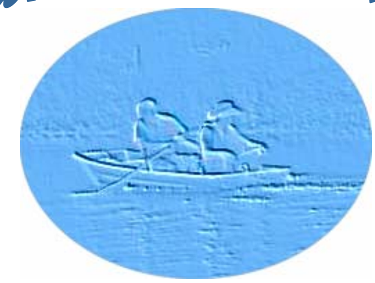
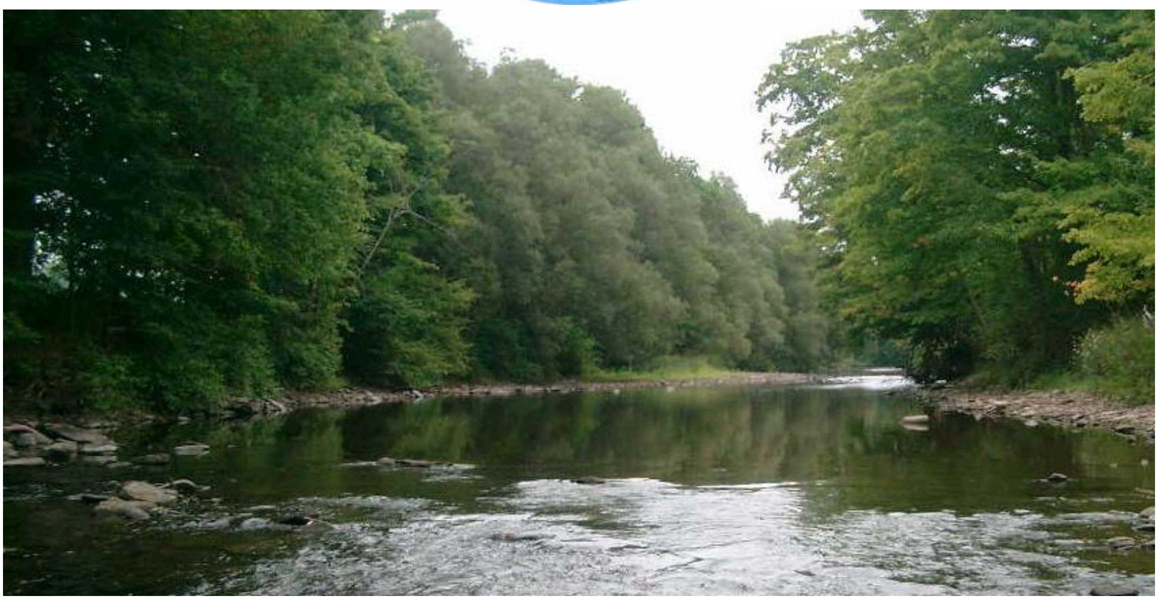
East Branch Delaware River





Stream Corridor Management Plan

Volume 2

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~ 1. Stream Corridor Assessments ~

This section presents the results of assessments performed in order to:

- *describe the character and condition of the stream corridor*
- *define the nature of problems associated with specific stream reaches*
- *provide the basis for management recommendations, or where needed, additional assessments to resolve problems along the stream*

The geomorphic condition of the East Branch and its sub-basins is a focal point for these assessments. The characteristics and morphology of each sub-basin and the delineated management units are described. Management units are homogenous sections of the stream corridor with management conditions or issues, and are used as the basis for describing the various segments of the stream, its morphology, and its management requirements. These units are numbered from the confluence to the headwaters of the stream. Due to time constraints, not all of the sub-basins within the East Branch Delaware River basin could be assessed as part of this effort. In addition, not all streams that were assessed within a sub-basin have complete data from confluence to headwater. Several levels of increasingly detailed assessments were used to collect data. Further data collection will be necessary in the future.

The East Branch Delaware River (EBDR) is the main drainage channel to the Pepacton Reservoir and delivers flows from northeast to southwest through a relatively narrow, flat-floored valley. Four major tributaries contribute to the mainstem, including the Platte Kill, Batavia Kill, Dry Brook, and Bush Kill (enters into Dry Brook). Terry Clove, Fall Clove, Tremper Kill and Mill Brook are four other tributaries that drain directly into the Pepacton Reservoir. **Table 1.1** shows the drainage areas and stream lengths for each of these identified sub-basins. The geographic extents of these sub-basins include numerous smaller tributaries that flow into the East Branch Delaware River and the Pepacton Reservoir, including but not limited to: Cat Hollow, Holliday Brook, Beech Hill Brook, Barkaboom, Huckleberry Brook, Bull Run, Hubble Hill Hollow, and Bragg Hollow[1].

Table 1.1 East Branch Delaware River Sub-basins

Sub-basin (alphabetical)	Watershed Area (sq. mi.)	Stream Miles
Batavia Kill	19.30	10.4
Bush Kill	47.18	14.2
Dry Brook	35.22	12.5
East Branch Headwaters	49.66	14.7
East Branch Mainstem	25.76	9.8
Fall Clove	11.18	7.6
Mill Brook	25.36	11.2
Pepacton Reservoir	73.38	0.0
Platte Kill	35.36	12.1
Terry Clove	15.08	6.1
Tremper Kill	33.52	10.5
Total	371.00	109.1

[1] The geographic extents of the sub-basins used in this plan are based upon NYC DEP GIS map layers derived from 1:24000 USGS topographic maps.

Stream Assessment Procedures

The collection and analysis of data from stream surveys is required for determining the condition of a stream. The East Branch Delaware River Stream Management assessment process evaluated six of the stream corridors contributing to the Pepacton Reservoir. This evaluation consisted of a tiered set of increasingly detailed assessments and analyses. The first step is a Geographic Information System (GIS) based evaluation of map layers developed from remotely sensed images and topographic maps. This was followed by a second step of targeted field surveys using Global Positioning Systems (GPS) to map the location and condition of critical stream features such as eroding streambanks, revetment, gravel deposits, woody debris obstructions, and other elements of concern. The third step was to perform a Rosgen Level II survey at locations that were deemed representative of longer management unit reaches.

Step I – GIS based Assessment:
The sub-basin streams were too large to assess in their entirety, so each stream was broken into manageable sections. This was done using the Stream Geomorphic Assessment Tools. The information collected helped target problem areas for further assessments. Stream Geomorphic Assessment Tools (SGAT) is a Geographic Information System (GIS)-based analysis that was developed and utilized by the State of Vermont Agency of Natural Resources. SGAT is utilized to determine stream conditions and is completed in the office before any field work is implemented. SGAT was developed to help divide a stream into management units based on five criteria: stream size, valley characteristic, stream confinement, tributary influence and valley slope.

This level of evaluation produced a set of watershed scale geomorphic statistics including valley slope, valley confinement, channel slope, stream geometry, riparian buffer width, and Rosgen Level I stream classification. Additionally, the SGAT included information on the extent of the stream corridor, location of bank erosion and gravel deposition, the potential impact of infrastructure and land use within the stream corridor. While the accuracy of SGAT is limited[2], it provided a rough overview of the factors affecting stream stability within each sub-basin and an indication of reaches where additional assessment may be merited. The results of the information from SGAT can be found in a summary table following each sub-basin description below.

The use of SGAT led to the segmentation of each stream into discrete management units. A management unit is a length of stream having common geomorphic attributes based primarily on five criteria: watershed area, valley characteristic, stream confinement, tributary influence and valley slope. Management units may be further defined by a set of common influences such as a common land use or level of land use pressure, or a distinct beginning and ending point such as a bridge or tributary confluence.

Data sources included 2001 high resolution digital orthophotographs, historic aerial photographs, and helicopter flyover video. The data was used to create a series of map

[2] by the resolution of the GIS data and imagery and the lack of other information such as a record of previous channel modifications

layers and analysis was accomplished using a set of SGAT worksheets. The map layers included:

- Stream Types: including information on stream bed elevations, valley length, valley slope, channel length, channel slope, sinuosity, watershed size, channel width, valley width, and confinement
- Basin Characteristics – Geology and Soils: location of alluvial fans, grade controls, geologic materials, valley side slopes, and soil properties
- Land Cover – Reach Hydrology: watershed land cover/use, stream corridor land cover/use, riparian buffers, groundwater inputs, right and left streambank information (percent of width and dominant width of riparian buffers)
- In-stream Channel Modification: the location of bridges, culverts, bank armoring, and channel modifications
- Floodplain Modifications and Planform Changes: an assessment of the impact or influence of berms, roads, river corridor development, depositional features, meander migration, meander width ratio, and wavelength ratio.
- Bed and Bank Windshield Survey: dominant soil material, bank erosion/ bank height and impacts, and ice and debris jam potential

Historic aerial photographs were scanned into the computer and geo-referenced (oriented to current mapping units). This data was used in mapping previous stream alignments as part of a general assessment of stream stability. Aerial photographs from the following years were processed: 1943, 1963, 1971, and 1983. The scanned historic aerial photograph information was used only during the information-gathering portion of the assessment and is available at the Delaware County Soil and Water Conservation District (DCSWCD) office.

Step II – GPS Walkover Stream feature inventory:
Global Positioning System (GPS) walkovers were completed by going to pre-determined stream locations, photo documenting observed features and mapping those features with a handheld GPS unit. The survey coordinates for the various features and the attributes of each feature were uploaded into the stream geodatabase (a predefined ArcGIS geodatabase) and linked with photographs of the features. The following features were the subject of this field reconnaissance:

- Berms
- Best Management Practice (BMP)
- Bridges
- Control (grade or lateral)
- Crossing
- Culverts
- Depositional Features
- Dumps
- Eroding Streambanks
- Stream Gages
- Large Wood Debris (LWD)
- Monitor Site
- Obstructions
- Pipe Outfalls
- Revetment (Rip rap, stacked wall, etc.)
- Riparian Vegetation
- Stream Features
- Tributary
- Utilities

Reaches were selected for GPS walkover based on representative condition of the watershed as a whole and information gathered could be used to validate the interpretation of aerial photos and maps in the SGAT procedure.

Step III - Rosgen Stream Classification

The selected locations that were deemed representative of longer sections of management units were determined after studying aerial photographs, analysis from SGAT data and GPS walkover. These locations received a Rosgen Level II survey to:

1. Validate our assessment based on the SGAT data and the GPS walkover
2. Derive dimensions and ratios that can be used to classify the stream and describe its condition based on Rosgen's classification system.

Information collected for a Rosgen Level II survey included:

- Surveyed stream bed elevation
- *Thalweg* and water surface profiles
- Documentation of bankfull indicators
- Pebble counts at the surveyed cross-sections
- Bulk gravel samples (bar samples)

At the same locations where Rosgen Level II surveys were conducted, the procedure described in the British Columbia Channel Assessment Procedure Field Guide book was also performed. This procedure measures such features as:

- Channel width and depth
- Channel slope
- Largest sediment size

Use of a nomograph and reference photos provided the type of condition of the reach. The procedure was used primarily to determine the relative degree of aggradation or degradation for the reach. It was a useful check on the condition indicator as determined by the Rosgen Level II survey, as well as staff impressions of the stream condition based on the GPS walkover."

The results of the Step I, II, and III assessments are described further below as part of the sub-basin and management unit descriptions.

DRY BROOK SUB-BASIN

(Towns of Middletown, Shandaken and Hardenburgh)

Introduction

The Dry Brook watershed is located within three different townships: the Town of Middletown in Delaware County, and the Towns of Shandaken and Hardenburgh in Ulster County. Arkville is the only population center in this sub-basin. The Dry Brook mainstem was divided into 10 management units based upon the SGAT protocol.

Figure 1.1 Bedrock Outcrop on Dry Brook Mainstem

Dry Brook is a fifth order stream with three major tributaries that enter the mainstem: Bush Kill, Rider Hollow, and Haynes Hollow. Numerous unnamed tributaries that have a small drainage area also contribute to the mainstem. Bush Kill and Dry Brook merge together approximately 1 mile upstream of where Dry Brook enters the East Branch mainstem. The drainage area of Dry Brook is approximately 82.3 square miles and the mainstem is 12.5 stream miles in length from the headwaters to the confluence with the East Branch Delaware River mainstem. In terms of its Rosgen classification, Dry Brook sub-basin is primarily a Rosgen C stream type with some D, F and B sections. The upper reaches of Dry Brook (DrB 09 and DrB 10), the stream are likely either a Rosgen B or A stream type. The confinement ratio shows that the valley is generally broad to very broad and the valley side slopes are very steep with high run-off potential soils, making this watershed prone to flash flooding. The land use is predominately forested, with some agricultural fields interspersed. The average annual rainfall in the watershed can range from 37-39 inches/year at the lower portion to 55-57 inches/year in the headwaters.

Stream Assessment

All three steps of assessment were conducted on sections of Dry Brook, with the entire stream assessed using the Step I – GIS based assessment protocol. Step II - GPS assessment data was collected for 6.5 miles of the Dry Brook mainstem and the near streambank conditions for the entire mainstem was captured in helicopter based video footage. **Figure 1.2** shows Delaware County Soil and Water Conservation District Stream Corridor Management Program (DCSWCD SCMPr) staff collecting GPS data and taking notes along the Dry Brook mainstem.

Step III – Rosgen stream classification were completed for management units DrB 03, DrB 04 and DrB 06. These locations were selected for classification because their form was considered to be fairly representative of the reaches along Dry Brook. Three stream profiles and twelve monumented cross sections were surveyed using electronic survey equipment. Pebble counts were completed on the cross section to sample the sediment being transported by the stream.

Figure 1.2 Data Collection along Dry Brook

DrB 09 and DrB 10 were not surveyed, nor were they walked over. The photography from the helicopter flight was inconclusive due to the view being obscured by tree cover. Similarly, 2001 aerial photography provided an incomplete view. The detail of stream features was so poor in the aerial photography of DrB 10 that no SGAT evaluation work was possible.

Geomorphic Conditions

The condition of Dry Brook can be described as follows:

- It is downcutting
- It contains excessive gravel deposition
- It has major areas of gravel deposition, especially in the downstream reaches
- The reaches of Dry Brook alternate between those that contribute deposition and those that store deposition
- It tends to be overly wide
- The geology and soils of the Dry Brook watershed are not the same as is commonly found in other East Branch Delaware sub-basins
- Bedrock serves as a grade control in numerous locations where the stream has scoured down to bedrock
- There are several locations where bed degradation or lateral migration has resulted in large slope failures

Figure 1.3 Dry Brook Mainstem

Generally speaking, Dry Brook is unstable with large and extensive sediment deposits and many raw eroding streambanks and slope failures. **Figure 1.3** shows a section of the Dry Brook mainstem with excess sediment and channel migration. A review of the 2001 aerial photographs will show many areas of deposition, including side bars and center bars. The depositional features are frequently found downstream of reaches where degradation and downcutting appear to be the trend. Overall, the stream system has actively downcut throughout the basin, and in many locations it has cut down to bedrock. Compared to the rest of the East Branch watershed, there are more stretches of bedrock channel than one would encounter elsewhere. Bedrock exposures are evidence of stream channel downcutting and are typical of incised stream channels. Gravel deposition is usually found downstream of these incised stream channel areas. The downstream reaches (DrB 01 to DrB 05) exhibit 7-10 depositional features per mile. The large number of depositional features in these downstream reaches is likely caused by:

- The large total bedload due to the increase in stream length and the consequent increase in exposed eroding banks
- The large total bedload due to sediment contributions from the tributaries
- The flatter valley gradient and stream slope which causes a loss in stream power, which causes the suspended load to drop out

The shape of the bed material in the channel is generally more rounded than the more plate-like bed material found elsewhere in the East Branch Delaware watershed and in the West Branch Delaware basin. It is not known if the rounded rocks of Dry Brook are more or less mobile than the plate-like material found else where. If they are more mobile, this could explain the frequent migration and large amount of depositional features.

Alluvial fans, delta like settings at the outlet or confluence of a river or stream, are areas of stream instability where the channel can laterally adjust rapidly as bedload exceeds the transport capacity of the stream. One significant and problematic alluvial fan on Dry Brook is located at the confluence of Bush Kill. At the upstream point of the fan on Dry Brook there is a series of four bends that are characterized by wide gravel point bars and long side bars. At point 1 in **Figure 1.4**, the stream exhibits a tendency to *braid* or break into multiple channels that interweave through the gravel deposits.

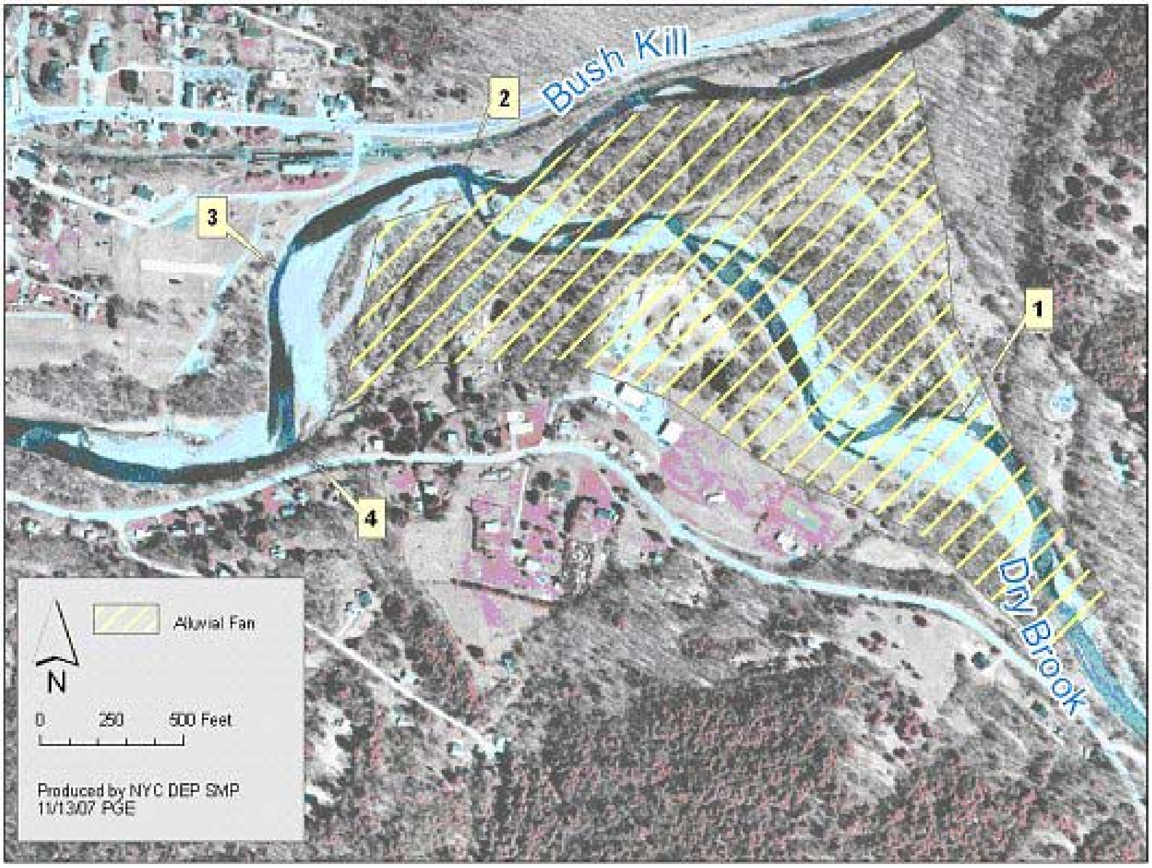


Figure 1. 4 Stream Alignment at Bush Kill Confluence in 2001

Historic aerial photographs of this location show that the stream is constantly changing. Below the alluvial fan for Dry Brook, where the two streams meet, is a very sharp bend that is not consistent with the general *planform* of the stream (point 2). Immediately downstream of Bush Kill confluence, along the Delaware and Ulster rail yard property is another large bend in the river. This bend has been extensively riprapped to prevent the stream channel from migrating further to the right (point 3). The point bar on the opposite bank is extremely large and there is a distinct cut-off channel through which the stream flows during high flow events. Downstream of this area, the stream makes another sharp bend to the right (point 4). The sharp bend is, again, inconsistent with the general planform of the stream. There is a large side bar along the right streambank at this location. The alignment is such that the water is forced to take a right angle turn, causing a significant stress on the left streambank. At this location, there is riprap to protect the streambank and Dry Brook Road.

Although Dry Brook Road is not immediately threatened with structural failure, flooding is a continual threat to property in the confluence area and the hamlet of Arkville. In the summer of 2006, a Federal Emergency Management Agency (FEMA) grant was obtained to enable the Town of Middletown to remove the tops of the gravel bars in this location in an attempt to improve the capacity of the stream channel. DCSWCD SCMPr staff has placed four monitoring cross sections with survey pins in this area and will be monitoring change in the stream capacity and changes in the size and height of the gravel bars. This entire reach of stream near the confluence with the Bush Kill is constantly evolving and needs to be monitored. Unfortunately, the problem is related to excessive sediment deposited from further upstream sources. The exact source and nature of sediment transport within the systems are currently not understood. Since no mitigation plan can be expected to succeed until the root cause of the high bedload problem is successfully addressed, further study is required.

The next alluvial fan downstream from Arkville also demonstrates the instability of streams in these depositional settings. As a result of storm events in 2004 and 2005, the location of the confluence of Dry Brook with the East Branch Delaware River moved approximately 1,400 feet upstream along the East Branch mainstem. DCSWCD has examined this new channel and has mapped its new location with GPS coordinates. Continued migration of the new channel could result in public property loss near the Arkville Pavilion. The old channel is now full of gravel deposits and only receives flow during high flow events. At present, the expense of relocating the channel to its previous alignment is not justified. This situation should be monitored and any intervention should be carefully considered. Until then, it can be used as an example of the instability of streams within an alluvial fan.

Reach DrB 01 and DrB 02 are in such poor condition and so heavily impacted with sediment deposits and man-made alterations that their classification or condition cannot be taken to represent the stream as a whole. In reaches DrB 09 and DrB 10, the stream gets very small and steep and any conclusions drawn from them based on Rosgen Level II survey are apt to be misleading. Therefore, on the basis of size and perceived condition based on the SGAT protocol, GPS walkovers, and aerial photographs, reaches DrB 03, DrB 04 and DrB 06 were selected for Rosgen Level II surveys. The Rosgen Level II surveys were supplemented with assessments from the Channel Assessment Procedure Field Guidebook, produced by the British Columbia Ministry of Forests in December 1996. This was done in order to gain further insight into the processes at work in the channel. These reaches were selected as being the best representative reaches for the stream and each location surveyed was judged to be representative of that particular reach. These surveys were performed shortly after the flood of June 2006. The magnitude of the flood event on Dry Brook is not known, but it must be presumed to be a large significant event. All the reaches showed signs of recent disturbance, but DrB 06 did exhibit moss on some of the rocks in the channel indicating stability. The following table highlights the significant findings from Rosgen Level II survey at these three sites:

Table 1.2 Significant Findings at Reaches DrB 03, 04, and 06

Reach	Drainage Area (sq. mi)	Bankfull Width (ft)	Bankfull Depth (ft)	Bankfull Area (sq. ft)	Width/Depth Ratio	Entrenchment Ration	Stream Type
DrB 03	32.5	127.5	1.8	230.3	70.83	2.35	C4
DrB 04	15.5	80.1	1.5	119.3	53.4	2.37	B3c
DrB 06	9	56.2	1.8	79.4	31.22	1.6	B3c

Notice the high width/depth ratios at DrB 03 and DrB 04. This is as sign of potential instability and braiding could easily happen at these high ratios. DrB 06 is slightly entrenched, but its width/depth ratio is reasonable.

The British Columbia Channel Assessment Field Procedure measures such features as:

- Channel width and depth
- Channel slope
- Largest sediment size

Use of a nomograph and reference photos provided the type of condition of the reach. The following table summarizes the findings based on the British Columbia Channel Assessment Field Procedure:

Table 1.3 British Columbia Channel Assessment Findings

Reach	Drainage Area (sq. mi)	Modal Type	Condition
DrB 03	32.5	cascade-pool	moderately aggraded
DrB 04	15.5	cascade-pool	moderately aggraded
DrB 06	9	cascade-pool	moderately degraded

The British Columbia findings illustrated in this table agree with the DCSWCD stream staff's visual observations. Note that the DrB 06 reach is degrading and the downstream reaches are aggrading. Most likely, some of the sediment being removed from DrB 06 is being deposited in DrB 03 and DrB 04. Of course, that does not mean that all the sediment at these two sites is coming from DrB 06. It does mean that this stream exhibits alternating reaches of aggradation and degradation. This matches DCSWCD staff's observation based on 2001 aerial photographs and GPS walkovers.

The British Columbia Field Procedure classifies all three reaches as cascade-pool. The Rosgen Level II classification is type B with some C features for DrB 04 and DrB 06 while reach DrB 03 is typed C. Two distinct classification systems are being used, therefore no direct comparison can be made. Instead, it is better to remember that, as is typical for streams in this setting of the Catskill region, that there will commonly be weak steps and that for some streams, a reach may appear to be transitioning between a B and C stream type. For any given reach the features of one type will dominate but features of the other type will be extant. Also, keep in mind that the SGAT protocol does not account for B features and its classification (while using the Rosgen system) is mainly based on stream slope. For management purposes, the SGAT is quite adequate for our assessments. Any construction activity or work in the stream channel would require a more detailed survey to provide a precise stream type for the subject reach.

Management Prescription for Dry Brook Sub-basin:

- *A sediment study to determine sediment sources and transport capacity of the Dry Brook system should be performed before substantial restoration is attempted in this sub-basin.*
- Any attempt to stabilize a section of the stream should account for sediment transport issues in the reach and adjoining upstream and downstream reaches. The sediment load and the unique features of this system could complicate any attempt to stabilize a single reach or site and result in unintended consequences.
- DrB 01 and DrB 02 should continue to be monitored. The results of the monitoring should be used to determine whether management interventions such as gravel removals are warranted and environmentally sound.
- Fluvial geomorphic principles and best management practices should be used when efforts are made to protect life and property in response to flood events.
- The development of a long term management plan of the floodplains near Arkville is suggested

Floodplains

The floodplain along the mainstem of Dry Brook is generally not developed, giving the stream freedom to meander in most locations. There are two locations that are developed along the mainstem of Dry Brook where flooding repeatedly occurs and damages property. The constriction of the floodplain at the NYS Route 28 bridge in Arkville as shown below in **Figure 1.5** has a significant impact both upstream and downstream of the bridge.

Flood flows in major events leave the channel at the rail station and cross the floodplain on the right bank resulting in flooding of house basements and first floors along Route 28 and along the side street on the north side of Route 28. The trailer park on the left bank downstream of the NYS Route 28 Bridge in Arkville is also significantly damaged in major flood events. A second floodplain area where development is affected by high flows is located about 1.4 miles upstream of Erpf Road. Elsewhere along Dry Brook, the floodplain functions without significantly impacting development, but flood flows frequently deposit sediment and debris on the flats which can affect land use.

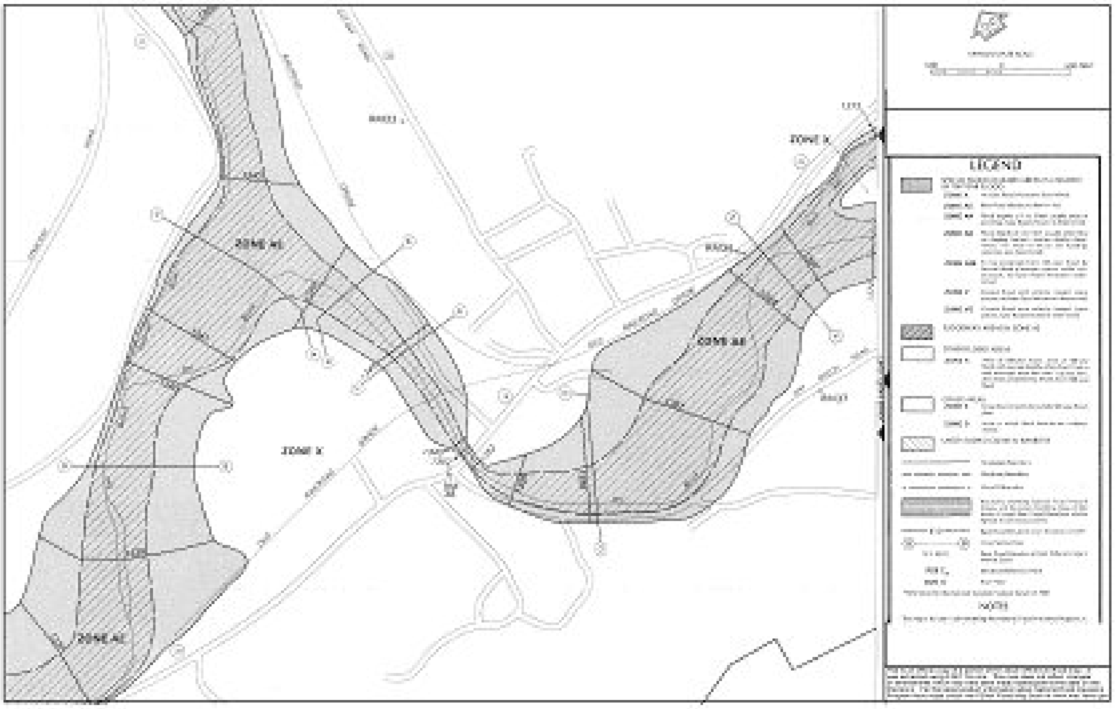


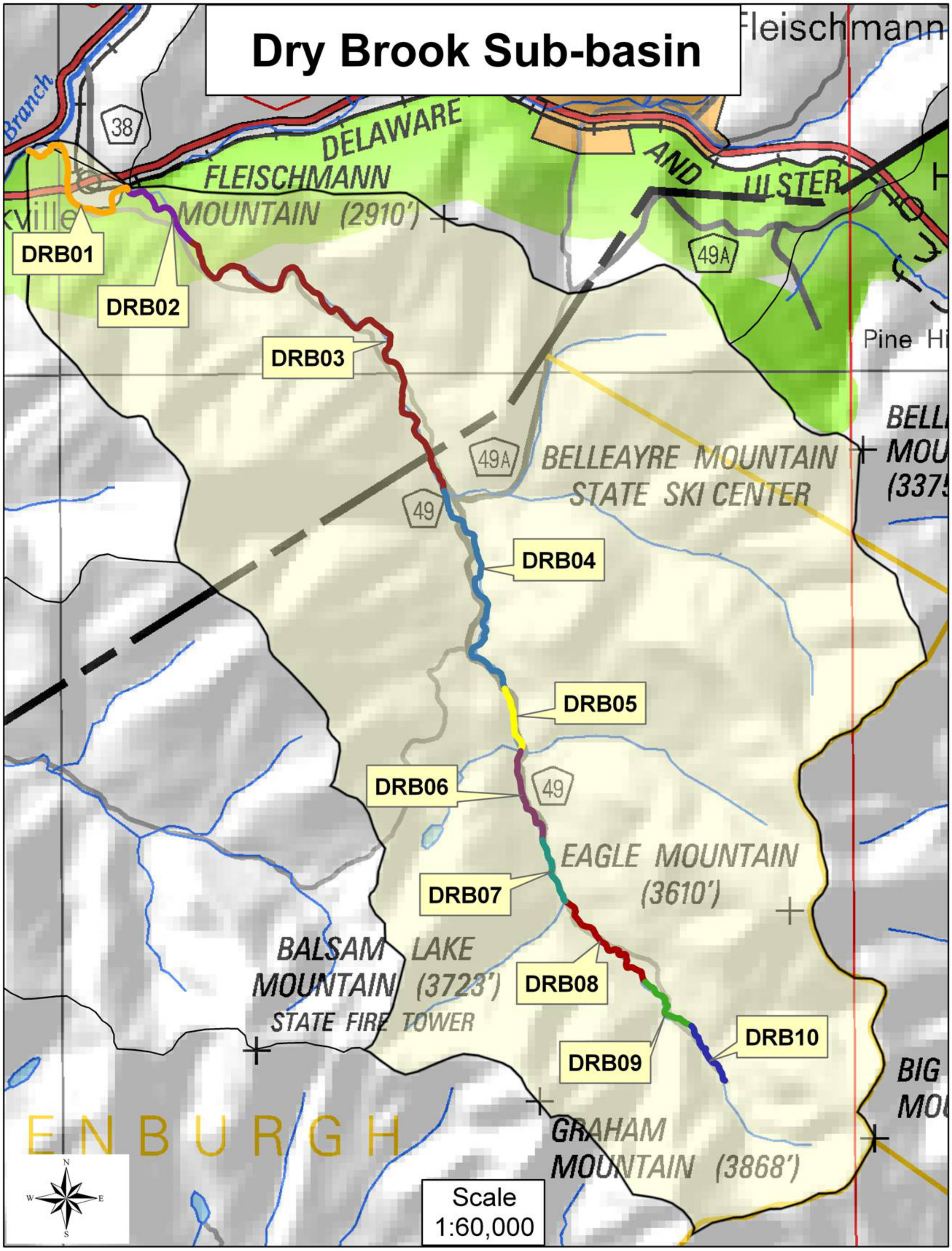
Figure 1.5 Section of Flood Insurance Rate Map for the Arkville area (Map panel 3602090037C)

Infrastructure

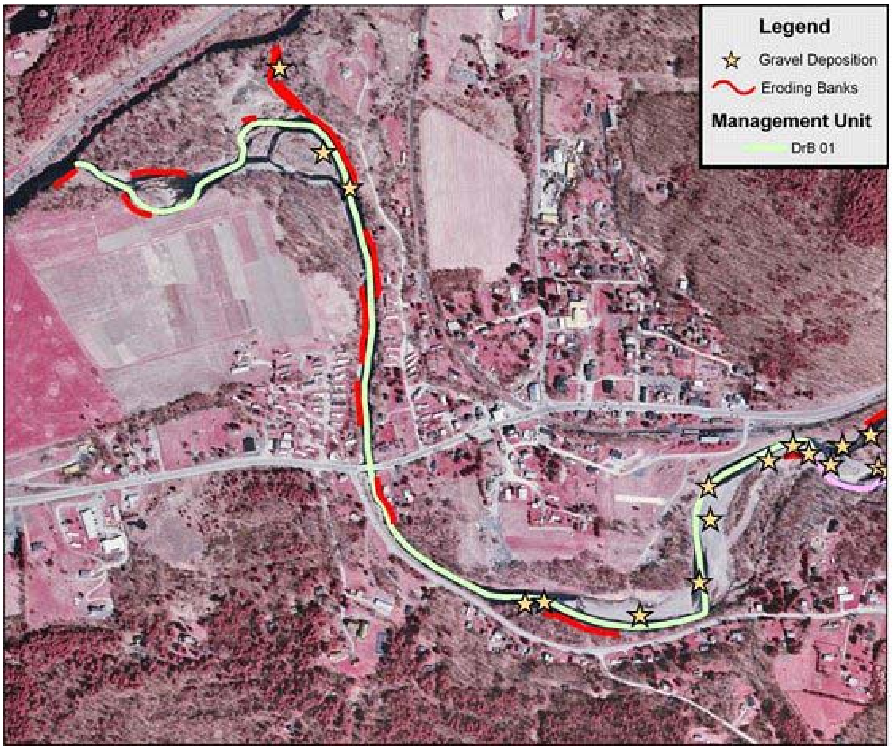
Dry Brook Road and Ulster County Route 49 run parallel to the Dry Brook mainstem and have some impact on the stream health. Stormwater runoff from the road ditches adds excess water and pollution directly to the streams without time for the ground and vegetation to absorb the pollutants. There are several locations where the stream is close to the road and revetment was placed along the streambanks in order to protect the road from channel migration (see **Figure 1.6**). There are eight municipal bridges and five private bridges located within this *sub-basin*.

