IV-D: Geology & Topography

In any watershed, the geologic and topographic features can be expected to exert significant influence on the character of the basin's stream system. As will be demonstrated in this stream management plan, the geology and topography of the Batavia Kill watershed have a major influence on the basin's runoff characteristics and water quality conditions.

In the Batavia Kill watershed, the fundamental features that are such critical considerations in today's stream management were determined many years ago in the time of glaciers. The following sections describe the glacial activities evidenced in the Batavia Kill watershed and the geology and topography they left behind.

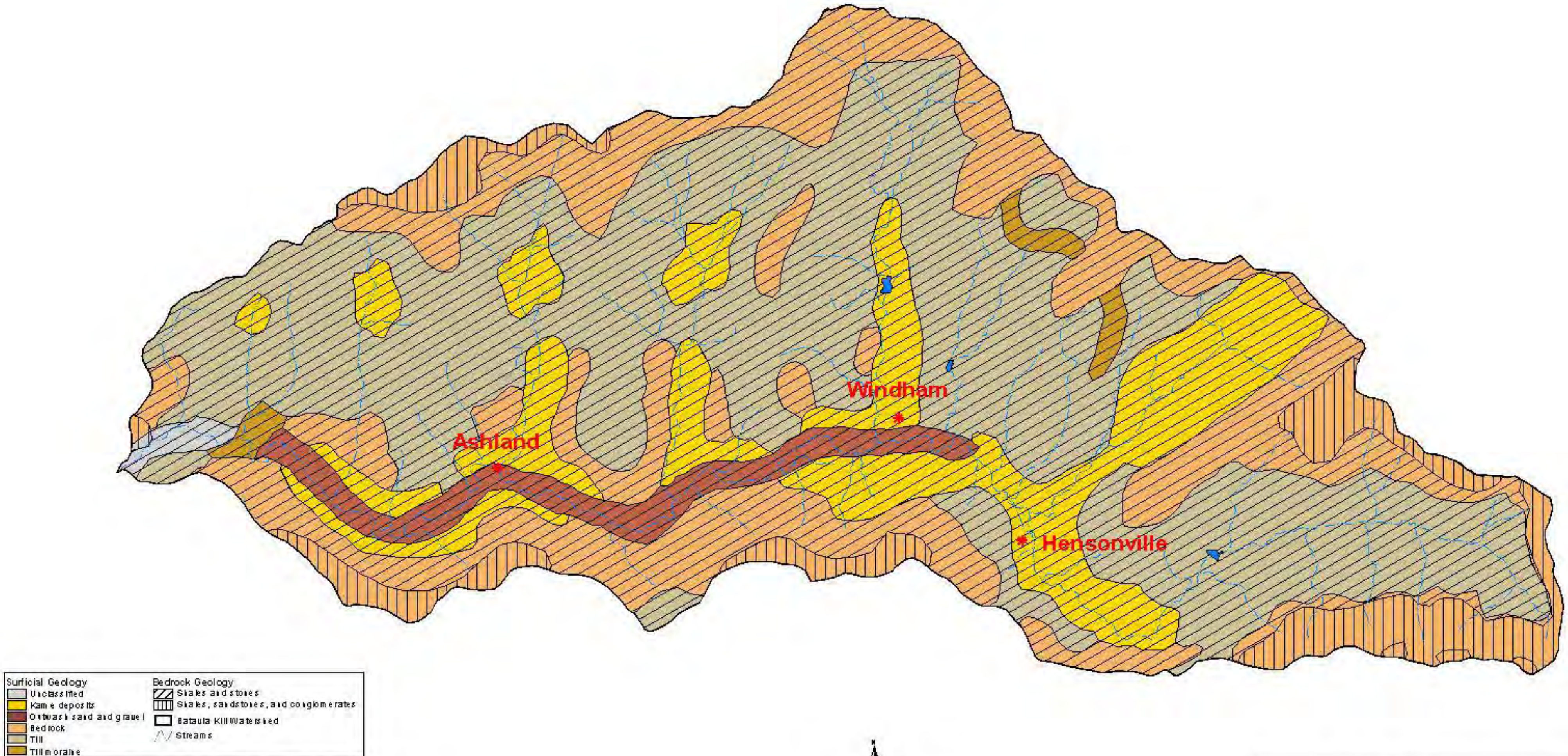
1. GEOLOGY

The geology of the Catskills is characterized by ancient sedimentation processes and the more recent influence of glaciation and stream erosion on these deposits. The bedrock of the Batavia Kill watershed is composed predominately of sedimentary rock, formed in the middle-to-late Devonian Period (450 to 360 million years ago). At the beginning of the Devonian, the Catskills did not exist and Earth's continents were in motion. A collision of the North American continent resulted in the uplifting of the Earth's surface and the formation of a very high mountain range (the Acadian Mountains) to the east of the present day Catskills (Titus, 1993).

Eventually, weathering and erosion of this mountain range produced great quantities of sediment which were carried to a shallow sea stretching from the approximate location of today's Taconic range all the way to the West Coast. As the eroded materials from the Acadian range were deposited in the subsiding sea, the Catskill Delta formed. The bedrock in the Batavia Kill watershed reflects the depositional cycles which formed the Catskill Delta, with layers of multiple sedimentary rock types 50 to 100 feet thick (Titus, 1993).

Typically, grey sandstones and conglomerates are found in the base of these depositional layers. These are followed by red sandstone, red siltstone and finally red shale or mudstone **(Map IV-1)** (Lucier 1966, Fletcher 1967). These depositional patterns were created by ancient rivers as they cut across the great Catskills Delta. This effect is observable at outcrops where the resistant sandstones form cliffs and the finer, more erodible materials form gentler slopes.

The bedrock in the watershed is more exposed in the higher elevations, with unconsolidated deposits covering the bedrock in the lower elevations and on the valley floor. The bedrock of the Batavia Kill watershed is fractured, which is a benefit for groundwater retention and recharge. The bedrock exhibits low angle fractures at the bedding planes between sedimentary layers and between the layers of the various types of bedrock. High angle fractures are also evident in the watershed, which are indicators of past uplifting of the mountains. The dominant bedrock fractures in the watershed have a regional orientation which closely parallels the orientation of the local valley segment (Hesig, 1999).



