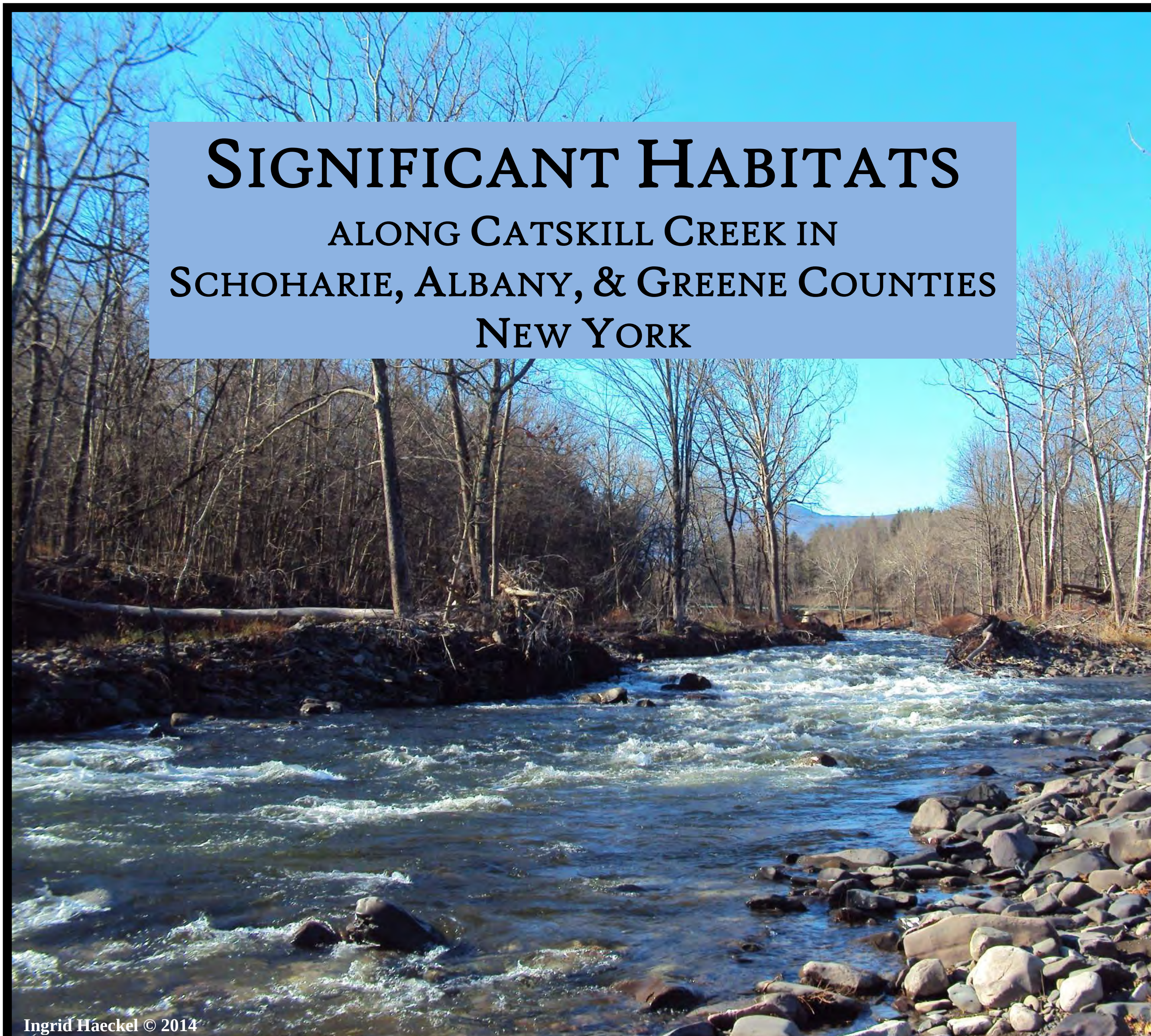
SIGNIFICANT HABITATS

ALONG CATSKILL CREEK IN SCHOHARIE, ALBANY, & GREENE COUNTIES NEW YORK



Report to the Hudson River Estuary Program,
the Department of Natural Resources at Cornell University, and
the Catskill Creek Watershed Advisory Committee

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EXECUTIVE SUMMARY

Flooding from large storm events in the last several years dramatically altered the stream channel alignment and floodplain of the Catskill Creek and some of its tributaries, and caused great damage to roads, bridges, buildings, farmland, and residential properties within the flood path.

The frequency and severity of storms are predicted to increase in the Northeast in the coming decades. To help landowners and communities in the Catskill Creek corridor plan for future flood events and reduce the physical damage and accompanying economic hardship, local, county, and state agencies are seeking to understand, harness, and accommodate the natural processes that govern stream dynamics.

In 2011-2012 Hudsonia biologists identified and mapped ecologically significant habitats within a 984-foot-wide (300-meter-wide) corridor centered on the Catskill Creek mainstem in Schoharie, Albany, and Greene counties, New York, running 35 miles (56 kilometers) from the creek's headwaters in the Franklinton Vlaie to just above the dam in Leeds. The work was funded by the New York State Environmental Protection Fund through the Hudson River Estuary Program of the New York State Department of Environmental Conservation in partnership with the Cornell University Department of Natural Resources.

The purposes of the project were to provide a better understanding of the Catskill Creek landscape, and to help identify needs for riparian buffer restoration and bank stabilization, and areas critical for maintaining the structural and biological integrity of the stream. The map also provides a baseline for future monitoring of habitat and land cover change within the stream corridor.

This document describes the habitats in the study area and their relationships to stream processes and biological resources, and provides some recommendations for land uses and land management in the corridor and throughout the Catskill Creek watershed that will improve the land's resiliency to future flood events.

Maintaining or restoring the dynamic interactions between streams and their floodplains, and promoting land cover and land uses compatible with occasional flooding will allow the floodplain to serve its manifold functions for storing flood waters, reducing the velocity of flood flows, stabilizing streambanks, reducing stream channel erosion, trapping and removing sediments, nutrients, and other contaminants from runoff, moderating stream water temperatures, contributing woody debris and other organic detritus to the habitat structure and food base for stream organisms, and providing habitat for terrestrial wildlife.

Additional measures that can be applied throughout the watershed will help to reduce floodwater volumes, and improve the water quality and instream habitats of the Catskill Creek; for example, maintaining forested landscapes as much as possible, minimizing pavement and other impervious surfaces, maximizing onsite infiltration of stormwater in developed areas, directing road runoff into treatment swales and basins (instead of streams), and reducing the use of fertilizers and pesticides wherever possible.

Landowners themselves can take measures to improve safety and resiliency on their own land in the face of large floods, such as maintaining well-vegetated floodplains and broad buffer zones of woody vegetation along streams, fencing livestock away from streams, and removing structures and hazardous materials from the floodplain wherever possible. When the opportunities arise during reconstruction and maintenance projects, municipal, county, and state agencies can redesign and reinstall culverts and bridges to accommodate the expected water volumes in future flood events. Municipalities can also use environmental reviews and local legislation to apply sound policies to the design and regulatory approvals of new land uses near streams and throughout watersheds.

Far from being a threat to property rights or economic development in the region, proactive planning for future land uses and infrastructure and restoration of key parts of the stream corridor will help to keep property safe from future large flood events, and reduce the economic burden on landowners and municipalities for repairs and restoration after each storm.


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INTRODUCTION

The large storm events of 2011 and 2012, including hurricanes Irene and Sandy, and tropical storm Lee, brought devastating floods to the Catskill Creek corridor and other parts of New York and the Northeast. Destruction of buildings, bridges, roads, and residential and agricultural land meant terrible economic losses to property owners and municipalities that have still not recovered three years later. Flood forces widened the stream channel and dramatically shifted the channel in many places, cut deeply into streamside slopes, and deposited large amounts of sediment—silt to large cobbles—in the floodplain.

According to the National Climate Assessment (Easterling et al. 2014), the Northeast has experienced a greater recent increase in extreme precipitation than any other region in the United States—an increase of more than a 70% since 1958 in the amount of precipitation falling in very heavy events. The frequency and severity of large storms is predicted to continue to increase in the coming decades. The recent experience in the Catskill Creek corridor brings into sharp relief the need for better understanding of the landscape processes related to flooding, and better planning, preparation for, and response to future such events.

In 2011 and 2012 Hudsonia prepared a map of ecologically significant habitats in a corridor along the Catskill Creek mainstem in Schoharie, Albany, and Greene counties. The purpose of the project was to provide habitat information for landowners and for town, county, and state agencies and others involved in land management, in environmental reviews, and in preparation for and response to flood events along the Catskill. The habitat map helps identify areas that are critical for maintaining stream structural and biological integrity, and needs for riparian buffer restoration and bank stabilization. The map also provides a baseline for future monitoring of habitat and land cover change within the stream corridor.

The habitat map depicts the locations of significant upland, wetland, and stream habitats, many of which are entirely unprotected by federal, state, or local statutes, yet are essential components of the ecosystems that support the human community, the stream itself, and the surrounding natural landscape. For example, forests are important for wildlife habitat, but also for carbon sequestration and for maintaining the quality and quantity of groundwater and stream flows. Shrubland, meadows, isolated wetlands, intermittent streams, and ledges are components of the habitat complexes required by many wildlife species, but also provide basic ecological services such as nutrient cycling, soil stabilization, water resource protection, climate moderation, and support of insect pollinators. These services are fundamental to maintaining the water quality and the structural and biological integrity of the Catskill Creek and surrounding landscape, as well as for fishing, hunting, and other forms of recreation, and to the overall quality of life for residents of the watershed.

Although many land use decisions in the region are necessarily made on a site-by-site basis, the long-term viability of biological communities, habitats, and ecosystems requires consideration of whole landscapes. This is well-illustrated in a stream system such as the Catskill Creek where land uses at one location can dramatically affect the upstream and downstream response to extreme events.

We hope that this map and report will help landowners understand how their properties contribute to the well-being of the Catskill Creek and the larger ecological landscape, and will inspire them to manage their land in ways that protect habitats and enhance the stream integrity. We also hope that the towns in the Catskill Creek corridor will engage in proactive land use and conservation planning to ensure that future land development and other activities near the stream are undertaken with a view to long-term accommodation of natural stream processes, and protection of infrastructure and of stream and floodplain habitats.

Hudsonia Ltd. is an independent, nonprofit, non-advocacy, environmental research and education institute that studies the natural environment and disseminates information to scientists, practitioners, and the public.

The habitat mapping project was funded by the New York State Environmental Protection Fund through the Hudson River Estuary Program of the NYSDEC in cooperation with the Department of Natural Resources at Cornell University.

What are Ecologically Significant Habitats?

For the purposes of this project, a "habitat" is simply the place where an organism or population lives or where a biological community occurs, and is defined according to both its biological and non-biological components. Individual species of plants and animals will be protected for the long term only if their habitats remain intact. The local or regional disappearance of a habitat can lead to the local or regional extinction of species that depend on that habitat. Habitats that we consider to be "ecologically significant" include:

- habitats that are rare or declining in the region.
- habitats that support (or may support) rare species and other species of conservation concern.
- high-quality examples of common habitats (e.g., those that are especially large, isolated from human activities, old, or lacking harmful invasive species).
- complexes of connected habitats that, by virtue of their size, composition, or configuration, have significant biodiversity value.
- habitat units that provide landscape connections between other important habitat patches.

Because most wildlife species need to travel among different habitats to satisfy their basic survival needs, landscape patterns can have a profound influence on wildlife populations. The size, connectivity, and juxtaposition of habitats in the landscape all have important implications for biological diversity and ecosystem health. By illustrating the locations and configurations of ecologically significant habitats throughout the Catskill Creek corridor, the large-format habitat map that accompanies this report provides ecological information that can be applied to planning for flood resiliency, and incorporated into local land use decision making.

The Study Area

The Catskill Creek and its tributaries constitute a 927-mile river system with a 415-mi^2 watershed in 14 towns in Schoharie, Albany, Ulster, and Greene counties of New York (Cornell Cooperative Extension 2014) (Figure 1). The Catskill rises in the Franklinton Vlaie, a large marsh and lake complex in the Town of Broome, Schoharie County, and flows generally southeast through seven towns approximately 36 miles (58 kilometers), and empties into the Hudson River estuary in the Village of Catskill, Greene County.

The bedrock geology throughout the Catskill Creek watershed is sedimentary rock—shales, siltstones, and sandstones—and the surficial material is mostly glacial till (Fisher et al. 1970, Cadwell et al. 1986). The stream itself runs through a narrow corridor of glacial outwash alternating with alluvial deposits for much of its length (Cadwell et al. 1986), and is controlled by bedrock exposures at some places, most prominently in the lower reaches.

The Catskill Creek watershed is hilly and largely forested, but also contains significant areas of active and abandoned farmland. The creek mainstem runs through rural forested and open landscapes and several hamlets—Livingstonville, Preston Hollow, Cooksburg, Oak Hill, East Durham, South Cairo, and Leeds. Major tributaries to the Catskill include the Potic Creek, Kaaterskill Creek, Basic Creek, and Tenmile Creek. (Figure 1). Most of the length of Catskill Creek mainstem is classified as a trout stream, and the reach above the Durham hamlet is classified as trout spawning habitat by the New York State Department of Environmental Conservation (NYSDEC), indicating cool, clean-water instream habitats with unsilted substrates, capable of supporting pollution-sensitive fish and other organisms.

The study area for this project was a 35-mile-long (56 km) corridor between the Franklinton Vlaie and the Leeds dam, approximately 984 ft (300 m) wide, centered on the Catskill Creek mainstem.

