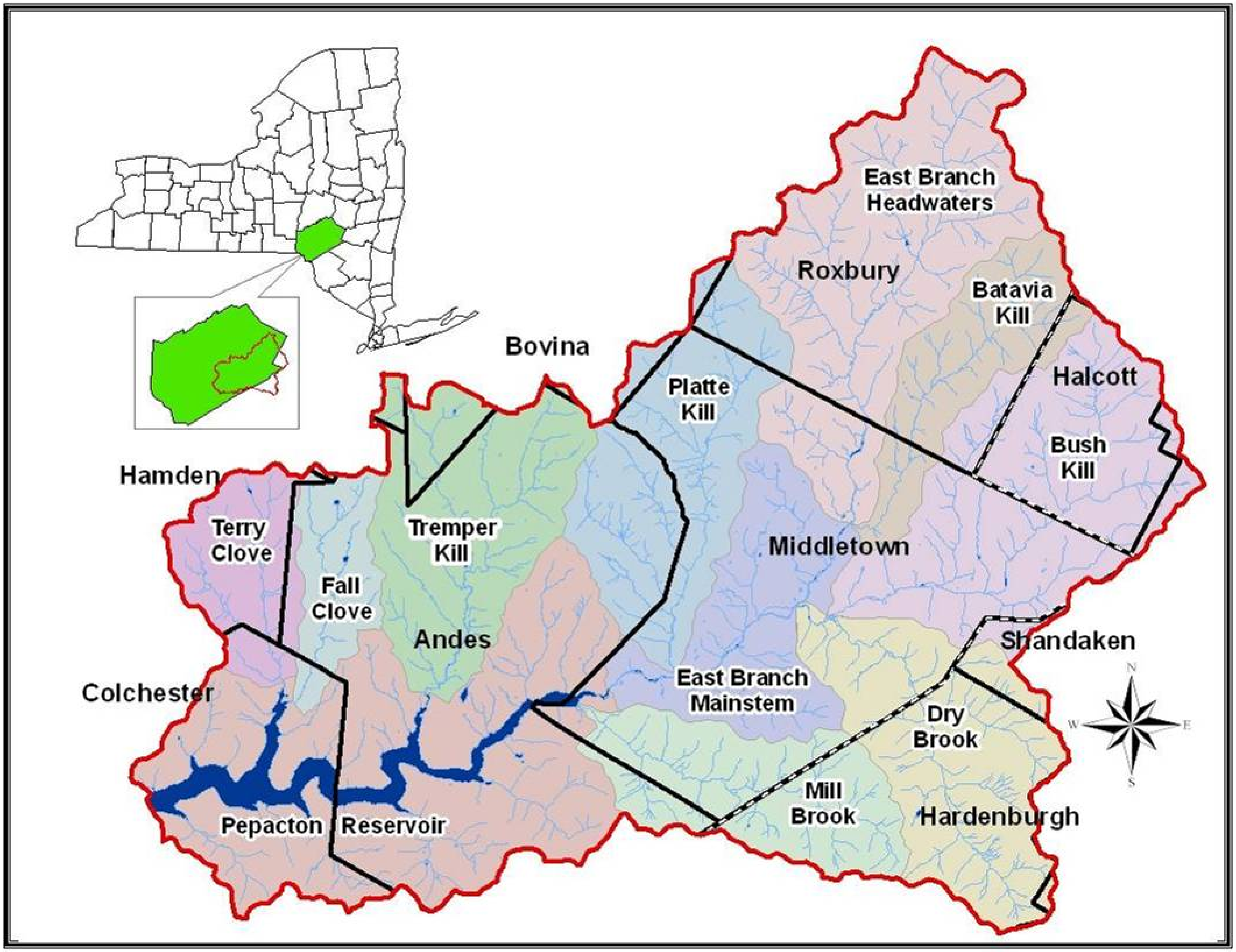
~ II. Watershed Overview ~

PHYSICAL CHARACTERISTICS

Physiography

The East Branch Delaware River is located in the eastern portion of the Allegheny Plateau physiographic province, which is the northern part of the Appalachian Plateaus that extend from southern New York to central Alabama. The East Branch Delaware River, along with eight additional sub-basins, contributes water to the Pepacton Reservoir. The total drainage area of the East Branch Delaware River watershed above the Pepacton Reservoir Dam is 371 square miles with 644.4 total stream miles. The entirety of the watershed is situated among rolling hills. The eastern portion of the watershed becomes rather steep, with portions of the Mill Brook and Dry Brook sub-basins bordering on the high peak region of the Catskills. Elevations within these sub-basins approach 3500 feet above sea level.

The watershed lies within the borders of three counties and at least portions of eleven townships. The location of the watershed and its sub-basins is indicated on **Map 1** (following page)**.** The majority of the watershed lies within Delaware County, with relatively smaller portions in Ulster and Greene County. The majority or entirety of the following towns are within the project area: Andes, Colchester, Halcott, Hardenburgh, Middletown, and Roxbury. These are all contiguous to the main stem of the East Branch and the mainstems of the sub-basins. Parts of the Towns of Bovina, Delhi, Hamden, Shandaken, and Lexington are also within the watershed. The only incorporated villages within the East Branch Delaware River watershed are Margaretville and Fleischmanns, while the remaining population centers are the recognized Hamlets of Arkville, Roxbury, Halcottsville, New Kingston and Andes.



Map 1. Pepacton Reservoir Watershed

Climate

The climate of Delaware County is considered "humid continental." Cool, dry air masses generally move eastward throughout the year, while warm, humid maritime air masses from the south move northeastward during the summer (Lumia, 1991). Relatively few hot days are experienced during the otherwise normally cool summers. Cold winter temperatures prevail whenever Arctic air masses flow southward from central Canada. Mean daily temperatures range from the low 20's in winter to the upper 60's in summer. Rainfall is usually adequate during the growing season (May – September), but deficiencies of precipitation sometimes occur.

Map 2 (following page) depicts the average annual precipitation distribution for the entire watershed. The legend at the right of the map shows the annual precipitation amounts. Note that Dry Brook and Mill Brook sub-basins are particularly prone to heavy rainfall, often sudden and brief, in their headwaters.

Increased rainfall has been experienced over the entire watershed over the past 100 years, with an additional 5.9 inches falling per year mostly due to extreme rain events. The topography of the East Branch Delaware watershed also has a significant effect on rainfall within the basin. Moisture-laden air is advected up the eastern slopes of the Catskills during northward-moving storms, causing heavier precipitation than is received on the western slopes. On the other hand, the western slopes receive more precipitation from eastern-moving storms[1]. This explains the heavier precipitation in the eastern portion of the watershed, since these areas lie on the western slopes of the Catskills.

Climate change models predict continued increases in precipitation over the next 50 years[2], with earlier ice off dates for streams in the spring and the likelihood of more frequent severe storm events and mid-summer droughts. These changes would likely impact the character of the streams, the landscape, the vegetation and the aquatic and terrestrial wildlife of the region.[3] Such changes would also affect the hydrology of the watershed (see next Section).

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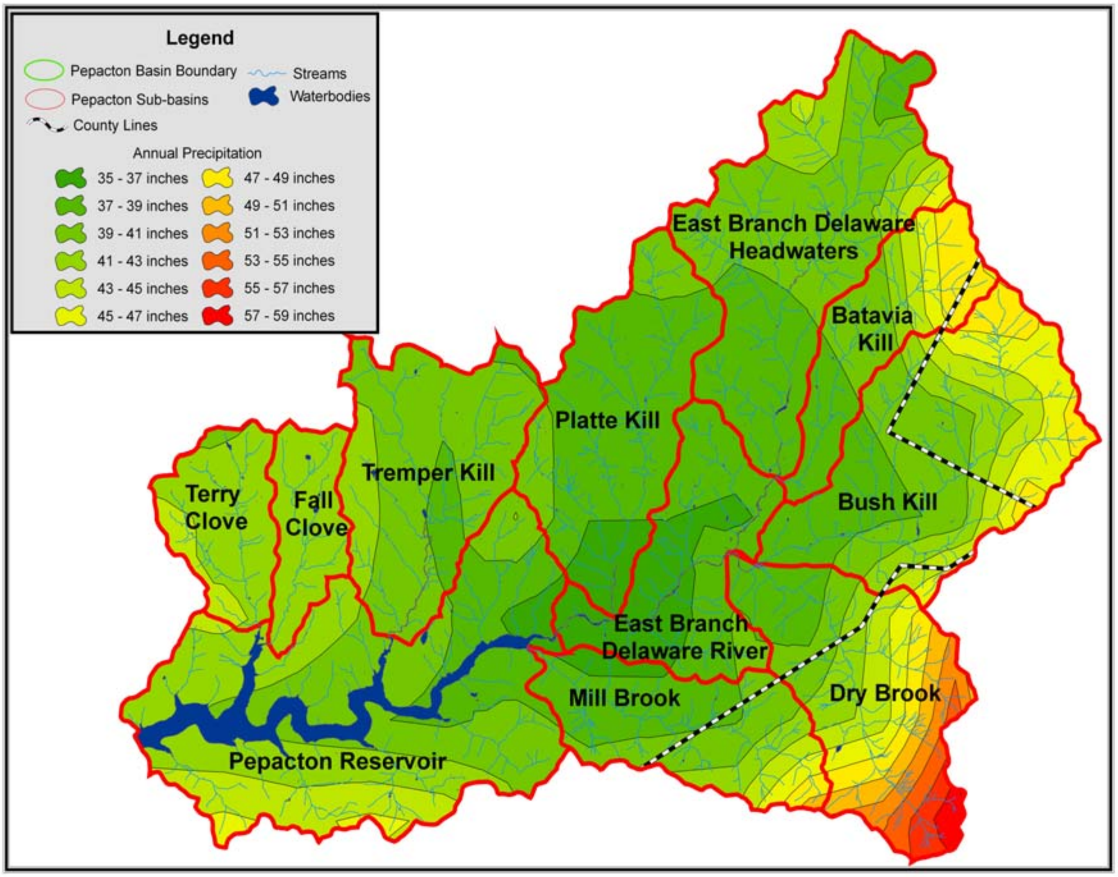
[1] Information obtained from "A Prospectus by the Cornell University Hydrologic Sciences Working Group."