Kame Deposits- coarse to fine gravel and/or sand, includes kames, eskers, kame terraces, kame deltas, ice-contact, or ice cored deposition, lateral variability in sorting, texture and permeability, may be firmly cemented with calcareous cement, thickness variable (10-30 meters).
Outwash sand & gravel- coarse to fine gravel with sand, proglacial fluvial deposition, well rounded and stratified, generally finer texture away from ice border, permeable, thickness variable (2-20 meters).
Bedrock- exposed or generally within 1 meter of surface, in some areas saprolite is preserved.
Till- variable texture (boulders to silt) and sorting, may be sand rich diamict but varies with location. Deposition beneath glacier ice, permeability varies with compaction, thickness variable (1-50 meters).
Till moraine- variable texture (size and sorting), generally low permeability, deposition adjacent to ice, thickness variable (10-30 meters).

Map produced by Greene County Soil & Water Conservation District, January 2001.
Note: GIS data are approximate according to their scale and resolution.
They may be subject to error and are not a substitute for on-site inspection or survey.
Data sources located in list of figures, tables, and maps.

Scale 1:72000

6000 0 6000 12000 Feet

Batavia Kill Watershed
Surficial and Bedrock Geology

Map IV-1
Greene County Soil & Water Conservation District
Batavia Kill Stream Corridor Management Plan

2. GLACIAL INFLUENCES

One of the more significant impacts on the Batavia Kill watershed involves the past activities of glaciers. While the Catskills have been impacted by glaciers for 1.2 million years, the most recent glacial activity, the Wisconsin Glaciation, occurred around 16,000 years ago and had the greatest impact on the landscape features present today. Geologists have studied the landscape clues left by glaciers and have developed theories on the advance of the great ice sheets over the North American continent.

Figure IV-11: Satellite View of Alpine Glacier. Ice lobes as shown would be similar to the glaciers which were active in the Catskills.

According to Dr. Robert Titus, a Professor of Geology at Hartwick College in Oneonta, NY, the Wisconsin ice sheet was comprised of three major lobes of southward moving ice. The eastern-most lobe of the ice sheet, or Labrador lobe, descended into the present day Hudson Valley, and it was this ice that last influenced the Batavia Kill watershed (Titus, 1996).

Figure IV-12: Typical eroding high terrace formed by glacial out wash, Big Hollow

As the glacial fringe advanced, the Helderbergs in Albany County proved no match for this towering wall of ice and sediment, but the Northern Escarpment of the Catskills was more resistant and somewhat of a barrier to its movement. Geological clues show that the Batavia Kill watershed was overtaken by ice from at least four different directions. As the glacier reached the Catskill front, it found breaks in the Northern Escarpment at East Windham and between Mount Pisgah and Mount Nebo. These gaps in the mountain range allowed ice to flow down present day Mitchell Hollow and into East Windham, at the point where NYS Route 23 passes through the notch at the edge of the escarpment . These glaciers moved down the Batavia Kill Valley almost all the way to the Schoharie Creek, with ice also pushing into the upper Batavia Kill watershed. At the same time, the Grand Gorge glacier was advancing up the Schoharie Valley and some of this ice pushed up the Batavia Kill Valley, almost colliding with the

Windham glaciers at a point near Red Falls (Titus, 1996).

As the climate warmed and the glaciers retreated, the Schoharie Valley was blocked by stalled ice in the area of Grand Gorge and a large lake developed. Arms of the lake extended high into the Batavia Kill watershed with present day evidence indicating that this lake extended as far as the upper reaches of Big Hollow. Based on geological evidence, the lake may have reached an elevation of 1,600 feet. As the Mitchell Hollow and East Windham glaciers retreated, their meltwater was trapped in this great lake. Numerous signs of depositional patterns associated with lakes can be found today in the valley (Titus, 1996).

On the valley floor, deep layers of fine clay and silt were deposited as they settled out of the glacial lake, while along the edge of the lake large deltas were formed from glacial out-wash as the surrounding streams carried meltwater and sediment from the retreating ice sheet. Today, these same glacial lake clay deposits present a challenge to maintaining water quality as the Batavia Kill stream erodes into these layers (**Figure IV-12**). Evidence of the deltas formed by streams flowing into the lake can be seen along Route 23 as you travel throughout the watershed.

3. WATERSHED SOILS

In the Northeast United States, it is impossible to find a landscape which has not been altered primarily by glacial activities, and the Batavia Kill is no exception. In the watershed, the soils are generally unconsolidated, and dominated by various types of glacial till and thick deposits of lacustrine clays and fine silt that were deposited in glacial lakes as the ice retreated from the valleys. These unconsolidated materials have been laid upon the underlying bedrock by various processes, which are responsible for the soil characteristics present today **(Map IV-2)**.

Figure IV-13: Glacial deposits of gravelly loam are desirable for fill as seen in this view of Tompkin's Quarry.

The former Soil Conservation Service, in cooperation with the GCSWCD, developed the first detailed soil survey for the county, published in 1993. The soil survey identifies three primary soil associations present in the Batavia Kill watershed. Soil associations are generalized groupings of soils that exhibit a distinctive pattern of soil type, relief, and drainage. Soil associations typically have one or more major (or dominant) soil types for which the association is named, as well as a number of minor soil types.

While soil associations do not provide the sensitivity necessary for site evaluations of specific activities (i.e. agriculture, building, and road construction), they can be useful in evaluating soil factors on a larger watershed level. The Soil Survey of Greene County [9] describes the soil associations present in the Batavia Kill watershed as follows:

Lewbeach-Willowemoc-Onteora

The largest soil association in the watershed, characterized by very deep soils, with gentle to steep slopes, found on the hills and valley sides. The lower valley sides are mostly smooth, and most of the soil units in the association have stones and boulders present at the surface. The dominant slope range is 8% to 25%, but it may range from 3% to 55%. The soils were formed in reddish glacial till derived from sandstone, siltstone and shale. Lewbeach comprises 49% of the association and is characterized by a fragipan which prohibits downward percolation of water. The Willowemoc (22%) and Onteora (16%) in the soil association also have a fragipan layer.