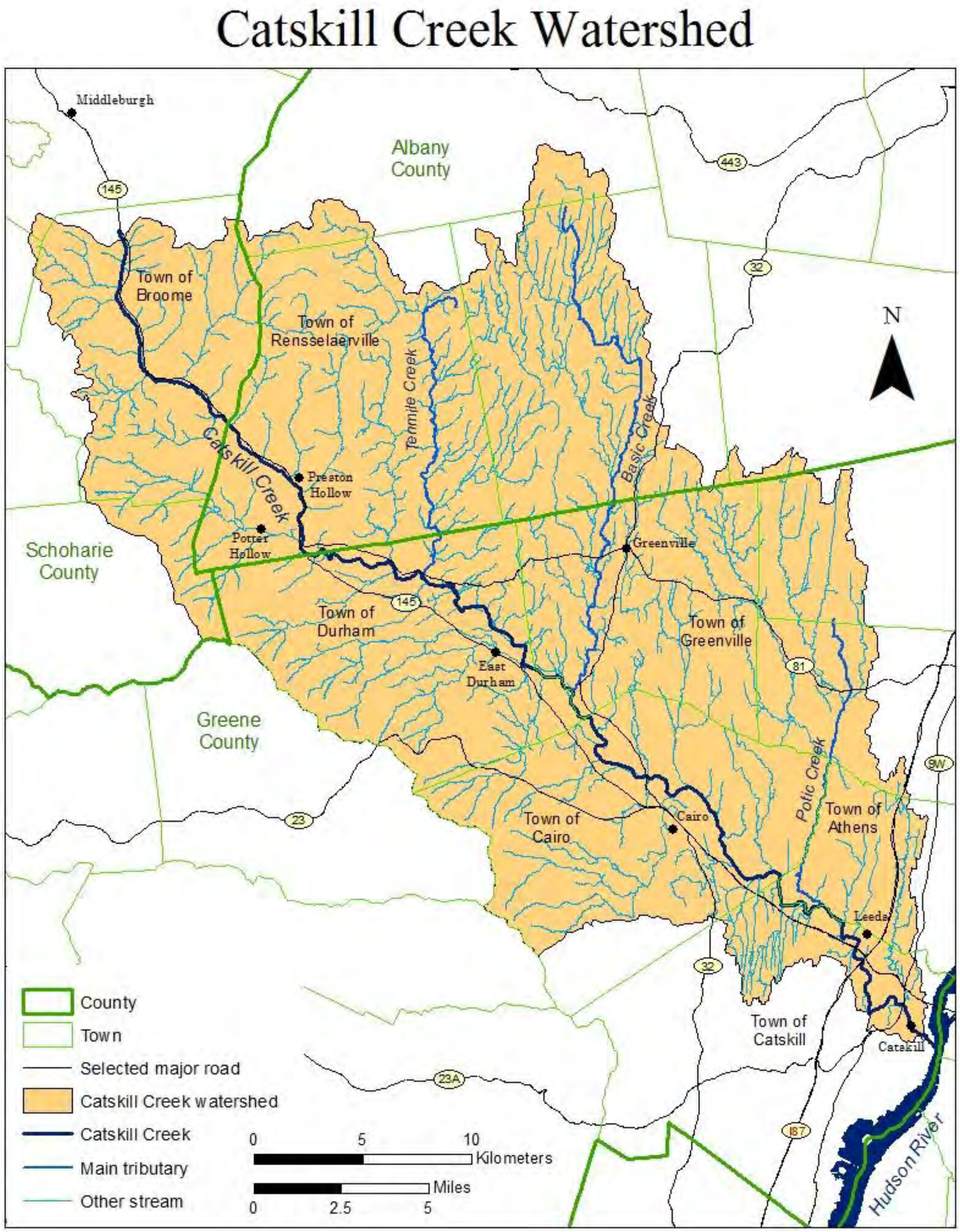

Figure 1. Catskill Creek watershed.

Services of Stream Corridor Habitats

Habitats in a stream corridor perform a range of ecological functions that serve the stream and the surrounding landscape, and play a large role in local and downstream flood dynamics; for example:

-- stabilizing streambanks and reducing stream channel erosion
-- storing flood waters and reducing the velocity of flood flows
-- moderating stream water temperatures
-- trapping and removing sediment from runoff and floodwaters
-- trapping and removing nutrients, pesticides, and other contaminants from runoff and floodwaters
-- contributing woody debris and other organic detritus to the habitat structure and food base for stream organisms
-- providing habitat for terrestrial organisms (Wenger 1999)

Characteristics of the topography, soils, and vegetation at any particular location govern the effectiveness of the streamside and floodplain habitats for providing these services.

Stabilizing Streambanks

Poorly vegetated streambanks are vulnerable to erosion during high water events. Woody vegetation (trees and shrubs) on stream banks helps to reduce the velocity (and thus the erosive force) of flood waters, and the roots of woody vegetation help to hold erodible soils in place.

Dampening Floodflows

The "roughness" created by the microtopography of the ground surface, the above-ground woody and herbaceous vegetation, woody debris, and rocks in the floodplain, as well as the floodplain width determine the degree to which the floodplain will reduce the velocity of floodflows. Densely-vegetated areas with a combination of woody and herbaceous plants are most effective at slowing floodwater and thus reducing the downstream flood forces.

Removing Contaminants

Suspended sediments entering a stream from tributaries, from sheet runoff, from streambank erosion, and from scouring of the stream channel affects the stream structure and habitat quality in many ways. Sediment deposited on stream beds degrades the nesting and foraging habitat for fish, and the habitat for aquatic invertebrates and other stream biota. Suspended sediment is especially harmful to filter-feeding organisms such as mollusks and crayfish. Well-vegetated riparian zones can reduce stream sedimentation by trapping sediments before they reach the stream; by reducing the velocity of sediment-bearing storm flows and thus allowing sediments to settle out; by stabilizing streambanks; and by contributing large woody debris to streams, which can temporarily capture large amounts of instream sediments.

Excess nutrients in the forms of nitrogen and phosphorus compounds can lead to the overfertilization ("eutrophication") of streams, ponds, and wetlands. These can cause large blooms of algae which, upon dying and decaying, depletes the dissolved oxygen that is essential to fish and other aquatic organisms. Prominent sources of phosphorus and nitrogen are fertilizers applied to lawns and agricultural fields and leachate from failing septic systems. Human and animal waste from those sources also carries pathogens harmful to humans and aquatic organisms. The breakdown of large amounts of manure or septage can also deplete the dissolved oxygen in a stream.

Phosphorus typically enters riparian zones attached to sediment or organic matter, so measures to remove sediment from runoff are likely to be effective at trapping phosphorus. Nitrogen compounds such as nitrate and ammonia can be toxic to humans and animals, including aquatic organisms, but vegetated riparian zones can be very effective at removing nitrogen from runoff by two main processes: uptake by plants, and denitrification—the reduction of nitrogen compounds (e.g., nitrate and nitrite) into nitrogen gas that can then escape into the atmosphere. Denitrifying bacteria are especially active in the carbon-rich soils of wetlands (Parkyn 2004).

Pesticides (including herbicides, algicides, fungicides, rodenticides, insecticides, and others) used on lawns, gardens, and crop fields can cause direct mortality to aquatic organisms as well as sublethal effects on nervous and reproductive systems that can reduce the viability of vertebrate and invertebrate populations (Cooper 1993). The soils of intact, vegetated riparian zones can break down some pesticides into non-toxic substances, and thus protect sensitive stream organisms.

Heavy metals and petroleum hydrocarbons, which are toxic to many stream organisms, are common contaminants of road runoff. Vegetated floodplains can be effective at removing these substances from surface runoff, depending on the particular characteristics of the soils (Wenger 1999, Rupprecht et al. 2009).

<u>Moderating Stream Water Temperatures</u>

Forests next to streams can have a large effect on reducing the temperature of stream water, both by directly shading the stream, and by shading the floodplain and other areas through which the steam is fed by tributary streams and shallow groundwater. High water temperatures reduces dissolved oxygen, a critical resource for stream organisms (Wenger 1999). Certain species of mollusks, amphibians, fish, and aquatic insect species that do not tolerate high temperatures, and have declined or disappeared from many Hudson Valley streams where previously forested riparian zones have been cleared.

METHODS

We employed a combination of remote sensing and field observations to identify and map habitats in the Catskill Creek study area—a 984-foot-wide (300-meter-wide) corridor along the Catskill Creek mainstem (Figure 2). Most of the mapping and field work were carried out by Hudsonia biologists Chris Graham, Ingrid Haeckel, and Othoniel Vazquez. Volunteers with the Catskill Watershed Advisory Committee assisted with field observations in fall 2011, and with obtaining landowner permissions. Gretchen Stevens participated in all aspects of the project, and was the primary author of this report. Below we describe each phase in the Catskill Creek habitat mapping project.

Gathering Information and Predicting Habitats

We used map features (e.g., slopes, bedrock chemistry, and soil texture, depth, and drainage) and features visible on stereoscopic aerial photographs (e.g., exposed bedrock, vegetation cover types) to predict the locations and extents of ecologically significant habitats. We employed the following resources to aid our remote sensing:

- *1:40,000 scale color infrared stereoscopic aerial photograph prints* from the National Aerial Photography Program series taken in spring 1994 and spring 1995 obtained from the U.S. Geological Survey. Viewed in pairs with a stereoscope, these prints ("stereo pairs") provide a three-dimensional view of the landscape and are extremely useful for identifying vegetation cover types, wetlands, streams, and cultural landscape features.

- *High-resolution (1 pixel = 24 in [65 cm]) color infrared digital orthophotos* taken in spring 2001 (Albany, Greene, and Schoharie counties), spring 2009 (Greene County), and spring 2010 (Schoharie County); as well as *true color digital aerial photograpy* taken in spring 2007 (Albany County), obtained from the New York State GIS Clearinghouse website (http://www.nysgis.state.ny.us; accessed September 2011). These digital aerial photos were used for on-screen digitizing of habitat boundaries.

- *Google Earth imagery* taken on 7 October 2011 along Catskill Creek in the Towns of Broome, Rensselaerville, Durham, Greenville, Cairo, Catskill, and Athens (accessed 23 November 2012). Google Earth images were georeferenced to the digital orthoimagery and used to detect changes to the stream channel and gravel bar boundaries from recent flood events.

- *U.S. Geological Survey (USGS) topographic maps* (Middleburgh, Livingstonville, Durham, Freehold, and Leeds 7.5 minute quadrangles). Topographic maps contain extensive information about landscape features, such as elevation contours, surface water features, and significant cultural features. We use contour lines on topographic maps to predict the occurrence of habitats such as cliffs, wetlands, intermittent streams, and seeps.

- *Bedrock and surficial geology maps* (Hudson-Mohawk Sheet) produced by the New York Geological Survey (Fisher et al. 1970, Cadwell et al. 1989). Along with topography, surficial and bedrock geology strongly influence the development of particular soil properties and aspects of groundwater and surface water chemistry, and thus have important implications for the biological communities that become established at any site.
- *Soil Surveys of Albany, Greene, and Schoharie Counties, New York* (Flora et al. 1969, Brown 1992, Broad 1993). Specific attributes of soils, such as depth, drainage, texture, and pH, convey much information about the types of habitats that are likely to occur in an area. Shallow soils, for example, may indicate the location of crest, ledge, and talus habitats. Poorly and very poorly drained soils usually indicate the location of wetland habitats such as swamps, marshes, and wet meadows. The presence of alkaline soils can be used to predict the occurrence of calcareous habitats.
- *GIS data*. A Geographic Information System enables us to overlay multiple data layers on a computer screen, greatly enhancing the efficiency and accuracy with which we can predict the diverse habitats that are closely linked to local topography, geology, hydrology, and soil conditions. GIS also enables us to create detailed, spatially accurate maps. We obtained several of our GIS data layers from the New York State GIS Clearinghouse, including municipal and tax parcel boundaries, roads, hydrological features, and public lands. Bedrock and surficial geology data were downloaded from the USGS and New York State Museum websites. National Wetlands Inventory data prepared by the US Fish and Wildlife Service were obtained from their website. We obtained soils data from the Natural Resources Conservation Service (NRCS) website and National Hydrography Dataset stream data from the USGS website. USGS 10-m digital elevation models were downloaded for each county in the study area from the Cornell University Geospatial Information Repository website.

Habitat Mapping and Field Verification

We prepared a preliminary map of predicted habitats based on map analysis and stereo interpretation of aerial photographs. We digitized the predicted habitats onscreen over the orthophoto images using ArcGIS Desktop 10.0 (Environmental Systems Research Institute 2011) computer mapping software. With these draft maps in hand we conducted field visits to as many of the mapped habitat units as possible to verify their presence and extent, assess their quality, find other habitats, and identify habitats that could not be identified remotely. We used Garmin GPSMAP 60Cx GPS units to identify the approximate locations and boundaries of certain habitats, streams, and other features seen in the field, but did not use GPS for detailed delineations of habitat boundaries.