Figure 1.6 Rock Revetment Along Ulster County Route 49

Management Unit Descriptions



DrB 01

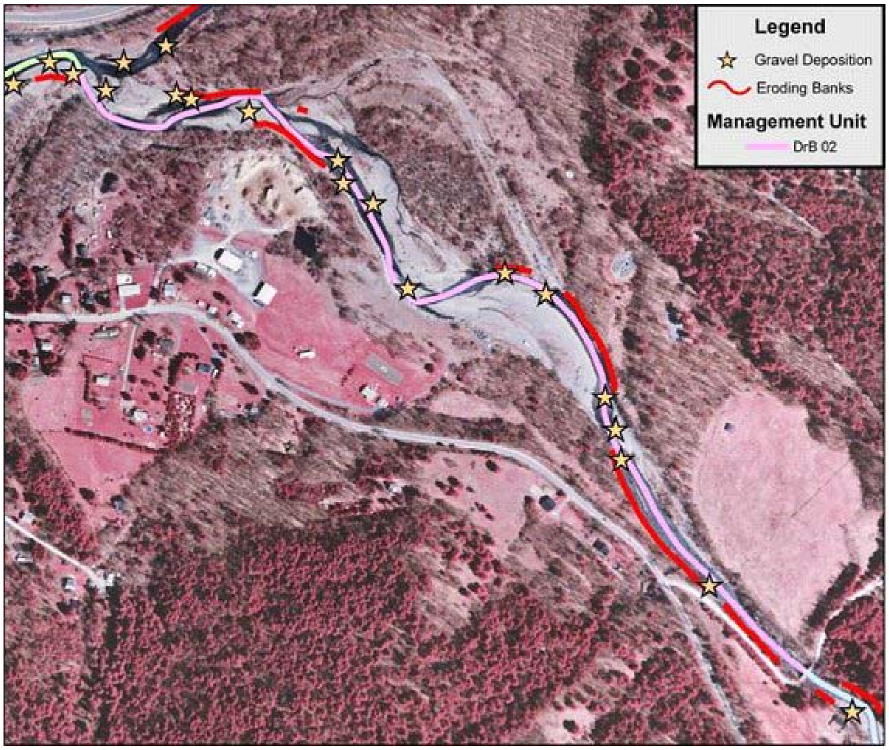


Management Unit DrB 01 is approximately 7,615 feet long with a very wide valley as it joins the East Branch Delaware Mainstem. United States Geological Survey (USGS) stream gage 01413408 (Dry Brook at Arkville NY) which is located on the left bank 80 ft upstream from bridge on State Route 28. The drainage area at the stream gage is 82.2 square miles. The period of records that are available for this gage is December 1996 to current year.

The lower portion of DrB 01 is the alluvial fan of the Dry Brook mainstem and the upper portion from New York State Highway 28 Bridge upstream is narrowed by the valley walls. This area of the stream is entrenched due to the revetment on the left bank, higher velocity, and the stream has down cut to bedrock. Bedrock in the streambed located just upstream of the bridge acts like a grade control for the bridge. There is no aggradation located immediately downstream of the bridge. There is some development along the floodplain on the upper portion of the reach in Arkville. The lower portion of DrB 01 has a trailer park on both sides of the floodplain and agricultural field on the lower left side. A box culvert located east of the Route 28 bridge acts as a floodplain drain for high flows on the right bank floodplain. An eroding bank, approximately 10 feet high, is located on the right streambank upstream of the NYS Route 28 bridge. Revetment bank protection is in place at this location but it is in poor condition. A house and a garage are located in this area and there is little to no riparian buffer along the property.

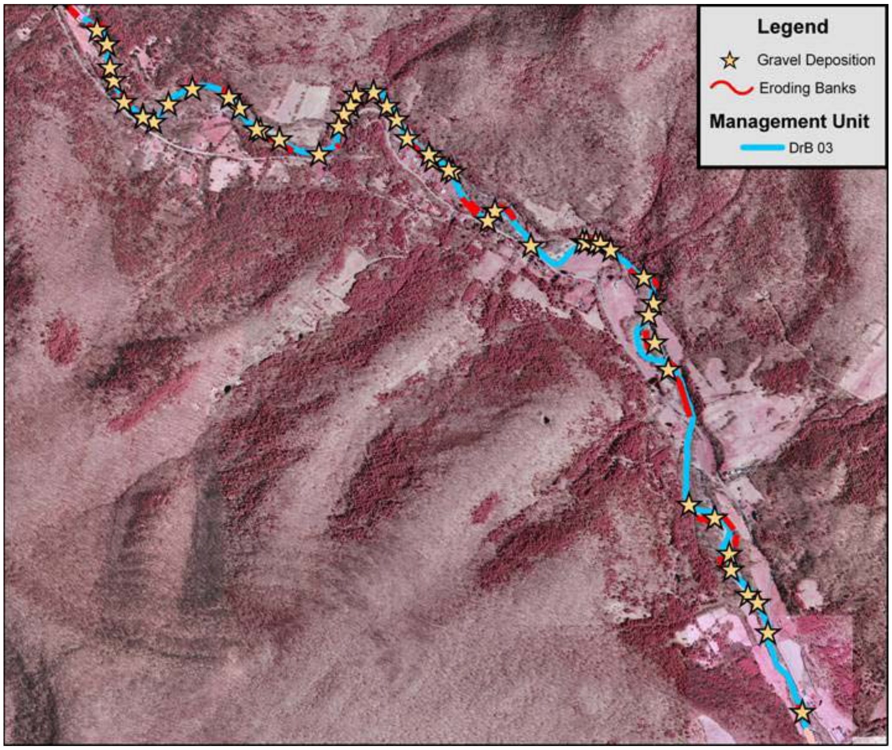
German Hollow and Bush Kill are tributaries that enter Dry Brook. The Bush Kill meanders across its alluvial fan and adds to the downstream gravel deposition. Monitored areas located near the railroad station were placed in the fall of 2005 to observe the difference in movement between multiple-sized sediment materials. There are five monumented cross sections, three of which contain scour chains and painted rocks of varying size. The painted rocks can be recovered after a high flow event, which demonstrates how far sediment can move.

DrB 02



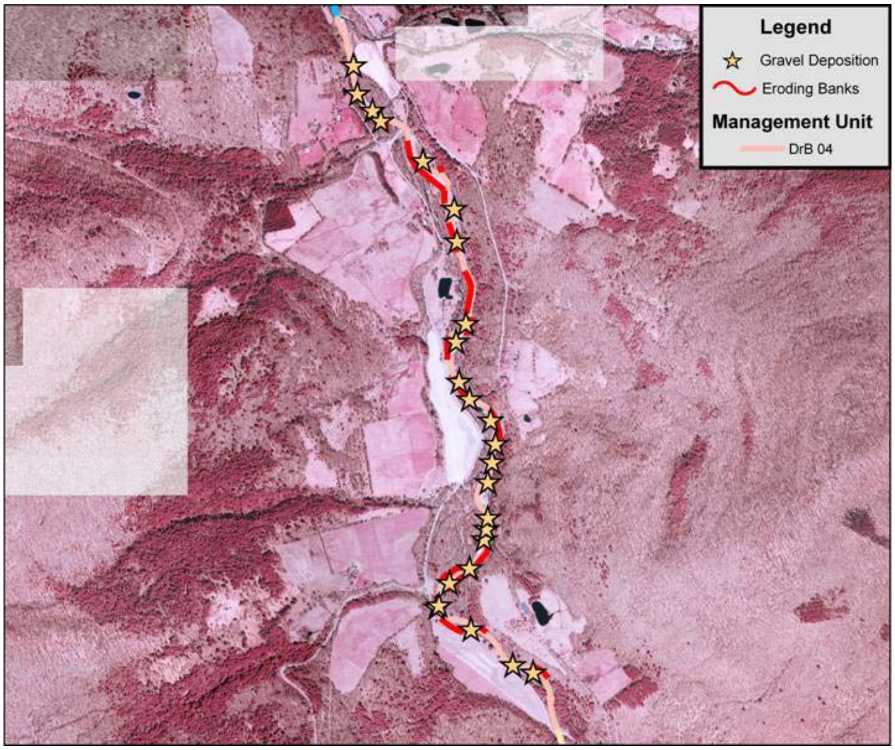
Management Unit DrB 02 is approximately 4,175 feet long with a very broad valley. Dry Brook has access to its floodplain in the lower portion of the reach, but is confined to the stream channel downstream of Erpf Road. Dry Brook comes in contact with the left streambank approximately 620 feet downstream of Delaware County Bridge 21 (Erpf Road). To protect the road infrastructure, the streambank was stabilized in this area during the summer of 2006. Historically, upstream of Bush Kill confluence, Dry Brook has been meandering on its floodplain. Areas of aggradation/bypass channels are numerous in this reach. The river is continually adjusting and depositing sediment on the floodplain and within the channel especially in the lower portion of the reach. One of the bypass channels is blocked with debris, limiting water access during high flow events. Delaware County Bridge 21 is located in this reach and has minimal impact on the stream. There is no aggradation downstream of the bridge and the stream has a planar bed shape. Rock rip rap is protecting the bridge abutments upstream and downstream of the infrastructure. Additional revetments are mainly located on the left bank where most of the development is encroaching on the floodplain. Reservoir Hollow enters Dry Brook in this reach, which may have some impact on the streambank erosion that is occurring.

DrB 03



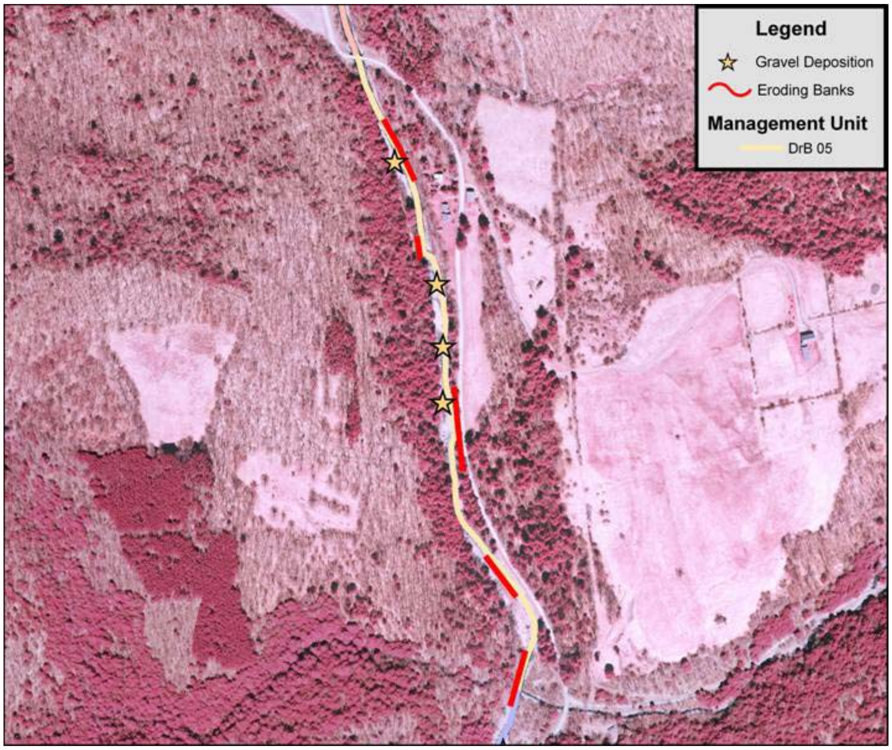
This reach runs upstream from the Erpf Road bridge for about 20,406 feet (3.8 miles) and ends at the confluence of Rider Hollow. In addition to Rider Hollow, there are about seven small unnamed tributaries that enter this reach. The two bridges that cross the river are Delaware County Bridge #151 on George Road and County Bridge #20 on Dry Brook Road. The river corridor consists of about 75% forest/wetland, the remainder being a mix of agricultural land, brush and residential. The river runs through a broad valley and regularly changes its location as the water makes its way through the many gravel depositional features. About 46% of the reach length is experiencing gravel deposition. These areas are unvegetated and change with each high flow event. Most depositional features are very large and located in an over-widened section of stream. The total deposition area is approximately 760,000 square feet, which is 37 square feet for every one foot of stream length. This is a lot of sediment that could eventually move downstream. Eroding streambanks can be found in 35% of the reach, which is about average for Dry Brook. Typically vegetated riparian buffers protect streambanks from excess erosion and help to stabilize gravel deposits. Unfortunately the riparian buffer vegetation is compromised in many sections of this reach. One third of the eroding streambanks have only a narrow riparian vegetation buffer ranging from 0-25 feet wide. Also, 37% of the entire reach has only a narrow vegetation buffer on one streambank or the other. Only 9% of stream length has revetment, which is mainly sloped stone to protect agricultural land and road embankments in areas where the river is making major shifts in stream alignment.

DrB 04



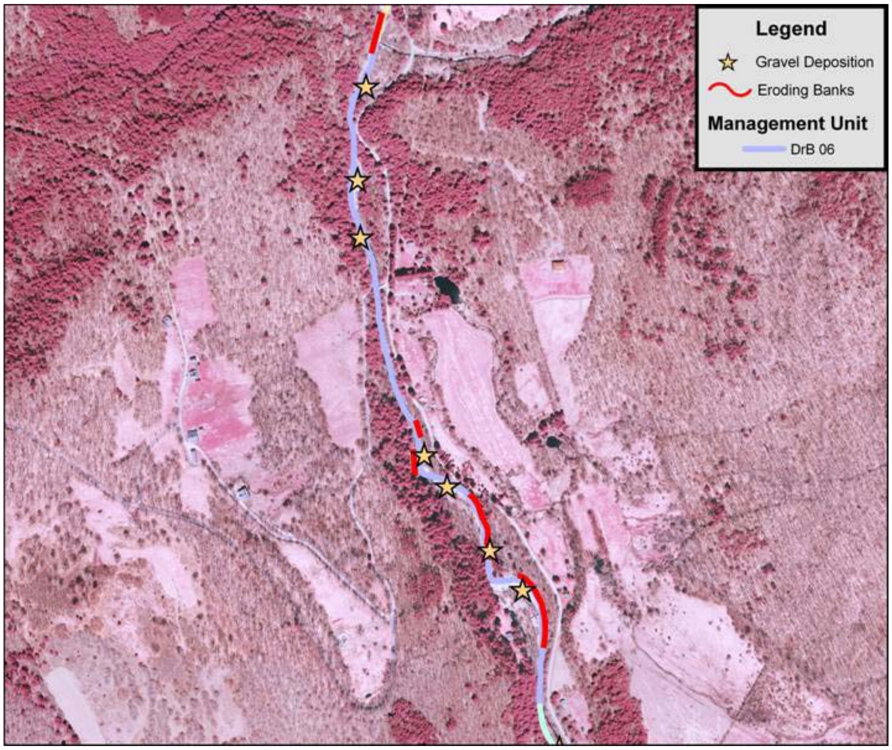
This reach is approximately 10,791 feet long and ends at a bridge on Dry Brook Road near Martin Road. There are seven tributaries including Tompkins Hollow and two bridges on Dry Brook Road that cross the stream. This reach is very similar to DrB 03, running through a broad valley, frequently changing course as it is affected by deposition. Large unvegetated gravel/cobble bars are formed within this reach and make up 52% of the reach length. The gravel/cobble bars cover an area of 395,000 square feet, which is the equivalent 37 square feet for every one foot of stream length. About 51% of the stream length contains eroding streambanks on one side or the other, totaling approximately 60,000 square feet of exposed bank. Much of this exposed area is from mass failures on high banks. Of all the eroding banks, only 12% have a narrow vegetation buffer width ranging from 0-25 feet and these are sections where the stream and Dry Brook Road are very close. About 23% of the entire reach has a narrow riparian vegetation buffer on one streambank or the other. There is little revetment in this reach, being short sections of rip rap for road embankment protection, totaling 37% of the reach. Large woody debris is abundant in this section, either already washed out and sitting on a gravel deposition bar or having fallen over from an eroding streambank where the stream is widening and temporarily held in place by a few roots. This debris could cause problems during high flow events and cause obstructions in the stream channel or at bridges. Debris management, slope stabilization and riparian buffer protection should be considered for sections of this reach.

DrB 05



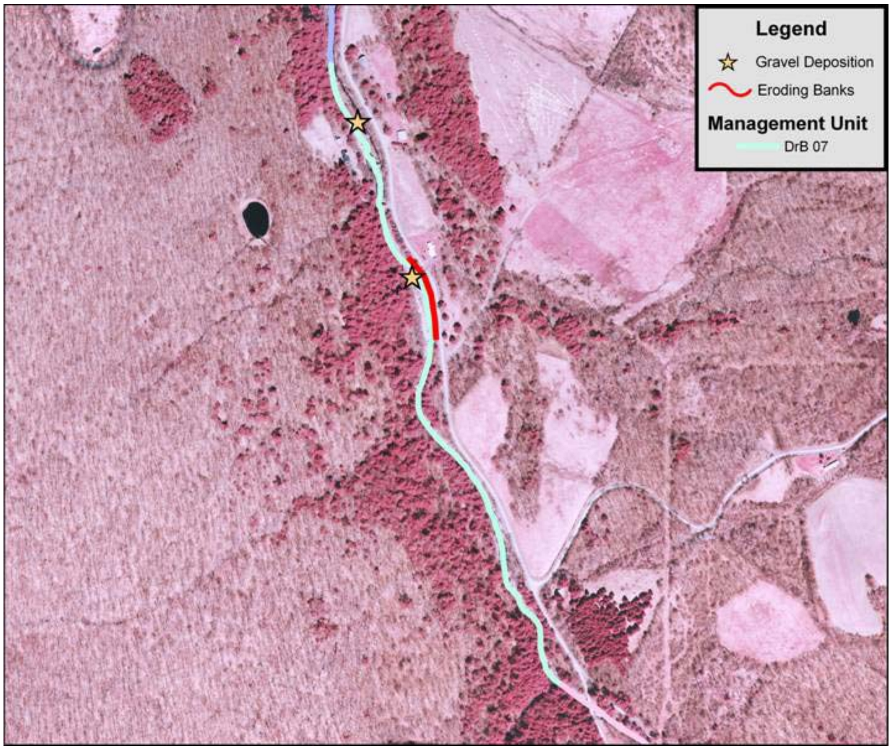
This reach is approximately 2,887 feet long and ends at the confluence of Haynes Hollow. This straight stream runs through a broad valley. There are three tributaries entering into this reach, including Haynes Hollow and two unnamed tributaries. Land cover in the stream corridor is about 85% forest and 10% residential/roads. Eroding streambanks make up 40% of the reach length. The bank material consists mostly of round cobbles that could easily be moved during high flow events. Gravel deposition covers about 38% of the reach length. This material is also large round cobble similar to the bank material. About 33% of the reach contains streambank revetments, most of this total consisting of two separate sections of revetment. One is a section of old log cribbing in poor condition, but there is some woodland vegetation buffer just behind the cribbing. The other section is made of recently placed sloped stone to protect Dry Brook Road from further bank erosion. A narrow riparian buffer between 0-25 feet wide on one bank or the other can be found in about 46% of the reach. The majority of this narrow buffer is located in areas where the road and stream are close to each other. As with DrB03, strengthening the riparian buffer along this reach may help reduce streambank loss and the mobilization of sediments from eroding streambanks.

DrB 06



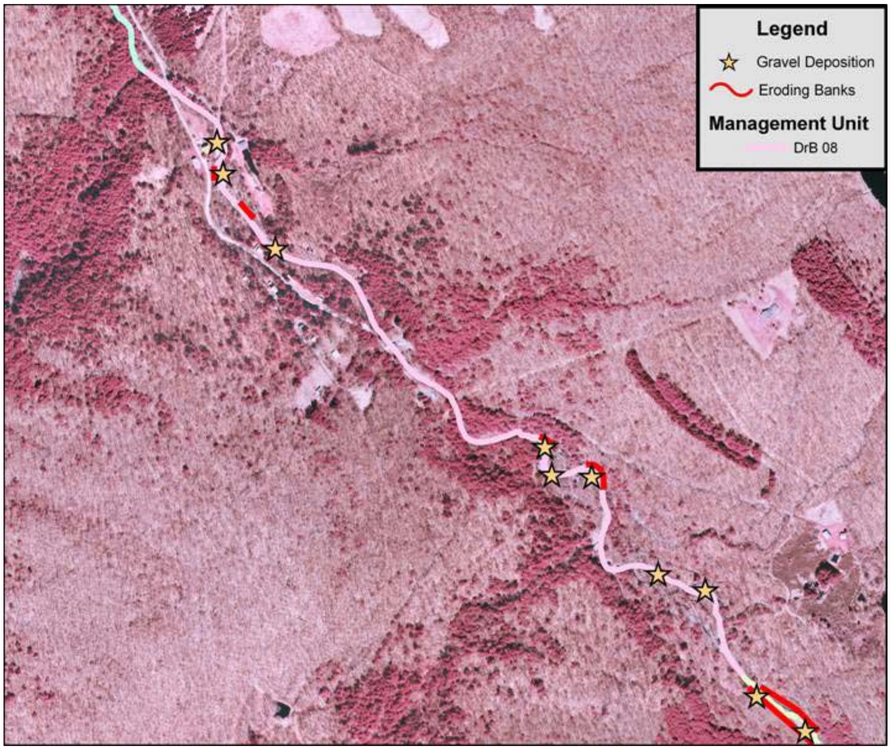
This reach is approximately 4,368 feet long and runs through a broad valley. The stream here is steeper than the other downstream reaches, being about 2% in slope. There are two foot bridges and two private bridges in this section. The stream corridor is 86% forested, 6% agricultural land, and 5% residential/roads. Most of the eroding streambanks located in this reach consist of cobble material except for the mass failure that consists of glacial till. The eroding streambanks are found in the upstream portion of the reach. Depositional features cover about 31% of the reach length. These are mostly side bars located where the stream is widening. They consist of gravel, cobble material, and no vegetation. About 12% of the reach is protected by revetment, consisting mostly of sloped stone on the streambanks against roads and stacked rock wall at the toe of the mass failure bank. A narrow riparian vegetation buffer between 0-25 feet wide occurs on 35% of reach length, all on the right bank where the stream and the road are close together. A more detailed survey was conducted in the mid-portion of the reach, which included cross sections, profiles, and pebble counts. This section of the reach is classified as a B3 stream type.

DrB 07



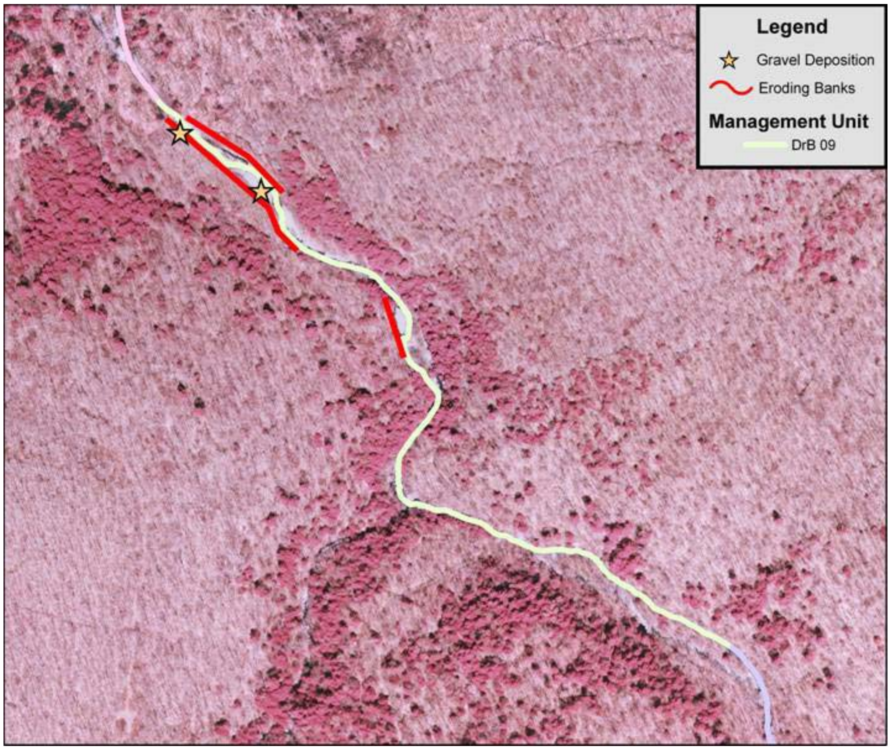
This reach runs for approximately 2,943 feet and ends at the confluence of Turner Hollow, the only tributary in this section. The valley is fairly broad, but in some sections of the reach the channel appears to be entrenched. Approximately 26% of the stream length contains exposed bedrock in the channel. There is one bridge in this section located on Erickson Road. Land cover in the stream corridor is about 80% forest, 10% agricultural land and 5% residential. About 13% of the length has an eroding streambank consisting of one long stretch at an area where the stream and Dry Brook road are very close to each other. The only revetment in this section covers about 13% of the reach which is also in a location where the road and river are close together. Two large depositional features make up 21% of the reach length. About 68% of the right streambank has a narrow vegetation buffer between 0-25 feet wide which is due to Dry Brook Road running parallel to the stream.

DrB 08



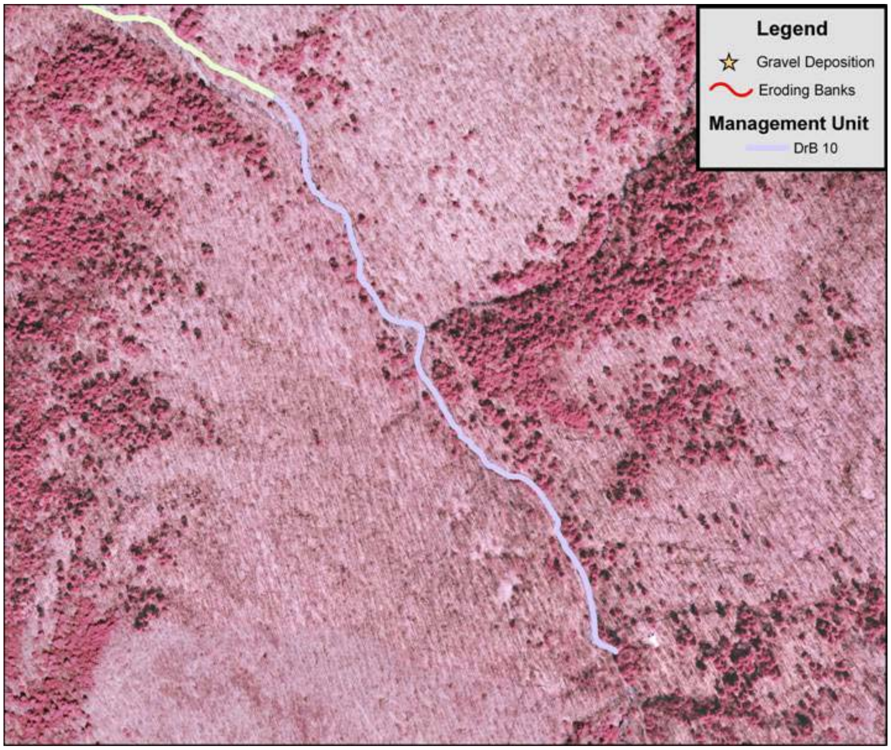
This reach is approximately 4,984 feet long. The valley is relatively broad compared to the smaller stream width. There are two bridges on Dry Brook Road that cross the stream in the downstream portion, and there are two unnamed tributaries that enter Dry Brook in this reach. Over 90% of the stream corridor is forested and about 4% is residential/roads. Bank erosion is occurring in 9% of this reach and the streambank material consists mainly of cobble within the valley and glacial till along the valley wall. Depositional features consist of point bars with cobble material deposits. There is one short section of revetment where the stream has previously eroded the bank along MacFarland Road. Narrow riparian vegetation buffer widths between 0-25 feet make up 27% of the reach. These narrow vegetation areas are in the downstream portion and are mostly where the road and stream are close together. Dry Brook Road ends about mid-way through this reach and therefore will not impact the upstream portion of the reach. The upstream portion still experiences erosion and deposition issues even though the road is no longer a factor and the area is all forested

DrB 09



This reach is approximately 3,231 feet long, entered by a few small unnamed tributaries as well as Flatiron Brook. The stream slope is about 2.5% and is slightly steeper than downstream reaches. The stream corridor land cover is 100% forested. Helicopter video logging was completed for this reach, but due to the density of the tree canopy much of the stream was not visible enough to identify the stream features as in previous reaches. A part of the downstream portion was walked and GPS data was collected. It appears that the stream has downcut, exhibiting 5 feet high streambanks, a wide stream channel, and gravel deposits that are starting to become evident. There are also large amounts of woody debris in the stream channel. Percentages of eroding banks and deposition for the total reach cannot be determined. About 84% of the soils in this part of the sub-basin are in hydrologic group C/D and D, which have high run-off potential. These soils, combined with steep side slopes, allow a larger percent of water run-off to reach the stream channel quicker than other sub-basins in the East Branch Delaware River watershed.

DrB 10



At approximately 2,972 feet long and with a slope of about 4.4%, this reach is the headwater of Dry Brook. Shandaken Brook joins Dry Brook in this section. The stream corridor is 100% forested. The soils in this part of the basin have high water run-off potential, consisting of 97% C/D and D hydrologic group soils. The combination of steep side slopes of the valley and high run-off potential of the soils combine to produce flash flood conditions where the water surface can rise quickly following a rainfall event.

Dry Brook Summary Sheet

Reach No.	Length Reach (feet)	Stream Type	Dominant Corridor Land Use/Cover	Sub-dominant Corridor Land Use/Cover	Riparian Buffer Width	Number Bridges and Culverts	% Impact of Bank Armoring
MU 1	7615	C	Wetland	Forest	Right Bank 0-25' Left Bank >100'	1	39% High
MU 2	4175	D	Wetland	Forest	Right Bank <100' Left Bank 0-25"	1	22% Low
MU 3	20406	C	Forest	Wetland	Right Bank >100' Left Bank >100'	3	8% Not Significant
MU 4	10791	B	Forest	Wetland	Right Bank >100' Left Bank >100'	2	6% Not Significant
MU 5	2887	C	Forest	Built-up	Right Bank 0-25' Left Bank >100'	0	11% Low
MU 6	4368	B	Forest	Brush	Right Bank 0-25' Left Bank >100'	4	4% Not Significant
MU 7	2943	C	Forest	Residential	Right Bank 0-25' Left Bank >100'	1	4% Not Significant
MU 8	5751	C	Forest	Residential	Right Bank >100' Left Bank >100'	2	2% Not Significant
MU 9	3231	B	Forest	Brush	Right Bank >100' Left Bank >100'	0	---
MU 10	2972	A/B	Forest	---	Right Bank >100' Left Bank >100'	0	---

Reach No.	% Impact Berms, Roads, Railroads, Paths	Impact Floodplain Development	Impact Depositional Features	Impact Meander Migration	Bank Erosion/ Bank Height	Ice/ Debris Jam Potential (Yes/No)
MU 1	69% High	High	High	High	High	Y
MU 2	33% High	Low	High	High	High	Y
MU 3	22% Low	Low	High	High	High	Y
MU 4	48% High	Not Significant	High	No Info	High	Y
MU 5	88% High	Low	High	No Info	High	N
MU 6	50% High	Low	High	No Info	High	Y
MU 7	93% High	Low	Low	No Info	Low	N
MU 8	20% Low	Low	High	No Info	Low	Y
MU 9	---	Not Significant	High	No Info	Low	Y
MU 10	---	Not Significant	No Info	No Info	Low	N

TREMPER KILL SUB-BASIN

(Towns of Andes, Bovina and Delhi)

Introduction

The Tremper Kill watershed is located within three different townships: Andes, Bovina, and Delhi in Delaware County. One population center, Andes, is located within this watershed. The Tremper Kill mainstem was broken up into 10 management units based upon the SGAT protocol.

The Tremper Kill mainstem is a fourth order stream. In addition to numerous unnamed tributaries, there are seven major tributaries that enter the mainstem which include Bussey Hollow, Campbell Hollow, Wolf Hollow, Liddle Brook, State Road Hollow, Gladstone Hollow and Bullet Hole. The drainage area of Tremper Kill is approximately 33.52 square miles and the total stream length is 10.5 stream miles from the headwaters to the Pepacton Reservoir. The Tremper Kill mainstem length is 7.1 miles from the Pepacton Reservoir to where it meets with Gladstone Hollow in the Hamlet of Andes. The Tremper Kill is primarily a C stream type. The valley width is generally broad to very broad with one section that is narrow. The land is predominately forested with some agricultural fields. The average annual rainfall in the watershed can range from 37-43 inches/year.

Stream Assessment

Methods of collecting data in this sub-basin include SGAT protocol, GPS walkover, helicopter video logging, and Rosgen Level II surveys. The SGAT protocol was used to divide the Tremper Kill mainstem into 10 management units from the Pepacton Reservoir to the Hamlet of Andes. Global Positioning System (GPS) data was collected for 6.3 miles of the Tremper Kill mainstem. Additional stream data to complete the entire mainstem was collected by using the helicopter video logging. The Rosgen Level II survey was completed in TrK 07 and this location was determined by picking a section that best represented all stream reaches. The Rosgen Level II survey consisted of a stream profile and five monumented cross sections that were surveyed using electronic survey equipment. Pebble counts were completed for five cross sections to determine the size of the sediment being transported by the stream and armoring the bed of the channel.

Geomorphic Conditions

Streambank erosion is a problem on the Tremper Kill, with eight out of ten reaches in the sub-basin impacted by erosion. TrK 01 and TrK 04 are the only reaches that have a low impact rating. Between 39% and 44% of the reach lengths of TrK 03, 05, 06, and 08 suffer from streambank erosion. Streambank revetment protection is found on 33% of TrK 04 and 28% of TrK 10. This is evidence of a former problem in these two management units. TrK 01 reach begins at the confluence of Tremper Kill into the Pepacton Reservoir and was found to be impacted by deposition. The SGAT protocol classifies all other reaches as having low or no significant impacts from deposition.

The riparian buffer width needs to be improved in this sub-basin. A wider, thicker riparian buffer containing woody vegetation would help to stabilize the channel streambanks. The following table shows the reaches with the narrowest dominant buffer width:

Table 1.4 Reaches Containing Narrow Buffers

Dominant Buffer Width 0'-25'		
Reach	LT Bank	RT Bank
MU2	X	
MU3	X	X
MU4	X	X
MU6	X	
MU9	X	
MU10	X	X

The SGAT protocol classifies all reaches in the Tremper Kill basin as stream type C. The bed material is mainly gravel and sinuosity is good, with an average sinuosity of 1.16. One reference reach was found in the Tremper Kill and is located in TrK 07. The reach upstream of TrK 07 is moderately aggraded and the reach downstream is beginning to aggrade. Thus, it is questionable what the long term prospects are for this reference reach to maintain stability. The drainage area is 21 square miles at the reference reach and the computed bankfull discharge (Q), using the regional curves and based on the channel geometry, is 606 cubic feet per second (cfs). The basic dimensions of this reach are:

Bankfull Width (W_{bkf})	**62.30'**
Mean Depth (d_{bkf})	2.10'
X-Sectional Area (A_{bkf})	128.10 sq.ft
W/d	29.67
Entrenchment Ratio	4.82
Channel Material D_{50}	47.3 mm
Bankfull Slope	0.68%
Stream Type	C4

Meander migration is common through the entire length of the stream. Places where the streams have broken out of the stream channel (avulsions) have been noted in TrK 03 and TrK 10. Every reach is listed as having stream channel migration, avulsion, or multi-channels.