[2] Burns, D.A., Klaus, J., McHale, M. R., 2007, Recent climate trends and implications for water resources in the Catskill Mountain region, New York, USA, Journal of Hydrology, 336, pg. 155-170, Elsevier.

[3] Climate change in the U.S. Northeast; A Report of Northeast Climate Impacts Assessment, The Union of Concerned Scientists, October 2006



Map 2. Average Annual Precipitation

Hydrology

Streams in the East Branch watershed are primarily perennial streams—they flow year round except in smaller headwater streams or in extreme drought conditions. The drainage pattern is generally dendritic (a branching, tree-like form), which is typical of watersheds in the Catskill Mountain region geology (see **Map 1** in the Physiography section).

Understanding the hydrology of a drainage basin is important to stream management because the rate of runoff affects flood behavior, water quality and quantity, *aquatic habitat*, and recreational use (Referring to the above Climate Section, increased runoff would likely result in changes in valley

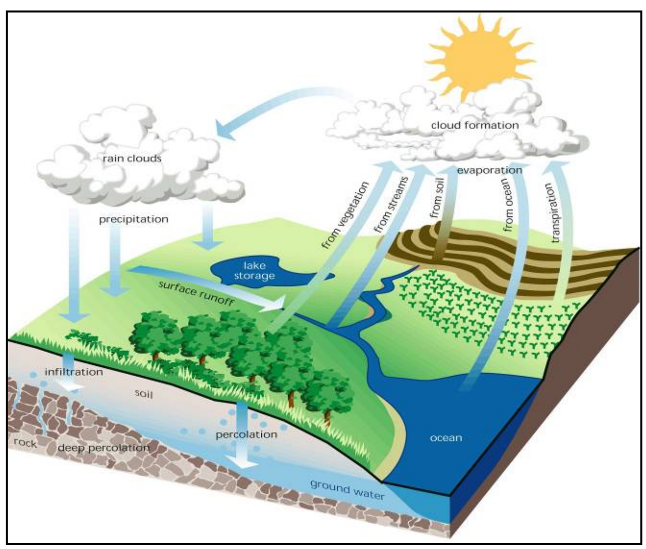


Figure 1. The Hydrologic Cycle

characteristics, stream channel dimensions, and stream sediment transport (see next Section) which could significantly affect how people live and work around streams and the surrounding landscape). Although it may not be obvious, the water flowing through the East Branch Delaware River drainage system reflects the integrated net effect of all the watershed characteristics that influence the hydrologic cycle (**Figure 1**). See **Volume 2, Section 3** for a more complete description.

The United States Geological Survey (USGS) maintains seven *continuous-recording stream gages* in the East Branch watershed and three inactive gages. These gages measure the stage, or height, of the water surface at a specific location, updating the measurement every 15 minutes. By knowing the stage, we can calculate the discharge (the volume of water flowing by that point every second) using a rating curve relationship developed by USGS. In this way, the discharge can be predicted for any stage of interest. We can also use the historic record of constantly changing stage values to evaluate stream response to rain storms, snow melt, extended periods of drought, to analyze seasonal patterns or flood characteristics. The gages in the East Branch basin have long enough periods of record to prepare hydrographs for their individual streams.

Table 1. USGS Stream Gages

Station ID	Station Name	Drainage Area (Mi^2)	Period of Record
01413088	East Branch Delaware River at Roxbury	13.5	June 2000 - present
01413398	Bush Kill Near Arkville NY	46.7	Oct 1997 - present
01413408	Dry Brook at Arkville NY	82.2	Dec 1996 - present
01413500	East Branch at Margaretville NY	163	Feb 1937 - present
01414000	Platte Kill at Dunraven NY	34.9	Oct 1941 - Sept 1962, Dec 1996 - present
01414500	Mill Brook Near Dunraven NY	25.2	Feb 1937 - present
01415000	Tremper Kill Near Andes NY	33.2	Feb 1937 - present
01415500	Terry Clove Kill Near Pepacton NY	13.6	Inactive
01416000	Fall Clove Kill Near Pepacton NY	11.3	Inactive
01416500	Coles Clove Kill Near Pepacton NY	28	Inactive

For example, information gathered from the gage at Margaretville shows that most of the runoff for the watershed above Margaretville occurs between mid March and mid May, with a second period of runoff in the fall in November and December. This is a period when the ground is often bare and *evapo-transpiration* from plants is low. The precipitation that falls during this period quickly runs off and the streams are full.

The USGS posts this information on their web site and it can be found at this address:
http://waterdata.usgs.gov/ny/nwis/current/?type=flow (Verified September 11, 2007)

Stream Characteristics

In the course of transporting water from the tops of mountains to the ocean, streams also transport sediment scoured from their own beds and banks. Streams and rivers are never constant, and it is important to understand how and why streams change. This understanding will help ensure that human activities do not inadvertently accelerate the rate of change.

Natural streams vary from steep to flat, wide to narrow, and relatively straight to a bending (or *sinuous*) flow pattern. The slope of a section of stream or "reach" largely depends on its position within a watershed. Streams are typically straighter and steeper in the headwaters where the valley is narrow and the slope is steep. As distance increases from the headwaters and the slopes begin to level in the lower, wider sections of the valley, the stream begins to meander. This is illustrated in **Figure 2**, where slope generally decreases from left to right and stream form is seen from both a cross-sectional and "aerial" view.