Catskill Creek Study Area

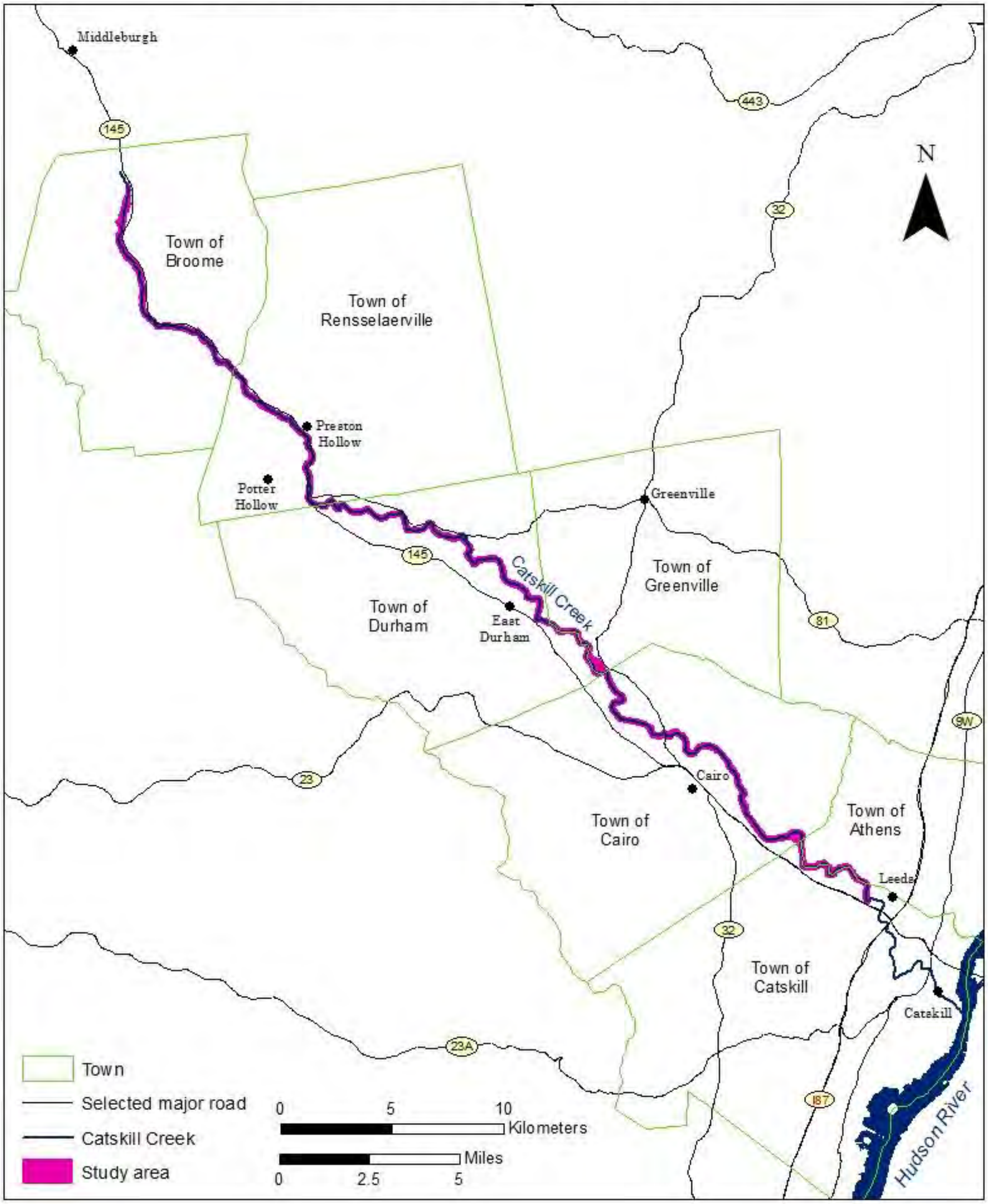

Figure 2. Study area corridor for the habitat mapping project.

We identified landowners using tax parcel data, and before visiting field sites we contacted landowners for permission to walk their land. We prioritized sites for field visits based both on opportunity (i.e., willing landowners) and our need to answer habitat questions that could not be answered remotely. In addition to conducting field work on private land, we viewed habitats from adjacent properties, public roads, and other public access areas. Because the schedule of this project (and non-participating landowners) prevented us from visiting every parcel in the study area, this strategy increased our efficiency while maintaining a high standard of accuracy.

In fall 2011 a team of volunteers with the Catskill Creek Watershed Advisory Committee began the field verification of the preliminary map, and Hudsonia completed the field work in 2012. We field-checked approximately 2070 ac (840 ha), which represents approximately 47% of the undeveloped area along the Catskill Creek corridor study area. Areas that could not be field checked show our remotely-mapped habitats. We assume that areas of the habitat map that were field checked are generally more accurate than areas we did not visit, particularly in the cases of the numerous small wetlands in forested areas which were difficult to map remotely. Once we had conducted field work in some areas, however, we were able to extrapolate our findings to adjacent parcels and similar settings throughout the corridor.

Defining Habitat Types

Habitats are useful for categorizing places according to apparent ecological function, and are manageable units for scientific inquiry and for land use planning. We have classified broad habitat types (Table 1) that are identifiable largely by their vegetation and visible physical properties. Habitats exist, however, as part of a continuum of intergrading biological communities and physical properties, and it is often difficult to draw a line to separate two habitats. Also, some distinct habitats are intermediates between two defined habitat types, and some habitat categories can be considered complexes of several habitats. In order to maintain consistency within and among habitat mapping projects, we have developed certain mapping conventions that we use to classify and delineate habitat boundaries. Some of these are described in Appendix A. Because much of the area along the Catskill Creek corridor was only mapped remotely, and all mapped habitat boundaries were drawn without survey or GPS equipment, all of the mapped features should be considered approximations.

We corrected and refined the preliminary map on the basis of our field observations to produce the final GIS database. The GIS files include additional information about many of the mapped habitat units, such as some of the plant and animal species observed in the field. Many notes on Catskill Creek channel characteristics are included in the natural history notes file. The GIS database and this report have been given to the Hudson River Estuary Program, the Department of Natural Resources at Cornell University, and the Catskill Creek Watershed Advisory Committee for use in conservation and land use planning and decision making. The data are also available to the municipalities of the study area. We request that any maps printed from this database for public viewing be printed at scales no larger than 1:10,000, and that the habitat map data be attributed to Hudsonia Ltd. Although the habitat map was carefully prepared and extensively field-checked, there are inevitable inaccuracies in the final map. Because of this, we request that the following caveat be printed prominently on all maps:

> *"This map is suitable for general land-use planning, but is not suitable for detailed planning and site design, or for jurisdictional determinations (e.g., for wetlands). Boundaries of wetlands and other habitats depicted here are only approximate."*

Table 1. Ecologically significant habitats identified by Hudsonia along Catskill Creek, Schoharie, Albany, and Greene counties, New York, 2012.

Upland Habitats	Wetland Habitats
Upland hardwood forest	Hardwood & shrub swamp
Upland conifer forest	Mixed forest swamp
Upland mixed forest	Floodplain hardwood forest
Orchard/plantation	Marsh
Upland shrubland	Wet meadow
Upland meadow	Constructed pond
Cultural	Open water
Waste ground	Spring/seep
Bare ground	Stream
Crest/ledge/talus	Gravel bar
Ledge	

HABITATS IN THE CATSKILL CREEK CORRIDOR

OVERVIEW

The printed, large-format habitat map that accompanies this report was produced as a series of several map sheets at a scale of 1:10,000, showing the Hudsonia-mapped habitats within the study area along the Catskill Creek, together with the land cover in the surrounding landscape (from the National Land Cover Database [NLCD] [Jin et al. 2011]) to provide some landscape context for the study area. The NLCD data, however, were developed at a much coarser scale than our habitat data, using automated interpretation of satellite imagery instead of our methods of hands-on interpretation of aerial photo imagery and other map data.

Here we describe some of the ecological attributes of the habitats identified in the study area, their contributions to the stream ecosystem, and some conservation measures that can help to protect these habitats, their services to the Catskill Creek, and the species of conservation concern they may support. We indicate plant and animal species of conservation concern (those that are listed as such by state agencies or by non-government organizations) by placing an asterisk (*) after the species name. Appendix C gives the common and scientific names of all plants mentioned in this report. The four large-format map sheets (scale of 1:10,000) accompanying this report depict the locations of habitats within the Catskill Creek corridor.

UPLAND HABITATS

UPLAND FORESTS

Ecological Attributes

We classified upland (i.e., non-wetland) forests into four general types for this project: upland hardwood forest, upland conifer forest, upland mixed forest, and floodplain hardwood forest. We recognize that upland forests are very variable in age, species composition, and other attributes, and that each of these four types encompass many distinct biological communities, but our broad forest types are useful for general planning purposes, and are also the most practical for our remote mapping methods.

<u>Upland Hardwood Forest</u>

Upland hardwood forest is the most common habitat type in the region, both within and outside the Catskill Creek corridor, and is extremely variable in species composition, size and age of trees, vegetation structure, soil drainage and texture, and other habitat factors. The habitat includes many different types of deciduous forest communities, and is used by a large array of plants and animals.

Common trees of upland hardwood forests in the region include maples (sugar, red), oaks (black, red, white, chestnut), hickories (shagbark, pignut), American beech, white ash, black birch, and black cherry. Individuals and small groves of eastern hemlock and white pine were here and there within the deciduous forests.

Upland Conifer Forest

Eastern hemlock and eastern white pine were the dominant species in upland conifer forests of the study area. Eastern red cedar occurred here and there, and especially in areas of exposed bedrock.

Upland Mixed Forest

We use the term "upland mixed forest" for non-wetland forested areas with both hardwood and conifer species in the overstory, where conifer cover is 25-75% of the canopy. In most cases, the distinction between conifer and mixed forest was made by aerial photograph interpretation. Mixed forests are less densely shaded at ground level and tend to support a higher diversity and greater abundance of understory species than pure conifer stands.

Floodplain Hardwood Forest

Floodplains are areas along a stream that experience flooding at intervals ranging from frequent (yearly or several times per year) to occasional (every few years or decades). Floodplains may support both wetland and non-wetland habitats, including upland forests and meadows, swamps, marshes, and wet meadows.

Forests on floodplains include both wetland (swamp) and non-wetland areas, often so intimately intertwined that the distinction is difficult to discern or map. For this reason we have mapped a habitat called "floodplain forest" that in most cases is substantially non-wetland, but may contain areas of forested swamp. Typical floodplain forests include a mixture of upland and wetland plant species and floodplain specialists such as sycamore, eastern cottonwood, and pin oak. They tend to have high species diversity and high biological productivity. Many species of fish and wildlife depend on riparian habitats in some way for their survival (Hubbard 1977, McCormick 1978). The soils of floodplains are often sandy or silty.

Common trees of floodplain forests in the Catskill Creek corridor included black locust, slippery elm, American sycamore, basswood, red maple, green ash, and American hornbeam. Japanese knotweed often formed dense stands within and at the edges of floodplain forests. Large and small woody debris was abundant, and flood-deposited patches of gravel were common, sometimes covering large areas.

Upland forests of all kinds provide habitat for a large array of wildlife, including many species of conservation concern. Eastern box turtle* spends most of its time in upland forests and meadows, finding shelter under logs and organic litter, while spotted turtle* uses upland forests for aestivation (summer dormancy) and travel. Many snake species, such as eastern rat snake,* eastern racer,* and red-bellied snake, forage widely in upland forests and other habitats. Upland hardwood forests provide important nesting habitat for raptors, including red-shouldered hawk,* Cooper's hawk,* sharp-shinned hawk,* broad-winged hawk, and barred owl,* and many species of songbirds, including warblers, vireos, thrushes, and flycatchers. American woodcock* forages and nests in young hardwood forests and shrublands. Acadian flycatcher,* wood thrush,* cerulean warbler,* Kentucky warbler,* and scarlet tanager* are some of the birds that may require large forest-interior areas to nest successfully and maintain populations in the long term. Large mammals such as black bear,* bobcat,* and fisher* also require large expanses of forest. Many small mammals are associated with upland hardwood forests, including eastern chipmunk, southern flying squirrel, and white-footed mouse. Higher densities of small mammals occur in forest areas with abundant logs and other woody debris, and these are favored by snakes such as copperhead, black rat snake, and black racer. Hardwood trees larger than 5 in (12.5 cm) dbh—especially those with loose, platy bark such as shagbark hickory, deeply furrowed bark such as black locust, or snags with peeling bark—can be used by Indiana bat* for summer roosting and nursery colonies.

Rare plants of floodplain forests in the region include cattail sedge,* Davis' sedge,* winged monkeyflower,* and goldenseal.* Beaver, American mink, and river otter* regularly use riparian corridors; we found much evidence of old and recent beaver activity up and down the Catskill Creek corridor. Louisiana waterthrush* uses the rocky banks of swift-running streams, and northern waterthrush nests in thick vegetation near slow-moving streams, ponds, and wetlands, but both are found mainly where large forests are adjacent to the streams. Wood duck* nests in tree cavities, and uses the stream and nearby wetlands for nursery and feeding areas. Acadian flycatcher,* if it occurs here at all, would nest in the interior areas of large forests associated with the Catskill Creek.

Services and Sensitivities

Forests within and outside the riparian zone do much to maintain water quality and quantity, habitat quality, and stream stability, as well as providing other irreplaceable services such as climate moderation, carbon sequestration, and wildlife habitat. Forests with intact vegetation and forest floors minimize the rapid runoff of rainwater and snowmelt that creates downgradient flood conditions. Forests intercept precipitation and promote infiltration of water to the soils and groundwater. Forest vegetation on floodplains and streambanks helps to attenuate floodwater energy, and the deep and tenacious root systems of woody vegetation helps to stabilize streambanks and floodplain soils. Forests also contribute coarse and fine woody debris and other organic matter to the stream, which creates valuable habitat and microhabitat structure in the stream, and constitutes the foundation of the stream food web.

Beaver activity was widespread in the Catskill Creek corridor.

Extensive forested areas that are unfragmented by roads, driveways, trails, utility corridors, residential lots, or meadows are especially important for certain area-sensitive organisms. Fragmenting features that divide large foreststs into smaller forest patches pose many threats to wildlife and the forest itself. Paved and unpaved roads act as barriers which many species will not cross or cannot safely cross (Forman and Deblinger 2000). For example, mortality from vehicles can significantly reduce the population densities of amphibians (Fahrig et al. 1995), and many animals will not breed near traffic noise (Trombulak and Frissell 2000). Long driveways intruding deep into forests cause significant fragmentation of core forest areas. Development along roads is far less disruptive, though it may still block important wildlife travel corridors between forested patches. Roadways, including driveways, can provide access to interior forest areas for nest predators (such as raccoon and opossum) and the brown-headed cowbird (a nest parasite), which reduce the reproductive success of many forest interior birds. Where dirt roads or trails cut through forest, vehicle, horse, and pedestrian traffic can harm tree roots and cause soil erosion. Runoff from roads and driveways can pollute nearby areas with road salt, heavy metals, petroleum hydrocarbons, and sediments (Trombulak and Frissell 2000). Forests are also susceptible to invasion by shade-tolerant non-native herbs and shrubs, which may easily be dispersed along roads and trails and by logging machinery, ATVs, and other vehicles.

In addition to fragmentation, forest habitats can be degraded in many other ways. Clearing the forest understory destroys habitat for birds such as wood thrush,* which nests in dense understory vegetation, and black-and-white warbler* and ovenbird,* which nest on the forest floor. Removal of mature and especially overmature (large) trees eliminates habitat for lichens, fungi, and bryophytes, as well as the many kinds of animals that use cavities and that forage in and around large and decaying trees. Selective logging can also damage the understory and cause soil erosion, compaction, and rutting, and sedimentation of streams. Soil compaction and removal of dead and downed wood and debris eliminates habitat for mosses, lichens, fungi, birds, amphibians, reptiles, small mammals, and insects.