The absence of a well vegetated riparian buffer along the Tremper Kill enables the stream channel to migrate across the valley. Once the stream breaks through its bank there is considerable bank erosion along the new channel alignment. Overwide and unstable, the stream is unable to carry the material from the eroding banks. When deposited in the channel, this material forms center bars that force the water toward the banks, which in turn accelerates streambank erosion. Eventually the channel re-establishes its dimensions and is able to return to a stable form. This evolution can require a significant period of time and may be interrupted by attempts to return the channel to its previous location without reestablishing the vegetation to protect the streambanks.

Management Prescriptions for Tremper Kill Sub-basin:

- Locate the worst areas of streambank erosion and stabilize the banks, preferably by planting vegetation to re-establish the riparian buffer
- Establish, protect, or enhance the riparian buffer along the length of the Tremper Kill
- At locations where avulsions are occurring, establish the channel to a dimension and alignment that is hydraulically adequate and geomorphically stable

Floodplains

The Tremper Kill has one location of floodplain development: the Hamlet of Andes. The stream is confined into its channel with stonewall built to keep the stream from meandering. Generally the stream has access to its floodplain and consists mostly of crop fields. Some berms were built along the agricultural field edge to protect the fields from flooding and also protect the sparse housing along the stream.

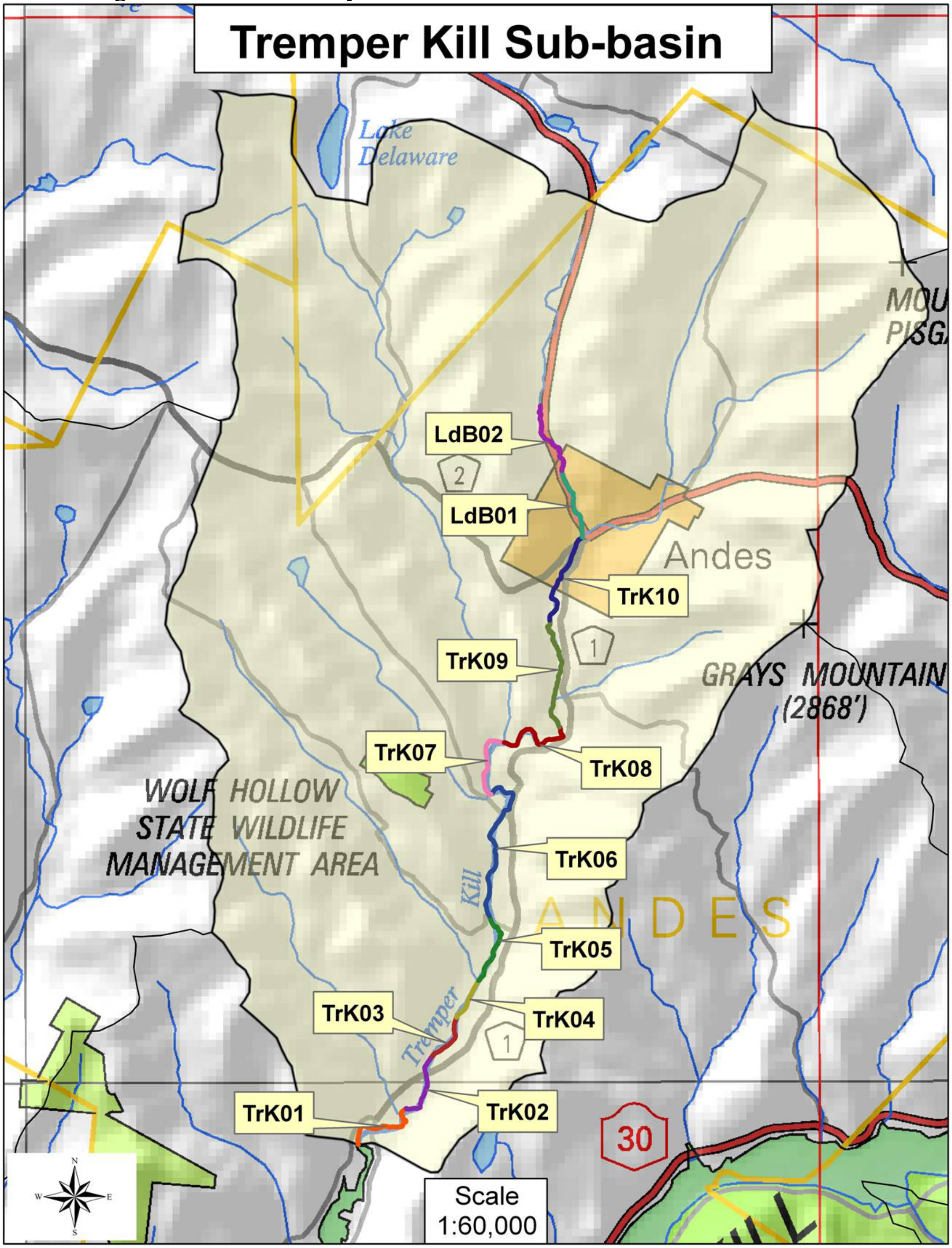
Infrastructure

Delaware County Route 1 runs parallel to the Tremper Kill mainstem and minimally impacts stream morphology. There are only two locations where Delaware County Route 1 crosses over the Tremper Kill. Wolf Hollow, State Road, Chapell Road and Cabin Hill Road all cross over the Tremper Kill and run perpendicular to the stream. Stormwater runoff from the road ditches adds excess water and pollution – including road salts – directly to the streams without allowing time for absorption into the ground.

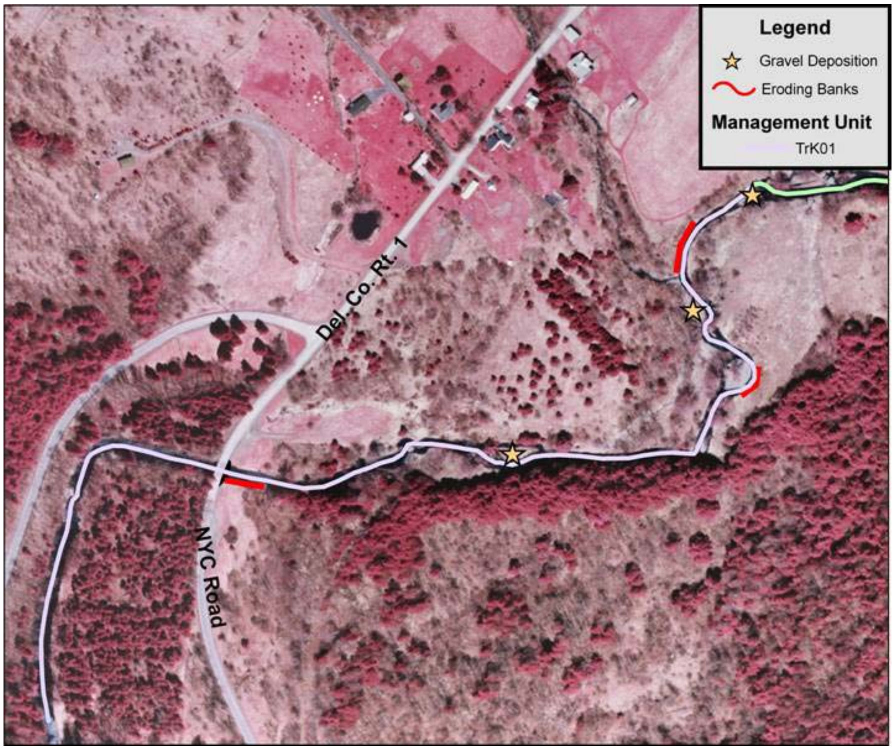
An old railroad bed runs parallel to the Tremper Kill mainstem and has some impacts on the stream. The railroad bed is no longer in use, but riprap had been placed along the streambanks where there was potential for streambank erosion. The riprap in these locations has not been maintained in years and in some locations are in poor condition.

Several bridges are located within this sub-basin at Cabin Hill Road, State Road, and Wolf Road. In addition there are Delaware County Route 1 Bridges #1-3 and #1-5, and some private bridges. Some of the bridges are experiencing erosion upstream and downstream of the structures. Delaware County Bridge #1-3 is creating deposition just upstream of the bridge. The bridge and elevated roadway restrict the flow of water, resulting in sediment deposition.

Management Unit Descriptions

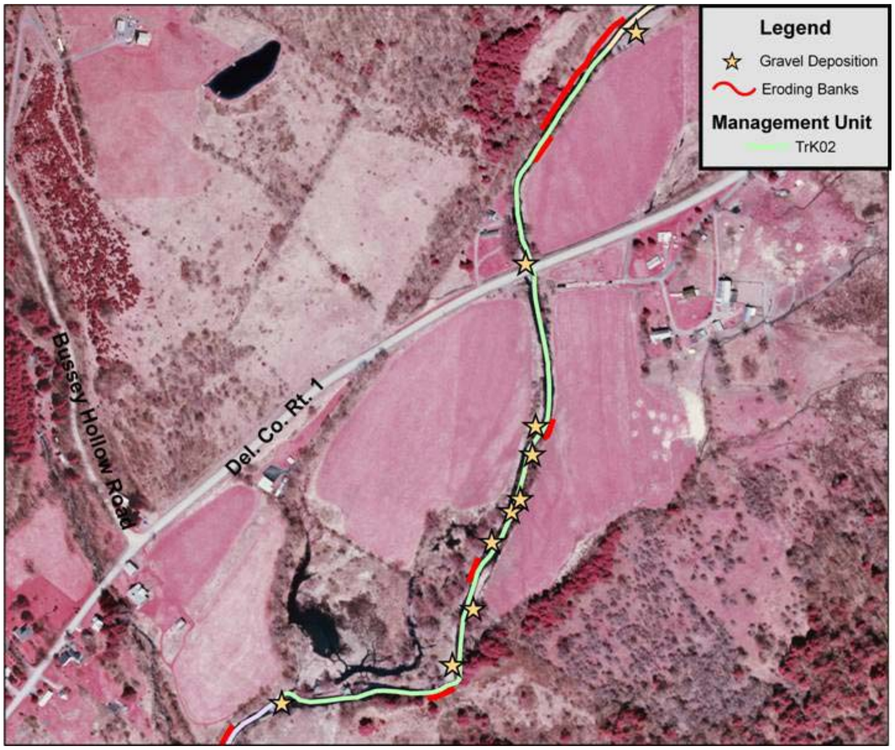


TrK 01



This reach starts approximately at the highwater mark of the Pepacton Reservoir and is about 3,677 feet long, ending about 360 feet upstream from the Bussey Hollow confluence. The stream runs through a broad valley but the upstream portion is greatly influenced by an alluvial fan deposited by Bussey Hollow. As the stream cuts through the highly erodible soil of the alluvial fan, it is constantly meandering and changing course. This creates a very unstable area. Bussey Hollow is the only tributary in this reach and is a significant sediment source to the Tremper Kill. As the stream meanders around the alluvial fan, it is pinched against the left valley wall and forced to make a right angle bend. This could eventually lead to mass bank failure in this area. Delaware County Bridge 1-5 is the only bridge in this reach. Upstream from the bridge is USGS Gage Station #0145000 (Tremper Kill near Andes NY), which is located on the right bank 500 feet upstream from the bridge on Delaware County Route 1. It is about 1,700 feet upstream from the Pepacton Reservoir and 5 miles south of Andes. The drainage area at the stream gage is 33.2 square miles. The period of record that is available for this gage is from February 1937 to the current year. There is a concrete dam at the gage station, which serves as grade control and may have some fish passage issues. There were no observed revetments in this reach, and eroding banks were found in the unstable upstream section of the reach.

TrK 02

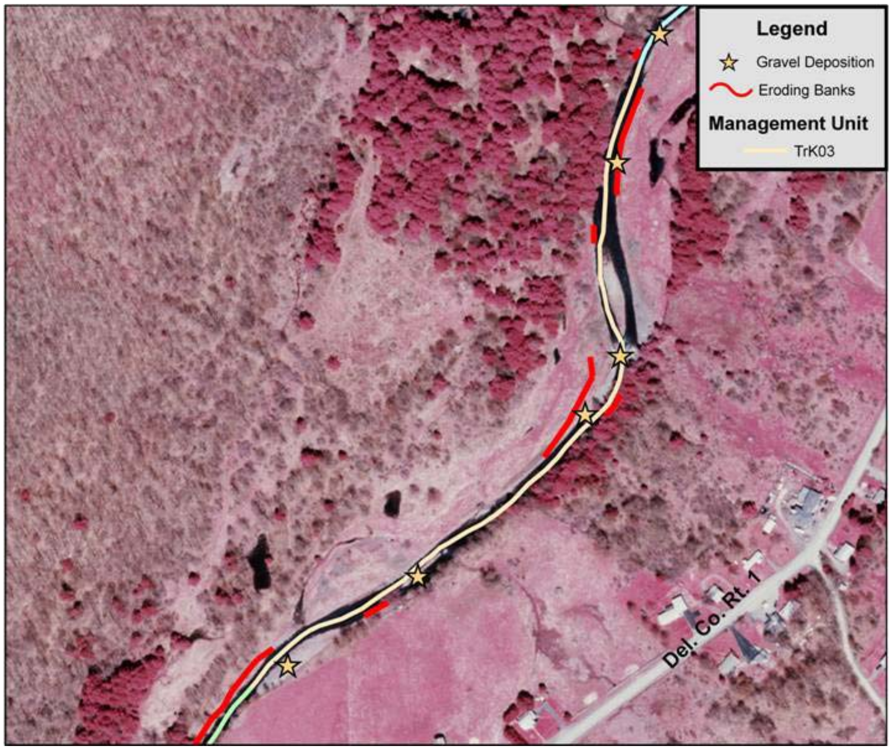


This reach is approximately 2,985 feet long and ends 860 feet upstream from Delaware County Bridge #1-3. The floodplain is very wide and the stream slope is approximately 0.5%, which is the flattest slope in this sub-basin. Above the bridge, the floodplain was cut off in a small upstream section by the old railroad bed. This section of stream appears to be incised for about 700 feet. Delaware County Route 1 bisects the floodplain as it crosses the valley. The elevated roadway and bridge constrict flood flows and results in deposition upstream of Delaware County Bridge #1-3.

Following the 2005 and 2006 flood event, dredging occurred downstream of the bridge and the gravel was stockpiled on the streambanks as a berm to minimize flooding. The stream continued to scour the left bank and floodplain below the bridge. To address the stress on the bank and restore floodplain function, a streambank stabilization project was designed and constructed for this area. The stream bank has been restored with live cribbing and an enhanced riparian buffer. All gravel berms were removed to allow flood flows to spread out onto the floodplain and reduce stress on the streambanks. This streambank project has been implemented by Delaware County SWCD Stream Corridor Management Program (SCMPr) along with the Watershed Agricultural Small Farm Program. A narrow strip of trees has been planted as part of the streambank stabilization project. Prior to the project, 70% of the entire left bank had very little (0-25 feet) woody vegetation.

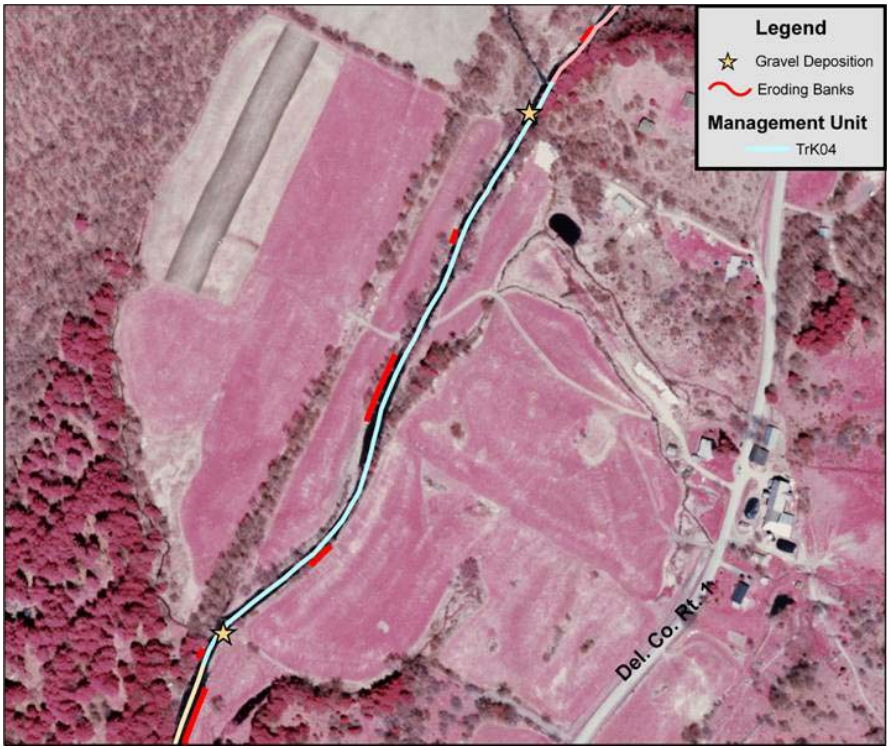
Downstream of this area, the left streambank is eroded where the stream cuts diagonally across the valley and comes in contact with the left valley wall. In this same area, the floodplain on the right is a large wetland. There is a large amount of deposition in the reach due to its flat slope and overly wide stream channel. This deposition is found along approximately 30% of the reach length. Only one unnamed tributary enters this reach.

TrK 03



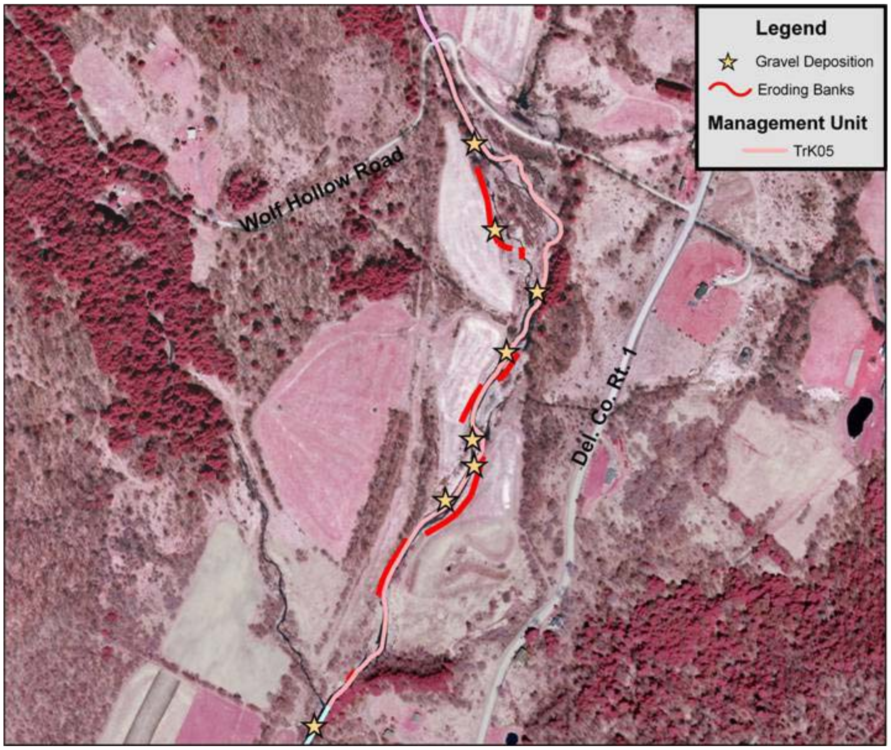
This reach is approximately 2,180 feet long. The valley is narrower through this section and the stream is fairly straight with a sinuosity of <1.1. There are no bridges or tributaries located in this reach. About 40% of the entire reach has eroding streambanks. All of the eroding streambanks have no streamside vegetation. About 70% of the right streambank and 50% of the left streambank has little to no vegetation. The root systems of streamside vegetation hold the bank material together and slow the rate of erosion. Depositional features are large and affect about 40% of the reach length. Along the upstream portion of this reach, the channel is very wide and continues to widen resulting in full-channel deposition and stream channel migration. The lack of riparian vegetation in this area is causing the streambanks to erode quickly. Cattle access to this section of stream could also be impacting the stability of the streambanks due to hoof shear. There is a Conservation Reserve Enhancement Program (CREP) project pending to exclude cattle from the stream and plant trees along the floodplain.

TrK 04



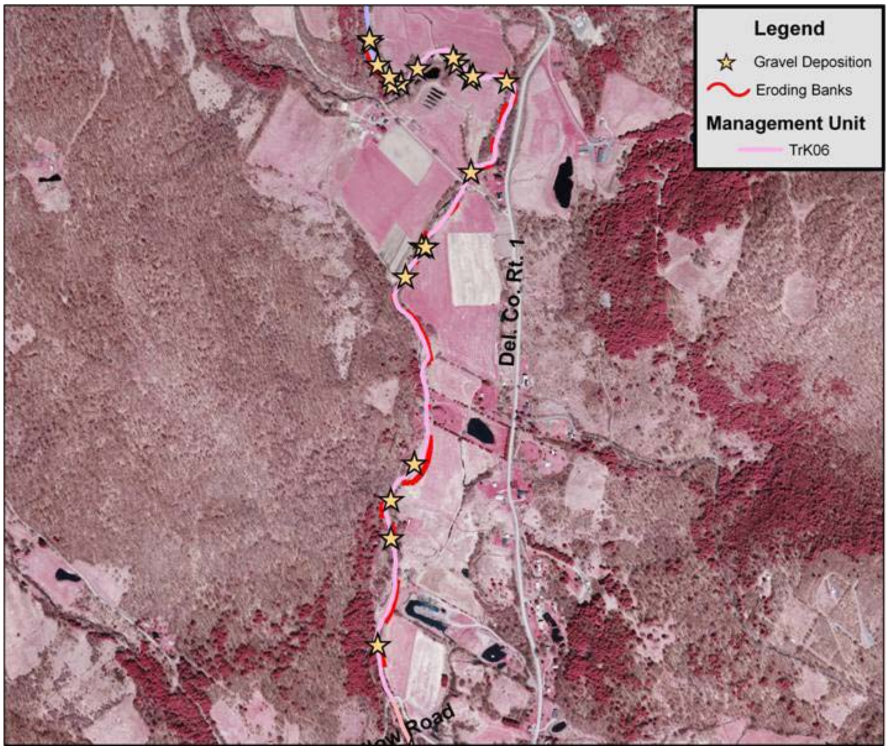
This reach is approximately 1,860 feet long and ends at the confluence with Wolf Hollow. The stream is straight in a very broad valley, but a large part of the floodplain has been cut off by the old railroad bed. The stream corridor land use/land cover is almost entirely agricultural fields. The streambanks generally do have some streamside vegetation, but the buffer is narrow along the top of the banks. About 59% of the left streambank and 45% of the right bank have less than 25 feet of vegetation buffer width. About 18% of the reach has eroding banks that are somewhat protected by the root systems of existing trees, but as mentioned this is a narrow strip of buffer. There is a potential for increase in erosion rate if even a short section of this buffer were to be removed by flood damage, continued erosion, or human activities. There is a 400 feet long berm in the downstream portion of this reach as a result of channel dredging and point bar removal. The stream is trying to put a bend in this location in order to increase the stream sinuosity and decrease the slope. This reach would benefit additional land along the stream set aside as a vegetated riparian buffer. Two tributaries enter into this reach, one unnamed and the other being Wolf Hollow. Wolf Hollow flows through its own alluvial fan, but there appears to be no problem with deposition at the confluence. There is a small delta bar here, but the main channel is transporting the sediment efficiently.

TrK 05



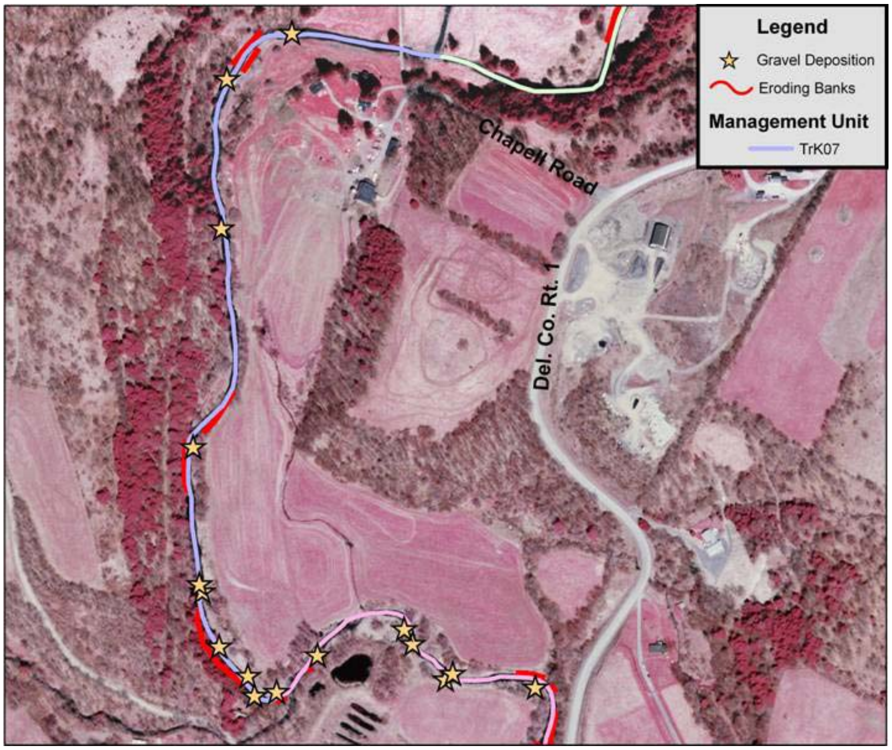
This reach is approximately 3,375 feet long and ends at the Wolf Hollow Road bridge. The valley is generally very broad except for a short section at the downstream end where the alluvial fan of Wolf Hollow pushes the stream up against the left valley wall. The stream is changing its planform in this area by widening its belt width via streambank erosion on the outside of bends and deposition on the inside of the bends. Bank erosion is extensive in this area; about 45% of the reach is experiencing bank erosion. Approximately 80% of the eroding banks have no streamside vegetation, and most of these are in agricultural areas used as corn fields. Deposition features are common in this reach, with transverse bars and side bars that are adjacent to the eroding banks. Stream channel movement and widening will continue to be an issue here due to the lack of streamside vegetation buffers.

TrK 06



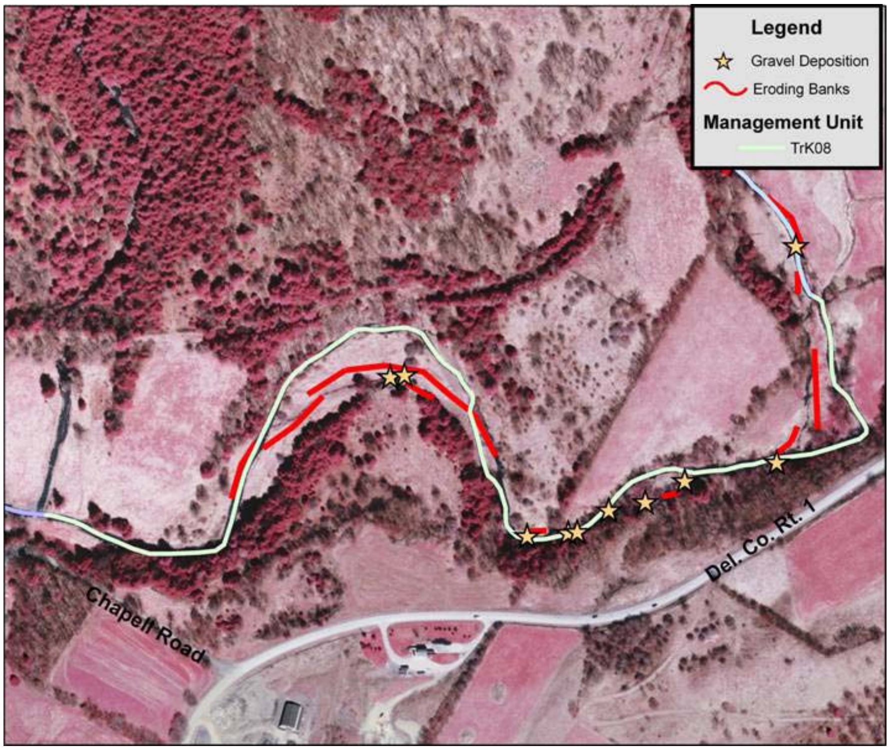
This reach is approximately 7,113 feet long and ends at the confluence of State Road Hollow. The valley is very broad with the stream following the right valley wall along most of the reach. The exception is for the upper portion of the reach, where the stream meanders on the alluvial fan from the State Road Hollow tributary. There are five tributaries that enter within this reach; State Road Hollow and four unnamed tributaries. There are three bridges: one private, the Wolf Hollow bridge, and the State Road bridge. TrK 06 exhibits characteristics similar to the TrK 05 reach. About 43% of the reach contains eroding banks, with 50% of these having a streamside vegetation buffer width less than 10 feet. One large eroding bank is located on the Tubb's property along a cornfield that has no streamside vegetation buffer. The stream is becoming wider and eroding into the corn field, which contains very erodible soil material. Depositional features affect 23% of the stream length, generally including side bars and point bars. Point bars are common in stable C stream type, but the bar forming opposite the Tubb's eroding bank is excessively large. Agricultural land consisting of hay and corn fields is the dominant land use/land cover in the entire reach. Therefore, woodland buffers are narrow or non-existent along the streambanks. About 64% of the stream has 0-25 feet of buffer on one or both banks.

TrK 07



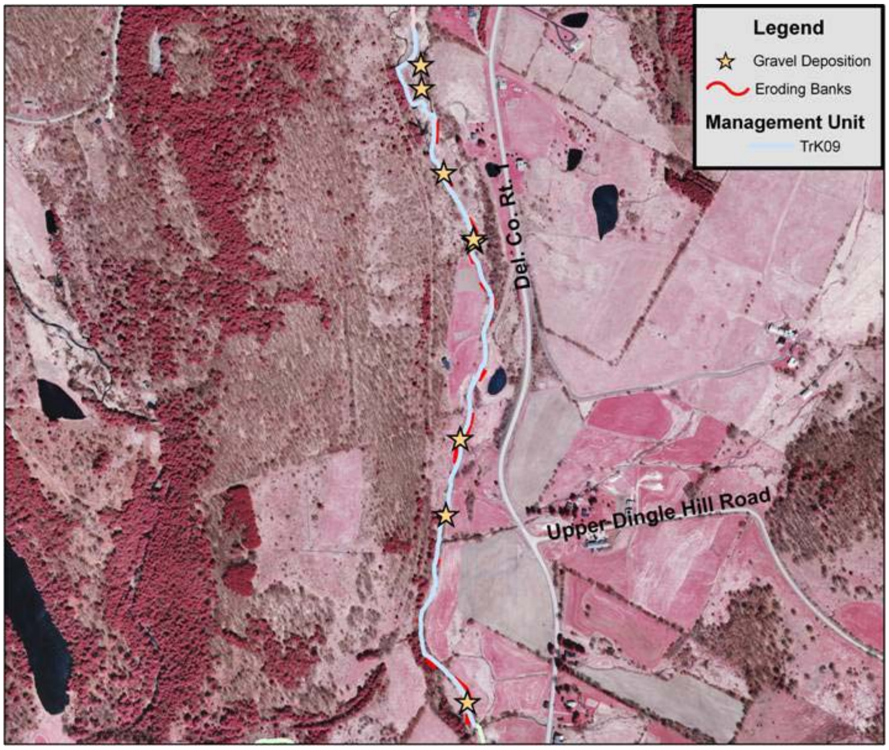
This reach is approximately 3,171 feet long and ends at the confluence with Biggar Hollow, which is the only tributary entering this reach. The stream runs through a very wide valley and is consistently against the right valley wall. The stream appears to have been historically moved against the valley wall and straightened for the agricultural land. There is one private bridge in this reach. The land use/land cover in the corridor is agricultural on the left side of the stream and forested on the right side along the steep valley wall. About 30% of the reach length exhibit eroding streambanks. In terms of area of eroding banks, 78% of the area contains mass failures on high streambanks near the valley wall. About 44% of the stream reach has streamside vegetation buffer widths between 0-25 feet on the left streambank. Depositional features can be found along 29% of the stream length and consist mainly of side bars and center bars in the downstream portion of the reach. One area of deposition across the entire channel allows high flow water to easily access the left floodplain and flow through a corn field. The transverse bar associated with this full-channel deposition is sending normal flow water into the high right bank, causing erosion. The toe of this high bank is being weakened, which could lead to mass failure of this bank. A Rosgen Level II survey consisting of a long profile, cross sections, and pebble counts has been done on about 900 feet of the stream in the middle portion of this reach. This data confirmed that this reach is a C4 stream type, which was originally determined via the SGAT protocol.

TrK 08



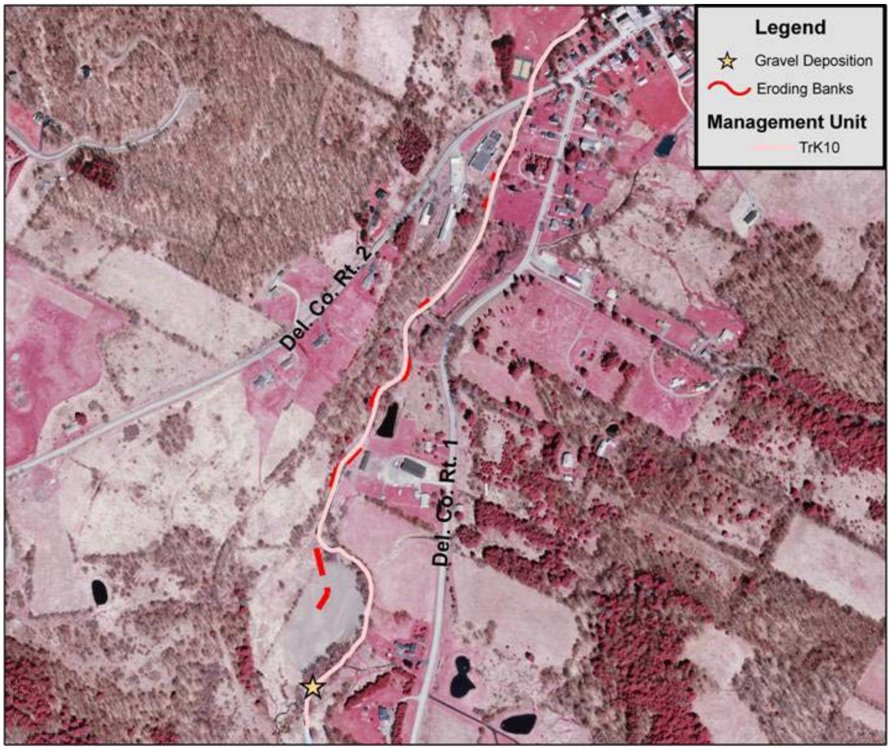
This reach is approximately 3,948 feet long and ends at the confluence of an unnamed tributary near Upper Dingle Hill Road. The valley is much narrower here, but not enough to confine the stream. The land cover within the corridor is forest along the steep streambanks/valley walls and brush/pasture along the floodplain. The stream has recently been changing course within the floodplain which is creating increased streambank erosion. About 44% of the reach length has an eroding bank occurring along it, while about 84% of the eroding banks have no streamside vegetation buffer due to stream channel movement through pasture areas. Depositional features cover 18% of the reach, all of which occur in the upper portion. The types of depositional features consist of a mixture of center bars, side bars and full-channel deposits. The unnamed tributary at the upstream end of this reach has brought large amounts of sediment into the Tremper Kill. Most deposition is just downstream of this point. The areas of the full channel deposition are susceptible to channel migration. There are no structures in the floodplain to protect, so the widely meandering stream is not an issue in that respect.