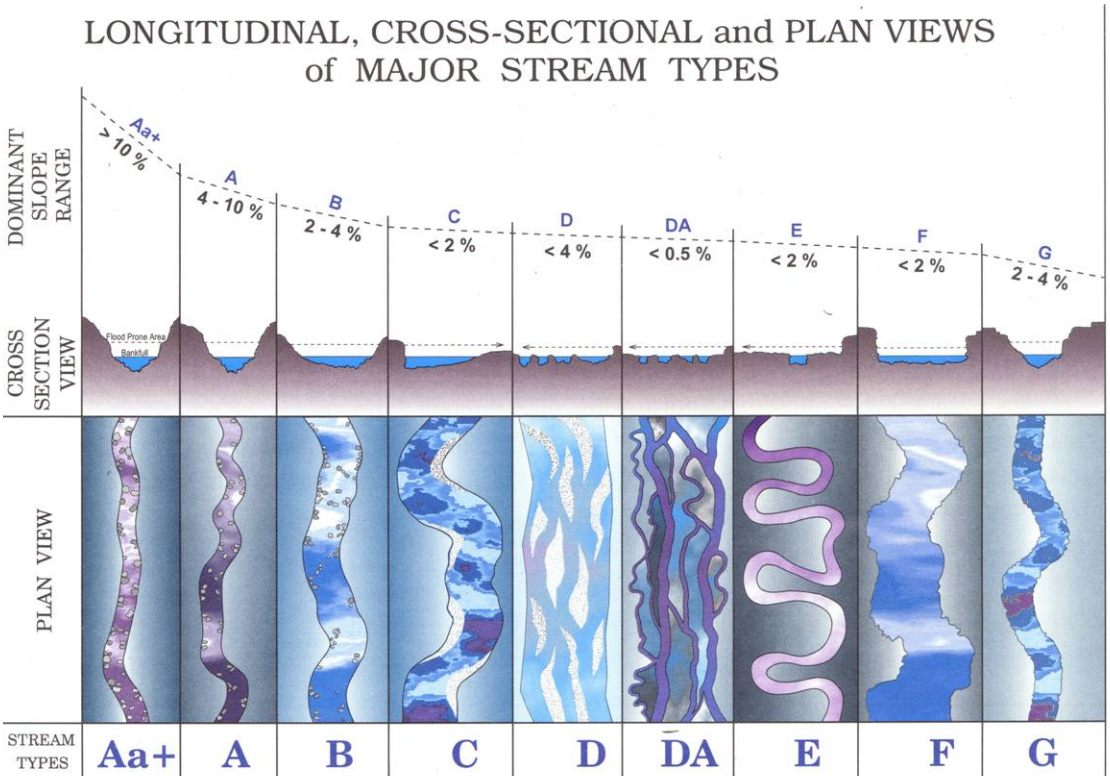


Figure 2. Views of Major Stream Types

Streams are constantly changing. During a storm event, the power or energy of water flowing in a stream is very noticeable. A large amount of sediment is moved during the peak flow of a high water event and that sediment is deposited as the water subsides. When there are low flow periods, the stream does not have enough energy to carry significant amounts of sediment. The sediment deposits in the form of gravel bars.

Under natural, undisturbed conditions, changes in the channel will be gradual. Where human development actions have changed conditions near the stream, the rate of change may be greatly accelerated or constrained. Streams that are in balance with their landscape can adapt a form that passes both the water and *bedload* (such as sediment, debris, etc.) associated with floods, regaining their previous form after the flood passes. These streams are considered to be stable, having a dimension and slope that is in balance with the location in the valley setting. In many situations, however, sections of stream can become *unstable* when human activities (such as bridge construction) have upset that balance, altering the stream's ability to move its water and bedload effectively.

Efforts to improve water movement during flood events have led people to make stream channels too wide, armor the stream banks, build berms or otherwise limit the extent of the floodplain. Increasing channel capacity by dredging to deepen or widen the stream provides only temporary relief and typically results in upstream and downstream channel instability. Armoring the bank with riprap can accelerate stream velocity and result in transferring erosion problems to downstream landowners. Berming the floodplain to protect development concentrates and accelerates flood flows and results in changes to the elevation of the stream bed[4]. Past stream interventions and channel alterations, such as dredging, channelization, straightening, berming, and rip-rapping, still affect the channel function today. For in-depth information on stream function and form in detail, refer to **Section 3** located in **Volume 2**.

During the assessments of the East Branch Delaware River watershed, the Delaware County Soil and Water Conservation District Stream Corridor Management Program (SCMPr) staff focused on trying to determine the relative stability of the streams in the watershed. They

- identified areas where the streams eroded their banks and deposited excess gravel
- examined the extent of streamside buffers to assess whether the streambank was protected with vegetation
- mapped and visited the location of bridges and culverts to assess whether the stream encountered problems flowing through these structures.

From these assessments the team described their findings in on a reach-by-reach basis for the East Branch Delaware mainstem and its tributaries. The complete description of the findings is located in **Section 1** of **Volume 2**.

Geology

In landscapes unchanged by human activities, streams reflect the regional climate, biology and geology. Climate was discussed in the preceding section, while biology, especially streamside vegetation, will be discussed in **Section 5** of **Volume 2**. The following section describes the basic geology of Delaware County and the East Branch basin.

Bedrock Geology

The bedrock underlying all of Delaware County is of sedimentary origin. Geologic research indicates that the *sediments* resulted from the *erosion* of a large mountain range that once existed to the east during the upper Devonian Period, some 370 million years ago. Westward flowing rivers carried the eroded sediments into the “Catskill Delta,” a vast marshy plain that was developing at the time. There the waters deposited layers of *sand*, *gravel*, *silt* and *clay* that eventually became the beds of sandstone, conglomerate (sandstone with pebbles), siltstone and shale rocks of today. The thickest and most uniform beds of certain sandstones are now valuable for local "bluestone" quarries.

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[4]2002, Riparian Areas: Functions and Strategies for Management, National Academy of Sciences, Washington, DC, pg. 155.

Important rock groups and some of their component rock formations in the East Branch watershed are shown in **Table 2**. None of these formations contain beds of limestone, but rather contain much silica; they are therefore considered to be "acidic" rocks, and spring water arising from bedrock cracks and fissures tends to be low in dissolved calcium and magnesium carbonates ("soft" water).

Some 330 to 250 million years ago, long after the sedimentary rocks had been formed, mountain-building forces began raising the large Appalachian mountain chain to the south. Being at the northern end of these rising mountains, the plateau that we know as the Catskill region was uplifted, acquiring vertical fractures in its rock layers during this time. Long periods of weathering and erosion wore down this plateau and created a drainage network along joints or fractures in the bedrock – an early version of the stream valleys we have today. Thus, the Catskill Mountains were created both by forces of erosion as well as those that build mountains upward. However, the shapes of the landscape have also been significantly remolded by glacial events, as described below.

Table 2. Bedrock Types in the East Branch Basin*

Geologic Group	Rock Formation	Type of Rocks Included
West Falls	**Honesdale**	Sandstone & shale
West Falls	**Slide Mountain**	Sandstone, shale & conglomerate
West Falls	**upper Walton**	Shale, sandstone & conglomerate
Sonyea	**lower Walton**	Shale, sandstone & conglomerate
Genesee	**Oneonta**	Shale, sandstone & conglomerate

* Like the bedrock formations themselves occur, the oldest rocks are listed on the bottom, the youngest at the top of the table.

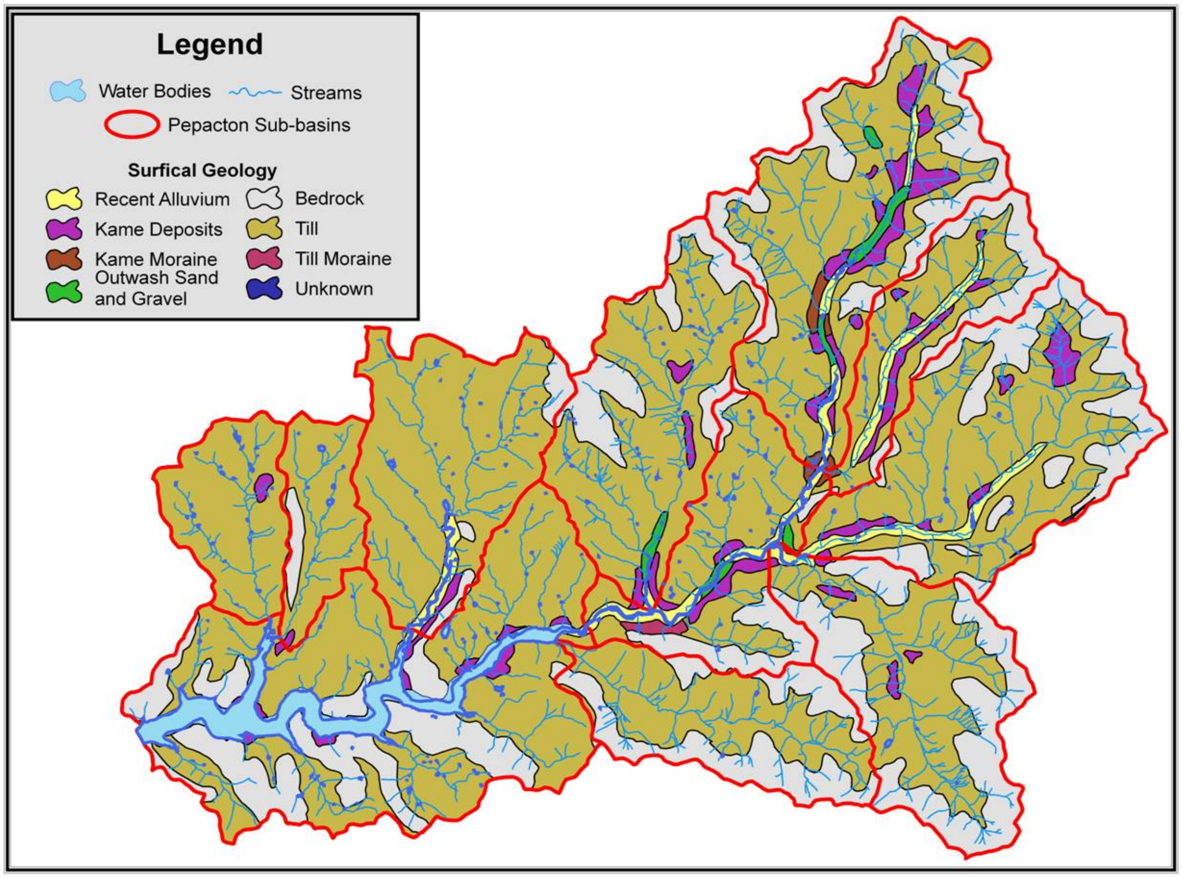
Glacial Geology

The most recent glaciation to leave this area (the Wisconsin glaciation) did so only some 10 to 12 thousand years ago. The processes of glacial erosion crushed and fragmented rocks into a slurry of *boulders*, angular stones and *gravel*, sand, silt and clay. This mixture was transported beneath, within and on top of the glacier, sometimes for many miles before being deposited by the ice or its meltwaters. Called glacial till, most uplands in the East Branch basin are covered with this kind of deposit (**Map 3**)[5]. For example, about 95% of Dry Brook's watershed is covered by varying thicknesses of glacial till.