Conservation Recommendations

1. **Protect and maintain forests within and near floodplains** wherever possible. Floodplain forests stabilize soils, dissipate flood energy, help to maintain cool stream temperatures, remove sediments and contaminants from runoff, provide organic detritus to the stream food web and habitat structure, and provide valuable habitat for wildlife.

2. **Protect forests throughout the watershed** wherever possible. Forests are perhaps the best cover type for absorbing precipitation and promoting infiltration to the soils. This prevents rapid runoff of rainwater and snowmelt into streams, and thus reduces downgradient flooding. Forests are also important for carbon sequestration, climate moderation, and wildlife habitat.

3. **Avoid fragmentation of large, contiguous forested areas** wherever possible. Locate new development and other disturbances near forest edges instead of in forest interiors.

4. **Maintain or restore broad corridors of intact habitat between large forested areas.** For example, a forested riparian corridor or a series of smaller forest patches may provide connections between larger forest areas. Forest patches on opposite sides of a road may provide a “bridge” across the road for forest-dwelling animals.

5. **Maintain the forest canopy, understory vegetation, standing dead wood, downed wood, and organic debris, and prevent disturbance or compaction of the forest floor**. These features help to maintain the forest ecosystem and provide habitats and microhabitats for forest wildlife and plants.

CREST/LEDGE/TALUS

Ecological Attributes

Rocky crest, ledge, and talus habitats often occur together, so they are described and mapped together for this project. Crest and ledge habitats occur where soils are very shallow and bedrock is partially exposed at the ground surface, either at the summit of a hill or knoll (crest) or elsewhere (ledge). Talus is the term for the fields of large rock fragments that often accumulate below steep ledges and cliffs. Some crest, ledge, and talus habitats support well-developed forests, while others have only sparse, patchy, and stunted vegetation. These rocky habitats often appear to be harsh and inhospitable, but they can support an extraordinary diversity of uncommon and rare plants and animals. Some species, such as wall-rue,* smooth cliffbrake,* purple cliffbrake,* and northern slimy salamander* are found only in and near rocky places in the region. The communities and species that occur at any particular location are determined by many factors, including bedrock type, outcrop size, aspect, exposure, slope, elevation, biotic influences, and kinds and intensity of human disturbance.

Many of the ledges that we observed in the Catskill Creek study area appeared to be at least somewhat calcareous, as indicated by plants such as maidenhair fern, maidenhair spleenwort, wild ginger, hepatica, and wild columbine. Such ledges could support rare plant species such as walking fern,* yellow harlequin,* and Carolina whitlow-grass.* Rare plants of non-calcareous crests and ledges include mountain spleenwort,* clustered sedge,* and slender knotweed.*

Rocky habitats with larger fissures, cavities, and exposed ledges may provide shelter, den, and basking habitat for black rat snake,* northern copperhead,* and other snakes of conservation concern. Northern slimy salamander* occurs in non-calcareous wooded ledge and talus areas. Breeding birds of crest habitats include blackburnian warbler,* worm-eating warbler,* and cerulean warbler.* Bobcat* and fisher* use crests and ledges for travel, hunting, and cover. Porcupine and bobcat use ledge and talus habitats for denning. Southern red-backed vole* is found in some rocky areas, and eastern small-footed bat* roosts in talus habitat.

Crest, ledge, and talus habitats were well-distributed throughout the length of the study area, but were especially prominent in Broome and along the Catskill Creek mainstem below Route 32 in Cairo. Ledge and talus habitats were often embedded within other habitat types, most common upland forests.

Sensitivities

Construction of trails, roads, and houses destroys crest, ledge, and talus habitats directly, and causes fragmentation of these habitats and the forested areas of which they are often a part. Rare plants of crests are vulnerable to trampling and collecting; rare snakes are susceptible to road mortality, intentional killing, and collecting; and rare breeding birds of crests are easily disturbed by human activities nearby. The shallow soils of these habitats are susceptible to erosion from construction and logging activities and from foot and ATV traffic.

Conservation Recommendations

1. **Avoid direct alteration of crest, ledge, and talus habitats** wherever possible, and concentrate any unavoidable development in a manner that maximizes the amount and contiguity of undisturbed rocky habitat.

2. **Maintain broad corridors** between crest, ledge, and talus habitats**.** Intervening areas between habitats provide travel corridors for species that migrate among different habitats for breeding, foraging, and dispersal.

3. **Protect large forested areas around crest, ledge, and talus habitats**, as these are important parts of the habitat complexes used by some of the ledge-associated wildlife**.**

4. **Consider the impacts of habitat disturbance** to crest, ledge, and talus when reviewing all applications for mined lands permits and other development proposals, keeping in mind that rare snakes typically travel long distances from their den sites.

5. **Educate construction workers and residents** about snake conservation and whom to contact to safely relocate snakes.

Ledge in upland mixed forest.

UPLAND SHRUBLAND

Ecological Attributes

We use the term "upland shrubland" for shrub-dominated upland (non-wetland) habitats. In most cases these are lands in transition between meadow and young forest, but they also occur along utility corridors maintained by cutting or herbicides, and in areas of recent forest clearing. Land use (both historical and current) and soil characteristics are important factors influencing the species composition of shrub communities. Shrublands may be dominated by non-native, invasive species such as Japanese barberry, Bell's honeysuckles, Oriental bittersweet, and multiflora rose, or they may have diverse native grasses and forbs; native shrubs such as meadowsweet, gray dogwood, northern blackberry, and raspberries; and seedlings and saplings of eastern red cedar, hawthorns, eastern white pine, gray birch, red maple, quaking aspen, and oaks. Many non-native, invasive plants tend to thrive in places with a history of agricultural use and fine soil texture (Lundgren et al. 2004, Johnson et al. 2006), and in areas that were heavily grazed in the past. Recently-logged areas tend to develop a shrub layer including abundant tree saplings and northern blackberry.

Rare butterflies such as Aphrodite fritillary,* dusted skipper,* and Leonard's skipper,* may occur in shrublands where their larval host plants are present (the fritillary uses violets and the skippers use native grasses such as little bluestem). Upland shrublands and other non-forested upland habitats may be used by turtles for nesting or aestivation (e.g., painted turtle, wood turtle,* spotted turtle,* and eastern box turtle*) or for foraging (eastern box turtle). Many bird species of conservation concern nest in upland shrublands and adjacent upland meadow habitats, including brown thrasher,* blue-winged warbler,* golden-winged warbler,* prairie warbler,* yellow-breasted chat,* clay-colored sparrow,* field sparrow,* eastern towhee,* and northern harrier.* Most of these birds avoid forest edges (Schlossberg & King 2008) and, consequently, extensive upland shrublands (>12.5 ac 5 ha]) and those that form large complexes with meadow habitats may be particularly important for the successful nesting of these birds (Shake et al. 2012). Several species of hawks and falcons use upland shrublands and adjacent meadows for hunting small mammals such as meadow vole, white-footed mouse, and eastern cottontail.

Shrublands were well-distributed in the study area, but more common and extensive in the mid- and upper reaches.

Services and Sensitivities

Shrublands and meadows are closely related habitats, and provide many of the same services to the larger landscape. Shrublands in floodplains and on streambanks may be especially important for stabilizing soils and for dampening flood flows.

Having a diversity of ages and structures in these habitats may promote overall biological diversity, and can be achieved by rotational mowing and/or brush-hogging. To reduce the impacts of these management activities on birds, mowing should be timed to coincide with the post-fledging season for most birds (e.g., August-October and later), and only take place every few years, if possible. Prescribed or spontaneous fires can also maintain shrublands and grasslands. As in upland meadows, soil compaction and erosion caused by ATVs, other vehicles, and equipment can reduce the habitat value for invertebrates, small mammals, nesting birds, and nesting turtles. If shrublands are left undisturbed, most will eventually become forests, which are also valuable habitats.

Conservation Recommendations

1. Protect shrublands bordering streams and in floodplains. The roots of woody plants help to hold the soils of streambanks and floodplains in place, and shrublands provide important wildlife habitats along streams.

2. Protect shrublands throughout the watershed wherever possible, especially where they are contiguous with other intact habitats. Like forests, shrublands intercept and absorb rainwater, and help to prevent the rapid surface runoff that leads to downgradient flooding. They also provide important habitat for birds, reptiles, small and large mammals, invertebrates, and other wildlife.

UPLAND MEADOWS

Ecological Attributes

We have identified and mapped cultivated fields, hayfields/pastures, and oldfields in the study area. The ecological values of these habitats can differ widely according to the types of vegetation present and the disturbance histories (e.g., tilling, mowing, grazing, pesticide applications). Extensive hayfields or pastures dominated by grasses, for example, may support grassland-breeding birds (depending on the mowing schedule or intensity of grazing), while intensively cultivated crop fields have comparatively little wildlife habitat value. Meadows of any size can be valuable habitats for small mammals, butterflies, dragonflies, native bees, and other invertebrates. Undisturbed meadows develop diverse plant communities of grasses, forbs, and shrubs and support an array of wildlife, including invertebrates, some frog species, reptiles, mammals, and birds. Meadows with shallow, nutrient-poor soils often support a higher abundance and diversity of native, warm-season grasses and other native plants (Vispo & Knab-Vispo 2012). It is for both present and potential ecological values that we consider all types of meadow habitat to be ecologically significant. Some of the places mapped as "oldfield" were dominated by Japanese knotweed, a robust non-native plant that seemed to readily colonize the highly disturbed sites in the floodway. Upland meadows, large and small, were common throughout the study area. Many were active hayfields or oldfields, and a few were pastures or cropfields.

Several species of rare butterflies, such as Aphrodite fritillary,* dusted skipper,* Leonard's skipper,* swarthy skipper,* meadow fritillary,* and striped hairstreak use upland meadows that support their particular host plants. Upland meadows are used for nesting by wood turtle,* spotted turtle,* eastern box turtle,* painted turtle, and snapping turtle. Grassland-breeding birds such as northern harrier,* grasshopper sparrow,* vesper sparrow,* savannah sparrow,* eastern meadowlark,* and bobolink* use large meadow habitats for nesting and/or foraging. Wild turkey forages on invertebrates and seeds in upland and wet meadows. Upland meadows often have large populations of small mammals (e.g., meadow vole) and can be important hunting grounds for raptors, foxes, and eastern coyote.

Services and Sensitivities

Densely-vegetated meadows, including non-wetland meadows, in the floodplain have significant value for capturing sediments in runoff and in mild flooding events, and for capturing phosphorus adsorbed to sediments. To the extent that they also facilitate infiltration of water to the soils, meadows can also help to remove dissolved nutrients from runoff and floodwaters. Tall, rank vegetation also provides hydraulic "roughness" which helps to dampen floodflows (Parkyn 2004).

The dramatic decline of grassland-breeding birds in the Northeast has been attributed to the loss of large patches of suitable meadow habitat; many of these birds need large meadows that are not divided by fences or hedgerows which can harbor predators (Wiens 1969). Mowing of upland meadows during the bird nesting season can cause extensive mortality of eggs, nestlings, and fledglings. Another threat to upland meadow habitats is the soil compaction and erosion caused by ATVs, other vehicles, and equipment, which can reduce the habitat value for invertebrates, small mammals, nesting birds, and nesting turtles. Destruction of vegetation can affect rare plants and reduce viable habitat for butterflies. Farmlands where pesticides and artificial fertilizers are used may have a reduced capacity to support native biodiversity.

Bare soils in floodplain agricultural fields are at risk of severe erosion in the event of flooding.

Conservation Recommendations

For farmland in active production

Row crops

1. On floodplains, **minimize tillage, and keep soils well-vegetated** as much as possible to reduce the soil erodibility in rainstorms and floods.

2. **Minimize applications of pesticides** (including herbicides, insecticides, fungicides).

3. Where possible, **leave some fields out of production each year.** This provides wildlife habitat as well as replenishing soils. A grass cover crop rotation can provide bird habitat while adding carbon to the soils.

Hayfields and Pastures (Some of these recommendations are adapted from Perlut & Strong [2011] and from Massachusetts Audubon [www.massaudubon.org]). In cases where farmers and other landowners have flexibility in their mowing and grazing practices, these measures will minimize harm to soils and to grassland birds.

1. **Reduce stocking rate and/or reduce the time animals spend in a given field.** Lower intensity grazing is better for meadow soils and for ground-nesting birds.
2. **Fence livestock away from streams.** Livestock grazing in and near streams contributes nutrients and pathogens (through excreta) to the stream water, damages streamside vegetation and mobilizes fine sediments (by trampling), and enables streambank erosion.
3. **Delay mowing.** The later in the season mowing occurs, the greater percentage of grassland birds will have fledged. Mowing after August 1 will avoid much of the nesting, nursery, and fledging seasons; mowing in the fall is even better. If mowing must occur before August, **leave some unmowed strips** or patches for nesting birds, invertebrates, and other meadow biota.
4. **Raise mower blades six inches or more, use flushing bars, and avoid night mowing** when birds are roosting to help reduce bird mortality. Leaving higher stubble has the added benefit of increasing moisture retention in the field, reducing erosion, and providing increased yield in the subsequent harvest (Saumure et al. 2007).
5. Where practical, **mow each field only once every 1-3 years**, or mow in rotation so that each part of a field is mowed once every 3 years, to maintain habitat for nesting birds and butterflies. Mowing should be frequent enough to prevent encroachment of woody vegetation.

ORCHARD/PLANTATION

This habitat type includes actively maintained or recently abandoned fruit orchards, tree farms, and plant nurseries. Christmas tree farms are potential northern harrier* nesting habitat. Fruit orchards with old trees may provide breeding habitat for eastern bluebird* and can be valuable to other cavity-using birds, bats, and other animals. The habitat values of active orchards or plantations are often compromised by frequent mowing, application of pesticides, and other human activities. We consider this an ecologically significant habitat type more for its future ecological values after abandonment than its current values. These habitats have some of the vegetation structure and ecological values of upland meadows and upland shrublands, and will ordinarily develop into young forests if they remain undisturbed after abandonment.