TrK 09



This reach is approximately 5,133 feet long and runs through a broad valley. Campbell Hollow and two unnamed tributaries enter Tremper Kill. There are two private bridges along this reach. The corridor is a mix of forest, brush land, agricultural land and wetland. The floodplain is primarily cropland, pasture and some wetland. Almost 60% of the reach has a narrow streamside vegetation buffer of less than 25 feet wide or none at all, most of this being on the left streambank. Eroding banks can be found in 31% of the reach length and about 88% of the eroding banks have no streamside vegetation buffer. Deposition is not a major problem in this reach and only 10% of the reach has a depositional feature present. The depositional features consist mostly of side bars. In the upper portion of the reach, the stream has changed course many times since 1963 and has moved across the entire floodplain. The floodplain was once an agricultural field.

TrK 10



This reach is approximately 4,240 feet long and ends at the confluence of Liddle Brook and Gladstone Hollow in the hamlet of Andes. The valley is very broad with the upstream portion containing more residential and commercial land use than the rest of the sub-basin. Within this reach, there is an unnamed tributary and one bridge on Cabin Hill Road. About 30% of the reach has some sort of rock revetment along the streambanks. The majority of the revetments are located in the straightened upper portion of the reach. Eroding banks cover only 21% of the reach. Two sections of eroding banks are categorized as mass failures on high streambanks and account for nearly half of the total area of eroding banks: 3,000 square feet of 6,400 square feet. About 52% of the total length of eroding banks has no streamside vegetation buffer. Deposition seems to occur only in the downstream portion of the reach. In 2005, the stream made a sharp turn left at a wide point in the stream bed about 400 feet downstream from the Andes fire house. During a high flow event, the stream dropped sediment in this wide area and then broke through the right bank into a corn field, creating a new channel and abandoning the old channel. There is no root mass to hold the streambank together in the corn field, so the stream is meandering through this unstable area.

Tremper Kill Summary Sheet

Reach No.	Length Reach (feet)	Stream Type	Dominant Corridor Land Use/Cover	Sub-dominant Corridor Land Use/Cover	Riparian Buffer Width	Number Bridges and Culverts	% Impact of Bank Armoring
TrK 01	3677.3	C	Forest	Brush	Right Bank >100' Left Bank >100'	1	---
TrK 02	2984.7	C	Forest	Brush	Right Bank >100' Left Bank 0-25'	1	5% Not Significant
TrK 03	2180.5	C	Forest	Agriculture	Right Bank 0-25' Left Bank 0-25'	0	8% Not Significant
TrK 04	1859.8	C	Brush	Forest	Right Bank 0-25' Left Bank 0-25'	1	33% High
TrK 05	3375.5	C	Forest	Brush	Right Bank >50-100' Left Bank >100'	0	---
TrK 06	7112.6	C	Forest	Turf	Right Bank >100' Left Bank 0-25'	3	8% Not Significant
TrK 07	3171	C	Agriculture	Forest	Right Bank 50-100' Left Bank 25-50'	1	6% Not Significant
TrK 08	3947.5	C	Forest	Agriculture	Right Bank >100' Left Bank >100'	0	---
TrK 09	5132.9	C	Forest	Wetland	Right Bank >100' Left Bank 0-25'	2	14% Low
TrK 10	4240.5	C	Forest	Brush	Right Bank 0-25' Left Bank 0-25'	1	28% Low

Reach No.	% Impact Berms, Roads, Railroads, Paths	Impact Floodplain Development	Impact Depositional Features	Impact Meander Migration	Bank Erosion/ Bank Height	Ice/ Debris Jam Potential (Yes/No)
TrK 01	23% High	Not Significant	High	High	Low	No Info
TrK 02	24% High	Low	Low	Low	High	No Info
TrK 03	---	Not Significant	Low	High	High	No Info
TrK 04	---	Not Significant	Not Significant	Low	Low	No Info
TrK 05	20% High	Not Significant	Low	High	High	No Info
TrK 06	10% Low	Low	Low	Low	High	No Info
TrK 07	---	Low	Low	Low	High	No Info
TrK 08	---	Not Significant	Low	Low	High	No Info
TrK 09	5% Low	Not Significant	Not Significant	High	High	No Info
TrK 10	9% Low	High	Low	Low	High	No Info

BUSH KILL SUB-BASIN

Towns of Middletown, Halcott, Roxbury and Shandaken

Introduction

The Bush Kill watershed is located within four different townships: the Town of Middletown and Roxbury in Delaware County, the Town of Halcott in Greene County, and the Town of Shandaken in Ulster County. The Village of Fleischmanns is the only population center along the Bush Kill mainstem. The Bush Kill mainstem was separated into six management units based upon the SGAT protocol. Vly Creek is a tributary to Bush Kill and flows from Halcott, south into the Bush Kill. Vly Creek was divided into 9 management units.

The Bush Kill mainstem, at the confluence with Dry Brook, is a fourth order stream. In addition to numerous unnamed tributaries, there are four major tributaries that enter the mainstem: Red Kill, Vly Creek, Little Red Kill, and Emory Brook. Tributaries entering the Bush Kill mainstem appear to have minimal impact on sediment load on the mainstem. The drainage area of the Bush Kill is approximately 47.18 square miles. The mainstem is 4.8 stream miles from the confluence of Dry Brook mainstem upstream to the confluence of Vly Creek and Emory Brook. The Vly Creek mainstem is approximately 9.4 stream miles long and the drainage area is 22.5 square miles. Both the Bush Kill and Vly Creek are primarily C stream types. Some sections of Vly Creek are C/B, B, and A. The Bush Kill watershed valley is generally broad to very broad towards the headwaters and narrow to broad near the confluence. The land is predominately forested and residential. The average annual rainfall in the watershed can range from 37-41 inches/year for the Bush Kill mainstem and 41-49 inches/year in the headwaters.

Stream Assessment

Data was collected using the SGAT protocol, two helicopter flights for Vly Creek and the Bush Kill, and Global Positioning System (GPS) walkover assessment were performed on 1.3 miles of the Bush Kill mainstem and 3.6 miles of Vly Creek. Additional stream data to complete the entire mainstem was collected using the helicopter video logging.

Figure 1.7 Vly Creek Step Pool Sequence

Monitoring sections were examined in two areas of the sub-basin: Vly Creek and Lake Switzerland. Rosgen Level II surveys were completed for one stream reach of Vly Creek. The analysis of the Rosgen

Level II resulted in an F stream type for the study reach. This area was identified as a possible reference during the Project Advisory Committee (PAC) visioning session processes. **Figure 1.7** illustrates a step pool sequence on Vly Creek.

The monitoring section in the Lake Switzerland project site examined channel migration in silty deposits of the old lake bed. Photo locations were established to ensure consistent documentation for channel and changes following high flow events.

Geomorphic Conditions

Bush Kill

The SGAT protocol classified the Bush Kill as a type C stream with sinuosity on the low side, ranging between 1.00 and 1.13. No Rosgen Level II survey was completed on the Bush Kill. The following statistics were generated from the various assessments of the Bush Kill:

- 23% of the total streambank length has revetment streambank protection.
- There are 25,414 feet of eroded streambanks at 37 separate locations.
- Approximately 11,552 feet of streambank are bermed (22.75%).
- There are 23 gravel deposition bars, which is equivalent to 1.6 features per mile of stream.

Based on the above information from the assessment, it is evident that the primary problem facing the Bush Kill is streambank erosion as a result of the impact of development. A significant percentage of the stream channel is bermed and revetted. The overall sinuosity is very low indicating that the stream has been straightened by development. The land use along the stream corridor in numerous locations is very intensive and encroaches or limits access of the stream to its floodplain. Confinement of the channel increases the energy of the storm flows which increases shear stress and erosion potential on the streambanks. This encroachment is especially significant within Fleischmanns and the downstream hamlet of Clovesville. Stormwater inputs to the system are likely impacting water quality.

In BsK 01, about 6,000 feet below the railroad bridge, the stream is migrating to the left according to historical aerial photographs. The stream makes a large bend to the right and hits directly against the steep slope embankment. Floodplain access is good at this location and the stream has room to adjust its course. This location should be monitored, but it is assumed that in time it will create its own bend to the left. Gravel deposits at the mouth of the Bush Kill near the confluence of Dry Brook do not appear to be a severe problem.

Vly Creek

The stream slope is in the range of 1% to 1.5% except in the upper reaches where the headwaters exhibit steeper slopes. The sinuosity is slightly low, ranging from 1.06 to 1.17 and the reaches are classified as stream types C, B, or Cb. The stream channel bed consists mainly of cobble material. Using the SGAT protocol supplemented by helicopter flyovers and GPS walkovers, the following descriptors for the stream condition can be listed:

- Gravel deposition is rated as having no significant impact
- There is approximately 3,900 feet of revetment and most of it is concentrated in VlC 01 with 1,935 feet and VlC 02 with 680 feet
- Few berms were located in Vly Creek, however, according to the SGAT protocol roads do impinge on the stream corridor. The extent of the impact is not clear from the level of assessment performed for this system.

Based on the above comments, it appears that erosion is the main problem facing Vly Creek. Overall, Vly Creek is in good condition. The main recommendation would be to use fluvial geomorphic principles to address any issues concerning stream performance that may arise. The goal would be to not upset the system or introduce disequilibrium to an otherwise well-functioning stream system.

The DCSWCD SCMPr staff has performed a Rosgen Level II survey at the Kasanoff property in reach VlC 06. This reach seemed to be fairly representative of what was seen repeatedly on Vly Creek. The drainage area at this location is 9.51 square miles and according to the regional curves, the bankfull discharge is 297 cubic feet per second (cfs). The following table compares the predicted dimensions of the stream (using the regional curves) to those measured in the field:

Table 1.5 Stream Dimensions

Computed From Regional Curve	Dimension	Measured in Field Survey
57 sq. ft.	A_{bf}	70 sq. ft.
31.1 feet	W_{bf}	40 feet
1.83 feet	D_{bf}	1.75 feet

Other important relations are:

1) Entrenchment ratio = 1.3
2) Width/depth ratio = 23
3) Shear stress = 0.9 pounds/square feet
4) Hydraulic radius = 1.7
5) Slope = 0.0083

An interesting feature of this reach is the series of four contiguous boulder pools at the upstream end of the reach. The pools were carefully surveyed to obtain plan and profile information about naturally occurring boulder pools for use in future restoration designs for high gradient streams. The survey also identified two terraces on the left streambank and a steep hillside on the right bank. Presumably, at one time all the floodplain was on the left side of the stream. It is likely that Vly Creek stream has downcut in the past and is in the process of downcutting again. It is not known for certain why this process is occurring. However, cows have access to the stream just upstream of the surveyed area. The stream at this upstream location is very wide, shallow, and choked with gravel deposition. It is possible that the stream deposits all of the bedload at this wide section, while downstream areas have become sediment starved. As it enters the pool at the top of the survey reach, the stream picks up the gravel and small cobbles, leaving behind large cobbles and boulders. Overall, this reach is classified as stream type F. The boulder pools may be an anomaly, or they may serve as a transition between this reach and the steeper upstream reach. Also, in this region step pools of various sorts are not unusual on a relatively flat stream. According to the British Columbia Channel Assessment Guide, this reach is classified as a riffle pool cobble (RPc) and is degraded.

The most pressing problem facing this reach is the lack of stream access to the floodplain. This reach is a convenient location for monitoring changes to the Vly Creek watershed.

Floodplains

The Village of Fleischmanns is built along the mainstem of Bush Kill. Revetment was used along the stream to protect development areas. The revetment is in poor condition and in need of repair in many locations. **Figure 1.8** shows a failing revetment wall protecting a developed area in the Village of Fleischmanns.

Figure 1.8 Failing Revetment Wall

Development along the Bush Kill is becoming a significant concern. Areas of the floodplain are being filled and used for material storage. This results in a net loss of floodplain and increased flood impacts for upstream and downstream landowners. Private driveways located in the floodplain were washed out in the recent high flow events and were replaced. The January 1996 flood disaster severely damaged homes and infrastructure within this corridor. Additional development within the floodplain has occurred since the 1996 flood and will likely increase the damages in future events of similar proportions. Downstream from Fleischmanns and Clovesville, New York State Route 28 and the railroad bed restrict the width of the floodplain. As they run parallel with the stream, the bridges severely pinch the floodplain down to only the bridge opening.

There is less development along Vly Creek mainstem and the land use is mainly forested and hay fields.

Infrastructure

Roads built in close proximity to streams are generally found to encroach on the floodplain. During the SGAT protocol Phase 1 assessment, it was difficult to determine if a road was in the floodplain or on a terrace above the floodplain. Many portions of the floodplain could be affected by roads cutting off available floodplain area. New York State Highway 28 and Old Route 28 run parallel to the Bush Kill mainstem. Several private driveways enter perpendicular to the stream and have an impact on stream access to the floodplain during high flow events. Delaware County Route 37 and Greene County Route 3 run parallel to the Vly Creek mainstem. There are a few areas in which the road is close to the mainstem where revetment was placed in order to protect the road (see **Figure 1.9**).

Figure 1.9 Revetment for Road Protection

There are bridges located on New York State Highway 28, Delaware County Route 37, Greene County Route 3, Old Route 28, Depot Street, Bridge Street, Main Street, and numerous private bridges.

The Delaware and Ulster railroad bed runs parallel to the Bush Kill mainstem and impacts the stream in places by narrowing the floodplain. The impact results in greater erosion pressure on the streambanks. To protect the railroad line from the erosion, revetment has been placed along the streambank. The railroad crosses over the river in one location just upstream of the confluence with Dry Brook.

Stream Management

Lake Switzerland is located in VlC 02 on Vly Creek. The dam was partially removed due to public safety concerns, leaving a short section intact to serve as grade control. The DCSWCD SCMPr received a grant to plant trees to stabilize the newly created stream channel flowing through highly erodable soil. Cross sections were placed in this reach in order to monitor the movement of the stream

Figure 1.10 Lake Switzerland Post-Dam Removal

and photo documentation is extensive for this area. **Figure 1.10** is a helicopter picture (04/28/05) of Lake Switzerland after the dam removal project. The lower left corner of the picture depicts the water spilling over the remnants of the dam.

Figure 1.11 June 2006 Knotweed Growth

A demonstration project for Japanese Knotweed eradication was identified in the Town of Halcott at the intersection of Greene County Route 3 and County Route 1. A volunteer group is working closely with the DCSWCD SCMPr staff to eradicate a patch of knotweed in the headwaters of the Bush Kill on the West Settlement Creek tributary. There are few knotweed patches along Vly Creek and this site was a good candidate for a project.

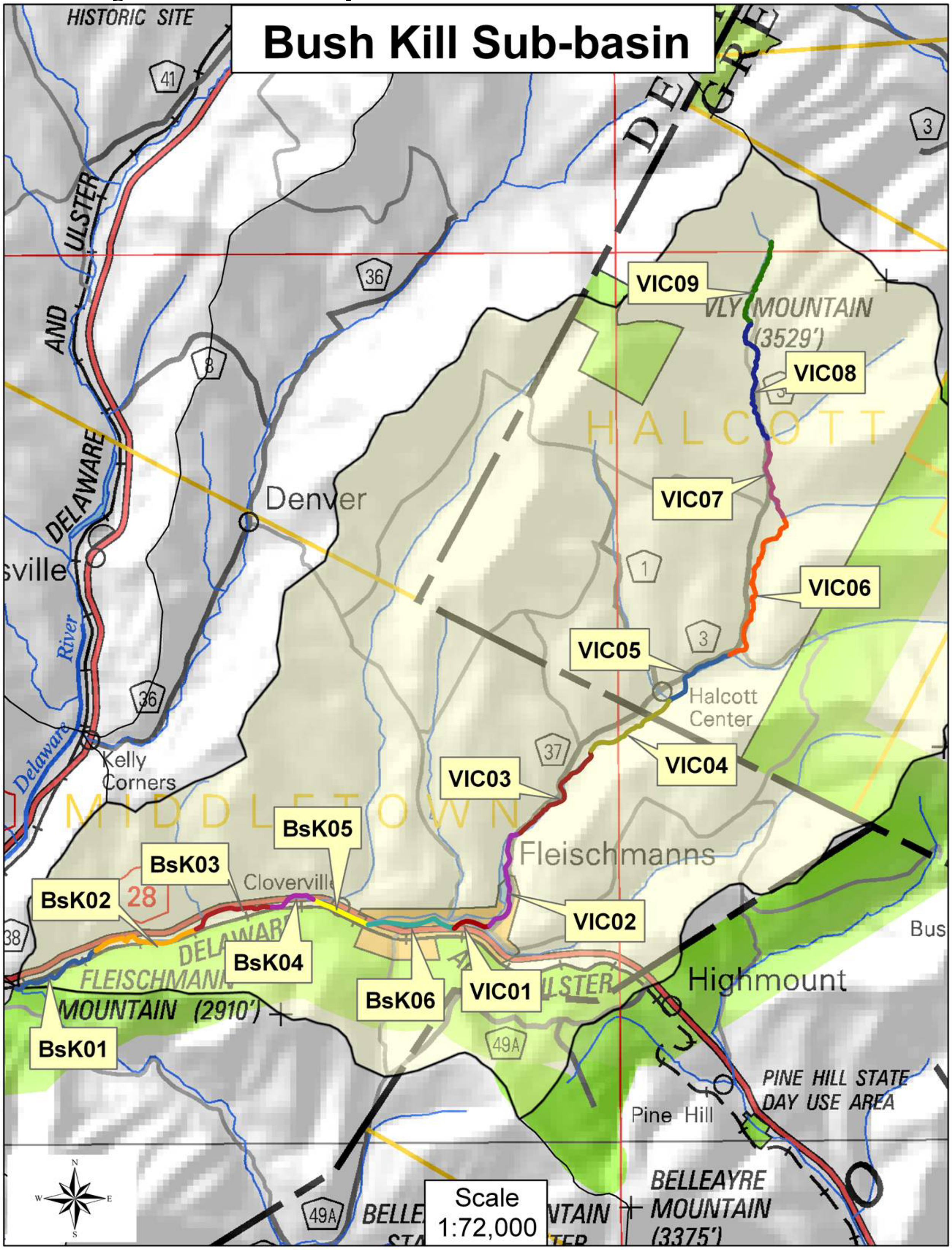
Figure 1.12 August 2006 Knotweed Growth

The group has named the project site "Knot-A-Lot". The area of the project is approximately 990 square feet on the left bank and 640 square feet on the right bank. An area of knotweed continues up onto the floodplain and the right side of the stream. This area was determined to be the control site for the demonstration project and identified as a possible candidate for a future eradication project. The knotweed height was approximately 8 feet tall when the first cutting was completed in June 2006. **Figure 1.11** shows the height of the knotweed prior to the first cutting, while **Figure 1.12**shows the knotweed re-growth in August 2006 after several cuttings. Every three weeks the plot was cut, the stalks were dried, and then burned. The height of the new growth in August and September was approximately 1-2 feet tall. September was the last cutting of the year and by then the knotweed plants were fewer and easier to pull out by hand. During the last visit, it was noticed that other types of vegetation were starting to grow in place of the knotweed.

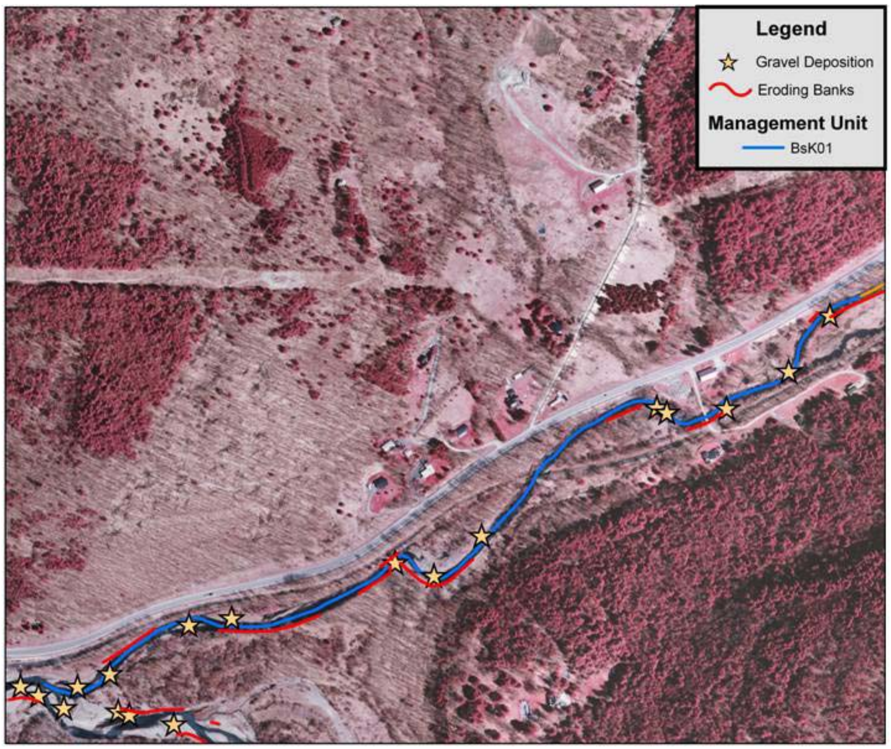
The project continued in 2007 growing season. The knotweed was found to be sparse and the height was approximately 12 inches high. The group planted lilies and irises on the left streambank to help fight the knotweed. **Figure 1.3** shows the left streambank after the second season of the eradication project. Education is a key role in knotweed awareness, so it was important to notify the community about the project. An article was written and published in the Halcott Times and a poster was on display at the Halcott Community Fair on July 21, 2007.

Figure 1.13 September 2007 Knotweed Growth

Management Unit Descriptions

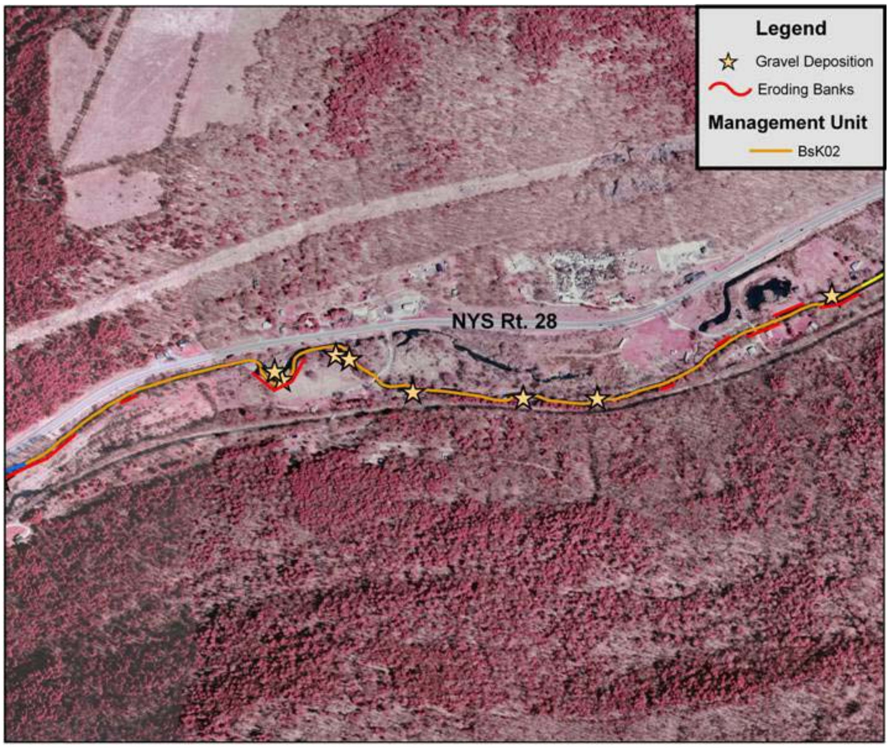


BsK 01



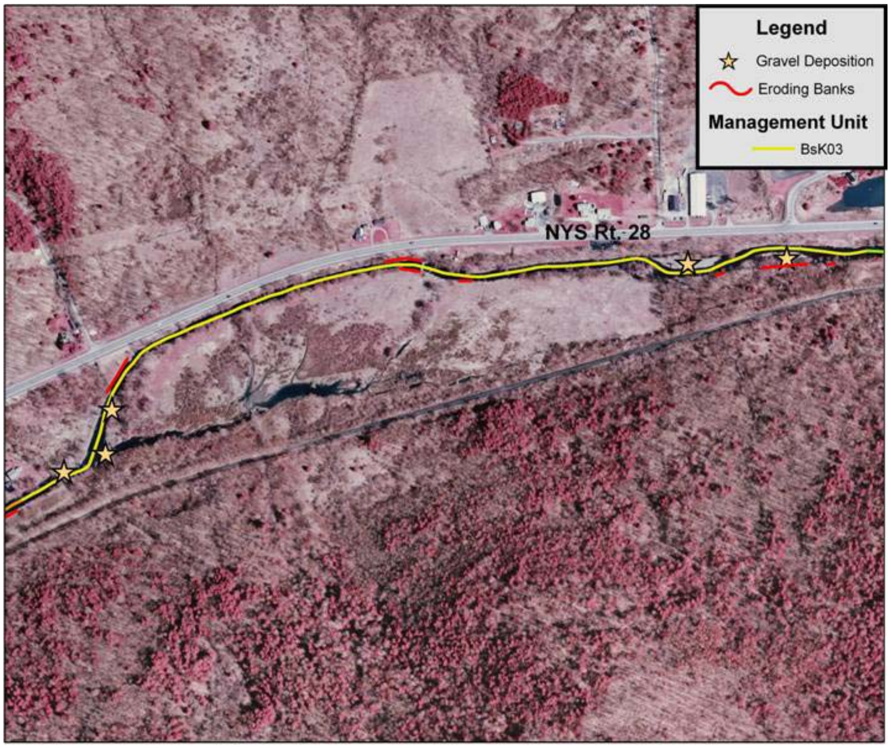
This reach begins at the confluence of Dry Brook and runs upstream for about 5,059 feet. One unnamed tributary enters into the upstream portion. Two bridges (a railroad and a private bridge) are in the reach along with USGS Gage Station #01413398 (Bush Kill near Arkville NY), which is located on the left bank 60 feet upstream from the private bridge. It is 0.7 miles upstream from the confluence and 2.35 miles east of Margaretville. The drainage area at the stream gage is 46.7 square miles. The period of records that are available for this gage is from October 1997 to the current year. The channel slope is fairly flat 0.004 (0.4%) and the stream's limited sinuosity (1.07) reflects the narrow valley setting and valley's principle land use as a major transportation corridor. The corridor is primarily forested, but about 20% of the corridor area is considered "built-up" due to impervious surfaces (NYS Rt. 28). Impervious surfaces lead to accelerated stormwater run-off. About 43% of the reach has a streamside vegetation buffer of less than 25 feet wide. This high percentage is due to the stream being close to the railroad bed or NYS Rt. 28. About 44% of the reach length has an eroding bank on one side of the stream bank or the other. Most of these eroding banks have streamside vegetation buffers and the tree roots on the streambanks are helping to slow the rate of erosion. There are 12 gravel depositional features in this section that make up 26% of the reach length. Four of these are identified as point bars which are expected in this "C" stream type. The rest of the gravel depositions are identified as side bars and center bars. The floodplain in the area of the railroad bridge is cut off by the raised railroad bed. During high flow events, water on the floodplain must funnel under the bridge. This concentrated flow may be creating too much energy and may be causing the odd meander bend downstream. Further study will be needed to determine if the stream function would benefit from an alignment adjustment in this area.

BsK 02



This reach is about 5,820 feet long with a slope of 0.0031 (0.31%) and a low sinuosity of 1.1. The stream appears to have historically been straightened through this narrow valley. There are two private bridges crossing over the stream. The corridor land cover is about 70% forest/brush, while 24% is considered urban partially due the impervious surface of NYS Rt. 28. About 93% of the reach length has a 0-25 feet wide riparian buffer on at least one side of the stream. This large percentage is because the stream is so close to NYS Rt. 28 and the railroad bed. Approximately 30% of the reach has streambank erosion on at least one bank. 72% of these eroding banks have no riparian vegetation buffer. Depositional features, consisting of side bars and center bars, can be found in 12% of the reach length. Streambank revetment is limited to the downstream portion of this reach where about 1,700 feet of sloped stone protects NYS Rt. 28. One small section of stream near this revetment has created a sharp meander bend. The stream has widened considerably at this point and formed two large center bars. From historic aerial photos, the stream has moved at least 160 feet since 1983. The eroding bank has no streamside vegetation and is an area that is maintained as a lawn.

BsK 03

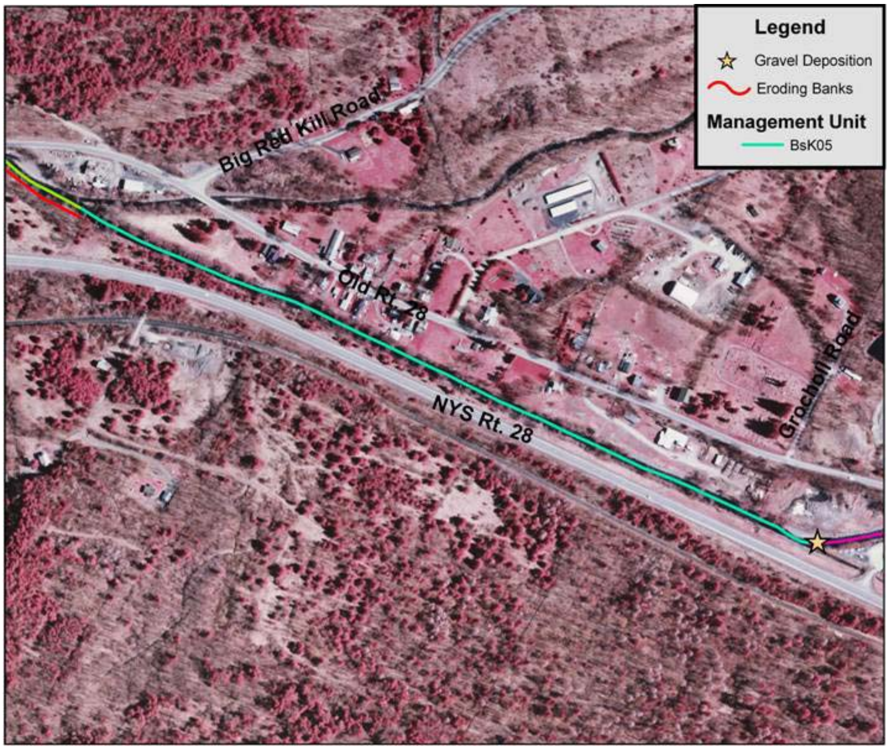


This reach is approximately 4,402 feet long, with characteristics similar to BsK 02. The straight stream runs through a broad valley. There is one unnamed tributary that enters the Bush Kill and one private bridge. The corridor is 60% forest/brush and about 23% urban or impervious. About 15% of the reach has an eroding bank and 42% of these banks have little to no woodland buffer for stabilization. About 13% of this section's length contains side bars and center bars as depositional features. There are 1,500 feet of sloped stone revetment placed along the right bank where the stream runs parallel to NYS Rt. 28. This section of stream is meandering in a fashion similar to BsK 02. According to historical aerial photography, there is a small meander and a side bar that has formed sometime since 1983 opposite of Kleis Road. One difference here is that the left bank on the outside of the bend has a sufficient riparian vegetation buffer.

BsK 04

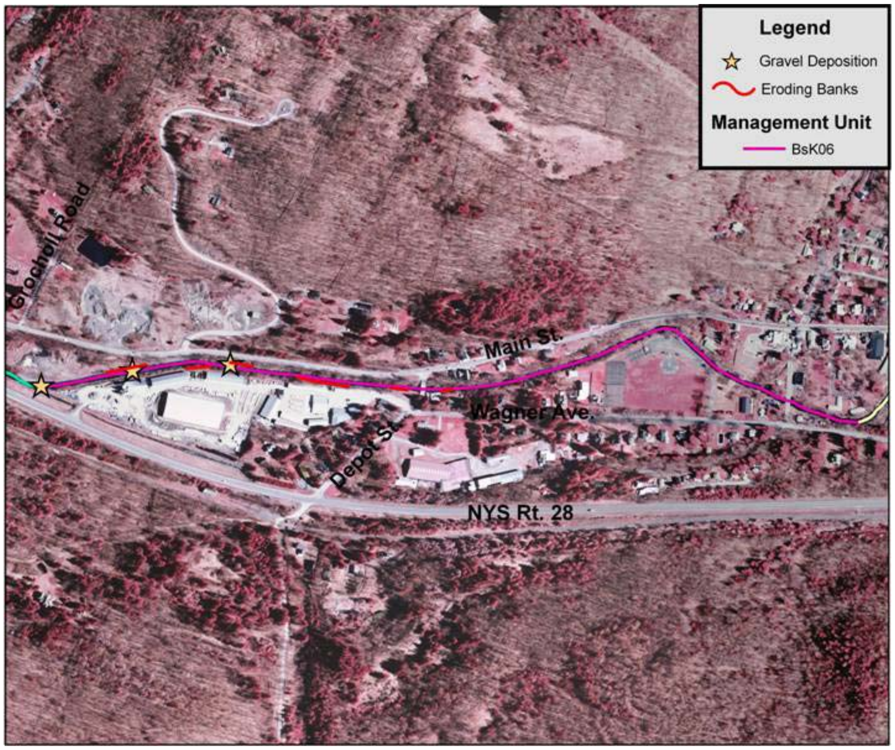
This reach is approximately 2,408 feet long and ends at the confluence with the Big Red Kill tributary. The valley is broad, but restricted by NYS Rt. 28 running parallel to the Bush Kill. The Red Kill has a delta bar forming downstream of its confluence with the Bush Kill. An unnamed tributary also enters the Bush Kill. Downstream of where the Bush Kill flows under the NYS Rt. 28 bridge, there is a side bar forming. The land cover in this stream corridor is about 60% forest/brush and 17% urban. Eroding banks are along approximately 18% of the reach and are mainly located in the area of the Red Kill confluence. The longest two eroding banks have a riparian vegetation buffer and the roots are helping to hold the bank soil material together. This reach was significantly impacted by the loss of access to a substantial floodplain with the re-alignment of NYS Rt. 28.

BsK 05



Situated in a narrow valley, this reach is approximately 3,097 feet long and nearly perfectly straight as it runs parallel to NYS Rt. 28. The straightened stream is steeper (1.0% slope) than upstream and downstream reaches. The narrow valley, steep slope, straight alignment, and confined channel contribute to accelerated stream flows through this reach. Land use in the corridor is primarily residential on the right side of the stream in the hamlet of Clovesville while NYS Rt. 28 occupies the left side. About 57% of the corridor is considered urban area, the impervious surface of which contributes to accelerated stormwater run-off rates. Approximately 80% of the left bank and 87% of the right bank have narrow riparian vegetation buffers between 0-25 feet wide. Riparian vegetation buffers, in addition to their roots holding the bank together, help to filter stormwater run-off pollutants and enhance water quality. There is extensive revetment in this reach. About 97% of the left bank along NYS Rt. 28 consists of sloped stone and almost 50% of the right bank has stone revetment. There were no observed eroding banks or depositional features. Residences along this reach were significantly impacted by flood waters and debris in the 1996 flood with several structures considered or approved for the flood buyout program. This reach should be considered for future flood hazard mitigation measures.