In locations where washed and sorted debris was deposited, usually the margins of major valleys such as the mouth of the Platte Kill along the East Branch, gravelly terraces and kame deposits occur (**Map 3**). These give such parts of the landscape a somewhat lumpy and bumpy appearance. Such deposits are often valuable sources of sand and gravel, although they typically

[5] Map 3 is based in part on the work of Rich and others. Isachsen and others (1991, pp. 161-193) discuss the glacial epoch and its effects on NY landscapes. Reynolds (2004), Titus (1996) and Rich (1935) give more detailed descriptions of glacial landforms in the Catskills Region than the summary provided here.

contain more silt and clay than is desirable. Sand and gravel deposits can also store considerable amounts of ground water, which is released gradually to form the base flow of streams. By contrast, the extensive glacial till deposits contribute only a minor amount of ground water to base flow (Reynolds, 2004).



Map 3. Surficial Geology

The stagnating remains of the valley glaciers blocked off the outlets of some meltwater streams, creating lakes until the dams of ice could melt, which took many years. In the quiet waters of deeper lakes, silts and clays settled out and accumulated while in shallower, more agitated lakes fine sand and silt was deposited. The finest-textured (clayey) sediments formed relatively small deposits. Coarser lake-laid deposits occur in the East Branch and other valleys, although more recent floodplain deposits often overlie them. The river itself winds through the relatively flat surface of accumulated sediments over the much deeper valley carved into the bedrock. Reynolds (2004) reported about 150 feet of sediment filling the valley floor where the Pepacton Reservoir’s Downsville dam was constructed.

Where relatively fast-flowing tributary streams enter major valleys, water velocity slows as they flow across the flatter river floodplain. The abrupt slowing of the stream's velocity causes it to drop its bedload of sand and gravel on the floodplains as a subtle fan or delta-shaped alluvial fan deposit. This process has been continuing since the waning stages of glaciation, and alluvial fans are commonplace in larger valleys. Because these deposits are fairly level and well drained, they make good farmland and building sites; the center of many villages and hamlets, including parts of Margaretville and Roxbury, are on alluvial fan landforms.

The glacial deposits described above are the parent materials in which the soils of today have developed. In terms of geology and soil formation, the Epoch since the glaciers left their deposits on the Delaware County landscape is a short period of time. Processes of erosion and sediment accumulation continue to affect the landscape, although their rates can be greatly accelerated by man's activities.

Applied Geology

Probably one of the least known but most appreciated aspects of geology in this region of the Catskills is closely related to maintaining fish habitat. It is well known that various sport fish, including trout, require relatively clean and cold water for their survival and especially for spawning. The best trout streams tend to have a steady supply of baseflow from cool groundwater. This requires a means of water storage and release, either natural or man-made, especially through the warm summer months. As mentioned before, the glacial till that covers over 90% of the East Branch watershed contributes little groundwater to maintain base flows between precipitation events, largely producing runoff instead. The primary soil materials that can store and steadily release groundwater are extensive areas of sand and gravel, due to their porosity. But the entire East Branch basin has only minor amounts of these deposits (5 to 7%) as kame, kame moraine, outwash and alluvium (**Map 3**).

The answer to this puzzle was first alluded to by a geologist from Binghamton University (Coates, 1971) and was more recently deduced by the United States Geological Survey (USGS) (Reynolds, 2000 & 2004). It turns out that of the sandstone, siltstone and shale bedrock types of the Catskill Mountains, sandstone is the most permeable, due primarily to its extensive joints and other fractures. A bedrock aquifer underlies the entire East Branch watershed, with the most massive sandstone occurring in the Mill Brook and Tremper Kill sub-basins. While all of the East Branch exhibits unusually high base flows for the small amount of sand and gravel deposits, these two sub-basins have the capacity to store and slowly release relatively large amounts of groundwater to stream baseflow — capacities greater than nearly all other basins in the Catskills (exceeded only by the Beaver Kill and Willowemoc Creek to the south). Stored groundwater is thus released from sandstone by springs and subsurface seepage into streams for extended periods through the summer, which maintains favorable trout habitat for most of the year.

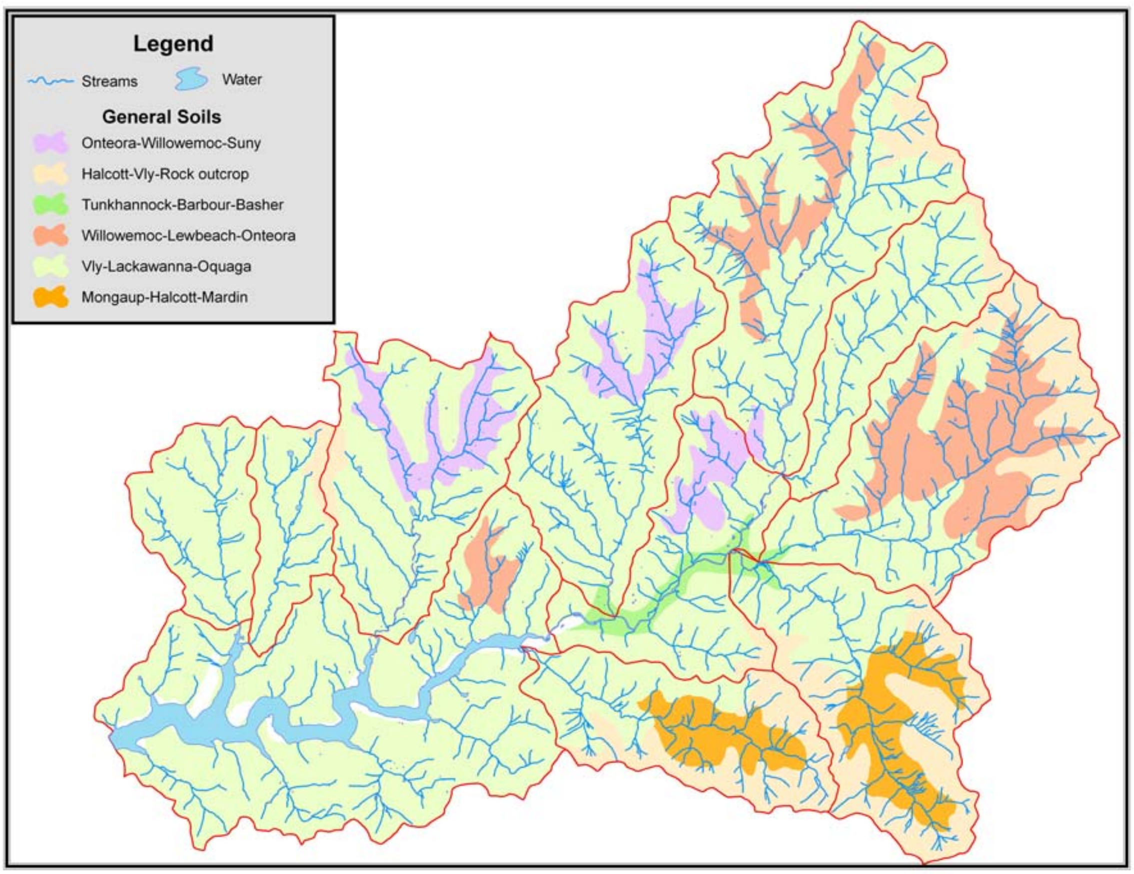
Soils

Over the 10,000 years or so since the glacial deposits were exposed to the elements, the influences of physical weathering and plant and animal life have been at work. The surface layer down to a depth of about 6 feet is generally considered to be “soil,” and the materials below this closely reflect the original geologic deposit in which the soils of today have developed. The study of soil is useful for this discussion primarily due to two aspects: a) water movement as runoff and infiltration, and b) as a source of nutrients and sediment that reach surface waters.