WASTE GROUND

Waste ground is an ecological term for land that has been severely altered by previous or current human activity, but lacks pavement or structures. Most waste ground areas have been stripped of vegetation and topsoil, or filled with soil or debris, and remain unvegetated or sparsely vegetated. This category encompasses a variety of highly altered areas. The "waste ground" areas mapped in in the study area included recently bulldozed areas, dump sites (e.g., old cars, and asphalt and gravel from flood cleanup), composting woody debris, piles of pulp wood, and vacant construction sites. Although waste ground often has low habitat value, there are notable exceptions. Several rare plant species are known to inhabit waste ground environments, including rattlebox,* slender pinweed,* field dodder,* and slender knotweed.* Several snake and turtle species of conservation concern, including eastern hognose snake* and wood turtle* may use the open, gravelly areas of waste grounds for burrowing, foraging, or nesting habitat. Bank swallow* and belted kingfisher often nest in the stable walls of active or inactive portions of soil mines and occasionally in piles of soil or sawdust. Bare, gravelly, or otherwise open areas provide nesting grounds for spotted sandpiper, killdeer, and possibly whip-poor-will* or common nighthawk.* Little is known of the invertebrate fauna of waste grounds in the region but these habitats might support rare species.

CULTURAL HABITATS

We define "cultural" habitats as areas that are significantly altered, and intensively managed (e.g., mowed) but are not otherwise developed with pavement or structures. These may include such places as athletic fields, large lawns, and cemeteries. We consider them to be ecologically significant when they are adjacent to other significant habitats (i.e., when they are not entirely surrounded by developed areas). We identified this as a significant habitat type more for its potential ecological values than its current values, which are reduced by frequent mowing, application of fertilizers and pesticides, or other types of management and intensive human uses.

Nonetheless, eastern screech-owl* and barn owl* are known to nest, forage, and roost in cultural areas. American kestrel,* spring migrating songbirds, and bats may forage in these habitats, and wood duck* and American kestrel* may nest here, as may several species of turtle. Large individual ornamental or fruit trees can provide habitat for cavity-nesting birds such as eastern bluebird,* roosting bats (including Indiana bat* and its nursery colonies), and many other animals, and for mosses, liverworts, and lichens, potentially including rare species. Many cultural areas have "open space" values for the human community (e.g., recreational or scenic), and some provide important services such as buffering less disturbed habitats from human activities and linking patches of undeveloped habitat. Because cultural areas are already significantly altered, however, their habitat values are greatly diminished compared to those of relatively undisturbed habitats.

Ledges and gravel bar in the lower reaches of the Catskill Creek.

WETLANDS, PONDS, AND STREAMS

HARDWOOD & SHRUB SWAMP

Ecological Attributes

A "swamp" is a wetland dominated by woody vegetation (trees or shrubs). In this project we combined deciduous forested and shrub swamps into a single habitat type because the two are often mixed and can be difficult to separate using remote sensing techniques. Common species of swamps in the study area included red maple, American elm, green ash, sycamore, and swamp white oak (trees); winterberry holly, highbush blueberry, silky dogwood, alder, willows (shrubs); skunk-cabbage, beggar-ticks, false-nettle, common jewelweed, Japanese knotweed, tussock sedge, and cinnamon, sensitive, and marsh ferns (herbaceous plants).

Swamps are important to a wide variety of birds, mammals, amphibians, reptiles, and invertebrates, especially swamps that are contiguous with other wetland types or embedded within large areas of upland forest. Hardwood and shrub swamps along the floodplains of clear, low-gradient streams can be an important component of wood turtle* habitat. Other turtles such as spotted turtle* and eastern box turtle* frequently use swamps for summer foraging, drought refuge, overwintering, and travel corridors. Pools within swamps are used by several pool-breeding amphibian species, and are the primary breeding habitat of blue-spotted salamander.* Four-toed salamander,* believed to be regionally scarce, uses swamps with rocks or abundant, moss-covered, downed wood or woody hummocks. Eastern ribbon snake* forages for frogs in swamps. Red-shouldered hawk,* barred owl,* great blue heron,* wood duck,* American black duck,* red-headed woodpecker,* prothonotary warbler,* Canada warbler,* and white-eyed vireo* nest in hardwood swamps.

Flooding in a Catskill Creek streamside swamp.

Swamps occurred in a variety of settings in the study area—on seepy slopes, along streams, in depressions, and as part of large wetland complexes. Except for several large swamps at and just below the Franklinton Vlaie, most others that we mapped were small. We expect that there are some unmapped hardwood swamps embedded in the "floodplain hardwood forest" habitat units.

Services and Sensitivities

Like other forested and shrubby habitats in the floodplains of streams, swamps are especially valuable for stabilizing streambanks and floodplain soils, dampening flood flows, moderating the force of flood waters, and keeping stream temperatures cool. Wetlands of all kinds are effective at removing excess nitrogen—by means of denitrification and plant uptake—from runoff before it enters a stream. Swamps are also effective at intercepting and settling out suspended sediments in surface runoff before it reaches the stream. Swamps both within and outside the floodplain are important for carbon sequestration, climate moderation, and wildlife habitat, and some swamps are sites of groundwater recharge.

While some swamps may be protected by federal or state laws, that protection is usually incomplete or inadequate, and most swamps are still threatened by a variety of land uses. Small swamps embedded in upland forest are often overlooked in environmental reviews, but can have extremely high biodiversity values, and play similar ecological roles to those of intermittent woodland pools. Swamps can easily be damaged by alterations to the quality or quantity of surface water runoff, or by disruptions of groundwater sources that feed them. Swamps that are surrounded by agricultural land are subject to runoff contaminated with agricultural chemicals, and those near roads and other developed areas often receive runoff high in sediment and toxins. Polluted runoff and groundwater can degrade a swamp's water quality, affecting the ecological condition (and thus habitat value) of the swamp and its associated streams. Maintaining flow patterns and water volumes in swamps is important to the plants and animals of these habitats. Connectivity between swamp habitats and nearby upland and wetland habitats is essential for amphibians that breed in swamps and for other resident and transient wildlife of swamps. Direct disturbance, such as logging, can damage soil structure, plant communities, and microhabitats, and provide access for invasive plants. Ponds for ornamental or other purposes are sometimes excavated or impounded in swamps, but the lost habitat values of the pre-existing swamp usually far outweigh any habitat values gained in the new, artificial pond environment.

Conservation Recommendations

Protect swamps from direct and indirect disturbances because of their importance for carbon sequestration, climate moderation, soil stabilization, removing excess nutrients and breaking down contaminants in runoff, slowing flood flows, and providing valuable plant and wildlife habitat.

MARSH

Ecological Attributes

A marsh is a wetland that has standing water for much or all of the growing season and is dominated by herbaceous (non-woody) vegetation. Marshes often occur at the fringes of deeper water bodies (e.g., lakes and ponds), or in close association with other wetland habitats such as wet meadows or swamps. The edges of marshes, where standing water is less permanent, often grade into wet meadows. Cattails, tussock sedge, lakeside sedge, woolgrass, reed canary-grass, common reed, water-plantain, and purple loosestrife are some typical emergent marsh plants in this region. Some marshes are dominated by floating-leaved plants such as pond-lilies, water-shield, and duckweeds.

Several rare plant species are known from marshes in the region, and the diverse plant communities of some marshes provide habitat for butterflies such as the Baltimore,* monarch,* and northern pearly eye. Marshes are also important habitats for reptiles and amphibians, including northern water snake, eastern painted turtle, snapping turtle, spotted turtle,* green frog, pickerel frog, and spring peeper. Numerous bird species, including marsh wren,* common moorhen,* American bittern,* least bittern,* great blue heron,* Virginia rail,* sora,* American black duck,* and wood duck* use marshes for nesting and nursery habitat. Pied-billed grebe* also uses this habitat where it occurs adjacent to open water areas. Many raptors, wading birds, and mammals use marshes for foraging.

Most of the marshes in the Catskill Creek corridor occurred in the upper reaches, in the Franklinton Vlaie and adjacent to the stream channel in the large wetland and pond complex extending 1.5 miles below the Vlaie dam.

Services and Sensitivities

Marshes are often closely associated with small and large streams, occurring both adjacent to the stream channel and elsewhere in the floodplain. They are thus intimately tied to the stream ecology, providing habitat for stream organisms and organic materials for the stream food web. Like those of other wetlands, the organic soil layer of marshes is especially effective at removing nitrogen from water via denitrification; plant uptake of nitrogen and phosphorus can also reduce nutrient concentrations in water significantly (Wenger 1999, Parkyn 2004). Marshes with dense vegetation can dampen flood flows and remove sediments from flood waters.

In addition to direct disturbances such as filling or draining, marshes are subject to stresses from offsite (upgradient) sources. Noise and direct disturbance from human activities can discourage breeding activities of marsh birds. Alteration of surface water runoff patterns or groundwater flows can lead to dramatic changes in the plant and animal communities of marshes. Polluted stormwater runoff from roads, parking lots, lawns, and farm fields carries sediments, nutrients, de-icing compounds, and other contaminants into the wetland.

Nutrient and sediment inputs and human or beaver alteration of water levels can also alter the plant community and facilitate invasion by non-native plants such as purple loosestrife and common reed. Because many animal species of marshes depend equally on surrounding upland habitats for their life history needs, protection of the ecological functions of marshes must go hand-in-hand with protection of the adjacent and nearby habitats.

Conservation Recommendations

Preserve marshes in floodplain and non-floodplain settings for their habitat values for wildlife and plants, and their water quality and water storage functions. Marshes and other wetlands throughout the watershed capture large volumes of water that would otherwise reach the Catskill Creek.

Protect marshes from human disturbances (e.g., noise, lights, mechanical disturbance) and from contaminated runoff (e.g., from roads, lawns, and agricultural fields) to maintain their habitat values and other services.

Marsh in the upper reach of the Catskill Creek.

WET MEADOW

Ecological Attributes

A wet meadow is a wetland dominated by herbaceous (non-woody) vegetation, and which retains little or no standing water during most of the growing season. The period of inundation or soil saturation is longer than that of an upland meadow, but shorter than that Some wet meadows are dominated by purple loosestrife, common reed, reed canary-grass, or tussock sedge, while others have a diverse mixture of wetland grasses, sedges, forbs, and scattered shrubs. Mannagrasses, woolgrass, reed canary-grass, soft rush, spotted Joe-Pye-weed, common jewelweed, sensitive fern, and marsh fern are some typical native plants of wet meadows.

Wet meadows with diverse plant communities may have rich invertebrate faunas. Blue flag and certain sedges and grasses of wet meadows are larval food plants for regionally-rare butterflies. Wet meadows provide nesting and foraging habitat for songbirds such as sedge wren,* wading birds such as American bittern,* and raptors such as northern harrier.* Wet meadows that are part of extensive meadow areas (both upland and wetland) may be especially important to species of grassland-breeding birds. Large and small mammals use wet meadows and a variety of other meadow habitats for foraging.

Wet meadows in the study area were small and few. Most were embedded in or at the edges of other kinds of wetlands or the Catskill Creek.

Services and Sensitivities

Wet meadows in and near floodplains have particular value for treating polluted surface runoff before it enters the stream. Wet meadows and other wetlands are important sites for denitrification as well as plant uptake of nutrients, and densely vegetated wet meadows are especially effective at capturing sediments. Floodplain wet meadows can help absorb and dampen floodwaters in mild to moderate flood events, but are overwhelmed by severe flooding (Wenger 1999).

Some wet meadows are able to withstand light grazing by livestock, but heavy grazing or frequent mowing can destroy the soil structure, eliminate sensitive plant species, and invite non-native weeds. Mowing and grazing when soils are dry, e.g., in late summer, is less damaging to the soils and the plant community, and postponing mowing until late August or September will help to protect late-nesting birds. Wet meadows that are part of larger complexes of meadow and shrubland habitats are prime sites for development or agricultural uses, and are often drained, filled, or excavated. Because many wet meadows are omitted from state, federal, and site-specific wetland maps, they are frequently overlooked in environmental reviews of development proposals.

Conservation Recommendations

Preserve wet meadows in floodplain and non-floodplain settings for their habitat values for wildlife and plants, and their water quality and water storage functions. Wet meadows and other wetlands throughout the watershed capture large volumes of water that would otherwise reach the Catskill Creek.

Protect wet meadows from human disturbances (e.g., noise, lights, soil disturbance), from contaminated runoff (e.g., from roads, driveways, lawns, and agricultural fields) to maintain their habitat values and other services.

SPRINGS & SEEPS

Ecological Attributes

Springs and seeps are places where groundwater discharges to the ground surface, either at a single point (a spring) or diffusely (a seep). Although springs often discharge into ponds, streams, or wetlands such as marshes or swamps, we generally mapped only springs and seeps that discharged conspicuously into upland locations. Springs and seeps originating from deep groundwater sources flow more or less continuously, and emerge at a fairly constant temperature, creating an environment that is cooler in summer and warmer in winter than the surroundings. For this reason, seeps and springs sometimes support aquatic species that are ordinarily found at more northern or southern latitudes. The habitats created at springs and seeps are determined in part by the hydroperiod and the chemistry of the soils and bedrock through which the groundwater flows before discharging. Springs and seeps are water sources for many streams, and they help maintain the cool water temperatures of streams—an important habitat characteristic for certain rare and declining fishes, amphibians, and other aquatic organisms. Springs and seeps also serve as water sources for animals during droughts and in winters when other water sources are frozen.

Very little is known about the ecology of seeps in the Northeast. Golden saxifrage is a plant more-or-less restricted to springs and groundwater-fed wetlands and streams. Herbaceous plant diversity may be higher in seeps than in surrounding upland forest (Morley and Calhoun 2009). A few rare invertebrates are restricted to springs in the region, and the Piedmont groundwater amphipod* could occur in the area (Smith 1988). Gray petaltail* and tiger spiketail* are two rare dragonflies found in seeps. Northern dusky salamander* uses seeps, springs, and cool streams.

We found only a handful of springs and seeps in the study area; some were isolated within upland forests, and some at the headwaters of small streams or at the edge of wetlands. Because the occurrence of springs and seeps is difficult to predict by remote sensing, we mapped only those we saw in the field and those that had a distinct signature on one of our map sources. We expect there are more springs and seeps in the study area that we did not map. More detailed surveys of these habitats should be conducted as needed on a site-by-site basis.