Vly-Halcott

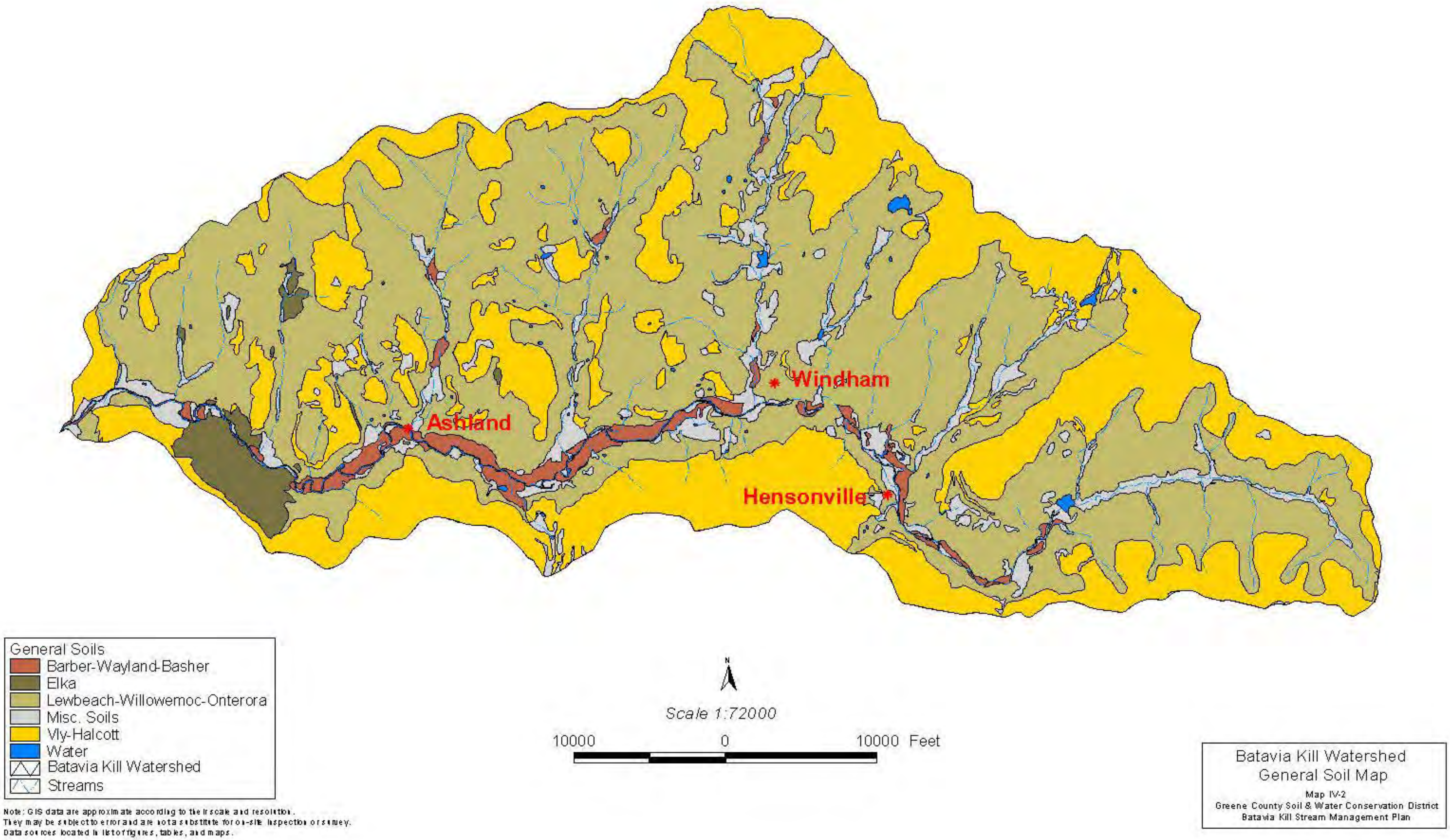
As the second largest soil association in the watershed, the Vly-Halcott is moderately deep to shallow, and may range from gently sloping to very steep. The soil is found primarily in the very upper slopes and on the ridgetops. Vly-Halcott is strongly influenced by the underlaying interbedded bedrock, which by the process of weathering forms a series of steps and short, very steep slopes. This association can be found on slopes from 3% to 55% and it is formed in glacial till derived from sandstones and siltstones. Vly is the major soil type at 43% of the association, with Halcott comprising 30% of the association. Both soils range from excessively well-drained to moderately well-drained, and are very rocky.

Barber-Wayland-Basher

This soil association is found in the floodplains located along the Batavia Kill, and is generally very deep and nearly level and may be subject to occasional flooding. The drainage features range from well drained Barber soil (53% of the association) to poorly or very poorly drained Wayland soils (17%) which are found in old oxbows, remnant channels or low depressions in the floodplain, away from the stream. Minor soil units in this association include the Fluvaquents and Udifluvents which are located in the active stream channel and immediately adjacent areas. These minor soils are characterized by frequent flooding, and are generally in the process of active transport through the stream system.

Elka

The Elka Soil Association is found in a small section of the watershed near lower Ashland and Red Falls. The section lies in the southern drainage adjacent to the Batavia Kill and close to the Batavia Kill convergence with Schoharie Creek. The Elka Association is well drained and very deep. It ranges in slope from a gentle incline to a very steep slope (Broad 1993). The soils are of medium texture and are found on the sides of valleys. The Elka Association is 82% Elka soils and 18% Lewbeach, Vly, or Onteora soils. Lewbeach soils are well drained, with a dense fragipan in the subsoil's lower portions. Vly soils are also well drained (Broad 1993). Onteora soils are poorly drained with a dense fragipan. These soils are found in flat areas where runoff often gathers.