BsK 06



This reach is approximately 4,627 feet long and ends where both Vly Creek and Emory Brook enter the Bust Kill mainstem. This channelized stream runs through a broad valley and through the Village of Fleischmanns. The Little Red Kill is the only tributary entering in this reach. There are two bridges that cross over the Bush Kill, both within the village on Depot Street and Bridge Street. The corridor is "built-up," with 60% considered urban area. Narrow riparian vegetation buffers that are 0-25 feet wide run the entire length of the left bank and almost 80% of the right bank. Eroding banks in this reach account for 19% of the entire stream length. There are only a few gravel deposition features in this reach due to the inability of the channelized stream to meander. Roughly half of the reach has a berm on at least one streambank. The downstream portion of this reach has a berm on the left bank and the right bank is a steep valley wall. The stream has no access to its floodplain in this area during high water events. This creates a very entrenched channel that puts more shear stress on the streambanks. About 95% of the eroding banks are located in this part of the stream. Revetments of many different types cover 41% of the entire stream reach length. This stream reach, like any stream that runs through a populated area, has been channelized, manipulated, and maintained for a long time. Through the Village of Fleischmanns, different types of walls were built to prevent the stream from meandering. Many of these walls are in poor condition and should be repaired or modified in places where there is potential for failure. This reach was severely impacted in the 1996 flood. The continued development and material storage within the floodplain since this event will only exacerbate damages in future similar sized floods. Flood hazard mitigation and improved floodplain management should be a priority for this reach.

Bush Kill Summary Sheet

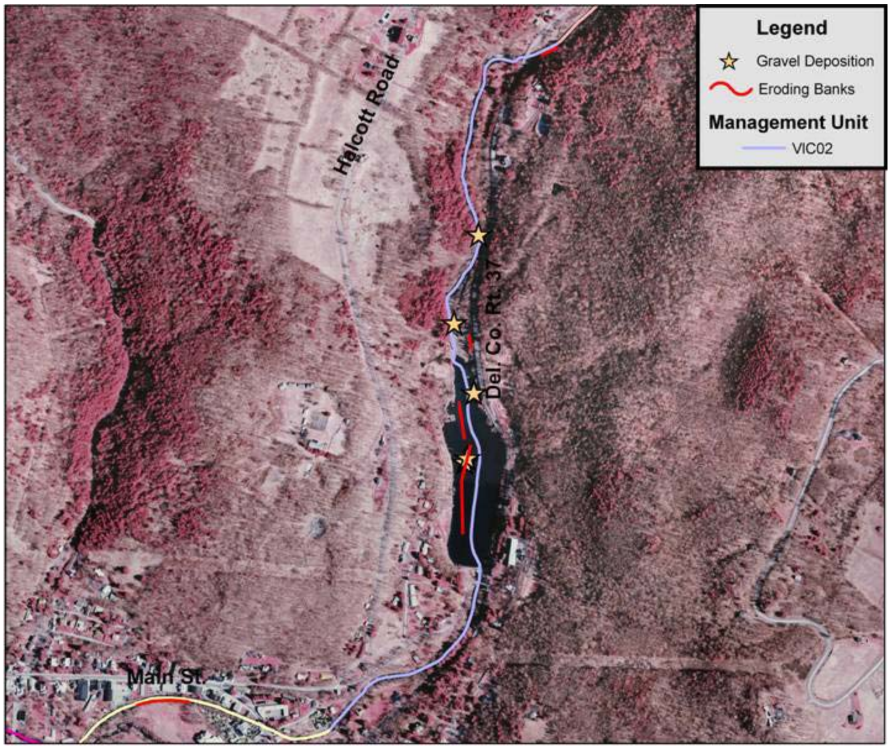
Reach No.	Length Reach (feet)	Stream Type	Dominant Corridor Land Use/Cover	Sub-dominant Corridor Land Use/Cover	Riparian Buffer Width	Number Bridges and Culverts	% Impact of Bank Armoring
BsK 01	5059	C	Forest	Residential	Right Bank >50-100' Left Bank >100'	2	9% Not significant
BsK 02	5821	C	Forest	Residential	Right Bank 0-25' Left Bank 0-25'	2	31% High
BsK 03	4401	C	Forest	Residential	Right Bank 0-25' Left Bank 0-25'	1	35% High
BsK 04	2408	C	Forest	Wetland	Right Bank 0-25' Left Bank >100'	1	27% Low
BsK 05	3096	C	Residential	Forest	Right Bank 0-25' Left Bank 0-25'	0	97% High
BsK 06	4626	C	Built-up	Forest	Right Bank 0-25' Left Bank 0-25'	2	57% High

Reach No.	% Impact Berms, Roads, Railroads, Paths	Impact Floodplain Development	Impact Depositional Features	Impact Meander Migration	Bank Erosion/ Bank Height	Ice/ Debris Jam Potential (Yes/No)
BsK 01	88% High	Low	High	High	High	Y
BsK 02	80% High	High	Low	Low	High	Y
BsK 03	87% High	Low	Low	Low	Low	N
BsK 04	100% High	Low	Low	Not significant	Low	Y
BsK 05	100% High	High	Not significant	Not significant	Not Significant	N
BsK 06	100% High	High	Not significant	Not significant	High	N

VlC 01

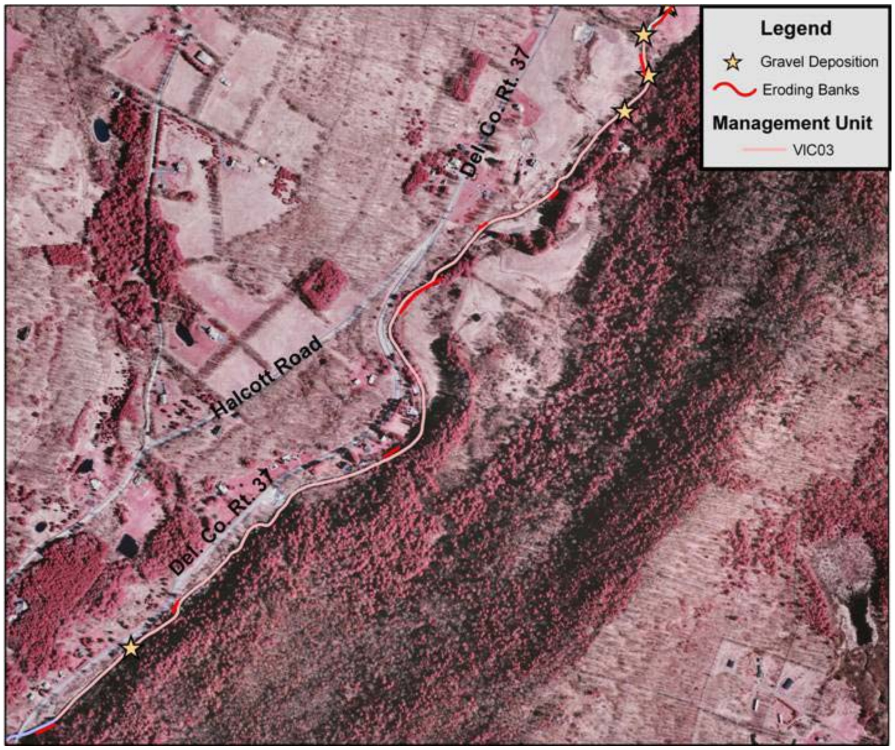
This reach is approximately 1,994 feet long and starts where both Emory Brook and Vly Creek flow into the Bush Kill mainstem. This section of stream is in a broad valley and runs through the Village of Fleischmanns. The stream corridor is built-up and is 67% urban. Two bridges, located on Main Street and Mill Street, cross the stream in this reach. There is one section of eroding bank that accounts for 18% of the reach length. The lower half of this area is an entrenched stream channel that shows slight erosion along the banks. The upper portion of the reach has a narrow woodland buffer where the roots are reinforcing the streambank soil materials. About 82% of the reach length has some form of revetment along the streambank through the Village of Fleischmanns. Many of these walls are in poor condition and should be repaired or modified in places where there is potential for failure. This reach is similar to BsK 06 in that it is entrenched and contained in its channel.

VIC 02



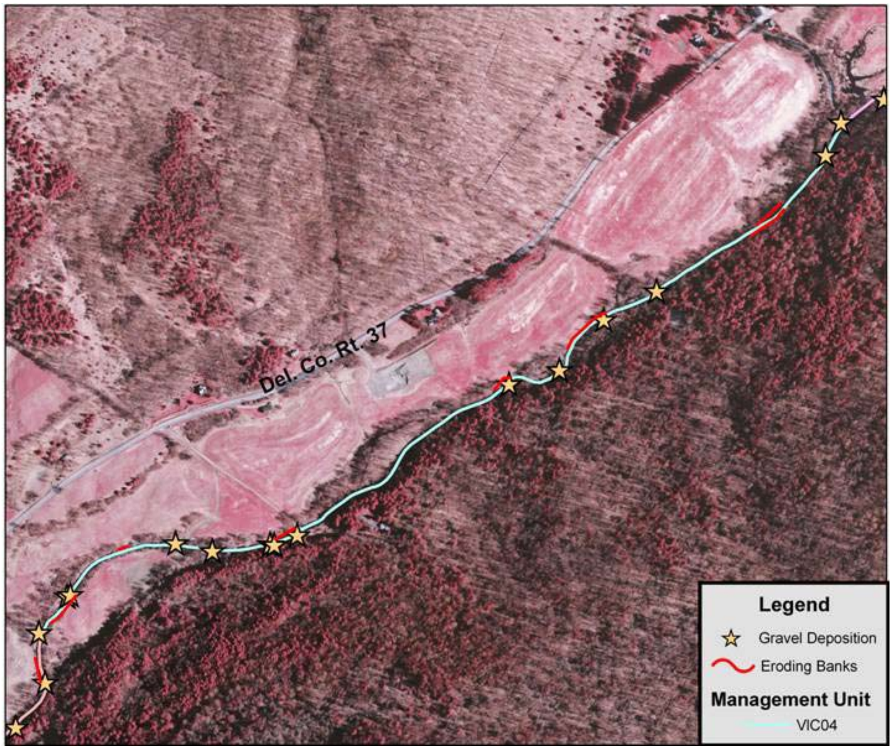
This reach is approximately 5,871 feet long and ends just upstream of Delaware County Bridge #37-1. The stream runs through a narrow valley with a slightly steeper channel slope (1.5%) than other stream reaches in this sub-basin. Almost 40% of the reach length has exposed bedrock on the streambank or in the channel bed, found mostly upstream of the former Lake Switzerland. Forest/brush land account for 80% of the stream corridor land cover. About 18% of the reach has eroding banks, primarily within the former Lake Switzerland where the stream is working through fine sediment deposits from the old lake bottom. The DCSWCD SCMPr staff planted willow fascines at the top of the streambanks to help hold the soil in place. Approximately 38% of the reach has a narrow riparian buffer due to the proximity of Delaware County Route 37 running parallel to the stream. One unnamed tributary enters at the upstream end of this reach and three bridges cross the stream: two foot bridges and Delaware County Bridge #37-1.

VIC 03



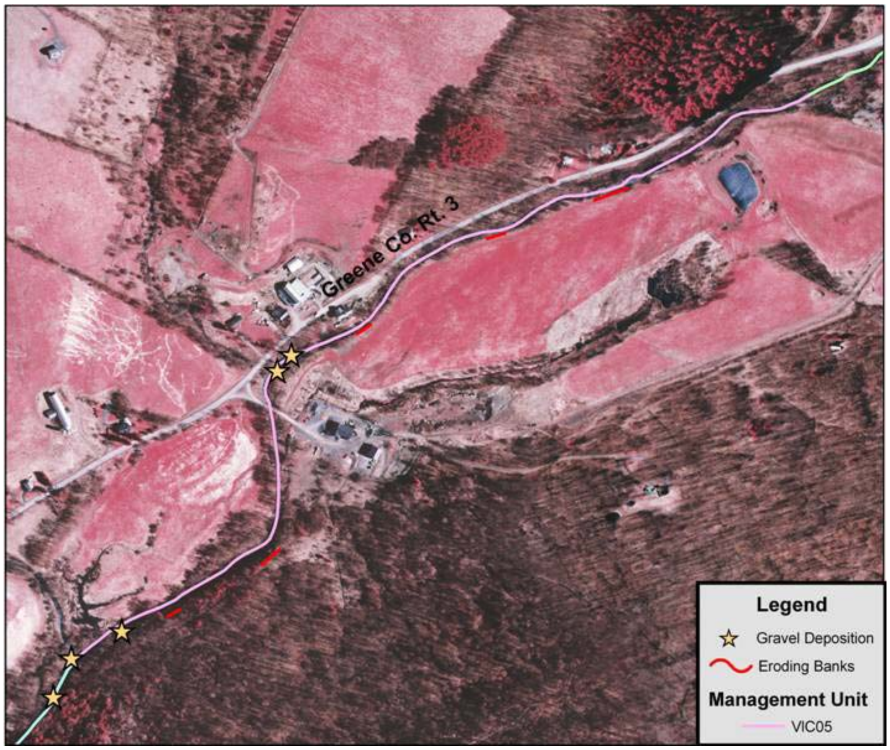
This reach is approximately 6,219 feet long and ends at the confluence with an unnamed tributary at Bruce Scudder road. There is one more unnamed tributary in this reach and one private bridge. The stream corridor is primarily 70% forested with residential areas and roadways covering another 10%. Old fields and brush also make up a small portion of land cover. Only 12% of the reach has an eroding streambank, but the majority of these banks are an average of 9 feet high and the streamside vegetation buffers are only 5 feet wide. Depositional features are few and are just downstream of the tributary at the end of this reach. Six sections of revetment make up 18% of the entire stream reach length. The largest section of revetment is located on Delaware County route 37 and consists of sheet piling, stacked rock wall, and riprap to protect the embankment near the intersection of Halcott Road.

VIC 04



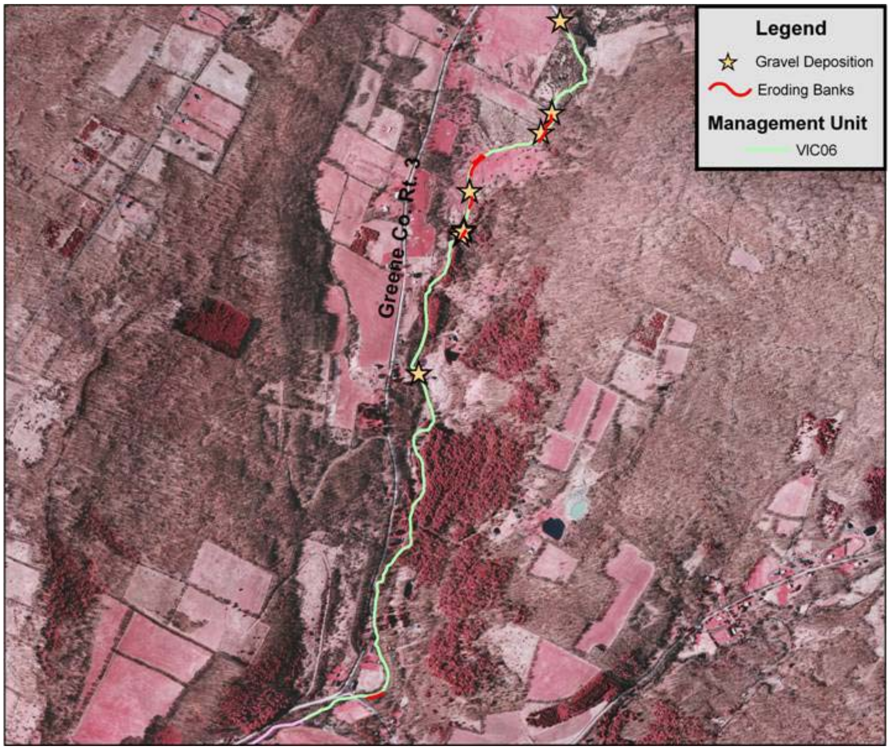
This reach is approximately 5,045 feet long and ends at the confluence with West Settlement Creek, the only tributary located in this reach. The stream generally hugs the left valley wall in a very broad valley. There is a small section of stream at the downstream end that leaves the valley wall and runs around an agricultural field. A full-channel deposition is causing high water flows to be directed toward this field. The stream corridor is forested on the left side, with a steep valley wall and a small crop field in the downstream portion of the reach. The right side consists mostly of hay fields. Riparian buffers on the right bank along the hay fields are better than many similar areas; only 10% of the right bank has a 0-25 feet wide buffer. About 20% of the reach has an eroding streambank, but these eroding banks all have some tree root protection. This reach has the greatest amount of deposition in the sub-basin, accounting for about 20% of the stream length. This reach has the flattest slope (0.9%) in the sub-basin, allowing for the extra deposition to take place. At this time there are no bank revetments located in this section of stream.

VIC 05



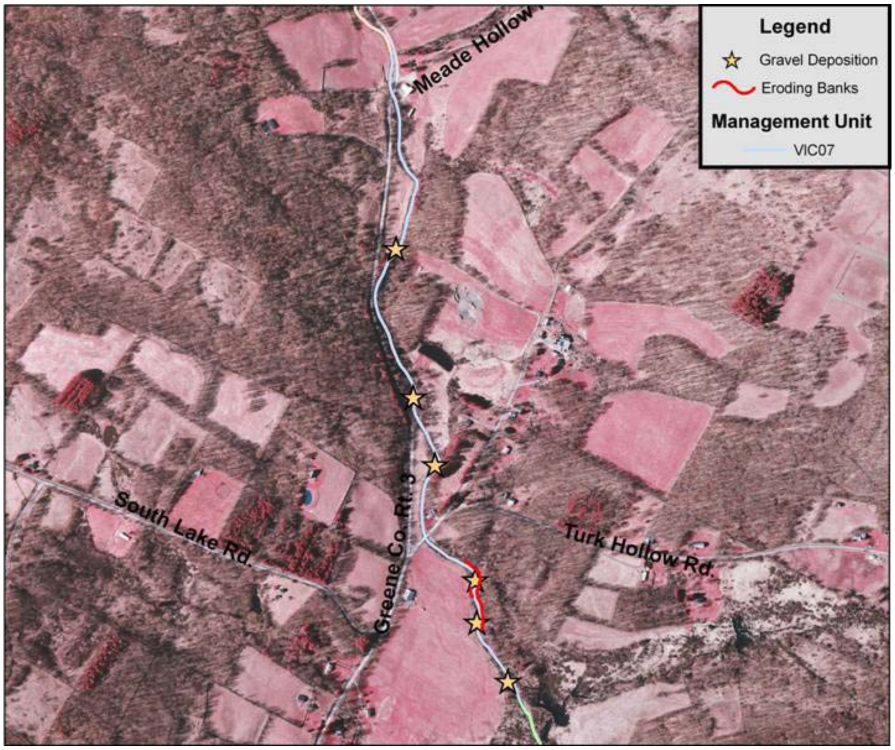
This reach is approximately 4,308 feet long and ends at the confluence with Elk Creek. There are two unnamed tributaries in this section of stream and one bridge. The valley is very broad and the upstream portion of the stream runs against the right valley wall then quickly crosses the valley and runs against the left valley wall. Land cover within the stream corridor is largely hay fields in the floodplain and forested on the valley walls. In the upstream portion, Greene County Rt. 3 is within the corridor on the right bank. About 11% of the reach has an eroded bank and there are two locations in the downstream portion that have been classified as mass failures on the steep left valley wall. Three locations of eroding stream were found in the upstream portion along the hay field on the left streambank. These three eroding banks will probably lengthen because of the narrow or non-existent woodland buffer. Approximately 63% of the reach length has a narrow buffer between 0-25 feet wide. Deposition features are few and only one short section of revetment was noted just upstream of the Halcott town barn bridge.

VIC 06



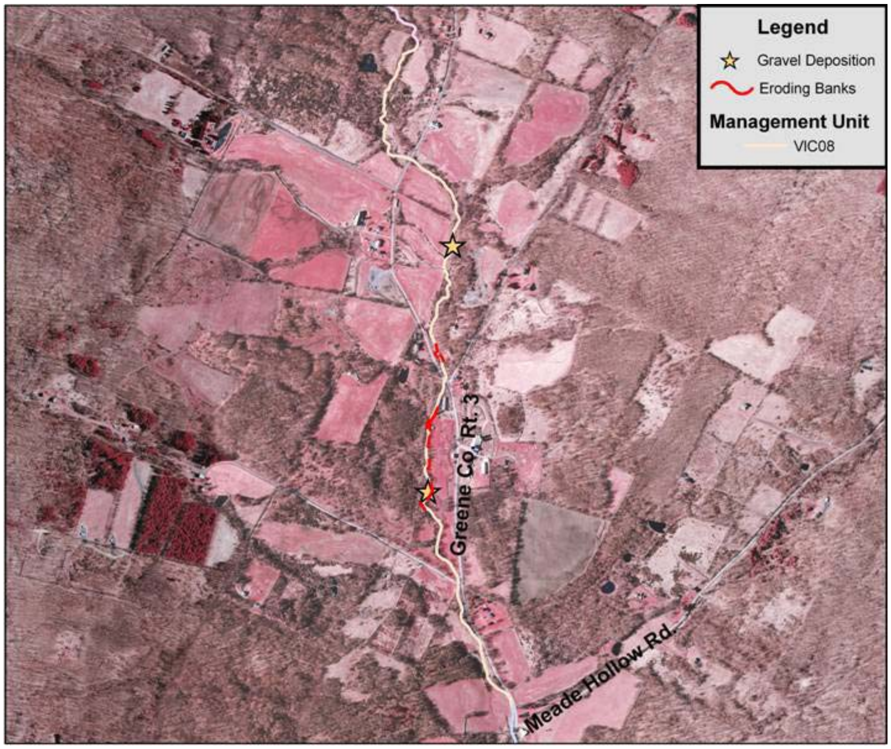
This reach is approximately 9,243 feet long. There are two bridges and one private driveway in this reach, both bridges being on Elk Creek Road. Turk Hollow and unnamed tributaries enter into this stream reach. The stream corridor is 70% forested with some areas of wetland and pastures. About 11% of the reach has an eroding streambank. Most of the streambank erosion is occurring in the upstream portion of the reach where the land use is pasture. Cattle have access to the stream channel and there are no riparian vegetation buffers on the streambank. About 3% of the reach length experiences deposition, mostly occurring in the same area as the eroding banks. Approximately 37% of the streambanks have a narrow (0-25 feet wide) riparian buffer. A more detailed survey was performed on a small section of this reach for classification. It was determined that this section of survey area was formerly a “Bc” stream channel and has evolved to an “F” stream type.

VIC 07



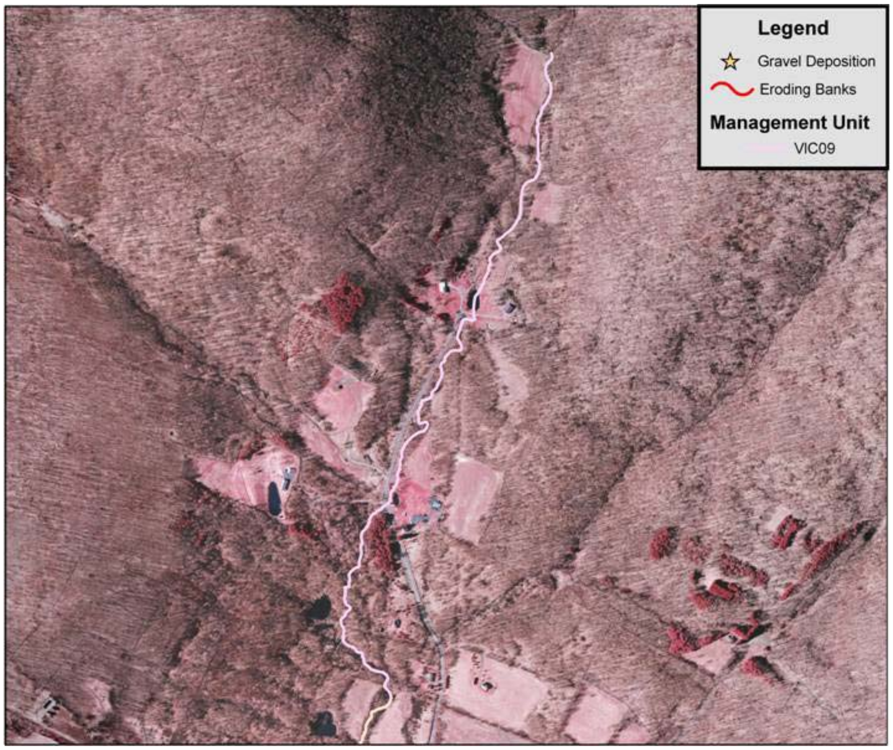
This reach is approximately 4,485 feet long and ends at the confluence of Se Meade Hollow, the only tributary in this reach. There are two bridges located on Greene County Rt. 3 and one on Bouton/Turk Hollow road. The stream corridor is slightly more than half forested and a large part of the land cover is hay field, abandoned field, and pasture. About 87% of the right bank has a narrow streamside vegetation buffer from 0-25 feet wide. In contrast, 24% of the left bank contains a narrow buffer. Only 12% of the reach experiences eroding banks, all of which are just downstream of Bouton/Turk Hollow Road Bridge and have a good riparian buffer. There is rock revetment at the bridge and a section of berm is located on the right bank downstream of the bridge. This area may experience problems with lack of stream access to the floodplain. As water is concentrated under the bridge, the water energy increases resulting in erosion. The eroding bank starts at the first bend just downstream of the berm.

VIC 08



This reach is approximately 6,989 feet long. The valley is fairly broad and the stream is becoming steeper (2.2% slope) as it gets closer to the headwaters. There is one bridge and two culverts in this section. Five unnamed tributaries enter into this reach. The stream corridor is about half forested, with the remainder predominantly agricultural land in corn/hay fields and pastures. This reach corridor contains the most agricultural land in this sub-basin. Bank erosion exists in only 12% of the reach but most of these, about 84%, have no riparian buffer. About 50% of the streambanks have a narrow (0-25 feet wide) riparian buffer. Depositional areas are few in this steeper stream. Only two vegetated gravel deposition bars were seen from helicopter video. Revetments are limited to the downstream portion where the stream and Greene County Route 3 meet. Riprap revetment was placed in this location to protect the road from channel migration.

VIC 09



This reach is approximately 5,242 feet long and is the topmost reach of the Bush Kill watershed. It is a headwater stream with a 5% slope in a confined valley. The stream corridor is about 70% forested with other land uses such as hay fields, abandoned fields, and a few residential areas. There is one small tributary entering into the stream. The stream water is conveyed through two culverts under Johnson Hollow Road. Other data information for this reach is unavailable at this time because no GPS data was collected and this area was not included in the helicopter flyover.

Vly Creek Summary Sheet

Reach No.	Length Reach (feet)	Stream Type	Dominant Corridor Land Use/Cover	Sub-dominant Corridor Land Use/Cover	Riparian Buffer Width	Number Bridges and Culverts	% Impact of Bank Armoring
VIC 01	1994	C	Built-up	Residential	Right Bank 0-25' Left Bank 0-25'	2	97% High
VIC 02	5871	C/B	Forest	Brush	Right Bank >100' Left Bank 0-25'	2	12% Low
VIC 03	6219	B	Forest	Wetland	Right Bank >50-100' Left Bank >100'	0	6% Not significant
VIC 04	5045	C	Forest	Wetland	Right Bank >25-50' Left Bank >100'	1	---
VIC 05	4308	B	Forest	Brush	Right Bank >50-100' Left Bank 0-25'	1	3% Not significant
VIC 06	9201	C	Forest	Wetland	Right Bank 0-25' Left Bank >100'	2	1% Not significant
VIC 07	4485	C/B	Forest	Turf	Right Bank 0-25' Left Bank >100'	2	11% Low
VIC 08	6989	B Plane Bed	Forest	Brush	Right Bank 0-25' Left Bank 0-25'	4	2% Not significant
VIC 09	5242	A Step pool	Forest	Residential	Right Bank 0-25' Left Bank>100'	2	---

Reach No.	% Impact Berms, Roads, Railroads, Paths	Impact Floodplain Development	Impact Depositional Features	Impact Meander Migration	Bank Erosion/ Bank Height	Ice/ Debris Jam Potential (Yes/No)
VIC 01	48% High	High	Not significant	Not significant	High	N
VIC 02	48% High	Low	Low	Low	Low	N
VIC 03	53% High	Low	Not significant	Not significant	High	N
VIC 04	0% Not significant	Not significant	Not significant	Not significant	Low	---
VIC 05	48% High	Low	Not significant	Not significant	High	Y
VIC 06	17% Low	Low	Low	Low	Low	N
VIC 07	56% High	Low	Low	---	Low	Y
VIC 08	28% High	Not significant	Low	---	Low	N
VIC 09	29% High	Not significant	---	---	Low	N

BATAVIA KILL SUB-BASIN

Towns of Middletown, Roxbury and Halcott

Introduction

The Batavia Kill watershed is located within three different townships: Middletown and Roxbury in Delaware County, and Halcott in Greene County. The drainage area of the Batavia Kill is approximately 19.3 square miles and the mainstem is 10.4 stream miles from the headwaters to the confluence with the East Branch Delaware River mainstem. The Batavia Kill mainstem was divided into 10 management units based upon the Vermont Protocol. Roxbury Run, Denver and Vega are small population centers located in this sub-basin.

The Batavia Kill sub-basin is primarily a C stream type with some B sections. There are two reaches in the basin where the valley is "pinched". BatK 03 is semi-confined (also has the steepest slope) and BatK 06 is narrow. The rest of the management units have valleys that are broad to very broad. The land use is predominately forested with some agricultural fields. The average annual rainfall in the watershed can range from 37-41 inches/year at the lower portion to 41-49 inches/year in the headwaters. The Dry Brook mainstem is a fourth order stream. There are numerous unnamed tributaries and two major tributaries that enter the mainstem: Bed Hollow and Buffalo Hollow.

Stream Assessment

Assessment data was collected using the SGAT protocol supplemented with video from the helicopter flyover of the sub-basin. GPS data collection from a stream walkover and Rosgen Level II surveys were not completed for this sub-basin due to time constraints**.**

Geomorphic Conditions

The stream length covered by the SGAT protocol was 8.36 miles. The uppermost 2.04 miles were not included in the assessment because the stream is very small and cannot be seen on the aerial photos due to tree cover. The average stream slope is 1.07% and the two steepest reaches are BatK 03 at 1.65% and BatK 04 at 1.7%. The other reaches have a slope between 1.3% and 0.7%.

There are 2,939 feet of streambanks that contain revetment protection. This is about 7% of the stream length or 3.5% of the total streambank length. The two reaches with the most bank protection are BatK 02 and BatK 06. The impact that the revetment has on the stream is quite low.

There are few depositional features in the Batavia Kill. The SGAT protocol rates the impact of the gravel deposition features as being low or not significant in all reaches. BatK 04 and BatK 05 are the only two reaches that are highly impacted by streambank erosion. Currently, the Batavia Kill does not suffer from a significant erosion problem and it is able to transport its available sediment successfully. Recent depositional features (mid-channel bars, lateral bars, delta bars, etc.) are an indication of increased sediment load. The Batavia Kill has depositional features that appear to be small in size and partially vegetated. This is a sign that the sediment load is remaining fairly constant. One area to observe is in reach BatK 09 (1/2 mi. downstream of Stewart Rd.) where there seems to be an area of deposition that the stream has historically (30 yrs.) been meandering through. A closer look may reveal why this deposition is here and what effects this deposition has downstream (aggrading/degrading stream bed). This area may have a flatter slope, which could account for the increased bedload at this location. In general, the Batavia Kill appears to be fairly stable (few depositional features) and it seems the stream is transporting the existing sediment load well. However, if areas of eroding banks begin to develop (likely in areas with no riparian buffer), more sediment may be added than the stream is able to transport. This aggradation will have a negative impact on the whole stream system.

One potential problem facing the Batavia Kill is the lack of significant streamside vegetation buffer. Six reaches have a high impact rating which means that 75% or more of the reach length has 0-25 feet of buffer. The six reaches that fall into this category are: BatK 01, BatK 02, BatK 05, BatK 07, BatK 09, and BatK 10. The limited vegetated riparian buffer suggests that the stream, especially in the upper reaches, may experience increasing bank erosion in the future if the condition is not addressed.

One of the factors that contributes to the relatively good condition of the Batavia Kill is the soil. All reaches, with the exception of BatK 03, are dominated by low run-off potential soils. This moderates peak run-off and keeps the Batavia Kill from quickly reacting to precipitation like most of the watersheds in the region.

All reaches on the Batavia Kill are classified as stream type C, except BatK 04 which is classified as a type Cb. No Rosgen Level II surveys were performed on the Batavia Kill so the classification is based on the Vermont Protocol.

Our recommendations in regard to the Batavia Kill are:

- Keep the floodplains open and undeveloped.
- Increase the width of the riparian buffers by planting trees.

Floodplains

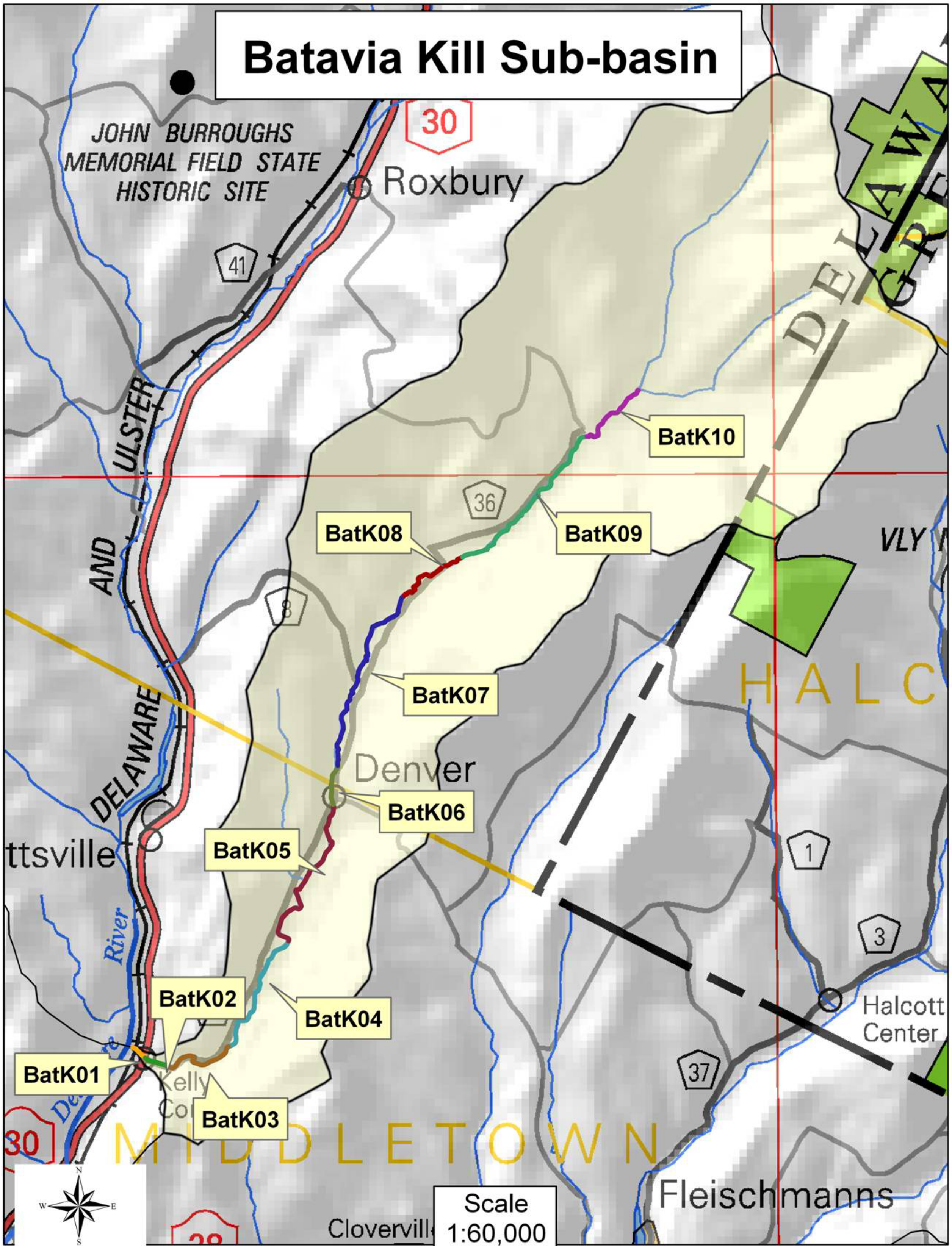
Houses and other buildings within the river corridor and floodplain may represent flood hazards and floodplain restrictions. In BatK 01 and BatK 02, nearly all of the corridor may be affected by river corridor development (based on development of one side of the stream or the other) resulting in a high impact rating. The remainder of the upstream corridor has a low impact rating (5% - 20% of reach length having development within the corridor).