The United States Department of Agriculture (USDA)-Natural Resources Conservation Service (NRCS) has mapped soils in Delaware County through their soil survey program. **Map 4** shows a generalized view of soils mapping in the study area, using only six map units instead of the 129 recognized in the detailed soil survey (for full detail see http://websoilsurvey.nrcs.usda.gov verified September 26, 2007).

Agriculture is a significant land use in the East Branch watershed, and it is linked to the land management changes that may be needed in the future to enable successful stream corridor management. Soil characteristics must be evaluated in order to design conservation practices that limit the loss of excess *nutrients* and eroded sediments from farmland and keep them from entering surface water.

The most extensive map unit along streams is Vly-Lackawanna-Oquaga, which consists of reddish brown soils that developed in upland glacial till. The sand and gravel "bottomland" soils of Tunkhannock-Barbour-Basher extend from Arkville and Margaretville along the East Branch main stem to the Pepacton Reservoir. The remaining soils are all variations of glacial till, the variations based mainly on either depth to bedrock, wetness or parent material color. For readers that are interested, these soil groups are further described on the following page (**Table 3**).



Map 4. General Soils

Table 3. General Soils

Soil Type	***Onteora-Willowemoc-Suny***	***Halcott-Vly-Rock Outcrop***
Slope (Range)	Strongly steep – level	Moderately steep – very steep
Depth (Range)	Very deep – bedrock	Moderately deep – shallow or exposed bedrock
Drainage (Range)	Moderately well drained – poorly drained	Somewhat excessively drained
Texture	Medium	Medium
Elevation	Uplands >1750 ft.	Uplands >1750 ft.
Suitability for Ag.	Fair	Unsuitable
Components	60% Onteora 21% Willowemoc 5% Suny 14% other	40% Halcott 25% Vly 13% Rock Outcrop 22% other

Soil Type	***Tunkhannock-Barbour-Basher***	***Willowemoc-Lewbeach-Onteora***
Slope (Range)	Steep – nearly level	Gently sloping - steep
Depth (Range)	Very deep – bedrock	Very deep - bedrock
Drainage (Range)	Moderately well drained – somewhat droughty	Well drained – somewhat poorly drained
Texture	Medium to moderately coarse	Medium
Elevation	Valleys <1750 ft.	Uplands >1750 ft.
Suitability for Ag.	Excellent (for slopes <15%)	Good (for slopes <15%)
Components	53% Tunkhannock 11% Barbour 6% Basher 30% other	41% Willowemoc 30% Lewbeach 10% Onteora 19% other soils

Soil Type	***Vly-Lackawanna-Oquaga***	***Mongaup-Halcott-Mardin***
Slope (Range)	Strongly sloping – very steep	Gently sloping – strongly sloping
Depth (Range)	Moderately deep – bedrock	Moderately deep – shallow – bedrock
Drainage (Range)	Somewhat excessively drained – well drained	Somewhat excessively drained – moderately well drained
Texture	Medium	Medium
Elevation	Uplands	Uplands
Suitability for Ag.	Fair	Fair to poor
Components	35% Vly 31% Lackawanna 26% Oquaga 8% other	55% Mongaup 16% Halcott 15% Mardin 14% other

Wetlands

Wet portions of the landscape such as marshes, wet meadows, swamps (forested wetlands), bogs, the shallow margins surrounding ponds, lakes or reservoirs, and seasonally-flooded floodplains are generally known as "wetlands". Over the last few decades, society and the scientific community have increasingly become aware of the functions of wetlands, their values to society, and the variety of forms they take. Differences arise from variation in vegetation, soils, hydrology, and position in the landscape, all of which can make some wetlands more "valuable" than others. In their natural condition, wetlands provide flood control, erosion control, water quality protection, fish and wildlife habitats, and opportunities for recreation, aesthetic appreciation and education.

The U.S. Fish and Wildlife Service published their inventory of wetlands for the entire New York City watershed in 1996. The data is available as printed maps and is also in digital format as a spatial and tabular database. The analysis of this information (without considering the shorelines and deepwater habitat of the Pepacton Reservoir itself) produced the following noteworthy wetland characteristics in the East Branch watershed:

1) The East Branch Headwaters contain more wetlands than other sub-basins in the watershed. However, at a total of only 359 acres, wetlands comprise a very small proportion of the land area. This acreage equals 1.1% of the sub-basin and is close to the maximum for all those contributing to the East Branch.

2) Most wetlands in each sub-basin are relatively small, with median wetland size ranging from 0.64 to 1.48 acres.

3) The most extensive wetland type is small marshes with *emergent* vegetation (such as cattails). The next most common type is small ponds, followed by scrub-shrub swamps and lower portions of perennial streams.

4) Wetlands seem to occur in patterns that roughly follow surface drainage channels (as opposed to being randomly scattered across the landscape).

The ability of wetlands in the East Branch watershed to abate flooding and perform other valuable functions is limited by their small aerial extent. However, it is more important than ever to protect existing wetlands for the functions they do provide. For a more in-depth discussion of wetlands in the watershed, please refer to **Volume 2** of the SCMP**, Section 2**.

HUMAN-ENVIRONMENTAL INTERACTIONS

Historical Land Use

In the early days of settlement, Delaware County was a veritable treasure trove of valuable natural resources. Originally blanketed by a forest including maples, oaks, beeches, elms, black cherries, white pines, hemlocks, hickories, spruces, and the now-rare chestnut, the county was largely cleared to make way for agriculture. While much of the wood was used for construction, tools, wagons, and furniture, certain tree species served more specialized purposes. The hard, uniquely colored wood of black cherry trees was superb for the manufacture of fine furniture. The tannins in the bark of hemlock trees were utilized for tanning leather, and the abundance of hemlock supported the multitudes of tanneries in Delaware County[6]. Tanneries also used water in their processing of the hides, which contributed to the pollution of the waterways at the time. Sugar maples, the sweet sap of which flows heavily during the cold nights and warm days of early spring, provided syrup and sugar to those who tapped the trees[6].

As the forests fell, man and horse alike strained and struggled to pick rocks, pull stumps, and plow the virgin soil. Given the steep terrain and thin topsoil of much of Delaware County, productive land was limited to the lowlands (often the floodplain). Buckwheat, rye, corn, oats, and some wheat was grown by local farmers, although rye was by far the best suited for poor soils. The necessity for milling facilities grew out of these crops, leading to the construction of grist mills across the county. Between sawmills and grist mills, most waterways were utilized for water power.

Upon the arrival of the railroad, the importance of growing breadstuffs for personal use lessened as grains could be shipped from other, more productive locations. The local abundance of water and cold-hardy grasses instead supported dairying as the primary agricultural focus. Eastern Delaware County was home to a booming dairy industry, boasting both farms and creameries. Milk was shipped by rail as far as New York City, with butter traveling as far as California. Later, in the 1900s, cauliflower began to accompany dairy products on the transportation routes. Bringing high prices, cauliflower was important to small farms until larger operations began to dominate the market mid-century[7].

The East Branch Delaware River was highly important to local residents. Providing a means of transportation and trade, commerce was made possible with other municipalities. Many families relied on fish caught in the river or its numerous tributaries for food, with the shad fishery in Colchester being exceptional. The East Branch Delaware River could also occasionally wreak havoc, with floods destroying homes, infrastructure, and crops. In the 1890s, an October flood washed away a cemetery containing the remains of prominent pioneers and Revolutionary War soldiers[8].

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[6] Griffin, Ira Mae. *The History of the Town of Roxbury.* Reprint 1975. page 4
[7] Galusha, Diane. *As The River Runs: A History of Halcottsville, New York.* Catskill Mountain Publishing Corp. Arkville, NY. 1990. pages 24-38 and pages 1, 17, 21
[8] W.W. Munsell & Co. *History of Delaware County, NY with Illustrations, Biographical Sketches, and Portraits of Some Pioneers and Prominent Residents.* W.E. Morrison & Co. Ovid, NY. Rep ublished 1976 (orig. 1880). page 137

The construction and operation of railroads had a significant impact on the East Branch Delaware. The Ulster and Delaware Railroad crossed the Bush Kill and East Branch Delaware at numerous locations and the rail bed affected flood flows and redirected stormwater through an extensive network of ditches and box culverts. Railway washouts in storm events frequently required expensive repairs that involved protecting the rebuilt streamside track sections and structures with large rock and concrete.

In the early 1800s, a dam was erected on the mainstem of the river within the township of Middletown at Halcottsville. Thirty-eight-acre Lake Wawaka was formed, which for over 125 years provided power for mills and industry, ice for farms and creameries, and later, electricity for the residents of Halcottsville. Enlarged in the early 1900s, the lake became the focus of a lawsuit after it allegedly inundated part of a local farm. This controversy would be mirrored — on a much larger scale — upon the construction of the Pepacton Reservoir downstream in the 1950s. Damaged by a flood in 1987, the Lake Wawaka dam was never repaired and the impoundment has since decreased in size[7].