Windham
Ashland
Hensonville
General Soils
Barber-Wayland-Basher
Elka
Lewbeach-Willowemoc-Onterora
Misc. Soils
Vly-Halcott
Water
Batavia Kill Watershed
Streams
Note: GIS data are approximate according to their scale and resolution.
They may be subject to error and are not a substitute for on-site inspection or survey.
Data sources located in list of figures, tables, and maps.
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Batavia Kill Watershed
General Soil Map
Map IV-2
Greene County Soil & Water Conservation District
Batavia Kill Stream Management Plan

Soil Hydrology Characteristics

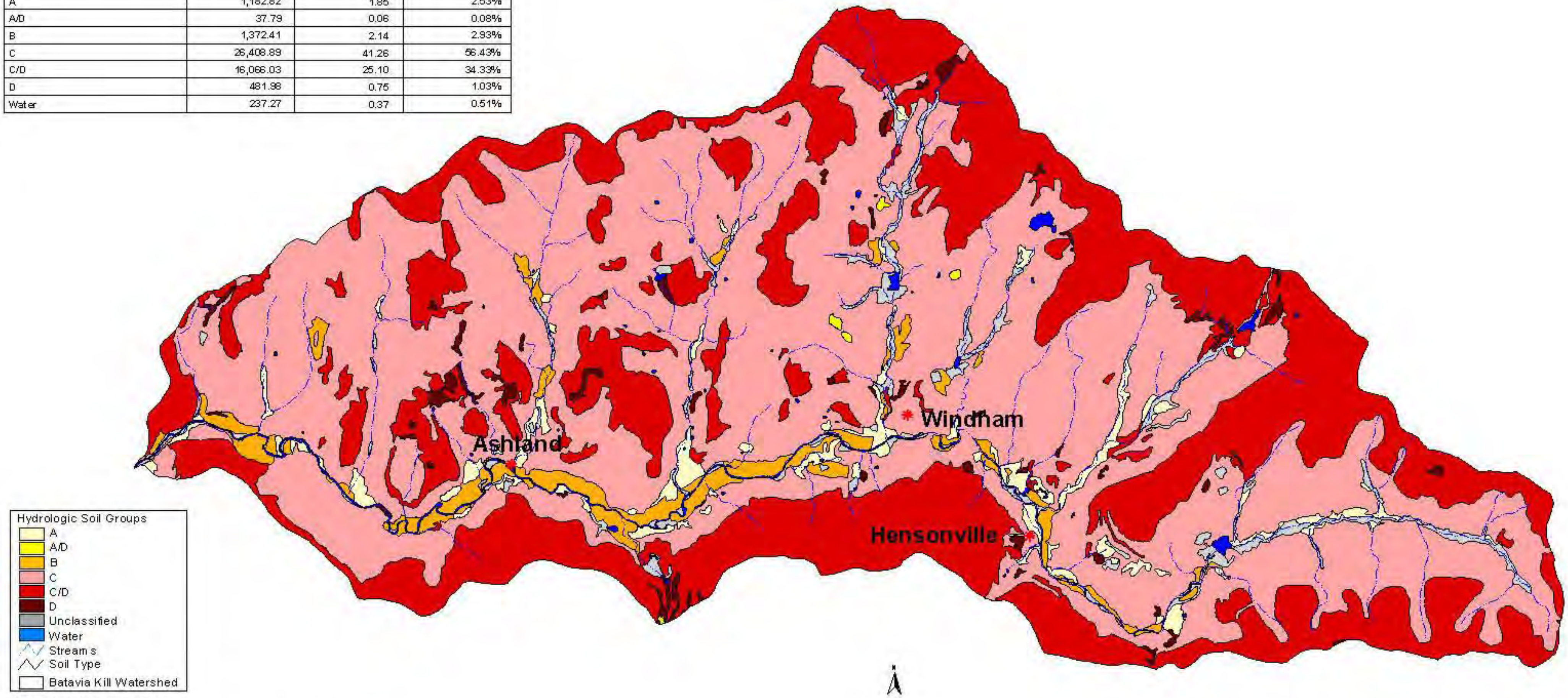
One of the primary influences of soils on watershed function is related to the soil's permeability, or ability to absorb water. In watersheds with a predominance of "tight", poorly drained soils, or soils with an impermeable fragipan layer, it is typical to see a greater runoff volume than from watersheds where soils are more permeable. The Batavia Kill is characterized mostly by soil features with only moderate to very poor permeability. As a result, the watershed is very sensitive to the effects of rainfall, with little precipitation infiltrating into the ground over a major portion of the watershed.

To account for the relationship between various soils and their permeability characteristics when estimating runoff from a watershed, the Natural Resources Conservation Service (formally the Soil Conservation Service) developed a system to classify all soil types based on their runoff characteristics. Hydrological classifications are based on a bare (no vegetation or other cover) soil runoff potential under conditions when the soil is both throughly wet and exposed to a long duration storm. The Hydrologic Soil Group classifications are essential for the use of standard hydrology models such as TR20 and TR55 which are used to estimate runoff from a variety of surfaces. The NRCS has grouped soils into four distinct hydrologic classes. In some cases, soils may have a dual designation, with one used for the soil in its natural condition and the other used when drainage systems have been installed (Soil Conservation Service, 1993). The four hydrologic classes are:

Group A - High Infiltration Rate
Group B - Moderate Infiltration Rate
Group C- Slow Infiltration Rate
Group D - Very Slow Infiltration Rate

As shown on **Map IV-3**, the majority of the soils in the Batavia Kill watershed are classified as Hydrologic Soil Group C, C/D or D. These soils have moderate to high runoff potential, and they produce significant surface runoff under storm conditions. In the Batavia Kill watershed, 90.76% of the watershed exhibits these runoff characteristics. Management recommendations set forth later in this SMP will address the sensitive hydrological nature of the watershed.