Infrastructure

Roads and berms can limit the lateral adjustments of the stream within its corridor and also limit access to the floodplain. The length of roads that are within the corridor was calculated for each reach and an impact rating was given. BatK 04, BatK 05, and BatK 07 received low ratings (5% - 20% of reach length has roads/berms) and the remaining reaches have a high rating (>20%). In some instances, the road may be above the floodplain (on a high terrace) and not affecting the stream. In other cases, the road may be on the floodplain (not built-up or raised) and become easily flooded.

Delaware County Route 36, Stewart Road, and Sally's Alley run parallel to the Batavia Kill mainstem, crossing over the stream in several places. These roads have some severe impacts to the stream's health. Stormwater runoff from the road ditches adds excess water and pollution directly to the streams without allowing time for ground absorption. There are several locations where the stream is close to the road and revetment was placed along the banks in order to protect the road from channel migration.

Management Unit Descriptions



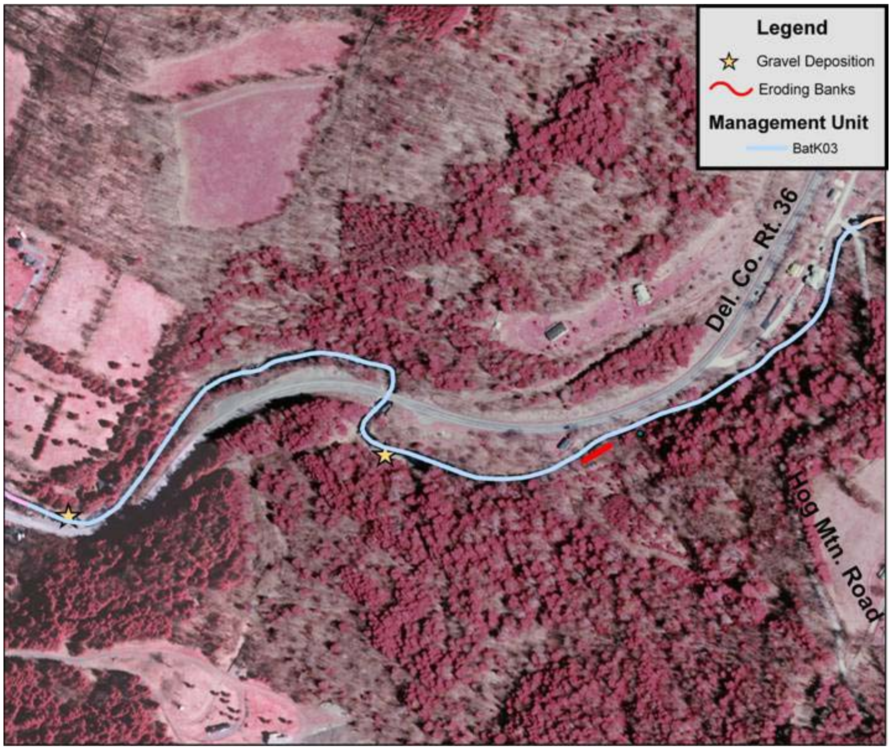
BatK 01

This is a short reach at approximately 706 feet in length. Starting at the confluence with the East Branch Delaware River, it continues upstream to the New York State Route 30 bridge. The NYS Rt. 30 bridge and a railroad bridge are in the upper portion of this reach. This section runs through the floodplain of East Branch Delaware River and was most likely channelized and straightened at one time. Soils in the corridor are hydrologic soil group A with a high infiltration rate. There are no eroding banks or depositional features at this time, but the banks of the channel in this reach are extensively revetted.

BatK 02

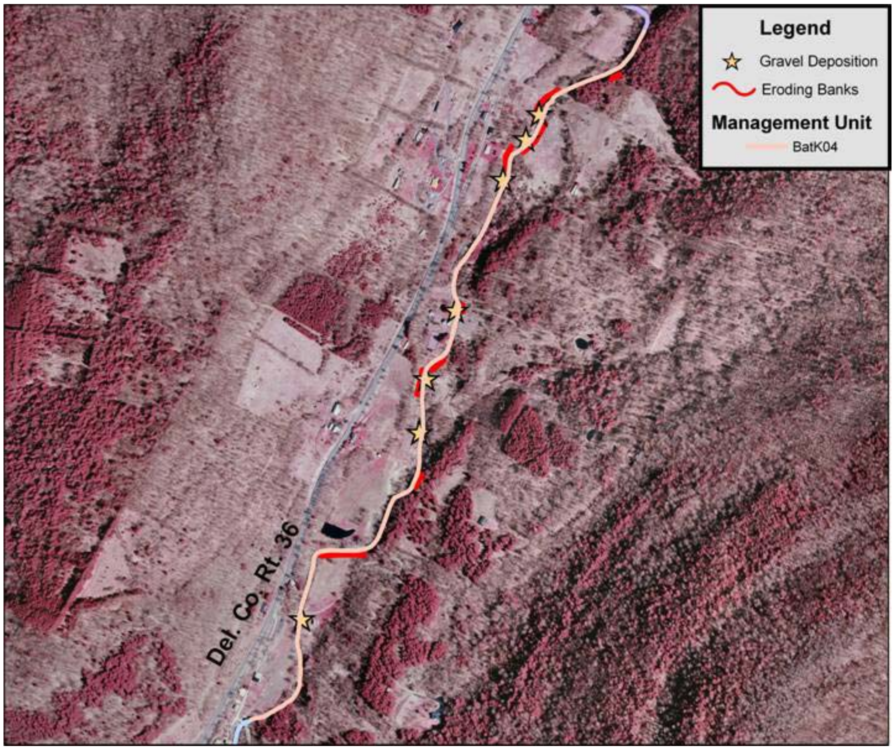
This reach is approximately 1,090 feet long and runs through a broad valley. Valley side slopes average about 24% on the right and 31% on the left. The stream is confined to the right side of Delaware County Route 36 and has some revetment to protect the road infrastructure. About 38% of the left bank has revetment to protect the road from stream channel migration. The corridor soils are hydrologic group A with a high infiltration rate. There are no eroding banks or deposition features within this reach. The stream is likely impacted due to its proximity to the road surface.

BatK 03



This reach is approximately 3,460 feet long and ends at the Delaware County Bridge #103 on Hog Mountain Road. The valley is narrow and twists as one progresses upstream. The stream slope is steeper (1.7%) than most reaches in this sub-basin. There are three bridges in this reach: Delaware County Bridge 36-1, Delaware County Bridge #103, and one private bridge. There is bedrock exposed throughout the upper portion, mainly on the left bank and in the bed of the stream. There is very little bank erosion since the bedrock protects the streambanks. Only small amounts of deposition can be seen, probably due to the steep stream slope and channel confinement. Hydrologic group C/D soils with undrained to high run-off rates are most often found in this area. Valley side slopes are an average of 16% on the right side and 22% on the left side.

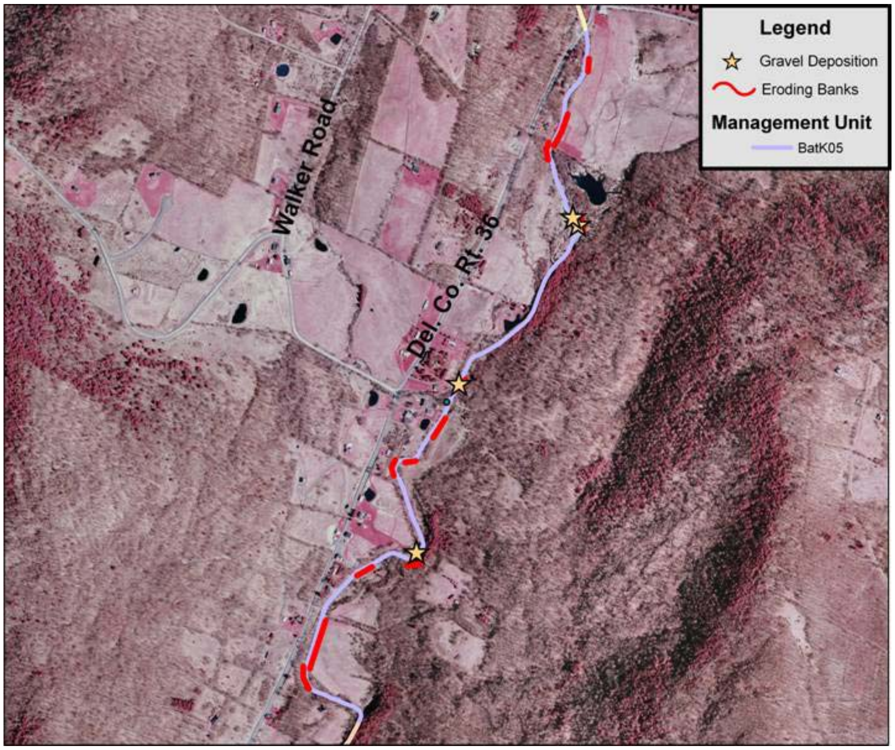
BatK 04



This reach is approximately 5,770 feet long and ends at a sharp bend in the stream. This section of the valley is also steep (1.7%), but the valley is wider and only two small sections of bedrock were observed. There are two private bridges located in this reach. Both bridges have side bars forming just downstream of each structure. Just upstream of one of the private bridges is a section of severe erosion on the left bank where the bridge approach is washed out. Bridge abutments are exposed, making the bridge unusable. This information was obtained from the helicopter video and it is currently unknown whether conditions at the bridge have been addressed.

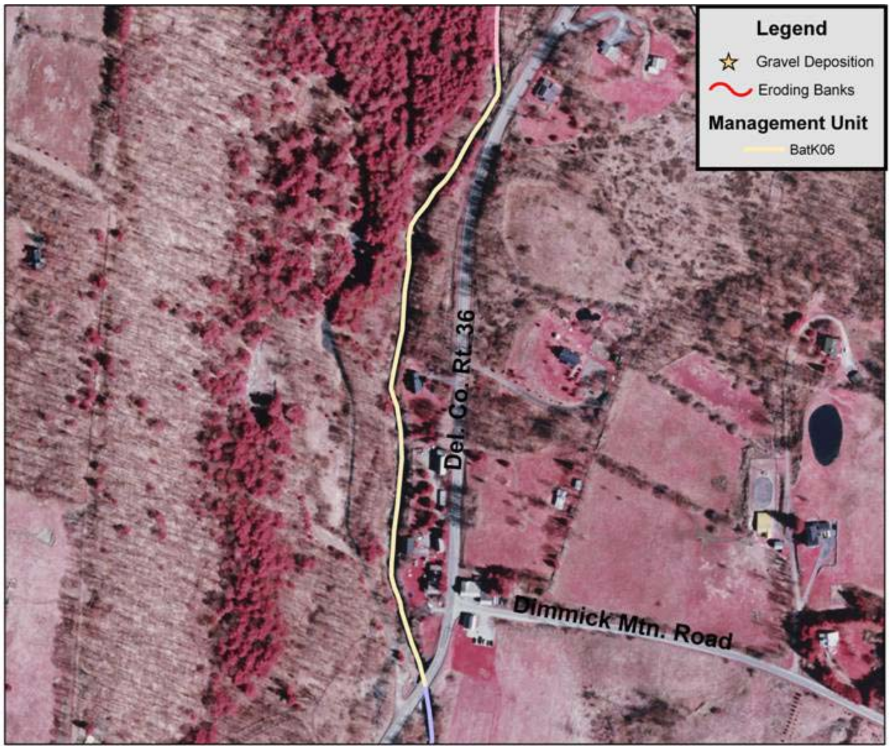
About 23% of this reach has eroding banks and approximately 62% of the eroding banks have no riparian vegetation buffer along the streambanks. Mass streambank failures account for 78% of the total area of eroding banks due to the bank height (10 feet to 40 feet high). This increase in sediment supply is also reflected in the amount of gravel deposition seen downstream. This reach also has the greatest length and area of center bars and side bars. These depositional features average about 11% of the entire reach. The surficial geologic material is predominantly alluvium which has a high potential for erodibility. Soils in this reach are in hydrologic group B with a medium to high infiltration rate. The valley side slopes are about 26%, which is fairly steep for this sub-basin.

BatK 05



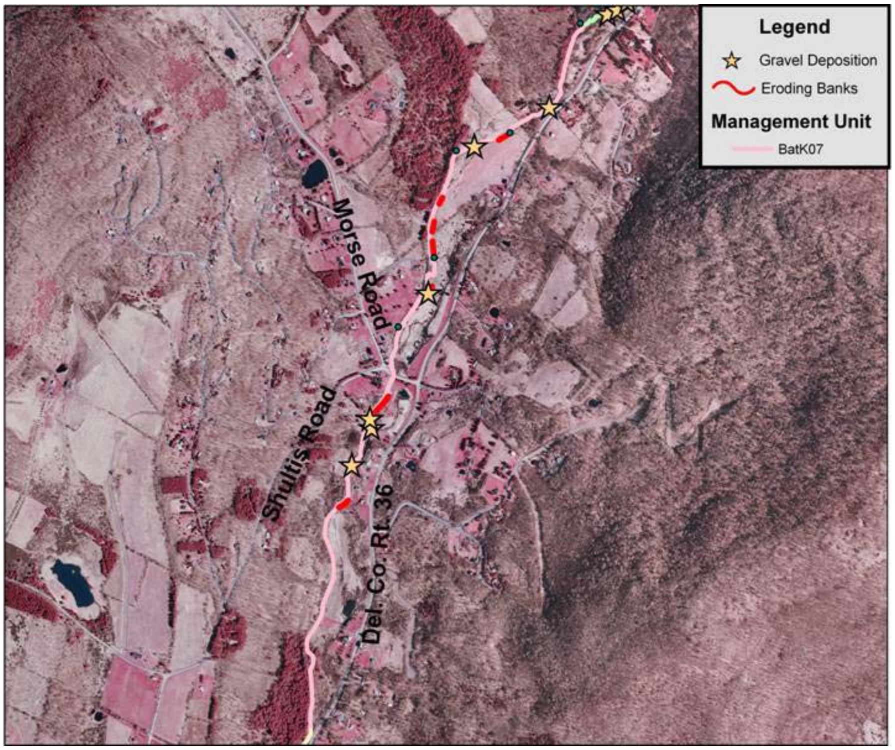
This reach is approximately 7,560 feet long and ends at Delaware County Bridge #36-3. The stream has a 0.8% slope and runs through a broad valley. With a sinuosity of 1.2, it is the greatest sinuosity in the sub-basin. There is one private bridge crossing in this reach. Similar to BatK 04, 28% of this reach length consists of eroding banks, with 60% of these eroding banks being mass failures on high streambanks (20 feet high). Almost 80% of all eroding banks have no riparian vegetation buffer. A narrow or absent buffer may lead to increase bank erosion and increase sediment supply, adversely affecting sediment transport. There are only four observed depositional features in this section. Two of these depositions consist of point bars, which are expected in a "C" stream type. From this we can assume sediment transport is not a problem through this reach. Surficial geologic material within the corridor is alluvium with high potential for erodibility. Hydrologic soil group B is dominant. Valley side slopes average 11% on the right and 20% on the left.

BatK 06



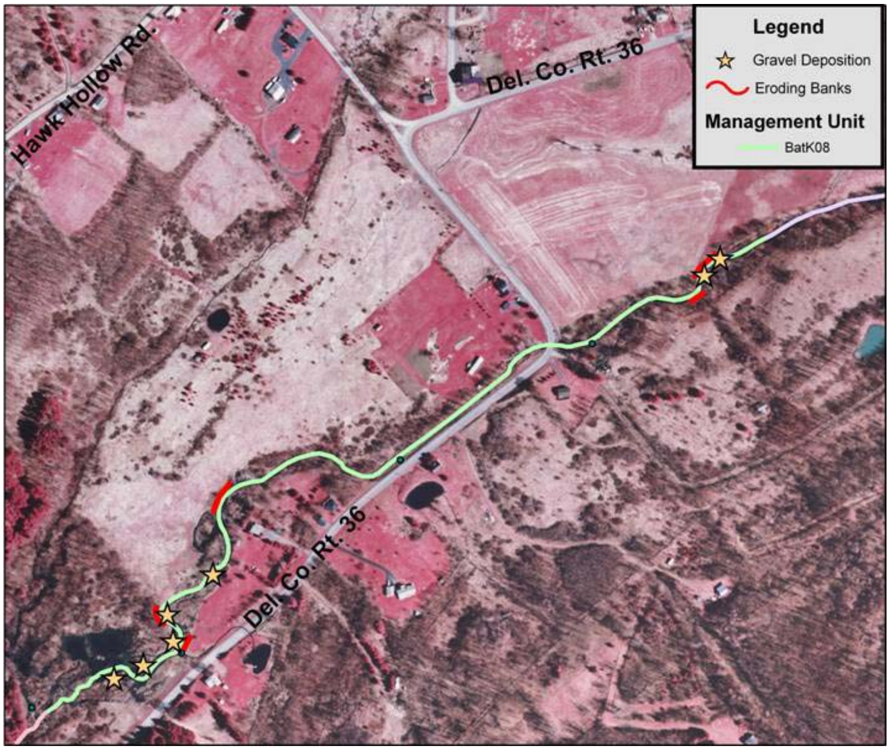
This reach is approximately 1,760 feet long and runs along the right wall of a narrow valley. Delaware County Route 36 travels the same narrow valley that the stream runs through, passing residential areas along the way. This doesn't allow for much room for a properly functioning floodplain or the channel migration normally associated with evolving streams. Delaware County Bridge #36-3 is located at the downstream end of this reach. One section of bedrock across the stream may be indicating that the stream has downcut in this section. No eroding streambanks or gravel deposition features were observed in this reach. Stream features were identified using observation of the helicopter video. Valley side slopes average 32% on the right and 19% on the left.

BatK 07



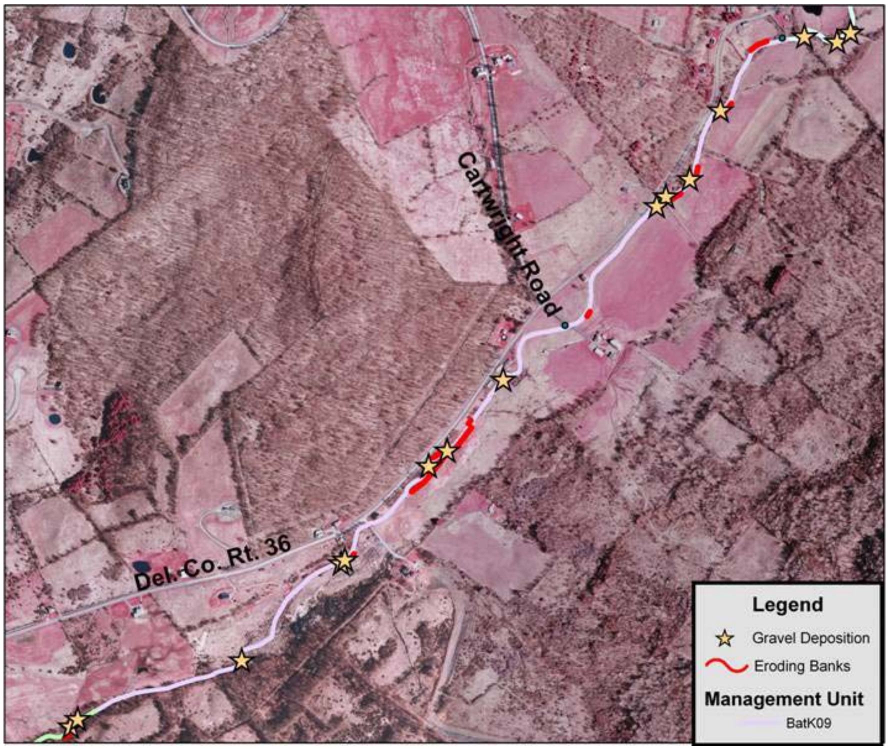
This reach is approximately 8,769 feet long and runs through a broad valley. The stream flows consistently against the right valley wall with a fairly flat overall slope of 0.7%. Delaware County Bridge #8-1 is the only crossing in this reach. Most of the stream has extensive areas of floodplain on the left side of the stream, but very little on the right side. A large wetland area is located upstream of Delaware County Bridge #8-1. There are five unnamed tributaries that enter the stream in this reach. Eroding banks account for about 12% of the total reach length, but 70% of the eroding streambanks have no riparian vegetation buffer. Six observed gravel deposition features are located within this reach, three of which are point bars that are normal for type C streams. The remaining three are not very large and consist of 1% of the total reach length. Valley side slopes average only 10% on the right, while the left is 24%.

BatK 08



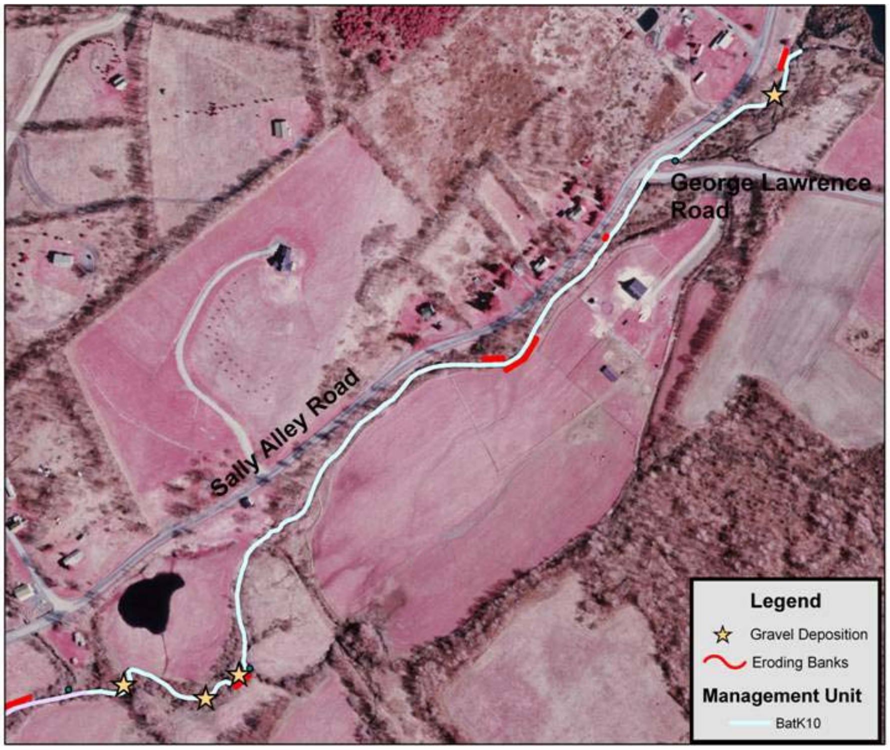
This reach is approximately 3,518 feet long and ends about 900 feet upstream of Delaware County Bridge #36-4, the only bridge in this section. There are three small unnamed tributaries that enter into this reach. In the upper half of this reach, the stream has historically been straightened and pushed to the left side of the very broad valley wall. The stream passes under Delaware County Bridge #36-4 and at times of moderate to high flow events, the stream jumps out of the bank just above the bridge. This floods Delaware County Route 36 and residences in that area. The stream meanders through many gravel depositional features at the downstream portion of this reach. This area looks like a braided “D” stream type reverting back to a stable “C” stream. There are some eroding streambanks in this area due to the evolution of the stream type from D to C. Valley side slopes average 23% on the left side and only 8% on the right.

BatK 09



This reach is approximately 8,111 feet long and ends near the confluence with an unnamed tributary from the north. The valley is very broad, with floodplains being mainly along agricultural fields or abandoned fields. Judging from historic aerial photos, this stream appears to have been straightened and moved to the side of the valley floor long ago. There are three bridges/culverts in this reach and two unnamed tributaries that enter the mainstem. About 20% of the reach has an eroding streambank. Most of these banks are on the outside of a small bend, indicating that the stream is too straight and is trying to increase sinuosity. A problem area that is located about 1,400 feet downstream of Cartwright Road has a 700 feet long eroding streambank on the left side of the stream. It appears that the stream has been cleaned out recently (prior to helicopter video) and the gravel was used to build a berm on the left of the straightened channel. This area will have high erosive forces on the streambanks. This area should be documented to determine whether erosion problems continue. The stream channel may react to the gravel dredging and berming by widening, gravel deposition, and/or headcutting upstream/downstream of this area. All of the eroding banks have no riparian vegetation buffer on either side of the streambanks. About 75% of the entire reach has 0 – 25 feet of streamside vegetation buffer on both sides of the banks. Hydrologic group B soils, with a medium to high infiltration rate, cover about 84% of the corridor. Valley side slopes average between 15% - 19%.

BatK 10



This reach is approximately 3,421 feet long and ends near the confluence of Bed Hollow and Buffalo Hollow. The valley is still very broad and the stream travels along both the right valley wall and the road near Sally's Alley. A short downstream section has some sinuosity and is also the area with the majority of gravel deposition (2 point bars and 1 center bar). About 9% of the reach has eroding banks of which almost 80% has no riparian vegetation buffer. About 91% of the left bank has a buffer width less than 25 feet. There is one culvert located on George Lawrence Road and two unnamed tributaries in this reach. Hydrologic soil group B is found in 94% of the corridor. Valley side slopes average 10% on the right side and 23% on the left. The dominant land use/land cover is agricultural.

Batavia Kill Summary Sheet

Reach No.	Length Reach (feet)	Stream Type	Dominant Corridor Land Use/Cover	Sub-dominant Corridor Land Use/Cover	Riparian Buffer Width	Number Bridges and Culverts	% Impact of Bank Armoring
BatK 01	705	C	Forest	Residential	Right Bank >100' Left Bank 0-25'	2	8% Not significant
BatK 02	1091	C	Residential	Forest	Right Bank 50-100' Left Bank 0-25'	0	38% High
BatK 03	3460	B	Forest	Residential	Right Bank >100' Left Bank >100'	3	7% Not significant
BatK 04	5772	C/B	Forest	Residential	Right Bank 0-25' Left Bank >100'	2	3% Not significant
BatK 05	7560	C	Forest	Brush	Right Bank 0-25' Left Bank 0-25'	1	---
BatK 06	1758	C	Forest	Residential	Right Bank >100' Left Bank 0-25'	1	25% Low
BatK 07	8769	C	Forest	Wetland	Right Bank >100' Left Bank 0-25'	1	---
BatK 08	3518	C	Forest	Brush	Right Bank 0-25' Left Bank 0-25'	1	23% Low
BatK 09	8111	C	Forest	Brush	Right Bank 0-25' Left Bank 0-25'	3	8% Not significant
BatK 10	3421	C	Turf	Forest	Right Bank 0-25' Left Bank 0-25'	1	6% Not significant

Reach No.	% Impact Berms, Roads, Railroads, Paths	Impact Floodplain Development	Impact Depositional Features	Impact Meander Migration	Bank Erosion/ Bank Height	Ice/ Debris Jam Potential (Yes/No)
BatK 01	100% High	High	Low	---	Not significant	N
BatK 02	100% High	High	Low	---	Not significant	N
BatK 03	85% High	Low	Not significant	---	Low	Y
BatK 04	19% Low	Low	Low	---	High	N
BatK 05	7% Low	Low	Low	---	High	Y
BatK 06	100% High	High	Not significant	---	Low	N
BatK 07	17% Low	Low	Low	---	Low	N
BatK 08	32% High	Low	Low	---	Low	Y
BatK 09	53% High	Low	Low	---	Low	Y
BatK 10	62% High	Not significant	Low	---	Low	N

PLATTE KILL SUB-BASIN

Towns of Middletown, Andes and Delhi

Introduction

The Platte Kill watershed is located within three different townships in Delaware County: Middletown, Andes, and a small portion of Delhi. New Kingston is the only population center in this sub-basin. The drainage area of the Platte Kill is approximately 35.36 square miles and the mainstem is 12.1 stream miles from the headwaters to the confluence with the East Branch Delaware River mainstem. The Platte Kill mainstem was divided into 11 management units based upon the SGAT protocol. The Platte Kill mainstem is a fifth order stream. There are 7 major tributaries that enter the mainstem in addition to the unnamed tributaries: Jones Hollow, Canada Hollow, Bryants Brook, Weaver Hollow, Sanford Hollow, Winter Hollow, and Thomas Hollow. The Platte Kill is primarily a C stream type with some B sections in the headwaters. The confinement ratio shows that the valley is generally broad to very broad with a few sections that are narrow. The land is predominately forested with some agricultural fields. The average annual rainfall in the watershed is predominately in the range of 35-30 inches/year with a couple of areas in the headwaters that experience 39-41 inches/year.

Stream Assessment

Assessment data was collected using the SGAT protocol supplemented with video from the helicopter flyover and a windshield survey of the sub-basin. GPS data collection from a stream walkover and Rosgen Level II surveys were not completed for this sub-basin due to time constraints**.** The entire length of the stream was analyzed using the SGAT assessment. The assessment for PK 07 through PK 11 did not identify some features such as erosion and gravel deposition bars as these reaches were not videoed during the helicopter flyover.

Geomorphic Conditions

From PK 01 to PK 07, the stream slope is approximately 1% and the stream type is C. From PK 08 to PK 10, the slope is approximately 1.46% and the stream type is a B. At PK 11, the stream slope is 4.25% and the stream is classified as a B stream type. Sinuosity is slightly low in this sub-basin ranging from 1.11 to 1.15.

The Platte Kill contains 6,907 feet of eroding streambanks. PK 06 has a mass failure of 177.4 feet in length. Bedrock is visible in the stream channel in PK 01 and PK 05 and this could be evidence of past scouring. There is a total of 6,685.7 feet of revetment, usually stone rip rap along the streambank. PK 04 has the largest amount of revetment with 2,536.4 feet along the streambank. This means that in PK 04 about 40% of the stream length for this reach has rock rip rap along it. Overall, for the reaches PK 01 through PK 06, about 18.6% of the stream has revetment and about 18.9% experiences erosion. About 37.5% of the stream in these reaches is or has been affected by streambank erosion. The SGAT protocol rates PK 01 and PK 03 as high impact areas for streambank erosion.

From PK 01 through PK 06, there are 23 gravel deposition bars, none of which are point bars. The highest incidence of gravel deposition bar formation is in PK 01 and PK 06, where both have a density of bar formation of 5 deposits per mile. However, in PK 06, many of the gravel bars are vegetated which suggests that they may become more stable in the future. PK 02 and PK 04 have the lowest rate of bar formation at 2 depositions per mile. All reaches are rated low or have no significant impacts on the stream according to the SGAT assessment.

The Platte Kill sub-basin, overall, has some issues with riparian vegetation buffers along the stream. PK 04, PK 05, and PK 06 have high impact ratings with a riparian buffer width of only 0-25 feet. PK 07 through PK 11 are included in the riparian buffer calculations since the riparian buffer width was obtained from the 2001 aerial photographs.

The most noteworthy problem in this sub-basin is located within the PK 02 reach. Bryant's Brook channel downcut into its bed during the June 2006 flood and sent large amounts of sediment into the Platte Kill. No deposition has been observed so apparently the Platte Kill is capable of moving this additional bedload. Debris also blocked the existing channel near James Hollow and diverted flows creating a new 1000 foot long stream channel through an unused pasture. To date, the stream is still located in this new channel.

The primary problem facing the Platte Kill is streambank erosion. The quantity of revetment indicates that this has been an ongoing problem. Since there is no Rosgen Level II survey completed in this sub-basin, it is not possible to determine if the stream has incised.

Management Prescription for Platte Kill Sub-basin:

- Consideration should be given to the possibility of restoring the Platte Kill near James Hollow
- Additional assessment should be undertaken to determine if the stream is incised and whether this process is contributing to the ongoing erosion problem
- Bank stabilization within the sub-basin, if attempted, should account for any possible incision and consider an alternative such as reconnecting the channel back to the stream's floodplain

Floodplains

There are few houses along the mainstem of the Platte Kill that impact or are affected by the flow of water on the floodplain during a high flow event. Agricultural fields and forested areas are found predominately along the floodplain. There is minimal impact from floodplain development along the stream corridor. PK 01 and PK 02 have a narrow valley and there is no floodplain in these areas due to NY State Route 28. Windshield surveys show that in PK 04, livestock have access to the stream and there is no floodplain at the lower end of the reach. Due to landscape features, PK 03, PK 04, and PK 05 have short sections with very little or no floodplain.

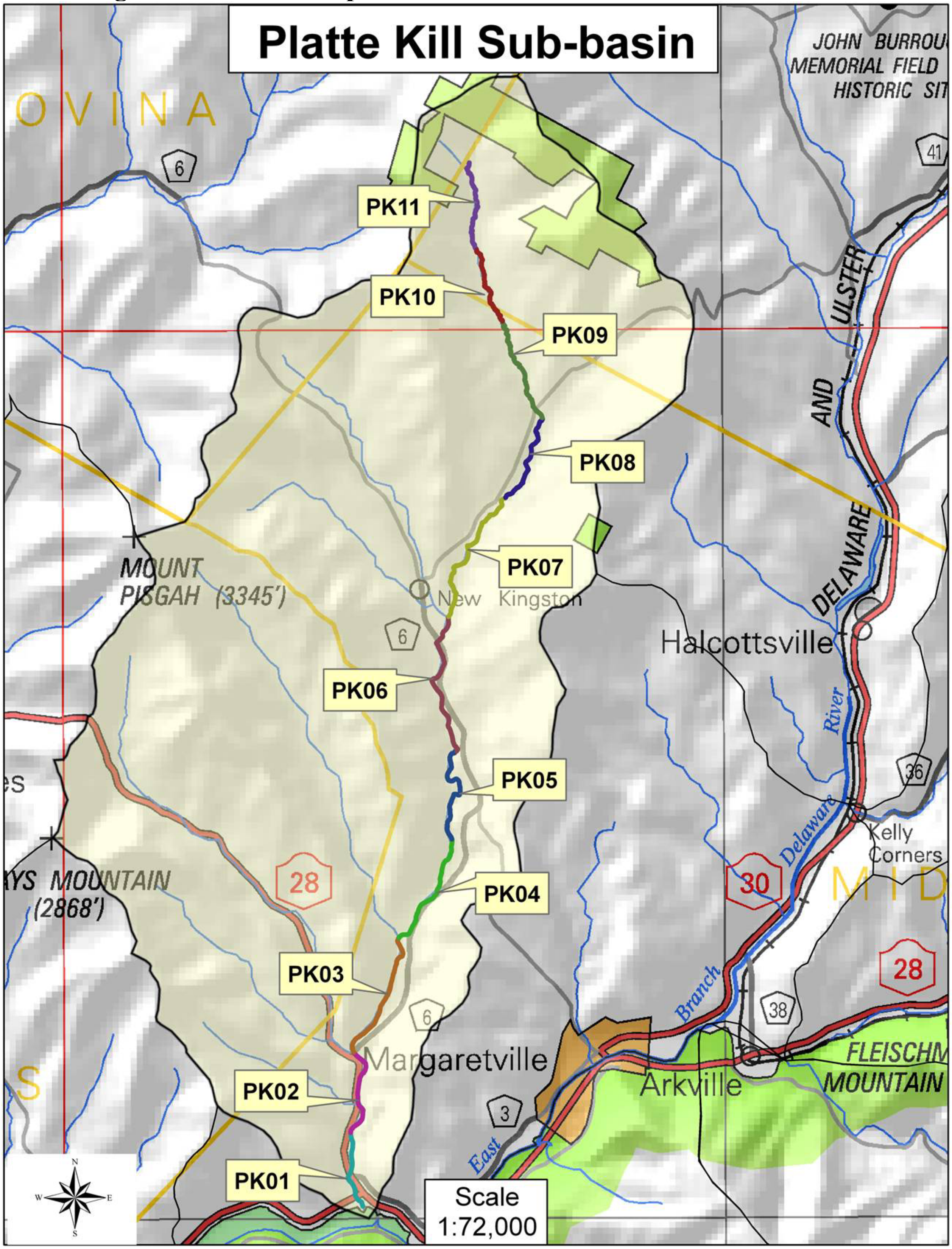
Infrastructure

New York State Highway 28, Delaware County Route 6, Brook Road, Thompson Hollow Road, and Harold Roberts Road run parallel to the Platte Kill mainstem and have severely impacted the stream health in some locations. In areas where the valley is narrow, the road pushes the stream against the valley wall, thereby restricting it. In these areas, stream impacts consist of floodplain restriction, downcutting, and erosion of steep streambanks.