Services and Sensitivities
Springs and seeps provide intermittent or year-round sources of cool water for streams and wetlands, but they are easily disrupted by disturbance to upgradient land or groundwater, altered patterns of surface water infiltration, or pollution of infiltrating waters. Pumping of groundwater for human or livestock water supply can deplete water available to nearby springs and seeps.

Conservation Recommendations

> **Protect springs and seeps themselves, and avoid disrupting (by pollution, excavation, or pumping) the groundwater that feeds them** wherever possible.

OPEN WATER

Ecological Attributes
In this project we use the term "open water" for naturally formed ponds and lakes, large pools lacking floating or emergent vegetation within marshes and swamps, and unvegetated ponds that may have originally been constructed by humans but have since reverted to a more natural state (e.g., surrounded by unmanaged vegetation).

Open water areas can be important habitat for many common species, including invertebrates, fishes, frogs, turtles, waterfowl, muskrat, beaver, and bats. Open water areas sometimes support submerged aquatic vegetation that can provide important habitat for aquatic invertebrates and fish. Spotted turtle* uses ponds and lakes during both drought and non-drought periods, and wood turtle* may overwinter and mate in open water areas. Wood duck,* American black duck,* pied-billed grebe,*osprey,* bald eagle,* American bittern,* and great blue heron* use open water areas as foraging habitat. Bats, mink, and river otter* also forage at open water habitats.

The largest open water habitats in the study area were the Franklinton Vlaie and the three large ponds in the wetland complex that extends ca 1.5 below the Vlaie dam. The habitat values of these ponds is greatly enhanced by their close association with floating-leaved and emergent marshes and extensive shrubby and forested swamps. They appear to provide high-quality habitat for diverse wildlife. Other open water areas included pools created in artificially widened streams, and other small constructed ponds surrounded by significant habitats.

Sensitivities

The habitat values of natural open water areas are often greater than those of constructed ponds, since the areas are less intensively managed, less disturbed by human activities, and surrounded by undeveloped land. Open water habitats are vulnerable to human impacts such as shoreline development, aquatic weed control, use of motorized watercraft, and runoff from roads, lawns, and agricultural areas. Aquatic weed control, which may include harvesting, herbicide application, or introduction of grass carp, is an especially important concern in open water habitats, and the potential negative impacts should be assessed carefully before any such activities are undertaken (Heady and Kiviat 2000, Kiviat 2009). Because open water areas are often within larger wetland and stream complexes, any disturbance to the habitat may have far-reaching effects on the surrounding landscape. To protect water quality and habitat values, broad zones of undisturbed vegetation and soils should be maintained around ponds and lakes. If part of a pond or lake must be kept open (unvegetated) for ornamental, recreational, or other reasons, it is best to avoid dredging and to allow other parts of the pond to develop abundant vegetation. This can be accomplished by harvesting aquatic vegetation only where necessary to create open lanes or pools for boating, fishing, or swimming.

CONSTRUCTED POND

Ecological Attributes

We use the term "constructed ponds" for waterbodies that have been excavated or dammed by humans, either in existing wetlands or stream beds, or in upland terrain, for fishing, watering livestock, irrigation, swimming, boating, and aesthetics. Some are constructed near houses or other structures for ornamental or recreational purposes, or to serve as a source of water in the event of a fire. Some were created where mining activities intersected the water table. If constructed ponds are not intensively managed by humans, they can be important habitats for many of the common and rare species associated with naturally formed open water habitats (see below). We have classified naturally formed water bodies that are now intensively managed by humans as constructed ponds to better represent their habitat values. Constructed ponds that have long been unmanaged, however, and are now surrounded by intact habitats were mapped as "open water" or "marsh," depending on the vegetation structure.

Constructed ponds were well-distributed throughout the study area. Many were ornamental ponds at residences, and a few were ponds created for agricultural uses.

Services and Sensitivities

The habitat values of constructed ponds vary depending on the landscape context and the extent of human disturbance. In general, the habitat value is higher when the ponds have undeveloped, unmanaged shorelines, are relatively undisturbed by human activities, have more vascular plant vegetation, and are embedded within an area of intact habitat. Because many constructed ponds are not buffered by sufficient natural vegetation and undisturbed soils, they are vulnerable to the adverse impacts of agricultural runoff, septic leachate, and pesticide or fertilizer runoff from lawns and gardens. We expect that many of the ponds maintained for ornamental purposes are treated with herbicides and perhaps other pesticides, or contain introduced fish such as grass carp and various game and forage fishes. Constructed ponds that are kept devoid of emergent or submerged vegetation have little habitat value, but are sometimes used as drought refuges by turtles, amphibians, and other wildlife, and as stopover resting sites for migrating waterfowl. Those with significant vegetation may have nesting waterfowl and resident turtles, frogs, and salamanders, Since constructed ponds can serve as habitat for a variety of common and rare native species, applications of pesticides should be minimized whenever possible, and polluted runoff from roads, lawns, and farm fields should be directed elsewhere.

The habitat values of constructed ponds (and especially intensively managed ornamental ponds) do not ordinarily justify altering streams or destroying natural wetland or upland habitats to create them. In most cases, the loss of ecological functions of the pre-existing natural habitats far outweighs any habitat value gained in the artificially created environments.

STREAMS

Ecological Attributes

Perennial streams flow continuously throughout years with normal precipitation, but some may dry up during droughts. They provide essential water sources for wildlife throughout the year, and are critical habitat for many plant, vertebrate, and invertebrate species. The Catskill Creek and its major tributaries are perennial streams, but they are fed by a multitude of intermittent streams.

Intermittent streams may flow for a few days or for many months during the year, but ordinarily dry up at some time during years of normal precipitation. They are the headwaters of most perennial streams, and are significant water sources for lakes, ponds, and wetlands of all kinds. The condition of these streams therefore influences the water quantity and quality of those larger water bodies and wetlands, and the land cover and land uses in the watersheds of these streams greatly influences the downstream response to large rainstorms and snowmelt events.

Intermittent streams provide microhabitats not present in perennial streams, supply aquatic organisms and organic drift to downstream reaches, and can be important local water sources for wildlife (Meyer et al. 2007). Their loss or degradation in a portion of the landscape can affect the presence and behavior of wildlife populations over a large area (Lowe and Likens 2005). Plants such as winged monkeyflower* and may-apple* are sometimes associated with intermittent streams. Although intermittent streams have been little studied by biologists, they have been found to support rich aquatic invertebrate communities, including regionally rare mollusks (Gremaud 1977) and dragonflies. Both perennial and intermittent streams provide breeding, larval, and adult habitat for northern dusky salamander* and northern two-lined salamander. The forests and, sometimes, meadows adjacent to streams provide foraging habitats for adults and juveniles of these species.

The fish and aquatic invertebrate communities of perennial streams may be diverse, especially in clean-water streams with unsilted bottoms. Brook trout* and slimy sculpin* are two native fish species that require clear, cool streams for successful spawning. Wood turtle* uses perennial streams with deep pools and recumbent logs, undercut banks, or muskrat or beaver burrows. Perennial streams and their riparian zones, including sand and gravel bars, provide nesting or foraging habitat for many species of birds, such as spotted sandpiper, belted kingfisher, tree swallow, bank swallow, winter wren,* Louisiana waterthrush,* great blue heron,* and green heron. Bats, including Indiana bat,* use perennial stream corridors for foraging. Muskrat, beaver, mink, and river otter* are some of the mammals that regularly use stream corridors.

We mapped many streams in the study area, and Figure 1 gives a sense of the abundance of streams throughout the Catskill Creek watershed.

Services and Sensitivities
Streams serve many recreational, aesthetic, and water supply functions for the human community, and are a critical component of the ecological landscape, providing essential habitats for permanent, seasonal, and transient wildlife, and essential processes that maintain floodplain habitats, and associated ponds and wetlands. Our treatment of stream channels and banks, floodplains, and watersheds has a large influence on flood volumes and flood damage.

Removal of trees or other shade-producing vegetation along a stream can lead to elevated water temperatures that adversely affect aquatic invertebrate and fish communities of streams. Clearing of vegetation in and near floodplains can reduce the important exchange of nutrients and organic materials between the stream and the floodplain, and reduce the amount and quality of organic detritus available to support the aquatic food web. It can also diminish the floodplain's capacity for floodwater attenuation, leading to increased flooding downstream, scouring and bank erosion, and sedimentation of downstream reaches. Any alteration of flooding regimes, stream water volumes, timing of runoff, and water quality can profoundly affect these habitats and the species that use them. Hardening of the stream banks with concrete, riprap, gabions, or other materials reduces the biological and physical interactions between the stream and floodplain, and tends to be harmful both to stream and floodplain habitats. Removal of snags (fallen trees or logs) from the streambed degrades habitat for fishes, turtles, snakes, birds, muskrats, and their food organisms. Japanese knotweed, an introduced plant that is spreading in the region (Talmage and Kiviat 2004), is especially associated with streambanks and floodplains, and has invaded many parts of the Catskill Creek corridor.

Gravel bar and undercut bank, Catskill Creek.

The habitat quality of a stream is affected not only by direct disturbance to the stream or its floodplain, but also by land uses throughout the watershed. (A watershed, or catchment, is the entire land area that drains into a given water body). Activities in the watershed that cause soil erosion, changes in surface water runoff, reduced groundwater infiltration, or contamination of surface water or groundwater are likely to affect stream habitats adversely. For example, an increase in impervious surfaces (roads, parking lots, roofs) may elevate runoff volumes, leading to erosion of stream banks and siltation of stream bottoms or incision (deep erosion of streambeds), degrading the habitat for invertebrates, fish, and other animals. Road runoff often carries contaminants such as petroleum hydrocarbons, heavy metals, road salt, sand, and silt into streams. Applications of fertilizers and pesticides to agricultural fields, golf courses, lawns, and gardens in or near the riparian zone can degrade the water quality and alter the biological communities of streams. Construction, logging, soil mining, clearing for vistas, creating lawns, and other disruptive activities in and near riparian zones can hamper riparian functions and adversely affect the species that depend on streams, riparian zones, and nearby upland habitats.

Conservation Recommendations

For whole watersheds:

1. **Maintain forested watersheds** as much as possible.
2. **Minimize impervious surfaces**.
3. **Facilitate onsite infiltration of stormwater** in developed areas.
4. **Direct road runoff into treatment swales and basins** (instead of streams).
5. **Reduce fertilizer applications and fix failing septic systems** to reduce excess nutrients reaching small and large streams.
6. **Reduce or eliminate use of pesticides**.

For streams, floodplains, and adjacent areas:

1. **Establish and maintain protected buffer zones** along streams to promote stream stability and water quality, and provide habitat and movement corridors for wildlife and plants.

a. The ideal buffer zone should encompass the entire width of the floodplain.

b. A buffer zone of 300 ft (100 m) width is effective at capturing sediments under most circumstances, and sustaining this function over the long term (Wenger 1999).

c. A buffer zone of 50-100 ft (15-30 m) width is recommended for effective nutrient removal, although zones as narrow as 30 ft (9 m) width can produce measurable improvements to water quality (Wenger 1999).

d. A buffer zone of 300 ft (100 m) or more may be needed for many stream-associated wildlife species (Kennedy et al. 2003).

e. A buffer zone with woody vegetation will be most effective for stabilizing streambank and floodplain soils.

2. **Protect the entire 100-year, 200-year, or 500-year floodplain** from development of structures or roads wherever possible.
3. **Keep floodplain areas well-vegetated**.
4. **Preserve riparian wetlands** of all kinds, for their ability to improve water quality attenuate flood flows, and capture sediments, and for their wildlife habitat values.
5. **Maintain, restore, and preserve forested and shrubby areas** throughout the floodplain, wherever possible.
6. **Remove constructed berms and levees** along streams to reestablish connections between streams and their floodplains wherever possible. (Always consult with an expert in stream geomorphology and stream processes before undertaking any earth-moving in the stream channel or on the streambanks. State or federal permits are often required.)

7. **Replace undersized and suspended culverts** with culverts properly installed and large enough to accommodate the full expected flood flows.
8. **Replace suspended culverts** with the invert embedded in the stream substrate to maintain stream continuity.

Gravel bar and woody debris, Catskill Creek.

GRAVEL BAR

Gravel bars are areas where cobbles, gravel, and sand carried by the stream during high-flow periods are deposited when the stream flow velocity slows. We mapped both those that have been in place for years and are now well-vegetated, as well as those deposited by recent storms. These deposits create islands and peninsulas within the stream channel itself, and also occur on the stream banks or the floodplain. Those in and near the stream channel tend to be dynamic features that are scoured by ice and moved or reconfigured by new storm events. Vegetation is absent or sparse on new deposits, but can be quite dense on gravel bars that have been in place for several years. Some develop shrubby and forested cover.

The habitat map shows the locations both of gravel bars in the stream channel, and areas where cobbles and gravel were deposited by flood waters in forests, shrublands, and meadows.

Mapping gravel bars posed particular problems because the best orthophoto images available for use as a base map for this project were taken in 2010, but the large storms in the late summer and fall of 2011 and 2012 dramatically altered the stream channel and the floodplain landscape. Before we finished the project, however, we had access to Google Earth imagery taken in early October 2011, so we updated the map to depict the stream channel, gravel deposits, and bare ground as they existed after hurricane Irene and tropical storm Lee.

Gravel bars are used for nesting by spotted sandpiper, killdeer, and black duck, foraging sites for frogs, and foraging and basking sites for snakes (garter, ribbon, water snake). Dragonflies and damselflies, including some rare species, hunt over gravel bars and over the stream itself. The Appalachian tiger beetle* has been found on gravel bars in Greene County, and several other ground beetles are known to use these habitats.

Appalachian tiger beetle (Cicindela ancocisconensis)

Services and Sensitivities

Instream gravel bars are part of the stream itself, and are routinely shifted and reconfigured as they absorb, respond to, and dissipate energy. Although gravel and cobbles deposited on the floodplain during high water events can damage agricultural land and transform floodplain habitats, such deposits are characteristic of floodplains and should be expected to occur repeatedly. Artificial shifting or removing gravel, cobbles, and boulders from the bed or banks of a stream may alter the stream response in unexpected ways, and should be undertaken only after careful analysis by an expert in stream geomorphology and process.