Hydrologic Soil Group	Area (Ac)	Area (Sq Mi)	% Area
Unclassified	1,014.32	1.58	2.17%
A	1,182.82	1.85	2.53%
A/D	37.79	0.06	0.08%
B	1,372.41	2.14	2.93%
C	26,408.89	41.26	56.43%
C/D	16,066.03	25.10	34.33%
D	481.98	0.75	1.03%
Water	237.27	0.37	0.51%



The four hydrologic soil groups are:
Group A-Soils having a high infiltration rate (low runoff potential) when thoroughly wet.
Group B-Soils having a moderate infiltration rate when thoroughly wet.
Group C-Soil having a slow infiltration rate when thoroughly wet.
Group D-Soils having a very slow infiltration rate when thoroughly wet.
For more detailed soil information refer to Soil Survey of Greene County New York, soil & water features (p161) and Table 17 (p337).
Hydrologic Soil Groups are used to estimate runoff from precipitation. Soils not protected by vegetation are assigned to one of four groups. They are grouped according to the infiltration of water when the soils are thoroughly wet and receive precipitation from long duration storms. Soils may be assigned to two hydrologic soils groups. Dual grouping is used for one of two reasons. Some soils have a seasonal high water table but can be drained. In this instance, the first letter is for drained areas and the second is for undrained areas. For some soils that are less than 20 in. deep over bedrock, the first letter is for areas where the bedrock is cracked and pervious and the second is for areas where the bedrock is impervious or where exposed bedrock makes up more than 25 % of the surface.

Data Sources: Hydrography- digitized by NYCDEP from USGS Quad and SCS Maps 1993, edited by GCSWCD to show only streams found on USGS topo quads
Watershed Boundary- NYCDEP derived from USGS topography 1965.
Soils-NYCDEP derived from USGS, SCS, ASCS air photos with development and digitizing by SCS.
Hydrologic Soil Groups-GCSWCD derived from Soil Survey of Greene County, New York
Map produced by Greene County Soil & Water Conservation District, January 2001.
Note: GIS data are approximate according to their scale and resolution. They may be subject to error and are not a substitute for on-site inspection or survey.

Scale 1:72000

6000 0 6000 12000 Feet

Batavia Kill Watershed Hydrologic Soil Group

Map IV-3
Greene County Soil & Water Conservation District
Batavia Kill Stream Corridor Management Plan

Soil Erosion Characteristics

A second feature of soils that figures predominately in any watershed management strategy is the potential for erosion. Stable stream systems must transport the sediment supply from their watershed. Thus, the rate of erosion in a watershed and the degree to which erosion happens either naturally or due to human activity are important to watershed managers. Using data on soils from around the world, the Natural Resources Conservation Service (NRCS) has determined soil erodibility factors (k values) for all soils and have been classified for every soil in the Greene County Soil Survey (Soil Conservation Service 1993).

Figure IV-14: Lighter colored soil seen in this bank in Big Hollow is an exposed clay lens.

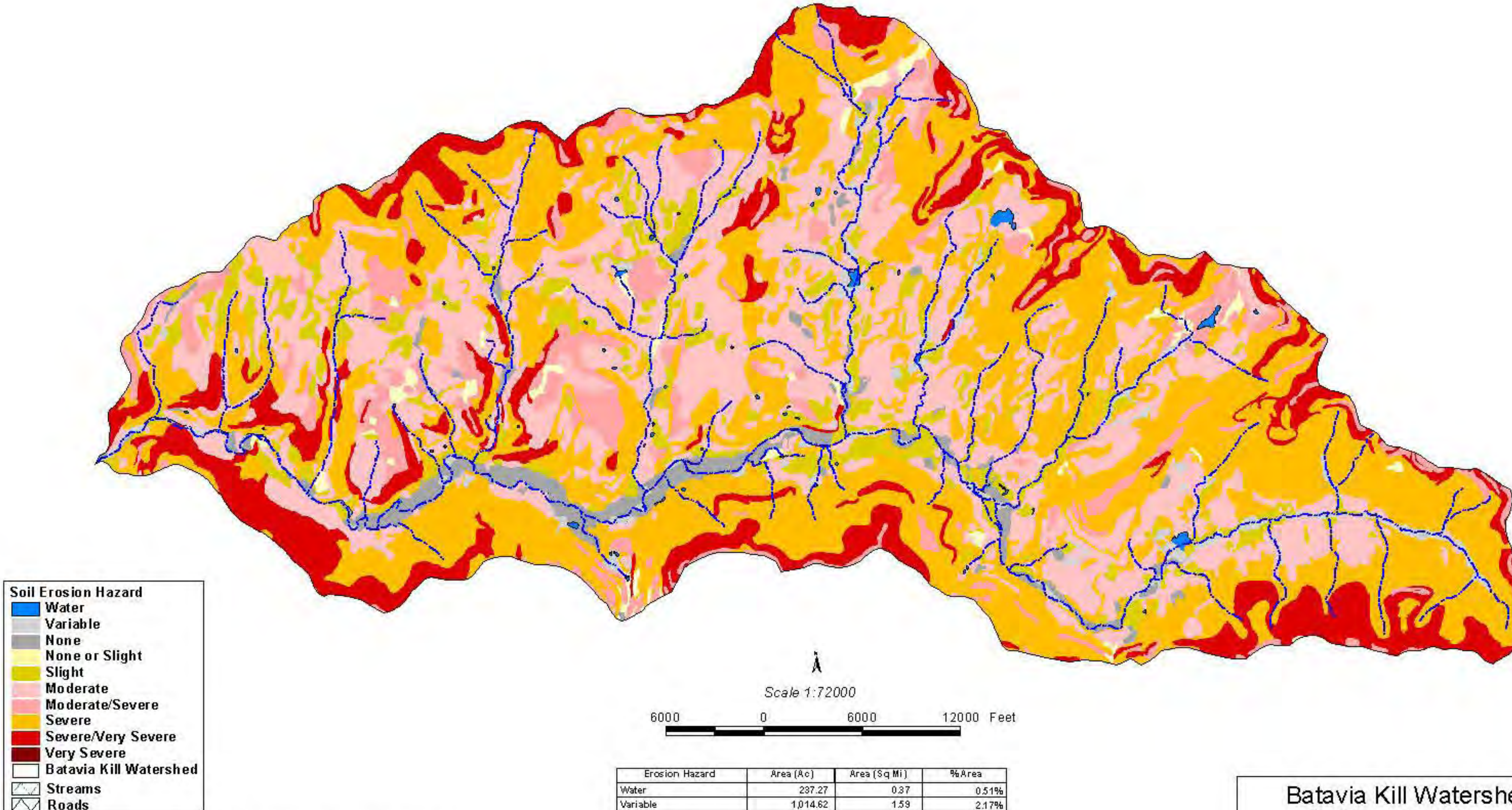
Soil erodibility factors are based on the soil type, size and shape of the soil particles, and the impact of rock fragments which may be present in the soil strata. These factors are also adjusted for freeze thaw cycles. Using the determined soil k values, as well as the slope of the soil, the NRCS has classified each soil based on each soil's probability for erosion during site preparation or other soil activities by which the soil is exposed to erosional forces. Erosion Hazard classifications range from none or slight to severe/very severe.

