gov/permits/357.html.
- New York State Department of State: Provides Land Use training and technical assistance at http://www.dos.state.ny.us/LG/lut-index.html.
- New York State Hudson River Valley Greenway: http://www.hudsongreenway.state.ny.us/home.aspx.

- New York State, Smart Growth Communities: http://smartgrowthny.org/.
- 1000 Friends of Minnesota, Conservation Design Scorecard: http://www.1000fom.org/sites/default/files/ConservationDesignScorecard1000FOM.pdf.
- Pace University, Land Use Law Center: http://web.pace.edu/page.cfm?doc_id=23239 provides access to local land use tools and strategies and model ordinances through the Gaining Ground Information Database.
- Scenic Hudson: http://www.scenichudson.org/.
- Smart Growth Network: http://www.smartgrowth.org/.
- Winnakee Land Trust: http://www.winnakeeland.org/.

REFERENCES

Alexander, Christopher, Sara Ishikawa, and Murray Silverstein. *A Pattern Language*. New York: Oxford University Press, 1977.

Alexander, Christopher. *The Nature of Order, An Essay on the Art of Building and the Nature of the Universe* (4 Volumes). New York: Oxford University Press, 2001-2004.

Dutchess County Department of Planning and Development. *Greenway Connections, Greenway Compact Program and Guides for Dutchess County Communities*. 2000. http://www.co.dutchess.ny.us/CountyGov/Departments/Planning/Publications.htm.

Dutchess County Planning Federation. *Plan on It*, "New Greenway Guide: Centers and Greenspaces," January/February, 2010. http://www.co.dutchess.ny.us/CountyGov/Departments/Planning/Publications.htm.

Forman, Richard T. T. *Land Mosaics, The ecology of landscapes and regions*. Cambridge: Cambridge University Press, 1995.

Forman, Richard T. T. *Urban Regions, Ecology and Planning Beyond the City*. Cambridge: Cambridge University Press, 2008.

Johnson, Elizabeth A. and Michael W. Klemens (eds). *Nature in Fragments, The Legacy of Sprawl.* New York: Columbia University Press, 2005.

Land Trust Alliance. "Conservation Easements." http://www.landtrustalliance.org/conservation/landowners/conservation-easements (accessed November 2010).

Leopold, Aldo. *A Sand County Almanac.* New York: Ballentine Books, 1996 (Originally published 1949).

McDonough, William and Michael Braumgart. *Cradle to Cradle, Remaking the Way We Make Things.* New York: North Point Press, 2002.

New York State Department of Environmental Conservation. "Critical Environmental Areas (CEAs)." http://www.dec.ny.gov/permits/6184.html (accessed November 2010).

New York State Statute on Local Governments Article 10, Section 6-7, http://law.justia.com/newyork/codes/2006/statute-of-local-governments/slg010_10.html (accessed November 2010).

Nolon, John. *New Ground: The Advent of Local Environmental Authority*. Washington, DC: The Environmental Law Institute, 2003.