CONSERVATION PRIORITIES AND PLANNING

Because of the great power of streams to alter landscapes, and damage human structures and infrastructure, learning how to live safely with streams is of urgent importance to communities in the Catskill Creek corridor. In addition to their destructive power, streams are also critical to the quality and quantity of our groundwater and surface water supplies, and provide irreplaceable services to habitats, plants, and wildlife. Fortunately, most or all of the measures that will help protect land and infrastructure in the vicinity of flooding streams will also benefit our water supplies, and the habitats, plants, and animals of streams, floodplains and watersheds.

Most local land-use decisions in the region are made on a site-by-site basis, without the benefit of good ecological information about the site or the surrounding lands, but the best approach to stream management and biodiversity conservation is from the perspective of whole landscapes. The Catskill Creek habitat map illustrates the locations and configuration of significant habitats throughout the corridor and, together with the information provided in this report, can be applied directly to land-use and conservation planning and decision-making at multiple scales.

In the following pages we outline recommendations for: 1) using the map to identify priorities for conservation and for restoration of streambanks and floodplains, 2) using the map as a resource for reviewing site-specific land-use proposals, and 3) some ideas for local planning, procedural, and regulatory measures to improve watershed resiliency.

By employing a proactive approach to land use and conservation planning, landowners and municipalities have the opportunity to protect land and structures from future flood damage, and to protect, restore, and improve the integrity of the Catskill Creek, its tributaries, and nearby habitats.

Using the Habitat Map for Conservation Planning

The Catskill Creek habitat map illustrates the sizes of habitat units, the degree of connectivity between habitats, and the juxtaposition of habitats in the stream corridor, all of which have important implications for stream integrity and biodiversity.

Well-vegetated streambanks and floodplains are essential to stream stability and flood attenuation. Shrubs and trees are the most effective kinds of vegetation for holding soils in place due to their deep, strong root systems. Meadow vegetation with dense grasses and forbs (e.g., hayfields and gently-grazed pastures) can help to intercept sediments and remove nutrients and other contaminants from the water, but are less effective at stabilizing soils during large flood events. Farmland with row crops such as corn and vegetables is highly vulnerable to erosion during flood events because of the (typically) large areas of exposed, unvegetated soils between rows. The habitat map can help identify areas of the stream corridor—such as forested floodplains—that appear to be best protected from the ravages of flooding, best able to absorb and dissipate flood forces, and best equipped to intercept and treat sediments, nutrients, and toxins before they enter the stream. The map can also be used to identify the areas most vulnerable to flood damage, such as fields of row crops in and near the floodplain, and especially those without a buffer zone of woody vegetation between the cultivated area and the stream. These areas might be prime candidates for proactive planting of trees and shrubs in the streamside zone.

The habitat map can be used to identify the contiguous habitat areas, both within and outside the study area, so that new land uses can be designed to substantially maintain the landscape connections and minimize fragmentation by roads, driveways, and other developed uses. Habitat fragmentation is among the primary threats to biodiversity worldwide (Davies et al. 2001) and in the Hudson Valley. While some species and habitats may be adequately protected in small patches, many wide-ranging species, such as black bear,* barred owl,* and red-shouldered hawk,* require large, unbroken blocks of habitat. Many species, such as wood turtle* and Jefferson salamander,* need to travel among different habitats to satisfy their basic needs for food, water, cover, nesting and nursery areas, and population dispersal. Landscapes that are fragmented by roads, utility corridors, and development limit animal movements and interactions, disrupting patterns of dispersal, reproduction, competition, and predation. Habitat patches surrounded by human development function as islands, and species unable to move between habitats are vulnerable to genetic isolation and possible extinction over the long term. Landscapes with interconnected networks of unfragmented habitat, on the other hand, are more likely to support a broad diversity of native species and the ecological processes and disturbance regimes that maintain those species. Corridors and habitat connectivity allow for the movement of organisms as they adapt to changing conditions, so will become even more important in the face of global climate change. Careful siting and design of new development can help to maintain the contiguity of large habitat patches.

The habitat map can also be used to identify priority habitats for conservation, including those that are rare or support rare species, or that seem particularly important to regional biodiversity.

Reviewing Site-Specific Land Use Proposals

In addition to townwide land use and conservation planning, the habitat map and report can be used for reviewing site-specific development proposals, providing ecological information about both the proposed development site and the surrounding areas that might be affected. We recommend that landowners and reviewers considering a new proposal for land development in the Catskill Creek corridor take the following steps to evaluate the impact of the proposed change on the habitats present on and near the site:

1. Consult the large-format habitat map to see which ecologically significant habitats, if any, are located on and near the site in question.
2. Read the descriptions of those habitats in this report; note the discussion of habitat sensitivities and conservation recommendations.
3. Consider whether the proposed development project can be designed or modified to ensure that the habitats of greatest ecological concern, as well as the ecological connections between them, are maintained substantially intact. Examples of design modifications include but are not limited to:
   - Locating human activity areas as far as possible from the most sensitive areas.
   - Minimizing intrusions into the interiors of large forested or meadow habitats.
   - Avoiding disturbances that would disrupt the quantity or quality of groundwater available to onsite or offsite streams or wetlands fed by groundwater.
   - Channeling stormwater runoff from paved areas or fertilized turf through oil-water separators and into detention basins or "rain gardens" instead of directly into ditches, streams, ponds, or wetlands.
   - Locating developed features such that broad corridors of undeveloped land are maintained between important habitats on and off the site.

Because the habitat map has not been 100% field-verified we emphasize that, at the site-specific scale, it should be used strictly as a general guide for land-use planning and decision making. Site visits by qualified professionals should be an integral part of the review process for any proposed land-use change.

Floodplain woody debris helps to slow flood flows and contributes to instream habitat structure.

Local Planning, Procedural, and Regulatory Measures to Improve Watershed Resiliency

To reduce vulnerability to flood damage and improve flood response, communities can incorporate many of the ideas outlined above into local policies and practices; for example:

- ✓ Identify the areas at greatest risk of future flooding.
- ✓ Develop action plans with landowners and residents in flood-prone areas to reduce risk and respond quickly during flood events.
- ✓ Identify areas throughout the watershed (such as upland forests, wetlands, and floodplains) that are most valuable for absorbing rainwater, snowmelt, and floodwaters, reducing sedimentation, and improving water quality and habitat quality of streams.
- ✓ Update the municipal Comprehensive Plan or Master Plan to direct inappropriate land uses away from high flood-risk areas and areas most important for absorbing precipitation and floodwaters.
- ✓ Update the local zoning ordinance, subdivision regulations, and stormwater management regulations. For example:
    - establish streamside protected buffer zones
    - establish floodplain overlay districts
    - adopt wetland and watercourse laws
    - adopt new standards for subdivision design and site plan review
    - adopt new standards for stormwater management along roadways and on land development sites to prevent rapid runoff and promote infiltration of rainwater and snowmelt to the soils
- ✓ Develop plans for incremental upgrades to infrastructure (roads, bridges, culverts) to better accommodate expected future flooding.
- ✓ Develop intermunicipal plans to coordinate efforts to reduce flooding risk and improve flood response.

RECOMMENDATIONS

We hope that the Catskill Creek habitat map and this report will help landowners understand how their land fits into the larger ecological landscape, and will help them to manage their land in ways that reduce harm to human structures and enterprises, and maintain and improve stream stability, stream habitats, and biodiversity. We also hope that towns, villages, and hamlets in the corridor will begin proactive planning for land uses and conservation to ensure that future infrastructure and land development is planned with a realistic anticipation of future flood events, and a view to long-term protection of infrastructure, the Catskill Creek, and valuable biological resources of the stream corridor.

A variety of regulatory and non-regulatory means can be employed by a municipality to achieve its conservation goals, including volunteer conservation efforts by landowners, master planning, zoning ordinances, tax incentives, land stewardship incentives, permit conditions, land acquisition, conservation easements, and public education. Several publications of the Metropolitan Conservation Alliance, the Pace University Land Use Law Center, and the Environmental Law Institute describe some of the tools and techniques available to municipalities for conservation planning. For example, *Conservation Thresholds for Land-Use Planners* (Kennedy et al. 2003) synthesizes information from the scientific literature to provide guidance to land use planners interested in establishing regulatory setbacks from sensitive habitats. A publication from the Metropolitan Conservation Alliance (2002) offers a model local ordinance to delineate a conservation overlay district that can be integrated into a comprehensive plan and local zoning ordinance. A publication from Cornell and NYSDEC, *Conserving Natural Areas and Wildlife in Your Community* (Strong 2008) describes the tools and resources available to municipalities to help protect their natural assets. *Living in Harmony with Streams: A Citizen's Handbook to How Streams Work* (Henzel 2012) is a good resource (for both landowners and municipal agencies) on stream dynamics, and on devising the best ways to accommodate stream forces when planning new land uses, land management, or land conservation.

In addition to regulations and incentives designed to protect specific parts of the landscape or particular types of habitat, municipalities can also apply some general practices to the larger landscape to protect land from flood damage, and to foster stream resilience and biodiversity conservation. Some of the examples listed below are adapted from Wenger (1999), Kiviat and Stevens (2001), Parkyn (2004), and Henzel (2012). We encourage landowners and municipalities in the Catskill Creek corridor to apply these measures to site-specific and larger-scale planning and decision-making.

For stream stability and flood resilience:

- **Consider the 200-year or 500-year floodplain** when planning new land uses near the Catskill Creek and other streams. Flood events are becoming more frequent and more severe, so planning to accommodate those events will prevent future damage to structures and habitats.

- **Maintain forested cover** wherever possible both within the floodplain and throughout the watershed. In addition to their importance for biodiversity, forests are the most effective kind of land cover for intercepting and storing rainwater, minimizing surface runoff, recharging groundwater, maintaining base flows of streams, and maintaining high-quality stream habitats.

- **Maintain or establish broad zones of woody vegetation along streams** wherever possible. Woody vegetation (trees and shrubs) is most effective for holding soils in place, so will help to maintain stream banks and floodplain soils during high water events.

- **Keep floodplains well-vegetated**. In crop fields, minimize tillage, seed immediately after tilling or other soil disturbance, leave thatch in place, and use cover crops after harvest. These measure will help minimize soil loss during floods.

- **Remove streamside berms or levees wherever possible**. These are often constructed to protect land from flooding, but they tend to increase the velocity of floodwaters in the stream channel, increase the severity of downstream flooding, increase the likelihood of erosion during flood events, prevent floodwaters from spreading over the floodplain, and prevent wildlife from moving in and out of the stream.

- **Consult with experts in stream geomorphology and processes before planning or conducting any artificial adjustments to stream banks or stream channel configuration**.

- **Replace low bridges and undersized culverts, and install new bridges and culverts that will accommodate the full volumes of anticipated storm flows**. Install culvert inverts well below the stream channel grade to maintain stream continuity for aquatic organisms, and to reduce the likelihood of undermining or washouts during high flow events.

- **Direct runoff from agricultural fields into vegetated swales or detention basins** to reduce the volume of surface runoff running directly into streams, and to allow filtering and settling of suspended materials.

- **Replace ditches with grassed swales**, which are more effective at intercepting runoff and facilitating infiltration to the soils.

- **Fence livestock away from streams** wherever possible. If a watering tank cannot be provided, then harden the streambank at one location to provide drinking access but align fence to keep livestock from walking in the stream.

- **Avoid or minimize pesticide & fertilizer applications** to agricultural fields, lawns, and gardens. If used, apply carefully and judiciously to minimize opportunities for contaminating runoff during small or large precipitation events and flood events

- **Remove buildings, walls, and pavement from the floodplain** wherever possible. These structures are vulnerable to damage or destruction from floodwaters; they reduce the capacity of floodplains to absorb floodwaters; and they tend to concentrate flood flows, increase flood velocity, and exacerbate downstream flood damage; the structural materials also can become hazards themselves if carried away by floodwaters.

- **Remove from the floodplain hazardous materials** and materials that can become hazardous in a flood, such as those stored in barns and sheds (e.g., pesticides, fertilizers, petroleum fuel and lubricants); farm equipment; above-ground and below-ground fuel tanks; stored or abandoned vehicles; septic tanks; glass, etc.

- **Shift to resilient land uses in the floodplain** wherever possible, such as those that can withstand slight to moderate flooding, and will not exacerbate floodflows or create hazards during minor or major floods. Some examples: pasture, hayfields, nurseries, or parks (such as ballfields, hiking trails, picnic areas, fishing access) without buildings or pavement, and with minimum infrastructure.

- **Add to the municipal code a 200year or 500-year floodplain overlay zone**, within which land uses are prohibited that would be vulnerable to flood damage, or would create local or downstream hazards during flood events. **Protect large, contiguous, undeveloped tracts** wherever possible.

For conservation of stream water quality, habitats, and biodiversity:

- **Plan landscapes with interconnected networks of undeveloped habitats** (preserve and restore links between natural habitats on adjacent properties). When considering protection for a particular species or group of species, design the networks according to the particular needs of the species of concern.

- **Preserve natural disturbance processes** such as fires, floods, seasonal water level changes, landslides, and wind exposures wherever possible, and design land uses and infrastructure to accommodate those disturbances.

- **Restore and maintain broad buffer zones** of natural vegetation along streams, shores of water bodies and wetlands, and around the perimeters of other sensitive habitats.

- **Maintain floodplain wetlands** wherever possible. Wetland soils are most effective at denitrification, and wetland vegetation takes up nutrients and intercepts sediments, thus helping to protect stream water quality.

- **Minimize applications of road salt** and other de-icing compounds on roads, parking lots, and driveways.

- **Minimize applications of fertilizers, pesticides and other contaminants** where they are likely to be washed into streams.

- **Direct human uses toward the least sensitive areas**, and minimize alteration of natural features, including vegetation, soils, bedrock, and waterways.

- **Encourage development of altered land instead of unaltered land**, and promote "infill" development and re-use of existing structures wherever possible.

- **Concentrate development near existing developed areas and along existing roads**; discourage construction of new roads in undeveloped areas.

- **Encourage landowners and developers to consider environmental concerns early in the planning process**, and to incorporate biodiversity and stream conservation principles into their choice of development sites, their site design, and their construction practices.