As shown on **Map IV-4**, the watershed is characterized by a predominance of soils which exhibit moderate to very severe erosion hazards. Based on soil erosion hazard classifications, the watershed is comprised of approximately 54% of soils classified as severe to very severe, with 88% of soils characterized as having a moderate erosion hazard or worse. As would be expected, the erosion hazard is directly related to soil slope, with steeper slopes being more erosion prone.

In the Batavia Kill watershed, the soils present are easily subjected to forces associated with soil erosion and have a high potential for contributing excess sediment to the stream system if not protected by vegetative cover or some other form of erosion management.

Batavia Kill Watershed
Soil Erosion Hazard

Map IV-4
Greene County Soil & Water Conservation District
Batavia Kill Stream Corridor Management Plan



Erosion Hazard	Area (Ac)	Area (Sq Mi)	%Area
Water	237.27	0.37	0.51%
Variable	1,014.62	1.59	2.17%
None	1,272.06	1.98	2.72%
None or Slight	427.56	0.67	0.91%
Slight	3,066.73	4.79	6.55%
Moderate	12,643.48	19.76	27.02%
Moderate/Severe	3,208.08	5.01	6.85%
Severe	19,020.52	29.72	40.64%
Severe/Very Severe	4.41	0.01	0.01%
Very Severe	5,906.55	9.23	12.62%

Note: Soil erosion hazard is defined as the probability that erosion can occur as the result of site preparation or cutting where the soil is exposed. Ratings of the erosion hazard are based on the percent of the slope and on the erosion factor K. Soil erosion hazard determined by GCSWCD using Soil Survey of Greene County, New York, soil description.
Data Sources: Hydrography- digitized by NYCDEP from USGS Quad and SCS Maps 1993, edited by GCSWCD to show only streams found on USGS topo quads.
Roads- US Department of Commerce, Bureau of the Census 1998, from 1995 TIGER/Line files.
Watershed Boundary- NYCDEP derived from USGS topography 1965.
Soils- NYCDEP derived from USGS, SCS, ASCS air photos with development and digitizing by SCS.
Map produced by Greene County Soil & Water Conservation District, January 2001.
Note: GIS data are approximate according to their scale and resolution. They may be subject to error and are not a substitute for on-site inspection or survey.

Lacustrine Soils

Figure IV-15: Clays exposed within the stream channel contribute to stream turbidity and reduce of water quality.

While in general, the soils in the Batavia Kill watershed present multiple challenges to the management of the stream system, one of the primary concerns is the impact on the water quality of soils with lacustrine origin. These soils are comprised of clays and extremely fine silt particles, which are very easily eroded. When these materials are entrained (suspended) in the water column, it requires a long period of time combined with still water to settle out. Fine materials suspended in the water can have pollutants attached, can mask the effects of treatment, and if severe, can require special treatment to clarify the water prior to chlorination.

The deposition of clay materials in glacial lakes resulted in the formation of deep sediment layers comprised primarily of extremely fine clay particles, often with thin layers of fine sand laid between successive clay plates. While geologists have theorized that the entire Schoharie Valley was under hundreds of feet of water when the retreating glacier formed a dam at Grand Gorge, it is thought that Lake Grand Gorge only reached an elevation of 1,600 feet [7] . If this is an accurate assumption, it would have resulted in a lake which reached up into the Batavia Kill valley to a point somewhere near Hensonville. In addition to Lake Grand Gorge, it is likely that terminal moraines, out-wash deltas, or other glacial deposits processes may have also created other impoundments of glacial meltwater that also resulted in settling of fine clays and development of lacustrine soils. One of the best signs of these moraines is present just above Red Falls.

In the summer of 1998, the GCSWCD investigated reports of increased siltation at the C.D. Lane flood control structure in Big Hollow, and observed clay deposits in the stream bottom upstream of the structure at elevations as high as 1,800 feet. At that time, the Hydrology Unit of NYCDEP, with assistance from GCSWCD, initiated a project to inventory and map clay exposures in the stream corridor.

3. TOPOGRAPHY

In the Batavia Kill watershed, topography plays a significant role in the stream hydrological regime. In the upper headwaters, the steep slopes of Windham High Peak, Burnt Knob, Acra Point, and the Blackhead Range form an elongated basin that narrows as the mountains close in on the valley near Hensonville **(Map IV-5)**. In this section of the watershed, slopes in excess of 11% make up approximately 3/4 of the basin, with the balance in gentle slopes at the base of the mountains and a narrow floodplain on the valley floor.