The only other dam on the mainstem of the East Branch is that of the Pepacton Reservoir at Downsville. The priority of the East Branch watershed became the provision of drinking water to New York City residents when thousands of acres of land were flooded in 1955. Four communities were inundated (Arena, Pepacton, Shavertown, and Union Grove), and 974 people were displaced. The largest reservoir by volume in the New York City system, the Pepacton contains 140.2 billion gallons at full capacity and provides the City of over 8 million people with 25% of its drinking water[9].

Current Land Use

Today, the forests have regained much of their original extent as agriculture has dwindled across the watershed. Dairy farming and forestry, however, remain the predominant active land uses within the basin. The trees are still used for lumber, furniture, pallets, and pulp, and people are still tapping the sweet resource of the sugar maples. The rural character of the East Branch Delaware River watershed makes it attractive to tourists and second-home buyers alike, which has increased recreational use of lands and waterways. Fishing, canoeing, kayaking, hiking, birding, and other pastimes are frequently enjoyed in, on, or near the East Branch and its tributaries. Prime trout fishing is legendary, both in the Pepacton Reservoir itself and in the East Branch Delaware. In winter, ample snowfall allows snowmobiles to travel the 354 miles of New York State-funded trails in Delaware County, many of which lie within watershed boundaries. Skiers and snowboarders descend upon resorts such as Plattekill Mountain in the town of Roxbury and Belleayre Mountain, which straddles the line between the East Branch Delaware River / and the Esopus Creek watershed. Tourism is now an integral part of the economy for communities within the watershed. The Delaware and Ulster Railroad – complete with its extensive streamside infrastructure - continues to function as an excursion train between Arkville and Roxbury and also provides hiking opportunities on sections of the railbed along the stream from the Village of Roxbury.

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[9] Information obtained from http://nyc.gov/html/dep/html/watershed_protection/html/pepactoninfo.html Verified on November 28, 2007.

Real estate prices have soared over the last thirty years, which in combination with the abandonment of many farms, has led to the parcelization of previously large tracts of land. This parcelization presents a challenge to unified stream management. An additional challenge is the fact that most villages and hamlets are located on or quite near waterways, increasing the amount of impervious surface and therefore the possibility of pollution. However, the communities within the East Branch watershed have adopted local land use laws including zoning, site plan review, subdivision regulations, and floodplain management laws. These tools are used by the local municipalities to protect the safety, health and general welfare of the residents. This includes protecting the environment and all natural resources.

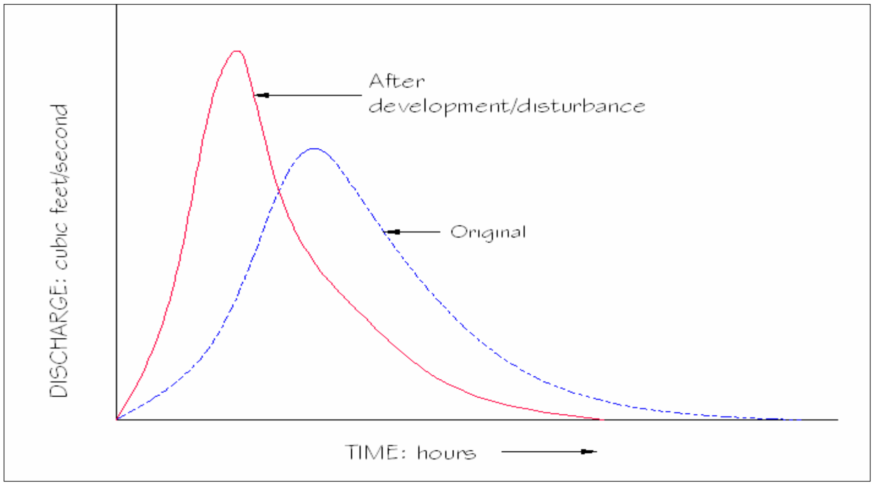


Figure 3. The Effect of Disturbance on Stream Discharge

Our activities have affected the landscape as previous generations cleared forests for pastures and cropland, or straightened stream channels to accommodate agriculture and/or development. The conversion of forest land for agriculture two centuries ago resulted in more frequent and severe flooding. The streams and associated erosion rapidly changed the landscape. The impact of these changes on the landscape is visible today as numerous small terraces along headwater streams indicating the process of bed degradation. The regeneration of the forest cover in the recent decades has helped moderate the runoff and changes in the stream channels. Unfortunately, the return of the forests is countered by trends in residential development. **Figure 3** illustrates what happens to a watershed after it is developed and green space is converted to impervious surfaces such as roads, parking areas and roof tops. Note that peak flow (discharge) increases. Also note that this increased discharge takes less time to reach its maximum. This double effect of a higher discharge occurring in less time usually initiates erosion and the destabilization of the drainage basin.

Infrastructure

In the basin there are two villages and five hamlets which serve as commercial centers for the surrounding towns. Village and hamlet tax parcels are primarily residential and commercial in nature, with the lot sizes substantially smaller. These smaller lots can be accommodated because of the use of municipal sewer and water systems.

The major municipal water supplies *within* the Pepacton Reservoir's contributing basin are for the Andes Water District, the Arkville Water District, the Village of Fleischmanns, the Halcottsville Water District, the Village of Margaretville, the Roxbury Water District, and the Denver Water District. There are numerous additional water supplies within the watershed, most supported by groundwater. These water supplies – often simple wells – sustain schools, hospitals, housing developments and mobile home parks, camps, hotels / inns, and businesses. Thousands of private residences and seasonal homes add to the number of springs and wells utilized for potable water.

The New York City Department of Environmental Protection operates two sewage treatment plants within the watershed, one located in Margaretville and one in Grand Gorge. Other municipal wastewater treatment plants serve the hamlet of Andes, the Village of Fleischmanns, and Denver / Roxbury Run. Like water supplies, there are many other wastewater treatment facilities for schools, housing developments, camps, hotels / inns, and businesses.

Linking the towns of the East Branch basin is a network of highways and bridges under three separate ownership and maintenance categories: New York State, Delaware County, and townships. They are all part of an infrastructure system on an inventory maintained by the New York State Department of Transportation (NYSDOT). Highways are inventoried according to political jurisdiction with subcategories including pavement type. All bridge structures with a span of 20 feet or greater are inventoried, numbered, rated, and periodically inspected for condition and safety by NYSDOT. In Delaware County, bridges on town highways with a 20 foot span and greater are inventoried, numbered (in addition to the NYSDOT inventory and numbering system), maintained, and periodically inspected for maintenance or repair scheduling by the county. On county highways, all structures with a span of 5 feet or greater are managed as bridge structures. Structures on town highways with less than 20 feet of span are the individual town's responsibility and are not inventoried by the county or state.

Highways

As depicted by **Map 5,** there are two state highways within the East Branch basin: 28 and 30. These are the major routes in the watershed. State Highway 28 enters the watershed from Delhi, travels through Andes, Margaretville, and Fleischmanns, and exits at the eastern bound of the basin. State Highway 30 enters the southeastern edge of the watershed from Downsville, runs along the southern edge of the Pepacton, and then crosses to the northern shore. Going through the Village of Margaretville, State Highway 30 continues on to Roxbury and leaves the watershed after passing through Grand Gorge. State Highways 28 and 30 intersect west of the Village of Margaretville.