- **Minimize areas of lawn and impervious surfaces** (roads, parking lots, sidewalks, driveways, roof surfaces) and design stormwater management to maintain pre-construction volumes and seasonal patterns of onsite runoff retention and infiltration. These measures will foster groundwater recharge, protect offsite surface water quality, and moderate downstream flood flows. Retrofit existing infrastructure to achieve these goals wherever possible.

- **Restore degraded habitats wherever possible**, but do not use restoration projects as a license to destroy existing habitats. Base any habitat restoration on sound scientific principles and research in order to maximize the likelihood of having the intended positive impacts on biodiversity and ecosystems. Any restoration plan should include monitoring of the restored habitat to assess the outcomes and regular maintenance to protect restored features from degradation.

- **Promote the establishment of conservation agreements** on parcels of greatest importance for stream resilience or apparent ecological value.

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APPENDIX A

Mapping Conventions

The following section describes the mapping conventions used to draw boundaries between habitat types and additional information on defining habitat types.

Crest, ledge, and talus. Because crest, ledge, and talus habitats are usually embedded within other habitat types (most commonly upland forest), they were depicted as an overlay over other habitats. Places where this overlay appears with an underlying habitat of "ledge" signify unvegetated bare rock exposures that were large enough to map as their own habitat, for example, exposed ledges along the creek channel. Except for the most exposed ledges, these habitats do not have distinct signatures on aerial photographs and were therefore mapped mostly based on a combination of field observations and locations of potential bedrock exposures inferred from the mapped locations of shallow soils (<20 inches [50 cm]) and shallow soils on steep slopes (>15%) in the county soil surveys. The final overlay of crest, ledge, and talus habitats is therefore an approximation; we expect that there are additional bedrock exposures outside the mapped areas. The precise locations and boundaries of these habitats should be determined in the field as needed. The distinction between calcareous and non-calcareous crest, ledge, and talus habitats can only be made in the field. The areas that appear on the map as calcareous crest, ledge and talus were extrapolated from the locations of calcareous outcrops observed in the field. Nevertheless, bedrock throughout the study area (mostly sandstone and shale) is potentially calcareous.

Cultural habitats. We define "cultural" habitats as areas that are significantly altered and intensively managed (e.g.,, mowed), but are not otherwise developed with wide pavement or structures. These include playing fields, cemeteries, and large lawns. On aerial photos it was sometimes difficult to distinguish extensive lawns from less intensively managed hayfields, so in the absence of field verification some lawns may have erroneously been mapped as "hayfield/pasture," and vice versa.

Developed areas. Paved and gravel roads, driveways, and parking lots; buildings; and adjacent lawns were considered "developed" and not mapped as significant habitats. Habitat areas surrounded by or intruding into developed land were identified as ecologically significant and mapped only if their dimensions exceeded 50 m (165 ft) in all directions, or when their total area was roughly two acres (0.8 ha) or larger. This area threshold was adjusted slightly to exclude the mapping of some areas slightly larger than two acres in heavily developed areas, and to include smaller areas when they were immediately adjacent to larger mapped habitats. Exceptions to this protocol were wetlands and waterbodies within developed areas, which we mapped (along with their immediately adjacent, non-cultural habitats) if they were identifiable on the aerial photographs or if we observed them in the field. Even though such wetlands may lack many of the habitat values of wetlands in more natural settings, they still may serve as important drought refuges for rare species and other species of conservation concern. Lawns near buildings and roads were mapped as developed; large lawns not adjacent to buildings or roads and adjacent to significant habitats were mapped as "cultural" habitats.

Gravel bar. Large deposits of cobble, gravel, sand, and silt were widespread in the Catskill Creek channel and low-lying areas of the floodplain. Places where this overlay appears with an underlying habitat of "gravel bar" signify primarily unvegetated fluvial deposits that were large enough to map as their own habitat. In other areas, gravel bar is shown as an overlay on other habitats, often where flood channels cut through the riparian forest.

Open water and constructed ponds. Many bodies of open water along Catskill Creek were created by damming or excavation. Those that we mapped as "open water" habitats included natural ponds; large, substantially unvegetated pools within marshes and swamps (including the Franklinton Vlaie); pools formed by flooding on perennial stream floodplains; and ponds that were constructed but are now surrounded by unmanaged vegetation (thus presumed to be unmanaged ponds). All other ponds were classified as "constructed pond."

Springs and seeps. Springs and seeps are difficult to identify by remote sensing. We mapped only the very few we happened to see in the field. We expect there were many more springs and seeps in the stsudy area that we did not map. The precise locations and boundaries of seeps and springs should be determined in the field on a site-by-site basis.

Streams. We created a streams map in our GIS that was based on field observations and interpretation of topographic maps and aerial photographs. We depicted streams as continuous where they flowed through ponds, impoundments, or large wetlands. We mapped the likely location of streams that are diverted underground only when they re-surfaced at a distance of less than 200 meters (650 ft). The courses of many small headwater streams we observed in the field were difficult to map based on aerial photographs and other remote sources, especially under conifers; when not visible remotely, we mapped them to the best of our ability based on locations and bearings taken in the field and GIS contour data. We expect there were additional intermittent streams that we did not map, and we recommend these be added to the database as information becomes available. Because it was often difficult to distinguish between perennial and intermittent streams based on aerial photograph and map interpretation, these distinctions were made using our best judgment. Streams that were channelized or diverted by humans (i.e., ditches) were mapped when observed in the field or on aerial photos; we included ditches as stream habitat because they function as such from a hydrological perspective.

Upland forests. We mapped just three general types of upland forests: hardwood, mixed, and conifer forest. Although these forests are extremely variable in their species composition, size and age of trees, vegetation structure, soil drainage and texture, and other factors, we used these broad categories for practical reasons. Hardwood and coniferous trees are generally distinguishable in aerial photos taken in the spring, although dead or deciduous conifers can be mistaken for hardwoods. Different forest communities and ages are not easily distinguished on aerial photographs, however, and we could not consistently and accurately separate forests according to dominant tree species or size of canopy trees. Our "upland forest" types therefore include non-wetland forests of all ages, at all elevations, and of all species mixtures, including floodplain forests. Grass and dirt roads (where identifiable) were mapped as boundaries between adjacent forested habitat areas, since they can be significant fragmenting features.

Upland meadows and upland shrubland. We mapped three types of upland meadow habitats: cultivated field, hayfield/pasture, and oldfield. Meadow habitat distinctions were made based on field verification in 2012 to the greatest extent possible given the large degree of change in meadow land use observed since the dates of the most recently available orthoimagery and the 2011 floods. We mapped meadow habitats divided by fences and hedgerows as separate polygons, to the extent that these features were visible on the aerial photographs or field verified. Because oldfields often have a substantial shrub component, the distinction between oldfield and upland shrubland habitats is somewhat arbitrary. We defined upland shrubland habitats as those with widely distributed shrubs that accounted for more than 20% of the cover.

Wetlands. We mapped wetlands remotely using topographic maps, soils data, and aerial photographs. In the field, we identified wetlands primarily by the predominance of hydrophytes and easily visible indicators of surface hydrology (Environmental Laboratory 1987). We did not examine soil profiles. Along stream corridors and in other low-lying areas with somewhat poorly drained soils, it was often difficult to distinguish between upland forest and hardwood swamp without the benefit of onsite soil data. On the ground, these areas were characterized by moist, fine-textured soils with common upland trees in the canopy, often dense thickets of herbs and shrubs (e.g., Japanese knotweed, Japanese barberry) in the understory, and facultative wetland and upland species of shrubs, forbs, and graminoids. In most cases, we mapped these areas as floodplain hardwood forest. Because we did not examine soil profiles in the field, and we only sketched the wetland boundaries (i.e., we did not use GPS or other land survey equipment), all wetland boundaries on the habitat map should be treated as approximations, and should not be used for jurisdictional determinations. Wherever the actual locations of wetland boundaries are needed to determine jurisdictional limits, the boundaries must be identified in the field by a wetland scientist and mapped by a land surveyor. We attempted to map all wetlands in the study area, including those that were isolated from other habitats by development.

APPENDIX B

Common and scientific names of plants mentioned in this report. This does not represent a complete list of our plant observations. Scientific nomenclature follows the New York Flora Atlas (Weldy and Werier 2014*).

alder	*Alnus*
ash, green	*Fraxinus pensylvanica*
ash, white	*Fraxinus americana*
aspen, quaking	*Populus tremuloides*
barberry, Japanese	*Berberis thunbergii*
basswood	*Tilia americana*
beech, American	*Fagus grandifolia*
beggar-ticks	*Bidens*
birch, black	*Betula lenta*
birch, gray	*Betula populifolia*
bittersweet, Oriental	*Celastrus scandens*
blackberry, northern	*Rubus allegheniensis*
blueberry, highbush	*Vaccinium corymbosum*
canary-grass, reed	*Phalaris arundinacea*
cattail	*Typha*
cedar, eastern red	*Juniperus virginiana*
cherry, black	*Prunus serotina*
cliffbrake, purple	*Pellaea atropurpurea*
cliffbrake, smooth	*Pellaea glabella* ssp. *glabella*
columbine, wild	*Aquilegia canadensis*
cottonwood, eastern	*Populus deltoides*
dodder, field	*Cuscuta campestris*
dogwood, gray	*Cornus racemosa*
dogwood, silky	*Cornus amomum*
elm, American	*Ulmus americana*
elm, slippery	*Ulmus rubra*
false-nettle	*Boehmeria cylindrica*
fern, cinnamon	*Osmunda cinnamomea*
fern, maidenhair	*Adiantum pedatum*
fern, marsh	*Thelypteris palustris* var. *pubescens*
fern, sensitive	*Onoclea sensibilis*
fern, walking	*Asplenium rhizophyllum*
flag, blue	*Iris versicolor*
ginger, wild	*Asarum canadense*
goldenseal	*Hydrastis canadensis*
harlequin, yellow	*Corydalis flavula*
hawthorn	*Crataegus*
hemlock, eastern	*Tsuga canadensis*
hepatica	*Hepatica*
hickory, pignut	*Carya glabra*
hickory, shagbark	*Carya ovata*
holly, winterberry	*Ilex verticillata*
honeysuckle, Bell's	*Lonicera x bella*
hornbeam, American	*Carpinus caroliniana*
jewelweed, common	*Impatiens capensis*
Joe-Pye-weed, spotted	*Eutrochium maculatum*
knotweed, Japanese	*Reynoutria japonica* var. *japonica*
knotweed, slender	*Polygonum tenue*
locust, black	*Robinia pseudoacacia*
loosestrife, purple	*Lythrum salicaria*
mannagrass	*Glyceria*
may-apple	*Podophyllum peltatum*
maple, red	*Acer rubrum*
maple, sugar	*Acer saccharum*
meadowsweet	*Spiraea alba* var. *latifolia*
monkeyflower, winged	*Mimulus alatus*
oak, black	*Quercus velutina*
oak, chestnut	*Quercus montana*
oak, pin	*Quercus palustris*
oak, red	*Quercus rubra*
oak, swamp white	*Quercus bicolor*
oak, white	*Quercus alba*
pine, eastern white	*Pinus strobus*
pinweed, slender	*Lechea tenuifolia*
raspberry, black	*Rubus occidentalis*
raspberry, red	*Rubus idaeus*
rattlebox	*Crotalaria sagittalis*
reed, common	*Phragmites australis*
rose, multiflora	*Rosa multiflora*
rush, soft	*Juncus effusus*
saxifrage, golden	*Chrysosplenium americanum*
sedge cattail	*Carex typhina*
sedge, clustered	*Carex cumulata*
sedge, Davis'	*Carex davisii*
sedge, lakeside	*Carex lacustris*
sedge, tussock	*Carex stricta*
skunk-cabbage	*Symplocarpus foetidus*
spleenwort, maidenhair	*Asplenium trichomanes*
spleenwort, mountain	*Asplenium montanum*
sycamore, American	*Platanus occidentalis*
wall-rue	*Asplenium ruta-muraria*
water-plantain	*Alisma*
whitlow-grass, Carolina	*Draba reptans*
willow	*Salix*
woolgrass	*Scirpus cyperinus*

*Weldy, T., D. Werier, and A. Nelson. 2014. New York Flora Atlas. (S. M. Landry and K. N. Campbell [original application development], Florida Center for Community Design and Research. University of South Florida). New York Flora Association, Albany, New York.

APPENDIX C

Literature resources on stream dynamics and flood resiliency

A Review of the Scientific Literature on Riparian Buffer Width, Extent and Vegetation
(S. Wenger 1999) Institute of Ecology, University of Georgia, Athens. 59 p.

Conservation Buffers: Design Guidelines for Buffers, Corridors, and Greenways.
(G. Bentrup 2008) General Technical Report SRS-109, Forest Service, Southern Research Station, Asheville, NC. 110 p.

Design Recommendations for Riparian Corridors and Vegetated Buffer Strips
(R.A. Fischer and J.C.Fischenich 2000) Research and Development Center, US Army Corps of Engineers, Vicksburg, MS. 17 p.

Living in Harmony with Streams: A Citizen's Handbook to How Streams Work
(L. Henzel 2012) Friends of the Winooski River, White River Natural Resources Conservation District, and Winooski Natural Resources Conservation District. 46 p.

Municipal Flood Prevention and Floodplain Protection
(Land Use Law Center, no date) Pace University School of Law, White Plains, NY. 11 p.

Planning for Flood Recovery and Long-Term Resilience in Vermont: Smart Growth Approaches for Disaster-Resilient Communities
(S. Bertaina et al. 2014) EPA 231-R-14-003 US Environmental Protection Agency, Washington, DC. 45 p. + appendices

Review of Riparian Buffer Zone Effectiveness
(S. Parkyn 2004) New Zealand Ministry of Agriculture and Forestry, Wellington. 31 p.

Riparian and Wetland Buffers for Water-Quality Protection
(R. Rupprecht, C.Kilgore, R. Gunther 2009) Stormwater, November-December:46-51.

Riparian Zones
(C.H. Green and R. Haney, no date) Natural Resources Conservation Service, US Department of Agriculture, Washington, DC. 2 p.

Stream Crossings: Protecting and Restoring Stream Continuity
New York State Department of Environmental Conservation
(http://www.dec.ny.gov/permits/49060.html [accessed August 2014] 8 p.