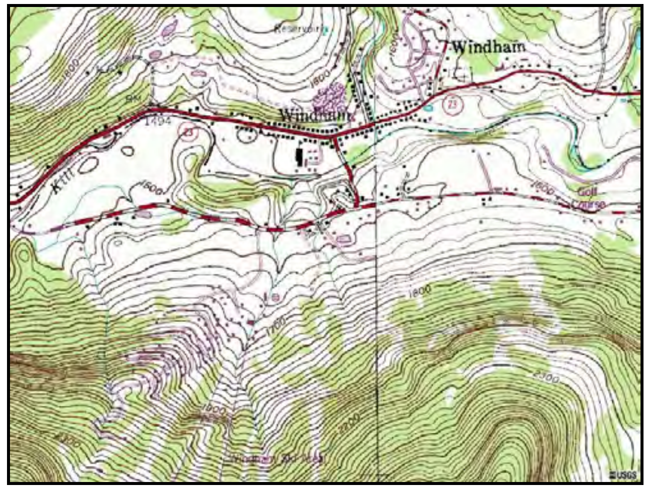


Figure IV-16: Steep topography in the area surrounding the Windham hamlet

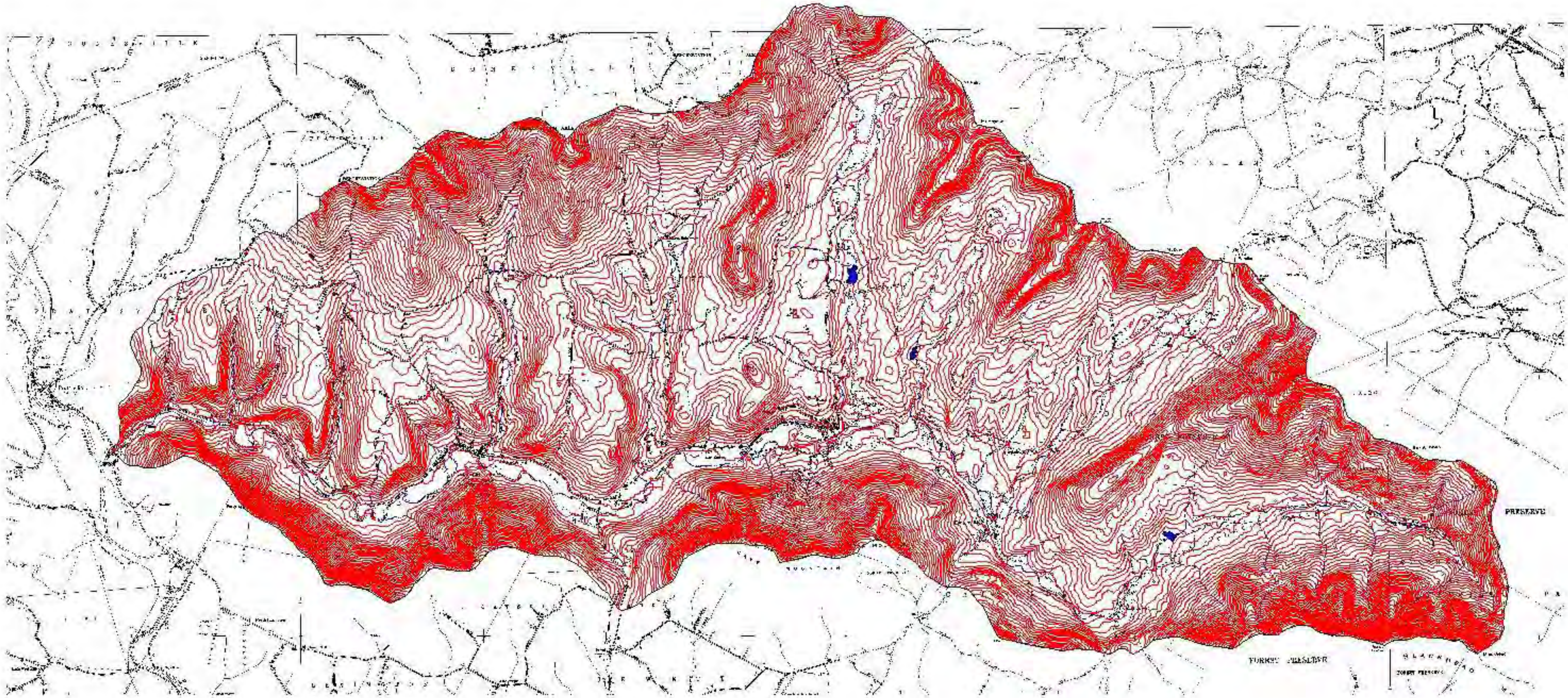
As you move down the valley below Hensonville, the basin's overall topography becomes more moderate. Increasing amounts of flatter terrain are present, with steeper slopes in excess of 21% primarily located at the outer margins of the watershed. As stated earlier in this document, the watershed is asymmetrical, with the drainage area north of the stream 2-3 times wider than the watershed located south of the stream. This narrow band of watershed to the south of the Batavia Kill stream is characterized by extremely steep slopes, with over 80% of this section of the watershed having a slope steeper than 20% **(Map IV-6)**.

The section of the watershed to the north of the Batavia Kill stream is overall more moderate in slope, with steeper sections along the northern watershed rim, as well as on the east and west fore slopes of the mountains. Large areas of flatter topography are present along the Batavia Kill stream as well as the Silver Lake and Mitchell Hollow sub-watersheds. As the watershed approaches the confluence with the Schoharie Creek the valley sides again enclose the watershed, with extremely steep slopes on both sides of the stream. The impact of the Batavia Kill watershed's topography on the stream form and function is discussed later in this document.

The fluvial and morphological character of modern rivers is often a function of the valley form through which the river must convey its flow and sediment. The diverse erosion and deposition processes associated with various valley types can promote the emergence of an array of stream channel morphological features. These channel features can be organized into categories or types by establishing relationships between the channel characteristics of dimension, pattern, longitudinal profile, and bed material.

The morphological character of rivers is more closely correlated to the valley type than to other indices of stream character such as stream order, drainage area, or bed composition. The lack of correlation between morphological character and stream order is made apparent by the observation that an isolated reach of any particular stream type may occur anywhere throughout the entire range of stream orders. Likewise, an isolated reach of any particular stream type may occur anywhere throughout the extent of a river system's watershed.