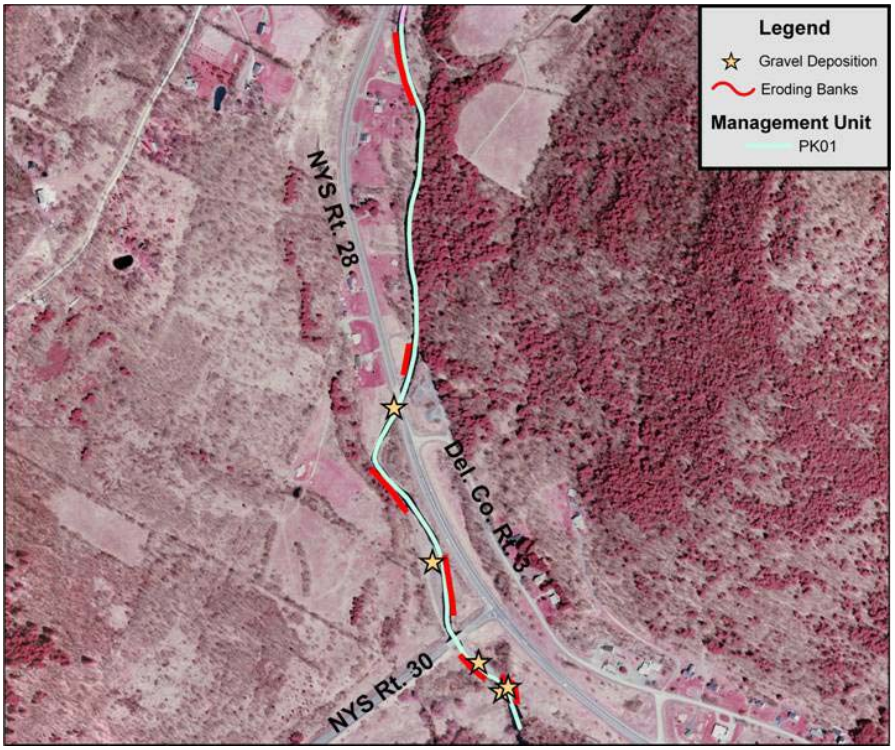
Stormwater run-off from the road ditches adds excess water and pollution directly to the streams without allowing time for absorption into the ground. There are several locations where the stream is close to the road and revetment was placed along the banks in order to protect the road from channel migration.

There are a number of bridges that are located within this sub-basin: New York State Highways 28 and 30, Delaware County Bridges #6-1 and #6-2, Town Bridges #16, #86, #87, #170, and #146, and some private bridges. In the headwaters, the Platte Kill has a small drainage area and culverts are installed to convey the water under the road. The impacts of the culvert can be erosion or gravel deposition upstream and/or downstream of the infrastructure if the culvert is improperly sized. Further inspection of these structures is needed in order to determine the impacts on the stream.

Management Unit Descriptions

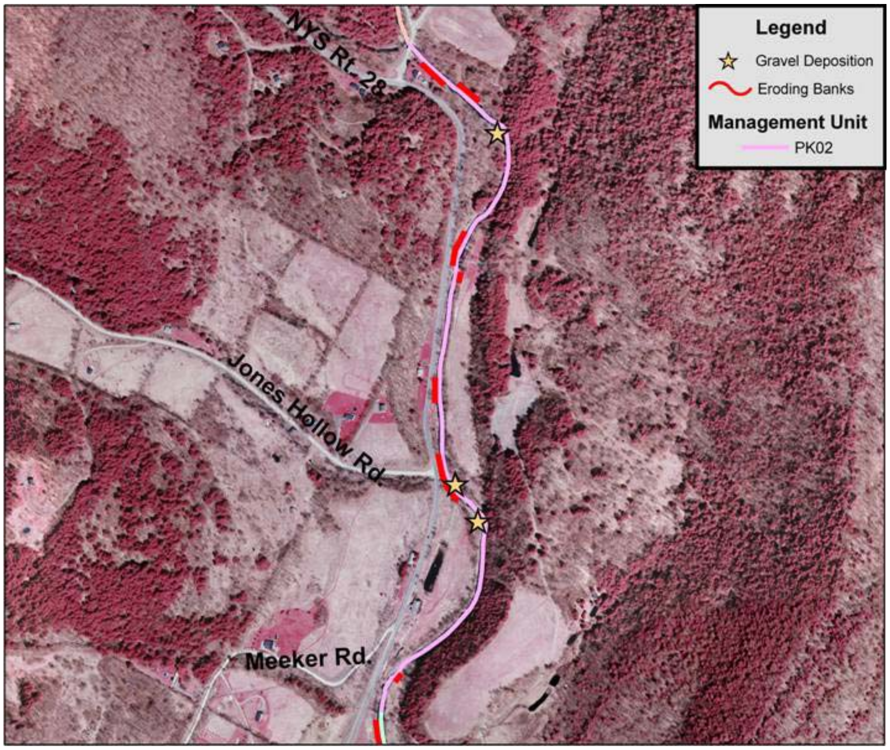


PK 01



PK 01 begins near the high water mark of the Pepacton Reservoir, about 600 feet downstream of New York State Route 30. The upper portion of this reach is approximately 2,075 feet upstream of the New York State Route 28 bridge that crosses the Platte Kill. The upper portion of the reach is near the confluence with an unnamed tributary adjacent to Meekers Hill Road. The total length of this reach is about 4,125 feet. Bridges within this reach are located on New York State Route 28 and 30. Upstream of the NYS Rt. 28 bridge, the stream appears to have downcut to bedrock in some areas. Downstream of these bridges, the stream has widened and become a gravel depositional area. The dominant surficial geologic material in this reach corridor is alluvium, which can have high potential for erodibility. About 87% of the corridor soils are in hydrologic group B, which have medium/high infiltration rates. Valley side slopes average 18% on the right side and 33% on the left side. This reach has a broad valley width. The USGS Stream Gage 01414000 (Platte Kill at Dunraven NY) is located on the right bank, 200 feet upstream from the bridge on NYS Route 28 in Dunraven and 2.5 miles southeast of Margaretville. The drainage area at the stream gage is 34.9 square miles. The period of records that is available for this gage is from October 1941 to September 1962 and December 1996 to the current year.

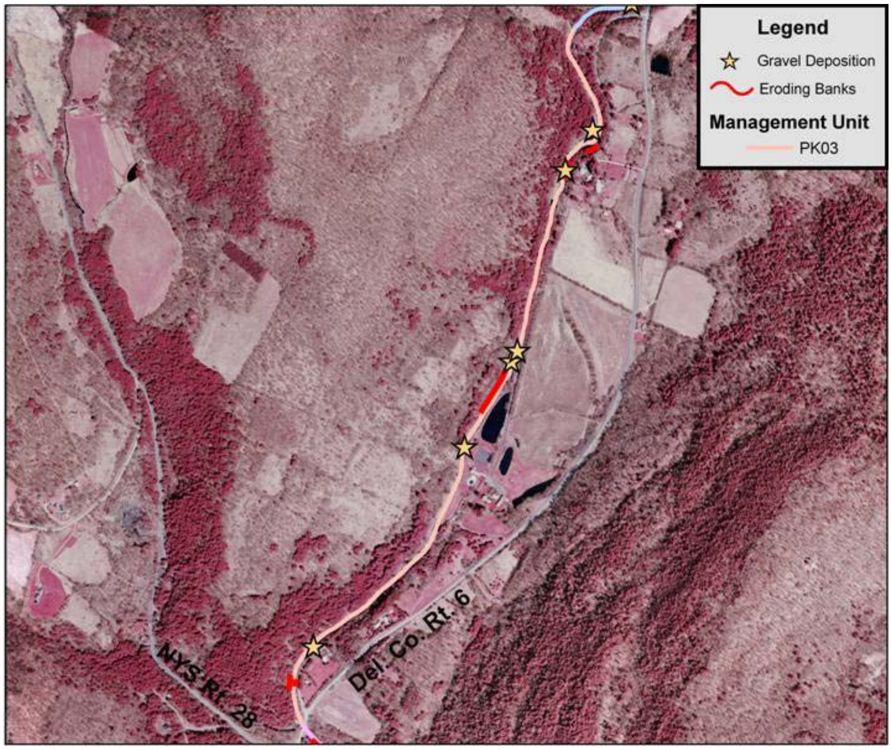
PK 02



PK 02 is approximately 4,850 feet long and ends at the confluence of Bryant's Brook, just upstream of Delaware County Bridge #6-1. Bridge #6-1 is the only bridge within this reach. Two tributaries that enter this reach are Bryant's Brook and Jones Hollow. Since June 2006, Bryant's Brook has downcut to bedrock and widened, sending large amounts of sediment into the Platte Kill. There is little gravel deposition in this area so far, indicating that the mainstem is able to transport this sediment. The large amount of woody debris and uprooted trees in Bryant's Brook may pose a threat to the Delaware County Bridge #6-1. If this debris should ever come downstream, it may become lodged under the bridge and cause problems during high flow events. Another problem area is near the confluence of Jones Hollow, where the stream channel has avulsed (changed course) through an abandoned agricultural field for approximately 1,000 feet before returning to the original stream channel.

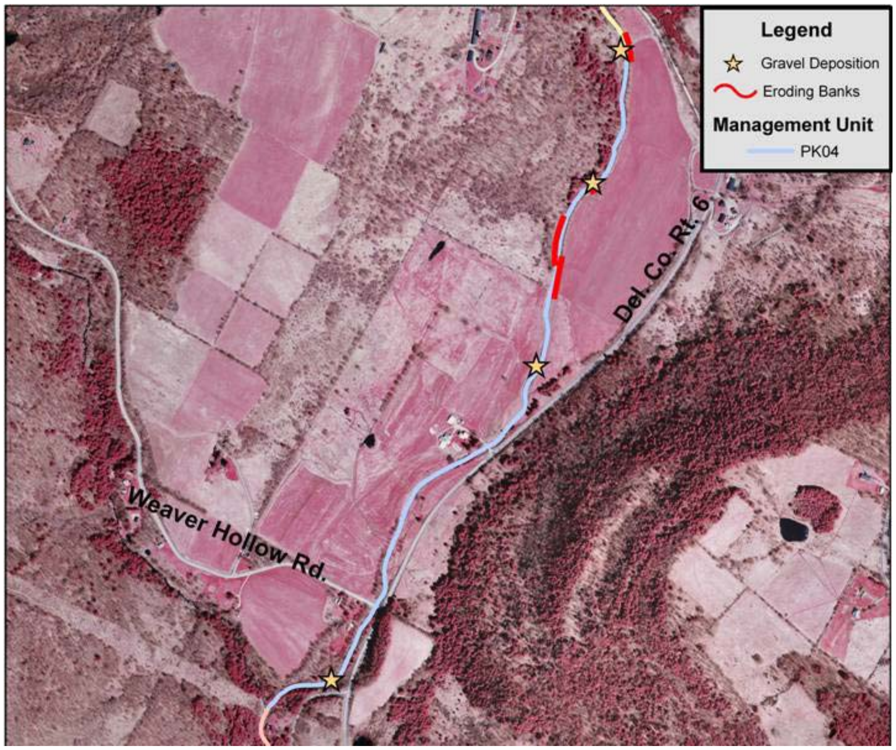
The dominant surficial geologic material in this reach corridor is glacial outwash, which can have a high potential for erodibility. About 87% of the corridor soils are in hydrologic group B, which have a moderate to high infiltration rate. This reach has a narrow valley that limits the lateral movement of the stream. Valley side slopes average 13% on the right side and 33% on the left.

PK 03



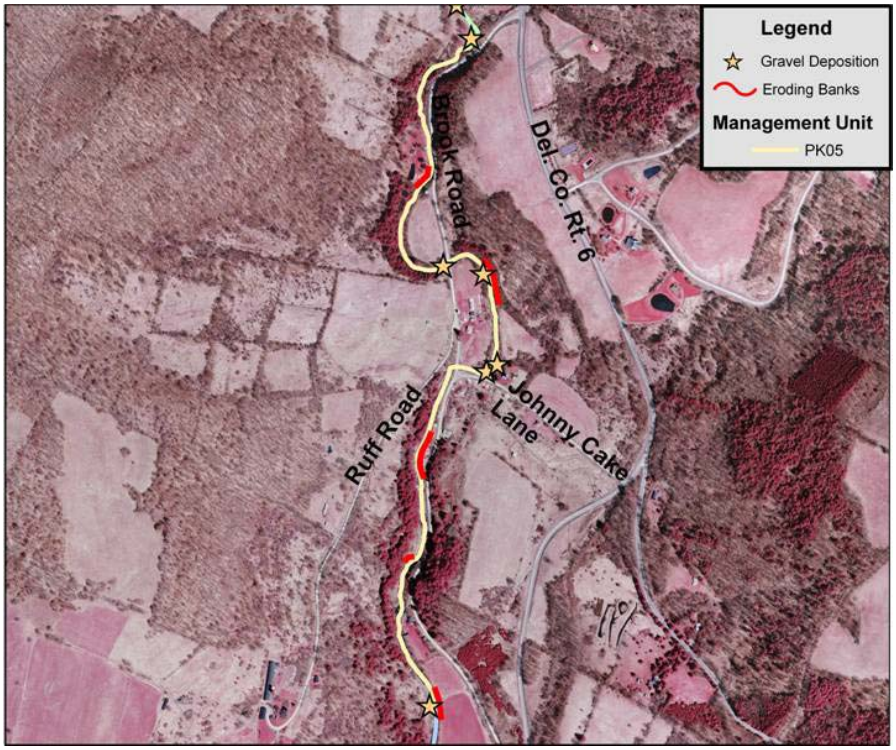
PK 03 is approximately 6,875 feet long and ends at the confluence of the Weaver Hollow tributary. There is one private bridge located in this reach. Weaver Hollow and a small unnamed tributary are the only tributaries that enter the mainstem. The valley is mainly narrow and there are many sections in the upper portion of the reach that contain bedrock on the streambank or in the channel bed (planform and/or grade control). There is also a concrete diversion dam in the middle portion of the reach. This dam appears (from helicopter video) to have trapped sediment behind itself, creating a large center bar upstream. Eroding banks are not a problem in this reach at present, except for a mass bank failure just upstream from Bryant's Brook. This once-wooded steep hillside has slid into the stream, creating a constriction of the channel and pushing water flows into the bank near the edge of Trow Bridge Road. Glacial outwash is the dominant surficial geologic material and has a high potential of erodibility. Hydrologic soil groups are more widespread in this reach, including B soils with medium/high infiltration rates, A soils with high infiltration rates, and C soils with medium/slow infiltration rates. Valley side slopes average about 22% for this reach.

PK 04



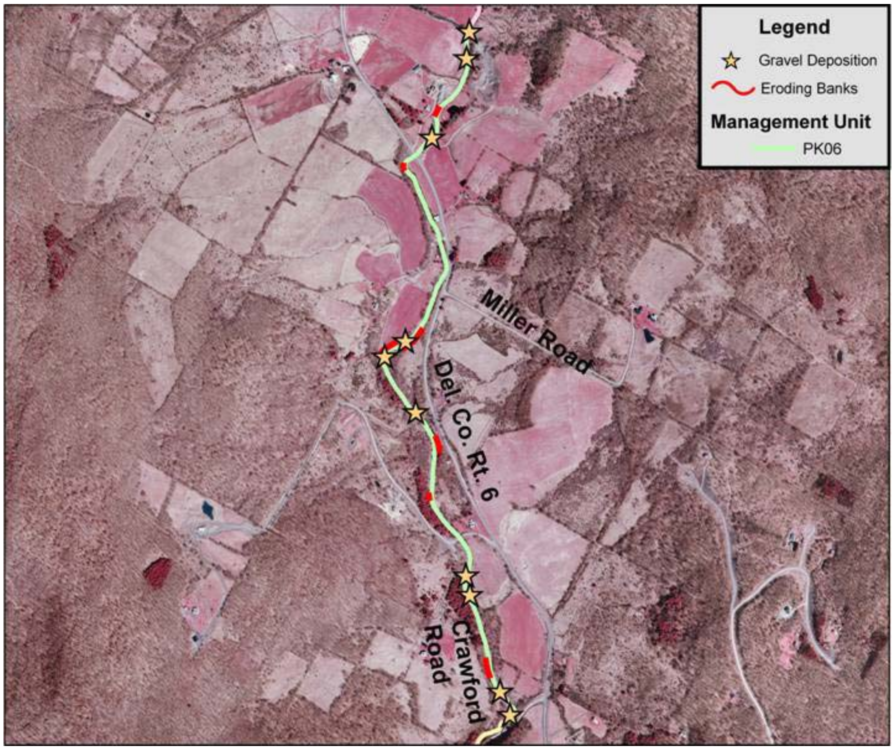
This reach is approximately 6,236 feet long and the valley is very broad with agriculture as its dominant land use. Two bridges located in this reach include one private bridge and Town Bridge #16 on Weaver Hollow Road. Two small unnamed tributaries enter the mainstem in this reach. Eroding streambanks can be seen in the upper 1/3 portion of this reach. The middle 1/3 has extensive revetments along the streambanks to protect them from erosion. Most of this reach has no riparian vegetation buffer along the banks, creating a higher potential for streambank erosion. The dominant surficial geologic material is glacial till with a moderate potential for erodibility. About 70% of the soils are hydrologic group B, which has a medium/high infiltration rate. Valley side slopes on both sides average about 21%.

PK 05



This reach is approximately 5,905 feet long and ends upstream of the former bridge on Crawford Road. This point is also about 2,000 feet downstream from Town Bridge #170. There are three bridges in this reach: Bridge #86, #87, and a private bridge. This section of stream is in a narrow, twisting valley. Information taken from the helicopter flyover video shows that there is one area of exposed bedrock that is acting like a grade control. There may be more bedrock located along the streambanks than can be identified from the video. Because of the narrowness of the valley, the Platte Kill and Brook Road run close together most of the time. There appears to be minimal revetment placed along the streambanks in this reach suggesting that the stream may be relatively stable. Surficial geologic materials are made up entirely of glacial till and have a moderate potential for erodibility. About 72% of the soils are in hydrologic group B with a medium/high infiltration rate. Valley side slops average 18% on both sides.

PK 06

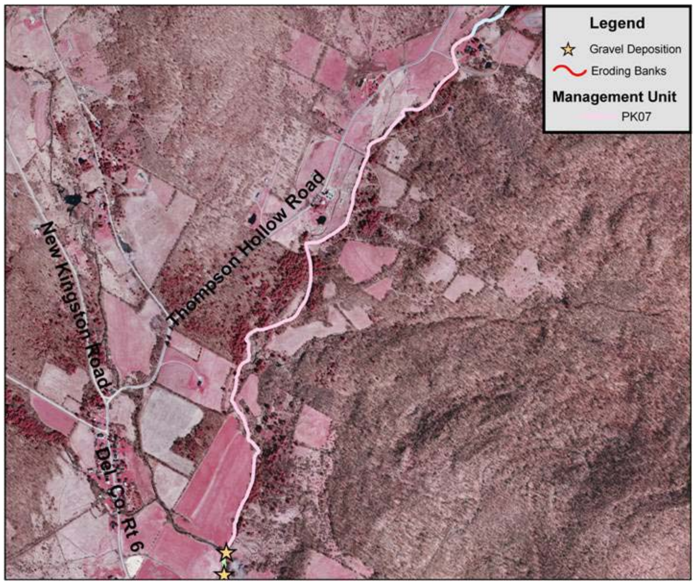


This reach is approximately 7,390 feet long and ends at the junction of Winter Hollow and Thompson Hollow. There are at least five small unnamed tributaries that enter this reach. The stream flows under three bridges: Delaware County Bridge #6-2, Town Bridges #170 and #146, and one private footbridge. The valley is fairly broad in most locations. Valley side slopes average 21% on the right side and 18% on the left side. Almost 50% of the left bank has little or no riparian vegetation buffers due to agricultural uses. In some locations, the narrow buffer stems from Delaware County Route 6 being very close to the stream. Only 7% of the reach has observed revetments and 15% of the length contains eroded streambanks. There is an increase in the number of depositional bars located in this reach. Most of these deposition bars are vegetated, suggesting that they are stable and have been in existence for a long time. Surficial geologic material in the corridor is entirely glacial till that has a moderate potential for erodibility. About 73% of the soils are hydrologic group B with a medium/high infiltration rate.

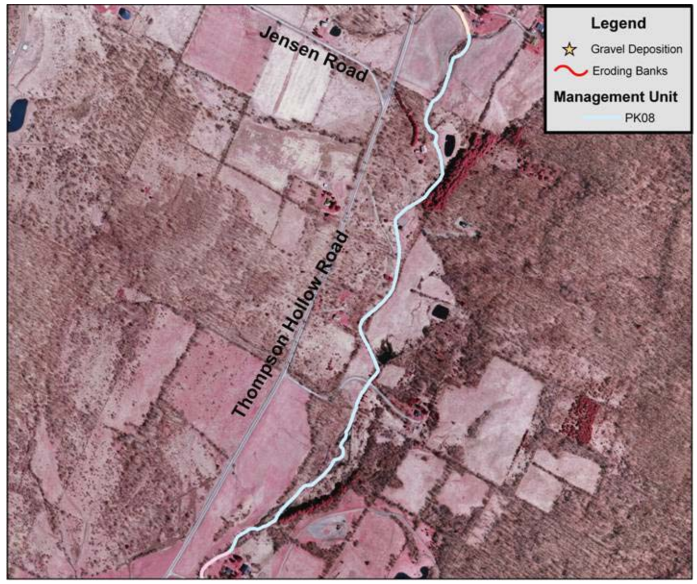
PK 07, 08, 09, 10

These four reaches are being combined because of their similarities. The helicopter video logging did not include these sections of stream therefore some of the data collected in previous reaches was not obtained. These units run upstream from PK 06 approximately 23,650 feet and end at a point in the stream at Bill Dougherty Road. There are about seven small unnamed tributaries that enter Thompson Hollow within this section. There are seven bridges and/or culverts in these reaches, which include both private and public structures. The land cover is primarily forest, abandoned agricultural fields reverting to brush and saplings, and some active agricultural fields. Riparian vegetation buffers are generally greater than 100 feet, except in PK 07 where 72% of that reach contains buffers less than 25 feet wide. Reach PK 08 has 48% of the left bank with less than 25 feet of buffer. Approximately 25% of PK 10 contains wetlands in the corridor. Many beaver ponds and swamps can be seen that create good storage areas for stormwater run-off and excess nutrients. The surficial geologic material in this unit is entirely glacial till that has a moderate potential of erodibility. Theses reaches have hydrologic group B soils with a medium/high infiltration rate. Valley side slopes average between 14% - 24%.

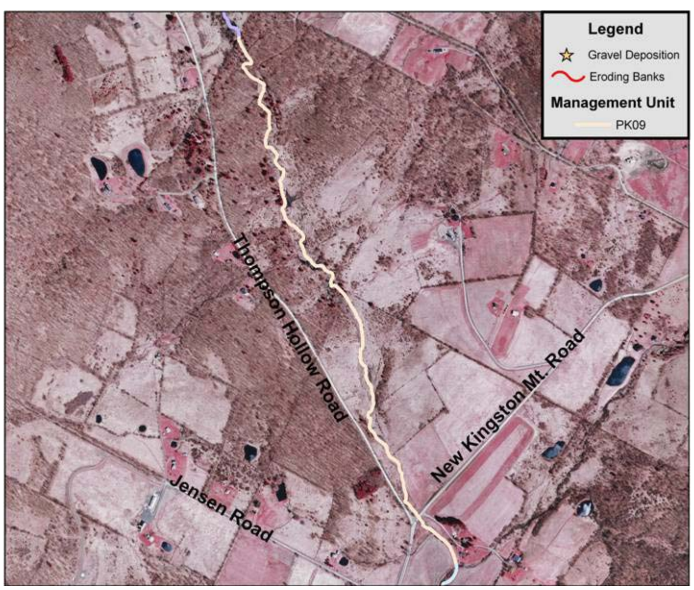
PK 07



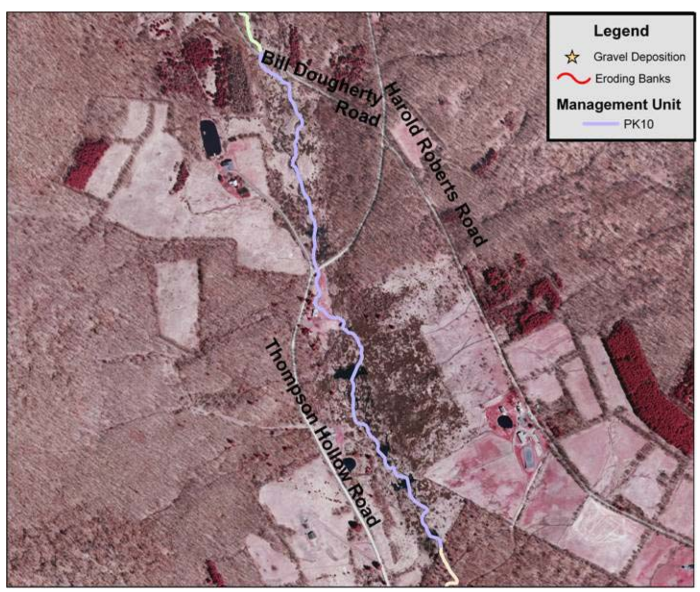
PK 08



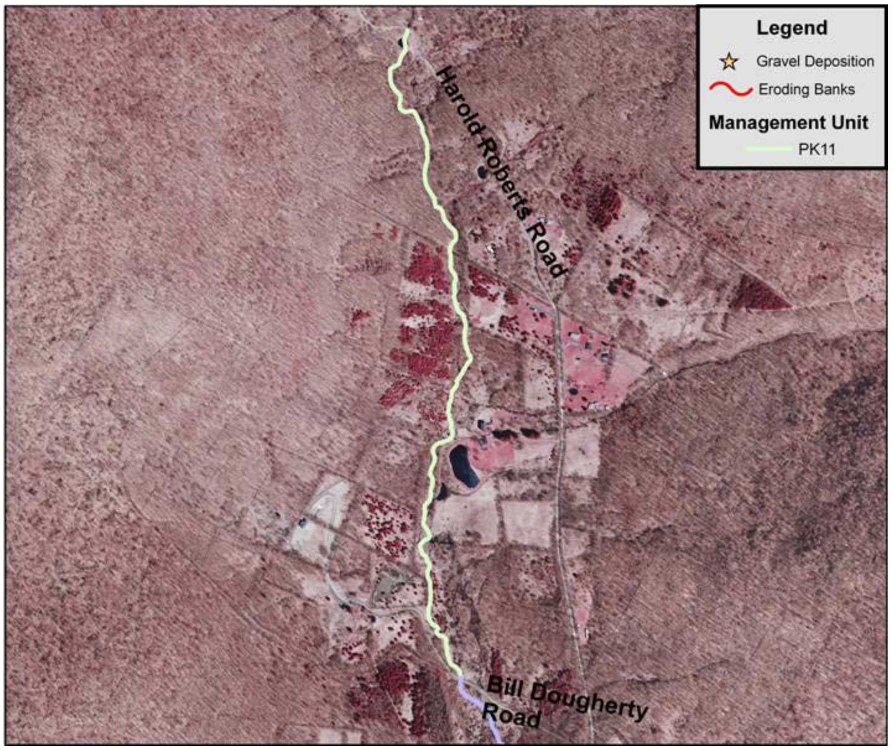
PK 09



PK 10



PK 11



This reach is located between Bill Dougherty Road and Harold Roberts Road and is approximately 5,130 feet long. This is a typical headwater section, somewhat confined within narrow valley side slopes and with a steep channel slope. Land cover in this corridor is 95% covered with forest and brush. Approximately 95% of the riparian vegetation buffer is greater than 100 feet wide on both sides of the streambanks. The surficial geologic material is mainly glacial till that has a moderate potential of erodibility. Hydrologic group C soils have a medium to slow infiltration rate, which is expected in the headwaters of a stream. On both sides of the valley, side slopes average about 25%.

Platte Kill Summary Sheet

Reach No.	Length Reach (feet)	Stream Type	Dominant Corridor Land Use/Cover	Sub-dominant Corridor Land Use/Cover	Riparian Buffer Width	Number Bridges and Culverts	% Impact of Bank Armoring
PK 01	4124.5	C	Forest	Brush	Right Bank 0-25' Left Bank >100'	2	25% Low
PK 02	4850.4	C	Forest	Brush	Right Bank >25-50' Left Bank >100'	1	13% Low
PK 03	6874.9	C	Forest	Brush	Right Bank >100' Left Bank >25-50'	1	17% Low
PK 04	6235.8	C	Forest	Agriculture	Right Bank 0-25' Left Bank 0-25'	2	41% High
PK 05	5904.6	C	Forest	Agriculture	Right Bank >100" Left Bank 0-25'	3	13% Low
PK 06	7970.3	C	Forest	Agriculture	Right Bank >100" Left Bank 0-25'	4	8% Not significant
PK 07	7897.1	C	Forest	Brush	Right Bank 0-25' Left Bank >100'	---	No info
PK 08	5130.8	C	Forest	Brush	Right Bank >100' Left Bank 0-25'	---	No info
PK 09	6124.1	B	Forest	Agriculture	Right Bank >100' Left Bank >100'	---	No info
PK 10	4498.3	B	Forest	Wetland	Right Bank >100' Left Bank >100'	---	No info
PK 11	5127.3	B	Forest	Brush	Right Bank >100' Left Bank >100'	---	No info

Reach No.	% Impact Berms, Roads, Railroads, Paths	Impact Floodplain Development	Impact Depositional Features	Impact Meander Migration	Bank Erosion/ Bank Height	Ice/ Debris Jam Potential (Y/N)
PK 01	54% High	Low	Low	No Info	High	No Info
PK 02	48% High	Low	Not significant	No Info	Low	No Info
PK 03	11% Low	Low	Low	No Info	High	No Info
PK 04	16% Low	Low	Low	No Info	Low	No Info
PK 05	42% High	Low	Low	No Info	Low	No Info
PK 06	14% Low	Low	Low	No Info	Low	No Info
PK 07	2% Not significant	Not significant	Not significant	No Info	No Info	No Info
PK 08	2% Not significant	Not significant	Low	No Info	No Info	No Info
PK 09	4% Not significant	Not significant	Not significant	No Info	No Info	No Info
PK 10	3% Not significant	Not significant	Not significant	No Info	No Info	No Info
PK 11	6% Low	Not significant	Not significant	No Info	No Info	No Info

EAST BRANCH DELAWARE RIVER MAINSTEM

Town of Middletown

Introduction

The East Branch Delaware River mainstem watershed is located within the Town of Middletown in Delaware County. The Village of Margaretville is the only population center within this sub-basin. East Branch Delaware River mainstem was divided into three management units based upon the Vermont Protocol.

The East Branch mainstem is a sixth order stream. Huckleberry Brook, Bull Run, Dry Brook, Hubbell Hill Hollow, Batavia Kill, and numerous unnamed tributaries enter the East Branch mainstem. Tributaries that are near highly populated areas are more likely to have been straightened and maintained. The drainage area of East Branch mainstem is approximately 25.76 square miles and the stream is 9.8 stream miles long from the confluence with the Batavia Kill to the high water mark of the Pepacton Reservoir. The East Branch mainstem is primarily a C stream type and the valley is generally broad. The land is predominately forested along the majority of the mainstem, with some built-up and/or brush areas. The average annual rainfall in the watershed can range from 35-39 inches/year.

Stream Assessment

Data was collected using several different methods. The first step was gathering information to separate the stream into manageable sections using the SGAT protocol. This data helped target problem areas that needed further assessments. There were two helicopter flights conducted in order to get a visual of the whole watershed from a bird's eye view. The first helicopter flight's main purpose was to take photographs of problem areas. **Figure 1.14** depicts the Village of Margaretville. The second helicopter flight by RETTEW, an engineering consulting firm with offices in Margaretville, produced a video log for the sub-basin. GPS synchronization with the video log enabled the assessment team to map and describe stream features, such as eroding stream bank locations, to the GIS. Rosgen Level II surveys were not completed in this stream reach due to time constraints.

Figure 1.14 Village of Margaretville

Geomorphic Conditions

The East Branch Delaware River mainstem begins at the end of the East Branch Delaware River headwaters and ends at the high water mark of the Pepacton Reservoir. The channel slope is flat and the stream type is classified as C. However, there is a reach of braided stream channels for about 3,500 feet in EBMS 01, a reach that is located between the Pepacton Reservoir stem and the lower limits of Margaretville. The "island" in this braided reach appears to be old since the island is covered with forest and brush. Therefore, while this reach is technically a type D or DA stream, it is not and unstable reach. This braided area, being less than a third of the overall length of EBMS 01, does not affect the management approach for this reach. Sinuosity is low for this sub-basin: EBMS 01 has a sinuosity of 1.11, EBMS 02 is 1.04, and EBMS 03 is 1.10. There are two unnaturally straight reaches in EBMS 02 that are particularly noticeable, one located upstream of the Margaretville firemen's pavilion and the other opposite the golf course. These straight portions of the stream are joined by a sharp, very small radius bend that most likely was created 100-200 years ago when the river was moved to this position. A similar condition occurs at the Hannah Country Club golf course, where the stream follows a very straight channel. All three reaches are highly impacted by urban areas and/or agricultural activities. Similarly, reaches EBMS 02 and EBMS 03 suffer from a lack of adequate riparian vegetation buffer. The dominant buffer width in these two reaches ranges from 0-25 feet wide. The dominant vegetation buffer of EBMS 01 is more effective at a width of 100 feet or more.