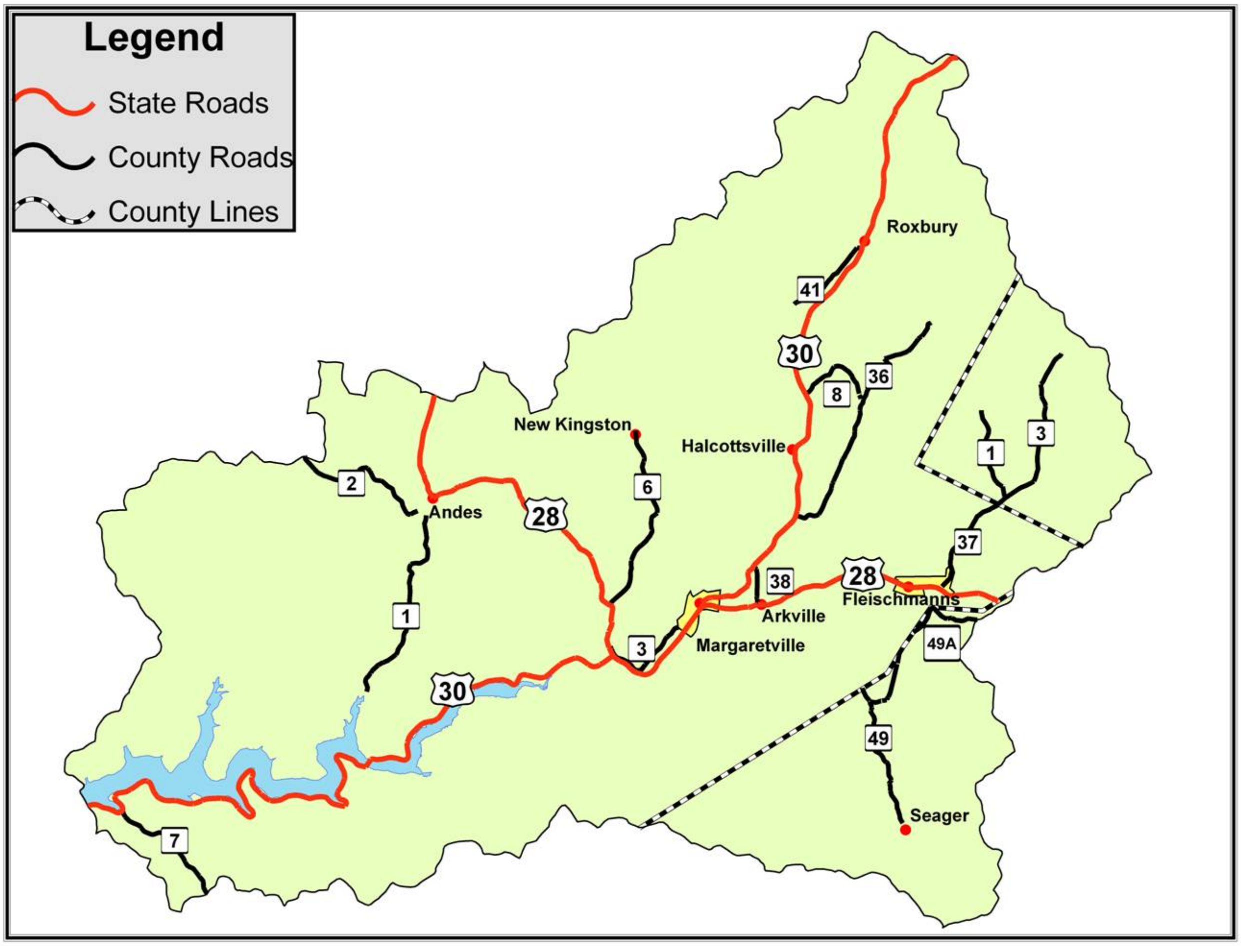
Portions of nine county highways traverse the watershed, five of which lie completely within the basin. In the eastern portion of the watershed are:

- County Route 41 in Roxbury
- County Route 36 between State Highway 30 and Vega
- County Route 8 connecting State Highway 30 and County Route 36
- County Route 37 from Fleischmanns to the Town of Halcott in Greene County
- County Route 38 connecting State Highway 30 and State Highway 28 east of Margaretville

In the central portion of the watershed are:

- County Route 6 between State Highway 30 and New Kingston
- County Routes 1 and 2 in Andes

County Route 7 lies in the western portion of the watershed, connecting State Highway 30 with Roscoe in Sullivan County.



Map 5. Watershed Highways

Most of the highway mileage in the watershed is divided among the jurisdictions of the eleven townships, although the townships with little land area within the watershed contain negligible road mileage. These roads run along streams, over mountaintops and connect with each other and the state and county highways. Town highways are constructed to various standards, with many having been constructed or rehabilitated to the Erwin and Donovan standards developed and financially supplemented by New York State from the period of 1952 through 1982. Town highways feature a variety of surfaces including improved dirt, gravel, or oil and stone. Most town highway mileage is a public right-of-way by usage according to the NYS Highway Law.

Stream Impacts from Highways

Many of these highways are in close proximity to streams and rivers, often crossing them. Highway maintenance can affect stream dynamics and water quality as a result of roadside drainage management, road surface repairs, bridge rehabilitation or replacement, snow and ice removal, and bank stabilization (which may be between the road and the stream). Road encroachment has already impacted many streams, ultimately leading to stream instability — rapid bank erosion, impaired water quality and stream health. Worse yet, these local changes can spread upstream and downstream, causing great lengths of stream instability. Roads near streams can also introduce pollutants or garbage from stormwater runoff, which negatively impacts aquatic habitat. Stormwater runoff is recognized as a significant water quality concern in Delaware County. As overland flow from impervious surfaces such as roads, rooftops and parking areas, it contains contaminants and nutrients that are delivered directly into stream systems. A good streamside buffer along roads could help minimize excess pollutants and garbage from entering the stream system.

Roadside ditches collect stormwater runoff and carry it away from the road, sometimes diverting it directly into the streams. However, getting the water to the streams faster can have negative impacts such as contaminated stormwater, excess sediment, and excess water entering the stream system without any filtration. Increased flooding can occur, due in part to more frequent, extreme rain events, but there are other factors at work. Impervious surfaces and drainage ditches do not allow water enough time to infiltrate the soil, resulting in excess water entering stream systems. Ditch maintenance without re-seeding can increase sediment and turbidity into the stream system, adding to gravel deposition problems. Proper culvert installation is important for stream stability as well, since incorrect culvert installation can increase streambank erosion and/or gravel deposition upstream and downstream of the culvert.

Stream Impacts from Bridges

Bridge design has become a complex issue between highway infrastructure and stream management. Of the 42 bridges in the East Branch Delaware watershed, 20 belong to New York State DOT[10] and 22 are county-owned bridges. The individual towns maintain an additional 42 stream crossing structures. Under many circumstances, bridges were built without any consideration given to stream system impacts, as long as a certain amount of water from a predicted flood event would pass under the bridge. Bridges that are built too wide for the stream will start to deposit sediment upstream or downstream of the structure during periods of low flow or base flow. Bridges that are built too narrow for the stream to pass under may cause streambank erosion upstream and/or downstream of the structure. Gradual rises in the highway leading up to a bridge (i.e. the bridge approach) typically fill a portion of the floodplain; during floods this constriction can force water that is normally on the wider floodplain through the narrow opening under the bridge. This concentrates the energy of the floodwaters, potentially causing erosion problems downstream and under the bridge.

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[10] According to Timothy Giblin, NYSDOT Region 9

Current Stream Impact Mitigation Efforts

Work is currently underway to address stormwater issues as related to development-related runoff and highway management. By following recommendations of the Delaware County Action Plan (DCAP) the county is developing and implementing programs for better stormwater and highway management. In addition, the Delaware County Planning Department (DCPD) and Department of Public Works (DPW) are answering the call for proper local stormwater management with Highway Management Plans, individually tailored for each town. Creating these plans helps identify existing infrastructure as well as historical or repetitive problems areas. Recommendations for road improvement and maintenance plus stormwater infrastructure at the township level are included.

Citizen Flood Response

Floods are an act of nature and, unfortunately, they can at times create immense damage to our homes and infrastructure. There are well documented events in 1942, 1955 (when the Pepacton Reservoir filled up for the first time), 1987, 1996, 2005, and 2007 to name a few. When floods occur, flow exceeds the "normal" rate, stream banks overtop, and water flows onto the floodplain. It is important to remember "*The floodplain is defined as the flat area bordering a stream, constructed by the river in the present climate and inundated during periods of high flow*" (Leopold, 1997). Flood flows over floodplains accomplish three natural functions: energy reduction, deposition of finer sediments (which enhances plant growth), and deposition of woody debris.

It is important to recognize that much of the property damage suffered during floods is directly related to development on the floodplain. For those who live in a flood-prone area, several practical steps can be taken to protect a home or business in preparation for future floods. Irreplaceable valuables should not be stored in the cellar and first floor. If an oil tank exists in the basement, it should be securely anchored according to code to prevent it from floating and spilling during a flood. Electrical components, including the washer and dryer, within the house should be raised above the level of potential flood waters. Consideration should be given whether to raise the furnace and water heater above the level of potential flood waters. These suggested actions could help avoid the common repairs homeowners may have to undertake after a flood. Propane tanks should also be secured in a manner that they will not float downstream in the event of a flood.