The correlation between morphological character and valley type suggests that assessment of valley types can provide a preliminary indication of river morphology. However, any interpretations of stream type made from course-scale assessment of valley type must be subject to "ground-truthing" through field verification processes. "Ground-truthing" is essential to the assessment process. River systems experiencing a period of disequilibrium may exhibit channel morphologies that are anomalous to the particular valley type in which they are found. These anomalous morphologies may be too localized to be detected through coarse scale assessment, and are often extremely unstable in combination with the particular valley type.



10 meter contour lines
Batavia Kill Watershed
Streams

Data Sources:
10 meter contours-NYCDEP digitized from USGS Quads, 1:24000
Watershed Boundary-NYCDEP derived from USGS topography 1965
Streams-digitized by NYCDEP from USGS Quads and SCS soil survey maps 1993, edited by GCSWCD to show only streams found on USGS quads
Planimetic Map-NYSDOT, digital process at 400dpi
Map Produced By Greene County Soil & Water Conservation District, January 2001
Note: GIS data area approximate according to their scale and resolution.
They may be subject to error and are not a substitute for on site inspection or survey.

N

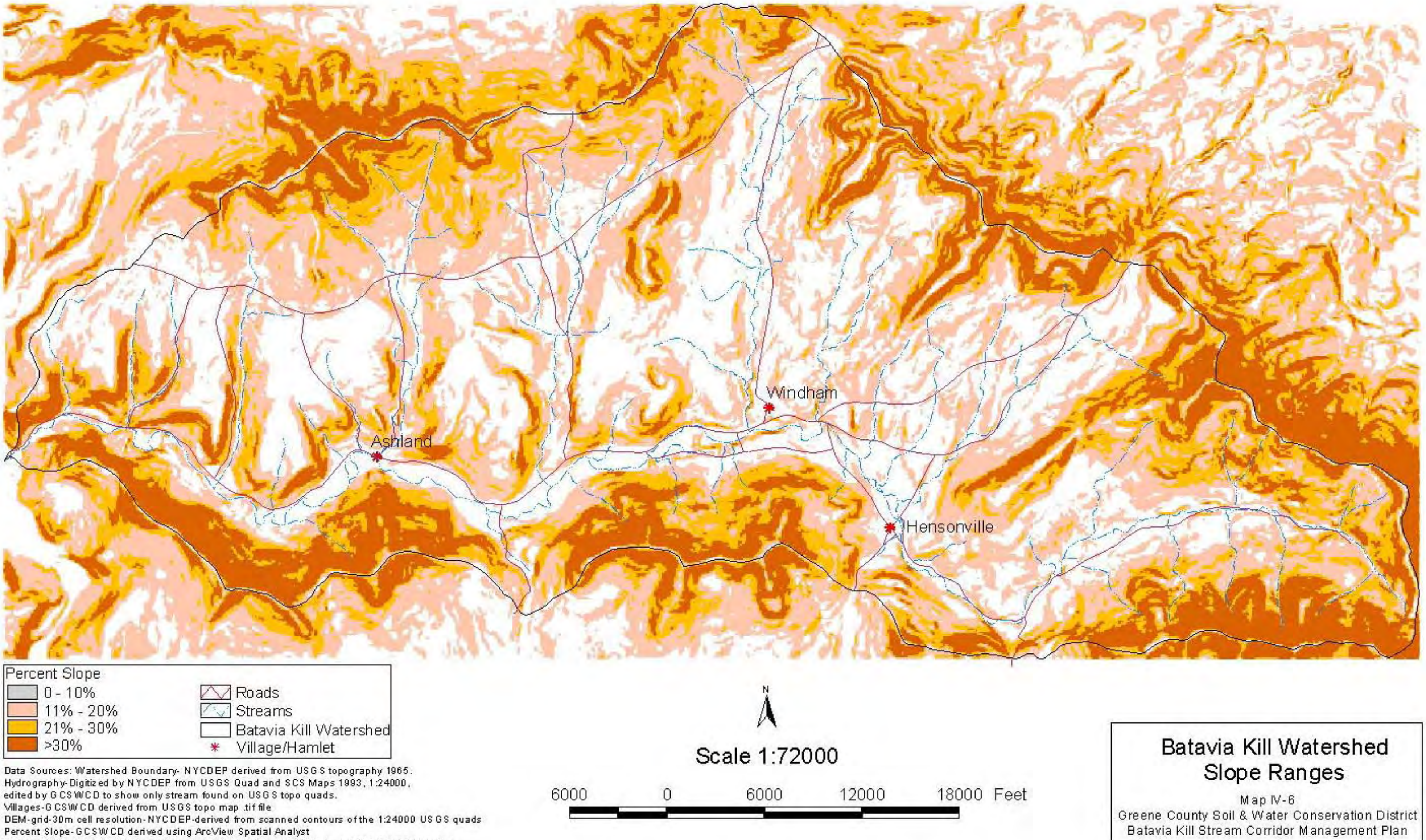
Scale 1:72000

6000 0 6000 12000 18000 Feet

Contour Interval 10 meters

Batavia Kill Watershed Topographic Map

Map IV-5
Greene County Soil & Water Conservation District
Batavia Kill Stream Corridor Management Plan



Data Sources: Watershed Boundary- NYCDEP derived from USGS topography 1965.
Hydrography-Digitized by NYCDEP from USGS Quad and SCS Maps 1993, 1:24000,
edited by GCSWCD to show only stream found on USGS topo quads.
Villages-GCSWCD derived from USGS topo map .tif file
DEM-grid-30m cell resolution-NYCDEP-derived from scanned contours of the 1:24000 USGS quads
Percent Slope-GCSWCD derived using ArcView Spatial Analyst
Roads-US Department of Commerce, Bureau of the Census 1998, from 1995 TIGER/Line files.
Map produced by Greene County Soil & Water Conservation District, January 2001.
Note: GIS data are approximate according to their scale and resolution.
They may be subject to error and are not a substitute for on-site inspection or survey.