In the event of a flood, FEMA recommends the following actions to make sure a family stays safe until the water levels recede:

- **Fill bathtubs, sinks, and jugs with clean water in case water becomes contaminated.**
- **Listen to a battery-operated radio for the latest storm information.**
- **If local authorities instruct the community to do so, turn off all utilities at the main power switch and close the main gas valve.**
- **If told to evacuate your home, do so immediately.**

- **If the waters start to rise inside a house before evacuation, retreat to the second floor, the attic, and if necessary, the roof.**
- **Floodwaters may carry raw sewage, chemical waste and other disease-spreading substances; wash hands with soap and disinfected water.**
- **Avoid walking through floodwaters. As little as six inches of moving water can knock a person off their feet.**
- **Don't drive through a flooded area. If you come upon a flooded road, turn around and go another way. A car can be carried away by just 2 feet of flood water, the depth of which can be very hard to judge.**
- **Electric current passes easily through water, so stay away from downed power lines and electrical wires.**

Following a flood, individuals should take special care to document their damages and losses. Receipts for repairs and materials as well as photographs of damages should all be kept by home and business owners.

June 2007 Flood Event

A very localized and devastating flood occurred on June 19, 2007. An intense storm dropped over eight inches of rain in two hours, causing severe flash flooding in a few small tributaries that discharge directly into the Pepacton Reservoir. Holliday Brook and Beech Hill were hardest hit (see **Map 6** below).

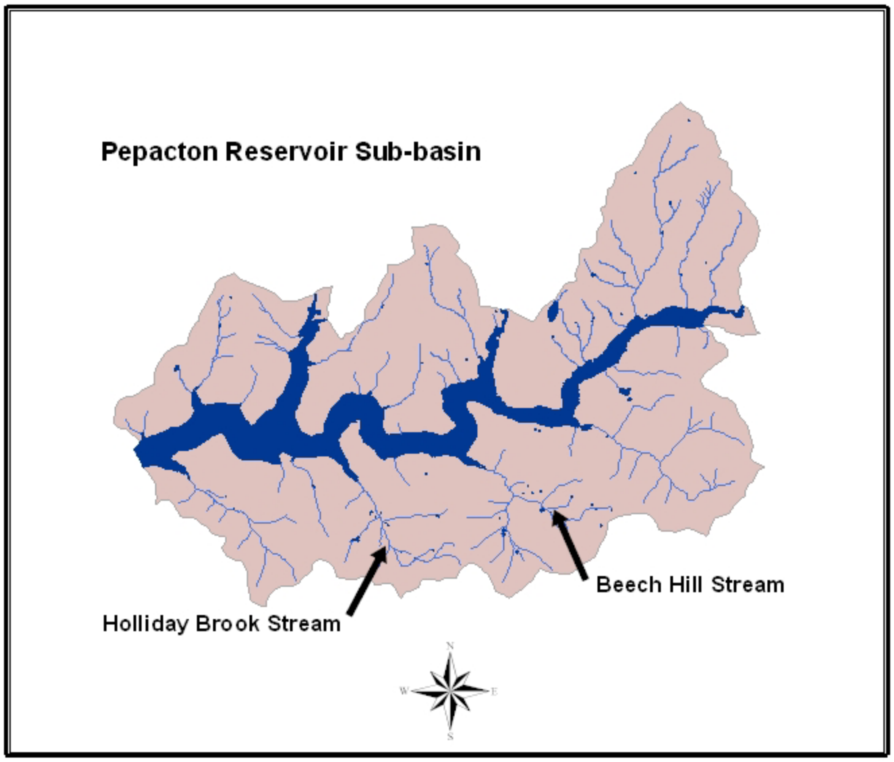
<u>Holliday Brook</u>

Along Holliday Brook, one house was completely washed away, one private bridge was obliterated, and another bridge disabled. Approximately three quarters of one mile of road – both Town of Colchester and New York City jurisdictions – was completely washed out, made both unrecognizable and impassable. An entire mile of stream upstream from the reservoir was significantly altered. Damage included channel avulsion (re-location), severe down-cutting, and debris deposition, all of which were most significant at the demolished private bridge. The impacts to water quality and aquatic habitat were severe.

Since the Holliday Brook Road is a connector road to a New York State Scenic Highway Corridor, the New York State Department of Transportation (NYSDOT) assisted the Town of Colchester and City of New York with flood response and recovery efforts. The Army National Guard was also made available to assist. At the request of NYSDOT, DCSWCD staff was dispatched to guide the National Guard with emergency stream restoration. DCSWCD staff protocol involved assessment of the stream reach, removal of large woody debris, returning the stream to its original channel, and establishment of adequate channel cross-sectional area. Approximate cross-sectional area was calculated from the DCSWCD Regional Hydraulic Relationship Curves (see **Volume 2, Section 3**). DCSWCD staff provided channel alignment, stream grade, and cross-section stakeout to guide National Guard operators.

Beech Hill

Impacts to the Beech Hill and Mary Smith Hill tributary were less significant, but still resulted in damage to public infrastructure in the form of failed highway embankments, temporary road closures, and impacts to water quality and aquatic habitat. DCSWCD staff assisted the USDA Natural Resources Conservation Service Emergency Watershed Protection Program with designs at two locations to repair approximately 1200 feet of stream channel and embankments.



Map 6. Location of Holliday Brook and Beech Hill

Delaware County's System for Flood Response

On July 21, 2004, the Delaware County Comprehensive Emergency Management Plan (CEMP) was adopted by the Delaware County Board of Supervisors. The CEMP resulted from recognition on the part of local government and state officials that a comprehensive plan was needed to enhance the county's ability to manage emergency/disaster situations. It was prepared by county officials working as a team in a planning effort recommended by the State Emergency Management Office (SEMO). The CEMP constitutes an integral part of a statewide emergency program and contributes to its effectiveness. It describes in detail the centralized direction of requests for assistance and the understanding that the governmental jurisdiction most affected by an emergency is required to involve itself prior to requesting assistance. The development of the CEMP included an analysis of potential hazards that could affect the county and an assessment of the capabilities existing in the county to deal with potential problems. Authority to undertake this effort was provided by both Article 2-B of the State Executive Law and New York State Defense Emergency Act.

Dealing with disasters is an ongoing and complex undertaking. However, lives can be saved and property damage minimized by reducing risk before a disaster occurs. Timely and effective response from appropriate officials and volunteers during an event helps provide both short and long term recovery assistance.

This process is called Comprehensive Emergency Management (CEM). CEM emphasizes the interrelationship of activities, functions, and expertise of local, county, state and federal departments and agencies necessary to deal with emergencies. The CEMP contains three sections to deal separately with each part of this ongoing process. The emergency management responsibilities of various county officials, departments and agencies are outlined in the CEMP. Assignments are made within the framework of the present county capability and existing organizational responsibilities. The Department of Emergency Services is designated to coordinate all emergency management activities of the county during the event and assist with coordination of all local efforts to respond.

Once the immediate response to an event is over and recovery efforts are under way the Delaware County Hazard Mitigation Coordinator becomes responsible for all county and local efforts to clean up and prepare long term mitigation programs. The designated Hazard Mitigation Coordinator is the Delaware County Planning Director to ensure all mitigation and recovery efforts are properly coordinated with all agencies and local entities.

County responsibilities are closely related to the responsibilities of the local officials within the county (cities, towns and villages). The county emergency management coordinator must officially open the county's Emergency Operations Center (EOC) and contact all partners involved in management phases of an emergency. Once the EOC is operating the municipalities have a location to send information and request additional support. The EOC is manned by all members of the emergency response team including emergency personnel, police, public works representatives, planning staff and administrative staff as well as any other essential personnel called upon. The county has the responsibility to assist the local governments in the event that they have fully committed their resources and are still unable to cope with disaster. Similarly, New York State is obligated to provide assistance to the county after resources have been exhausted and the county is unable to cope with the disaster.

Delaware County uses the Incident Command System (ICS) to respond to emergencies. The ICS is a management tool for the command, control and coordination of resources and personnel in an emergency. Specific emergency management guidance for situations requiring special knowledge, technical expertise, and resources may be addressed in separate annexes attached to the CEMP. Examples of this type of situation are emergencies resulting from floods, hazardous chemical releases, dam failure, and power outage. The CEMP provides general all-hazards management guidance—using existing organizations—to allow the county to meet its responsibilities before, during and after an emergency.[11]

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[11] Delaware County, *Delaware County Comprehensive Emergency Management Plan*, July 2004, pages i-ii, paraphrased.

Although the CEMP addresses all emergency/disaster situations, flooding has been the most prevalent in the East Branch watershed. During major flood events and other disasters that can cause road and bridge closures, the Delaware County Department of Emergency Services (DCDES) activates its emergency operations center and ICS. All emergency response agencies including Federal Emergency Management Agency (FEMA), SEMO, the NYS Office of Fire Prevention Control, law enforcement agencies, and fire departments are contacted and put on alert. The Department of Emergency Services monitors all emergency situations and provides for emergency evacuations, if necessary.