Reaches EBMS 01 and EBMS 02 both contain large amounts of streambank erosion and gravel deposition. Reach EBMS 01 has 7,506 linear feet of eroding banks and 11 areas of gravel deposition; reach EBMS 02 has 2,050 linear feet of eroding banks and 8 areas of gravel deposition; reach EBMS 03 has only 822 linear feet of eroding banks and 7 areas of gravel deposition. Streambank protection, such as riprap, is extensive in reach EBMS 02, which has 2,415 linear feet of streambank revetment. There are fewer revetments located in reaches EBMS 01 and EBMS 03, which have 670 linear feet and 850 linear feet respectively. The presence of revetment, especially the high amount in reach EBMS 02, is evidence of a historic and possibly continuing streambank erosion problem. Dry Brook is a tributary that enters the mainstem and contributes a large amount of sediment. Whether this sediment drops out in reaches EBMS 01 and EBMS 02 is not known. It should be noted that repairing the streambanks in these reaches could be helpful, but may not solve the problem entirely.

Figure 1.15 Binnekill and Bull Run Tributaries

The East Branch mainstem and tributaries have been maintained since the stream was confined within its banks in populated areas. **Figure 1.15** shows the Binnekill and Bull Run tributaries after gravel had been removed near the confluence with the East Branch mainstem. Gravel will continue to deposit in this location since the tributaries transport excess sediment and the slope is quite level.

Figure 1.16 Binnekill Headwall

In EBMS 02, a portion of the East Branch mainstem is diverted into maintained channel known as the Binnekill. This diverted water flows through the Village of Margaretville and is used by the community for fire control. Bull Run, a tributary from the north side of the village, and the Binnekill enter the East Branch Mainstem at the same location. Gravel deposits can be a problem at this location and are regularly removed to maintain flows. **Figure 1.16** shows the headwall where the mainstem enters and becomes the Binnekill.

Gravel deposits along EBMS 02 are a concern for the Village of Margaretville. Gravel deposits at four locations along the reach: below the village near the Margaretville Wastewater Treatment facility, across from Margaretville High School upstream from the Fair Street Bridge, upstream of the Bridge Street bridge opposite the Pavilion, and below the inlet to the Binnekill. In the summer of 2006, some gravel was removed from a large point bar on the left side of the stream upstream of the Bridge Street bridge in an attempt to restore channel capacity in reach EBMS 02 (near the Margaretville Pavilion). On the right bank, a metal boilerplate wall was removed that had failed during the June 2006 flood. This wall – and the stone fill behind it – was placed 50 years ago to protect the streambanks. The boilerplate wall was determined to be in disrepair, ineffective, and a dangerous structure for recreational activities. In the summer of 2007, the DCSWCD SCMPr and NYCDEP constructed a demonstration project to reduce bank erosion. Rock vanes were used to reduce shear stress on the bank and the bank was strengthened with vegetation (See **Volume 1, Section III**).

No Rosgen Level II survey was performed on these reaches due to the lack of time and the depth of the stream. A complete topographic survey including cross sections was completed for use in the design of the demonstration restoration project. According to the SGAT protocol, these three stream reaches are able to access their floodplains.

Management Prescription for East Branch Delaware River Mainstem Sub-basin:

- Address streambank erosion
- Access to the floodplain must be maintained. No development or modification to the floodplain must be permitted as this would increase bank erosion,

accelerate channel evolution, and could easily lead to the destabilization of the stream system.

- Since it is known that the channel has been altered, any repair work or changes must be based on geomorphic principles to assure that no instabilities are created and that the sediment transport is adequately addressed

Floodplains

The floodplain is predominantly undeveloped, except within the Village of Margaretville. Numerous houses and business are located within the 100 year floodplain in the Village of Margaretville. Some of the pre-FIRM development within a natural floodplain has constricted flows and raised flood elevations and velocities resulting in damage to upstream and downstream properties. Additional development within the floodplain should be avoided as it will likely raise the flood elevations, affect the stream alignment, increase the stream's energy within the channel, and produce accelerated bank erosion near the developed area.

Figure 1.17 Golf Course

The upper portion of the sub-basin's floodplain is less developed with the exception of the Hannah Golf Course. While the course does not necessarily restrict the floodplain, the products used to manage the turf can impact water quality with the addition of excess nutrients, pesticides and herbicides. Stormwater runoff may pick up the excess nutrients and deliver it to the streams without a sufficient buffer to absorb the nutrients. This can result in algae growth and other related problems. Riparian vegetation buffers along the golf course may reduce the nutrient load. **Figure 1.17** is a helicopter photo of the golf course that depicts little to no riparian buffer. This area would be an excellent place for the development of a riparian buffer program to establish trees along the streambanks.

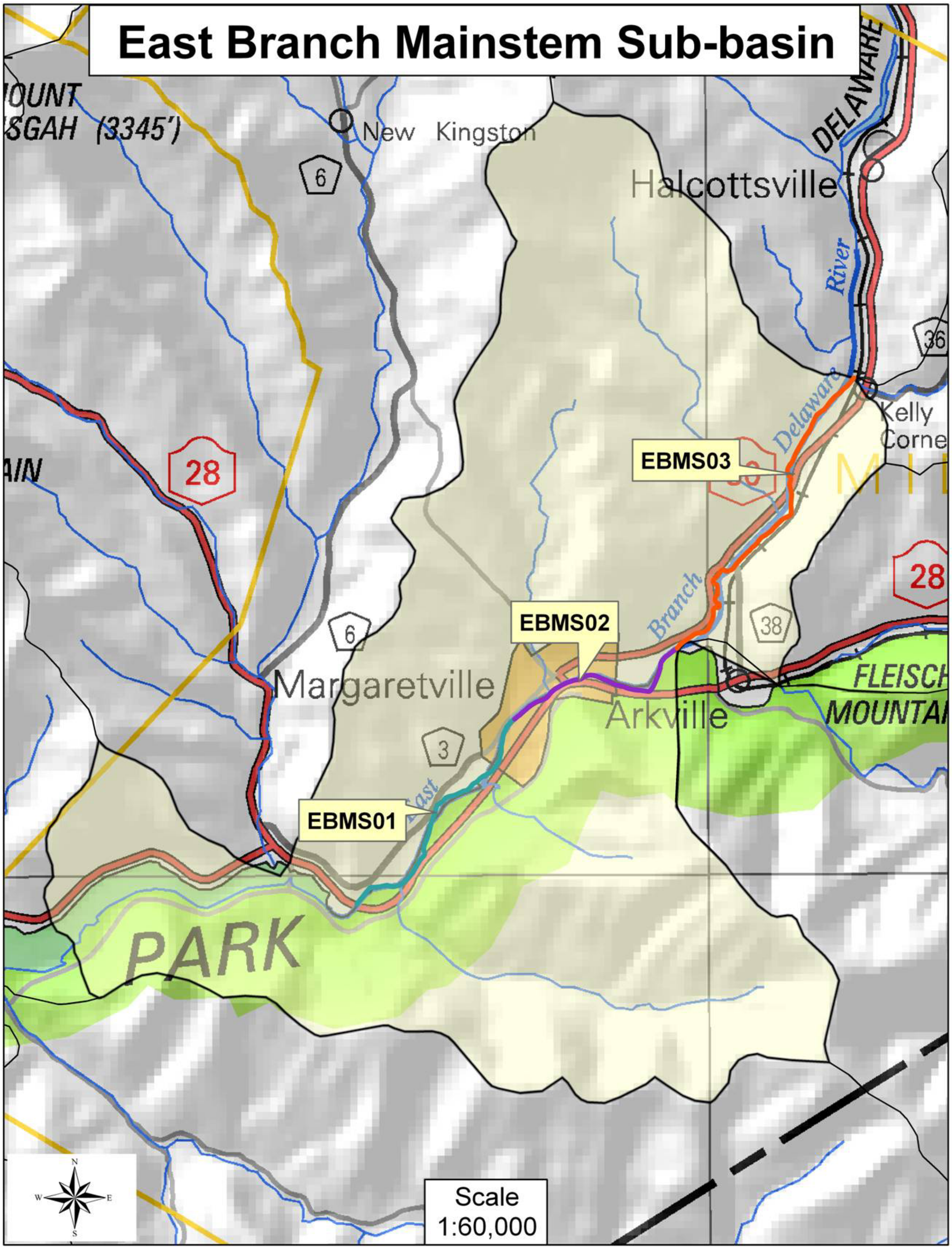
The valley is broad along the mainstem and the road follows along the stream. The road cuts off the stream's floodplain in several locations, causing problems upstream and downstream of the bridges that include bank and bed scour, gravel deposition, and debris jams.

Infrastructure

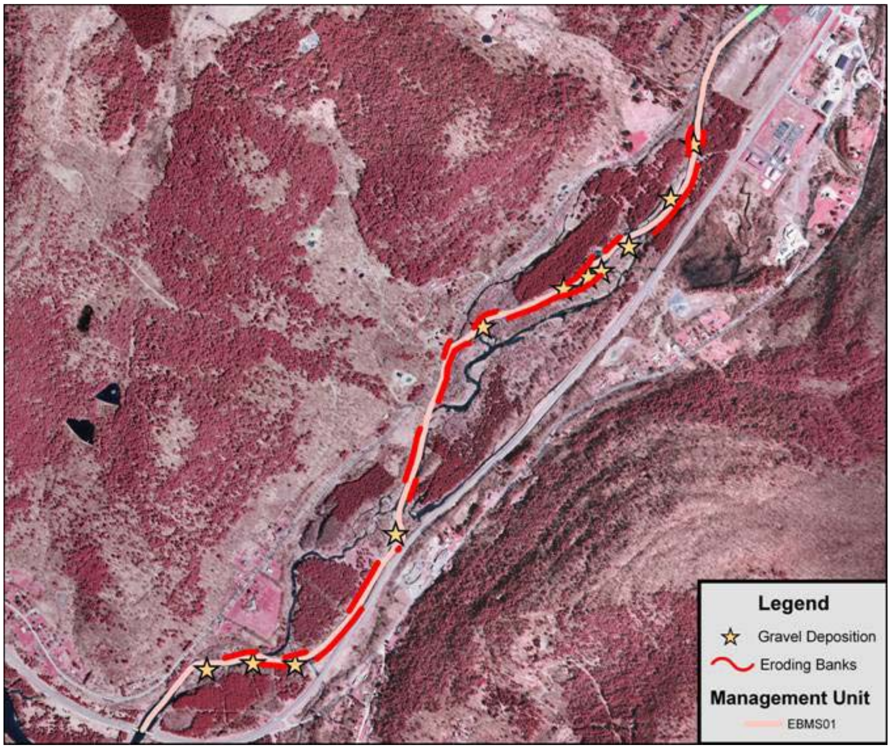
New York State Route 28 and 30, Delaware County Route 3, and a railroad bed run parallel to the East Branch mainstem. The roads adversely impact the stream health and can cause floodplain restriction in areas. Stormwater runoff from the road ditches adds excess water and pollution directly to the streams without allowing time for absorption into the ground. In the several locations where the stream is close to the road, revetment was placed along the banks in order to protect the road from channel migration.

Town Bridge #24, Delaware County Bridge #38-1, three bridges on New York State Highway 30, and some private bridges are located within this sub-basin. The impacts of these structures are sediment deposition and log debris jams. Further inspection of these structures is needed in order to determine the impacts of the bridges on the stream system.

Management Unit Descriptions

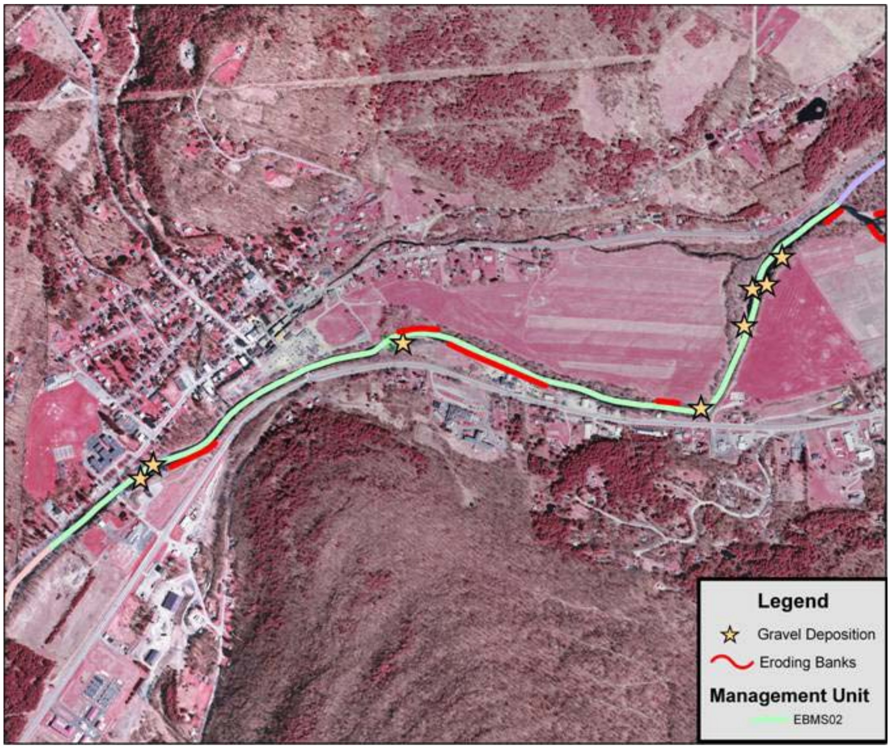


EBMS 01



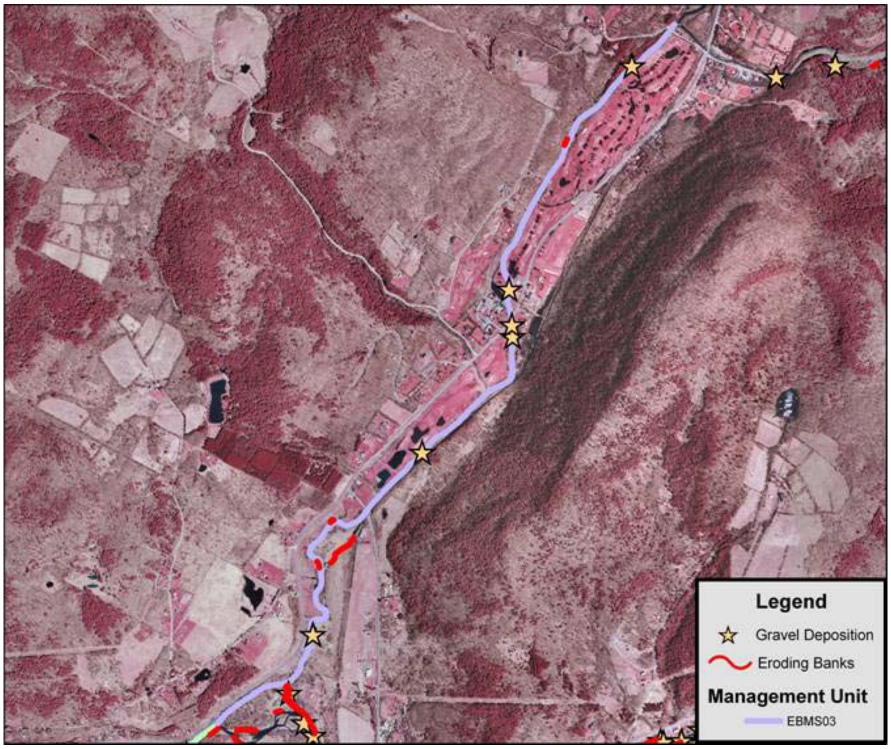
This reach begins near the high water mark of the Pepacton Reservoir (at the NYS Route 28/30 bridge) and runs upstream for about 11,440 feet. In many parts of this reach, the stream contains multiple channels as it runs through a broad valley. Huckleberry Brook and at least two other unnamed tributaries enter into this reach. Land within the stream corridor is 70% forested and wetlands. About 20% of the land is considered built-up, which includes the paved roads of NYS Route 28/30 and Delaware County Route 3. About 59% of the reach has an eroding streambank along the main channel and 31% of these eroding banks have little to no riparian buffer. Approximately 34% of the reach length contains a narrow buffer of 0-25 feet wide. Most of these narrow buffers occur when a road closely parallels the river. At least 26% of the main channel experiences gravel deposition, mostly consisting of large side bars. Revetments affect only 6% of the reach length while protecting the streambanks near the road and bridges. This section of river has plenty of available floodplain and there are no residential areas in the floodplain area. There is a short section of confined stream near the confluence with Huckleberry Brook. The river's floodplain is restricted by NYS Route 28/30 at the bridge in the downstream end of the reach. The state road cuts across the floodplain and funnels all flow under the bridge during high flow events.

EBMS 02



This reach is about 8,746 feet long and ends at the Dry Brook confluence. This reach has been straightened in the past and it flows through a very broad valley. Bull Run is the only tributary in this reach that contributes water and sediment. The Village of Margaretville is built on the ancient alluvial fan for the Bull Run Hollow. The broad valley is naturally constricted at the outlet of Bull Run by the alluvium from the tributary on the right bank and the steep hillside on the left bank. Two bridges, located on Fair Street and Bridge Street, cross over the river in this reach and essentially define the extent of the valley/floodplain constriction. USGS Stream Gage 01413500 (East Branch Delaware River at Margaretville NY) is located on the right bank downstream of the bridge on Fair Street. The drainage area at the stream gage is 163 square miles. The period of records that is available for this gage is from February 1937 to the current year. The stream corridor, which runs through a portion of the Village of Margaretville, is about 37% built-up/residential and about 33% fields/open area. Narrow riparian buffer widths of 0-25 feet wide are common along the streambanks. About 99% of the length has a narrow vegetation buffer on one streambank or the other bank. Revetments on the streambank cover 30% of the reach length. At the beginning of the reach, the stream flows along the right valley wall before cutting diagonally across to the left valley wall. The slope of the river becomes more level at the point where it moves across the valley. This short section exhibits half the deposition (10%) of the entire stream reach (20%). Upstream of the Village of Margaretville, the East Branch Delaware River branches off into the Binnekill through the bulkhead. Historically, the Binnekill was used to feed water to a mill, but is now used as a tourist attraction for the Village of Margaretville. A FEMA grant has been obtained to improve the bulkhead. As previously described, a DCSWCD/DEP demonstration stream restoration project was constructed during the summer of 2007 within this reach upstream of the Bridge Street bridge near the village fair grounds.

EBMS 03



This reach is approximately 15,514 feet long and ends at the confluence with the Batavia Kill and the East Branch Delaware River headwaters. The valley is very broad and most of the stream is straightened as it flows against the valley wall. A 2,000-feet-long section downstream from Delaware County Bridge #38-1 appears to have been less manipulated as it flows in the center part of the valley and is much more sinuous. The reach has excellent streamside vegetation, which helps maintain the stability of this reach. There are seven tributaries that enter into this reach, including Hubbell Hill Hollow and the Batavia Kill. The four bridges in this reach are Delaware County Bridge #38-1, the NYS Route 30 bridge, the East Hubbell Hill Road bridge, and a golf cart path bridge. The stream corridor is forested on the valley walls while the floodplain is covered with brush, abandoned fields, and a golf course. Eroding streambanks and revetment lengths each total 5% of the total reach length. Depositional features are also low at 4% of the reach length. A narrow riparian vegetation buffer of 0-25 feet wide can be seen on one streambank or the other for about 72% of this reach, mostly due to the golf course and abandoned fields located in the downstream portion. At this time, the narrow buffers are not affecting streambank stability but may not be wide enough to help water quality issues.

East Branch Mainstem Summary Sheet

Reach No.	Length Reach (feet)	Stream Type	Dominant Corridor Land Use/Cover	Sub-dominant Corridor Land Use/Cover	Riparian Buffer Width	Number Bridges and Culverts	% Impact of Bank Armoring
MU 1	11440	C	Forest	Built-up	Right Bank >100' Left Bank >100'	1	6% Not Significant
MU 2	8746	C	Forest	Built-up	Right Bank 0-25' Left Bank 0-25'	2	28% Low
MU 3	15514	C	Forest	Brush	Right Bank 0-25' Left Bank 0-25'	4	5% Not Significant

Reach No.	% Impact Berms, Roads, Railroads, Paths	Impact Floodplain Development	Impact Depositional Features	Impact Meander Migration	Bank Erosion/ Bank Height	Ice/ Debris Jam Potential (Y/N)
MU 1	10% Low	Low	High	Low	High	Y
MU 2	32% High	High	High	Low	Low	Y
MU 3	14% Low	Low	Low	Low	Low	Y

EAST BRANCH DELAWARE RIVER HEADWATERS

Towns of Middletown and Roxbury

Introduction

The East Branch headwaters are located within two townships in Delaware County: Middletown and Roxbury. Roxbury and Halcottsville are the population centers within this sub-basin. The East Branch Delaware River headwaters were not separated into management units due to time constraints, and windshield surveys determined that the stream appeared to be relatively stable. Additional research should be done along the stream in the future.

The East Branch headwater is a fourth order stream. Bragg Hollow, Meeker Hollow, Pleasant Valley Brook, Montgomery Hollow, and numerous unnamed tributaries enter the East Branch headwaters. Tributaries within this sub-basin seem to have minimal impact on stream health and appear to be fairly stable. Tributaries that are near highly populated areas are more likely to have been straightened and maintained. The East Branch headwaters are 14.7 stream miles long from the upper reaches to the East Branch mainstem, draining approximately 49.66 square miles. The land use is predominately residential along the majority of the headwaters. The average annual rainfall in the watershed can range from 37-39 inches/year in the lower reaches to 39-45 inches/year in the upper reaches.

Stream Assessment

Data was collected via windshield surveys, 2001 aerial photography, and helicopter video logging. Portions of the stream could not be seen from the road. Due to time constraints, this sub-basin was not determined a priority to complete GPS data collection or the SGAT protocol. Future stream assessment is recommended.

Geomorphic Conditions

For the purpose of this plan, the headwater is considered to begin at a pond located near Grand Gorge and end at the confluence with the Batavia Kill tributary.

The East Branch Delaware River headwaters have been classified as a type C stream based on the 2001 aerial photographs. According to USGS topography quad maps, the slope is about 0.4%. Near Mac More Road, the stream appears to have been straightened and could have been pushed up against the valley wall. From this location to Roxbury, the stream appears to meander across the floodplain. South of Roxbury, the stream enters a wetland and then emerges to continue on its course until it enters Wawaka Lake. It exits the lake and continues south until its meets the Batavia Kill tributary near Kelly's Corners.

According to 2001 aerial photography, the East Branch headwaters appear to have large amounts of sediment being transported and deposited throughout the entire stream system. The Wawaka Lake dam impounds water, slowing flow and causing deposition to occur. Windshield surveys have identified some locations of deposition and problem areas in the headwaters of the sub-basin. The majority of the stream cannot be seen from the road, so further inspection of the mainstem is recommended in order to identify problem areas of deposition and their causes.

Approximately 3.2 miles (or 53% of the total stream length) appears to have inadequate riparian vegetation buffer on one or both streambanks. This information was obtained by a conservative interpretation of the 2001 aerial photographs and helicopter video. A GPS walkover and subsequent analysis of the collected data would probably show that much of the perceived vegetation buffer is too narrow to be an effective. Generally speaking, the riparian vegetation buffer appears to be sufficient except where the stream runs through agricultural fields or developing areas.

Based on 2001 aerial photographs, there appears to be several locations where the stream is running along the valley wall. Comparison of this visual data to USGS quad maps seems to verify this interpretation. This area has the potential to be unstable depending on the soils present, which determine the stability of the streambank. For example, a bedrock valley wall will probably remain stable, but a colluvium-based valley wall is potentially unstable.

Management Prescription for East Branch Delaware River Headwaters Sub-basin:

- A GPS walkover should be completed for this sub-basin
- A Rosgen Level II survey should be completed to verify stream type
- Eroded areas should be located and related to existing vegetation buffers or the lack thereof
- Instances where the stream is against the valley wall should be recorded during GPS data collection, along with any stream issues that may be occurring

Floodplains

There are several areas of development along the floodplain. Development leads to floodplain constriction and areas may be prone to flooding during high flow events. Halcottsville and Roxbury – located on the floodplain – have encroached on the floodplain and may have altered the path of the stream.

The valley is narrow along most of the mainstem and the road follows along the stream. The road cuts off the stream's floodplain in several locations, causing problems upstream and downstream such as channel migration, gravel deposition, and debris jams. Further studies are needed to determine additional causes of the channel migration.

Infrastructure

New York State Route 30, Frog Alley Road, Old River Road, Delaware County Route 41, and an abandoned railroad bed all run parallel to the East Branch headwaters. The roads have adverse impacts on stream health and can cause floodplain restriction in certain areas. Stormwater runoff from the road ditches adds excess water and pollution directly to the streams without allowing time for absorption into the ground. There are several locations where the stream is close to the road and revetment was placed along the banks in order to protect the road from channel migration. Further inspections will be required in order to document additional stream impacts.

Town Bridges #25, #53, #26, #102, #143, Delaware County Bridge #41-2, one bridge on New York State Highway 30, and some private bridges are located within this sub-basin. The small drainage area in the upper portions of the headwaters allows for culverts to be installed, conveying the water under the road. According the windshield survey, the impacts of these structures are deposition and log debris. Culvert impacts can also be erosion or deposition upstream and/or downstream of the structure if the culvert is improperly sized. Further inspection of these structures is needed in order to determine the impacts on the stream.

TERRY CLOVE SUB-BASIN

Towns of Hamden, Andes and Colchester

Introduction

The Terry Clove watershed is located within three different townships in Delaware County: Hamden, Colchester, and a small portion of Andes. There are no population centers located in this sub-basin. Terry Clove was not separated into management units due to time constraints, and it was determined during windshield surveys that the sub-basin appears to be stable. Additional assessment should be conducted along the stream in the future as time and resources permit. The Terry Clove mainstem drains directly into the Pepacton Reservoir.

The Terry Clove mainstem is a third order stream. In addition to unnamed tributaries, there are two major tributaries that enter the mainstem: Bryden Hill Brook and Basin Clove. The drainage area of Terry Clove is approximately 15.08 square miles, and the mainstem runs 6.1 stream miles from the headwaters to the confluence with the Pepacton Reservoir. The land use is predominately agricultural along the majority of the mainstem. The average annual rainfall for the majority of Terry Clove watershed ranges from 41-43 inches/year, while the headwaters experience 39-41 inches/year. The Basin Clove and Bryden Hill Brook tributaries range from 43-45 inches/year in the headwaters.

Stream Assessment

Data was collected using observations from windshield surveys and 2001 aerial photographs. Portions of the stream could not be seen from the road and tree cover made it difficult to see the stream from aerial photographs. Due to time constraints, this sub-basin was not determined a priority for the collection of GPS data, the completion of SGAT protocol, or a helicopter flyover. Future stream assessment is recommended for this sub-basin.

Geomorphic Conditions

Based on the 2001 aerial photographs, Terry Clove has been classified as type C stream. According to USGS quad maps, the slope is about 1.7%. The stream generally meanders throughout the sub-basin. However, for about the first 6,000 feet of the headwaters, the stream is rather straight with small, sharp radius bends. The stream channel planform, as seen on the 2001 aerial photographs, resembles a stream type B. From this location on downstream, the stream meanders and the bends become a combination of long bends with larger radii and short bends with small, angular radii.

Approximately 2.0 miles of the stream (33% of the stream length) appear to have inadequate riparian vegetation buffer on one or both streambanks. This information is based on a conservative visual interpretation of the 2001 aerial photographs. A GPS walkover and subsequent analysis of the collected data would probably show that much of the perceived buffer is too narrow or less vegetated than would be effective. Therefore, the amount of inadequate buffer is probably higher than 33%.

Based on 2001 aerial photographs, there appears to be several locations where the stream is running along the valley wall. Comparison of this visual data to USGS quad maps seems to verify this interpretation. This area has the potential to be unstable depending on the soils present, which determine the stability of the streambank. For example, a bedrock valley wall will probably remain stable, but a colluvium-based valley wall is potentially unstable. These areas should be inspected in the future.

Management Prescription for Terry Clove Sub-basin:

- A GPS walkover should be completed for this sub-basin
- A Rosgen Level II survey should be completed to verify stream type
- Eroded areas should be located and related to existing vegetation buffers or the lack thereof

Infrastructure

East Terry Clove Road, Terry Clove Road, and Coles Clove Road run parallel to the Terry Clove mainstem. Edwards Road, Basin Clove Road, and West Terry Clove Road are perpendicular to the mainstem. The roads have made little adverse impacts to the stream health. Stormwater runoff from the road ditches adds excess water and pollution directly to the streams without allowing time for absorption into the ground. There are several locations where the stream is close to the road and revetment was placed along the banks in order to protect the road from channel migration. Location of revetment or problem areas should be identified in the future.

Town Bridges #76 and #165 and some private bridges are located within this sub-basin. In the headwaters, the Terry Clove mainstem has a small drainage area and culverts are installed to convey the water under the road. The impacts of the culverts can be erosion or deposition upstream and/or downstream of the structure if the culvert is improperly sized. Further inspection of these structures is needed in order to determine their impacts on the stream.

FALL CLOVE SUB-BASIN

Towns of Andes, Colchester and Hamden

Introduction

The Fall Clove watershed is located within three different townships in Delaware County: Andes, Colchester, and a small piece of Hamden. There are no population centers located within this sub-basin. Fall Clove was not separated into management units due to time constraints and it was determined during windshield surveys that the stream appeared to be stable. Additional research should be completed along the stream in the future. The Fall Clove mainstem drains directly into the Pepacton Reservoir.

The Fall Clove mainstem is a third order stream. There are two major tributaries that enter the mainstem: Skunk Hollow and Fish Hollow, and there are numerous unnamed tributaries. Tributaries within this sub-basin seem to have minimal impact and the mainstem appears to be very stable. The drainage area of Fall Clove is approximately 11.18 square miles and the mainstem is 7.6 stream miles from the headwaters to the outlet at the Pepacton Reservoir. The land use is predominately agricultural along the mainstem. The average annual rainfall for the entire watershed ranges from 41-43 inches/year.

Stream Assessment

Data was collected via windshield surveys and 2001 aerial photographs. Portions of the stream could not be seen from the road and tree cover made it difficult to see portions of the stream from the aerial photographs. Due to time constraints, this sub-basin was not determined a priority for GPS data collection, the completion of the SGAT protocol, and/or a helicopter flyover. Future stream assessment is recommended for this sub-basin.

Geomorphic Conditions

Based on 2001 aerial photographs, Fall Clove has been classified as a type C stream. According to the USGS quad maps, the overall slope is about 2%. The stream appears to meander throughout the sub-basin. Near Brace Hollow Road, there is a stretch of stream about 4,000 feet long that flows through a straight stream channel. It is possible that this reach was, at some time in the past, moved or channelized to this location. Near the stream's outlet at the Pepacton Reservoir, the stream runs fairly straight until it reaches a location that contains bedrock control.

Approximately 3.4 miles of stream appear to have inadequate riparian vegetation buffers on one or both streambanks, equaling 45% of the total reach length. This information is based on a conservative visual interpretation of the 2001 aerial photographs. A GPS walkover and a subsequent analysis of the data would probably show that much of the perceived vegetation buffer is too narrow to provide effective bank protection.

There appears to be several locations where the stream flows along the valley wall. This was observed on 2001 aerial photographs and compared to the USGS quad maps, which seems to verify the data. . This area has the potential to be unstable depending on the soils present, which determine the stability of the streambank. For example, a bedrock valley wall will probably remain stable, but a colluvium-based valley wall is potentially unstable. These areas should be inspected in the future.

Management Prescription for Fall Clove Sub-basin:

- A GPS walkover should be completed for this sub-basin
- A Rosgen Level II survey should be completed to verify stream type
- Eroded areas should be located and related to existing vegetation buffers or the lack thereof

Floodplains

The Fall Clove mainstem has access to the floodplain. Development along the floodplain is very sparse and minimally impacts the stream. Farms and fields occur along the mainstem. Roads that run parallel to the stream may cause some floodplain restriction in certain areas, but further research is needed to determine their impact on the stream.

Infrastructure

Fall Clove Road runs parallel to the Fall Clove mainstem and minimally impacted the stream health. The mainstem is generally located away from the road, and in most areas can hardly be seen from the road. Stormwater runoff has a minimal impact on the streams, especially since this is a small watershed. Further research is needed to determine any additional stormwater runoff impact in this sub-basin.

Bridges located within this sub-basin are Town Bridge #164 and some private bridges. The drainage area in the headwaters is so small that only culverts are needed to convey the water under the roads. The bridges and culverts have minimal impact to the stream health. Some impacts of the culvert can be erosion or deposition upstream and/or downstream of the structure if the culvert is improperly sized. Further inspection of these structures is needed in order to determine the impacts on the stream.

MILL BROOK SUB-BASIN

Towns of Middletown, Hardenburgh and Colchester

Introduction

The Mill Brook watershed is located within three different townships: Middletown and a small portion of Colchester in Delaware County, and Hardenburgh in Ulster County. There are no population centers located in this sub-basin. Mill Brook was not divided into management units due to time constraints and it was determined during windshield surveys of the sub-basin that the stream appeared to be relatively stable. Additional research should be done along the stream in the future. The Mill Brook mainstem drains directly into the Pepacton Reservoir. The majority of the land along Mill Brook mainstem is owned by a private club called the Tuscarora Club. The stream is managed by the Tuscarora Club to preserve quality fishing habitat along the mainstem.

The Mill Brook mainstem is a fourth order stream. Clark Hollow is one major tributary that enters the Mill Brook mainstem in addition to numerous unnamed tributaries. Tributaries within this sub-basin seem to have a small impact on the mainstem and appear to be fairly stable. The drainage area of Mill Brook is approximately 25.36 square miles and the mainstem is 11.2 stream miles from the headwaters to the outlet of the Pepacton Reservoir. The land is predominately forested along the majority of the mainstem. The average annual rainfall in the watershed can range from 35-41 inches/year at the lower portion of the sub-basin to 41-51 inches/year in the headwaters. The USGS Stream Gage 01414500 (Mill Brook Near Dunraven NY) is located on the left bank 0.4 miles upstream from the bridge on New York City Road 9 and 2.7 miles southwest of Dunraven. The drainage area at the stream gage is 25.2 square miles. The period of records that is available for this gage is from February 1937 to the current year, and some of these records are published as "at Arena" 1937-67.

Stream Assessment

Data was collected via windshield surveys, 2001 aerial photographs, and USGS topographic quad maps. Portions of the stream could not be seen from the road. Due to time constraints and general knowledge of its relatively stable condition, this sub-basin was not determined a priority for GPS data collection, completion of the SGAT protocol, and/or a helicopter flyover. Future stream assessment is recommended for this sub-basin.

Geomorphic Conditions

Based on the 2001 aerial photographs, Mill Brook has been classified as a type C stream. The upper reaches are steep and the stream can be assumed to be a type B or even a type A stream. According to the USGS quad maps, the overall slope is about 3.2%. Mill Brook meanders throughout the sub-basin, but tends to run in a straight channel for the last half mile just before entering the Pepacton Reservoir. The stream at this location is confined by the valley walls and there are roads located on either side of the stream.

There are four locations (totaling 1,850 feet) where the stream exhibits excessive gravel deposition. These areas of the stream have a tendency to braid through the gravel deposition. Gravel deposits represent 3% of the total stream length; data was obtained using visual inspection from 2001 aerial photographs. Generally speaking, the riparian vegetation buffer is quite good. It should be noted that each gravel depositional area exhibits poor or non-existent riparian buffer. Possibly, the stream has become too wide and has lost its ability to transport the sediment, causing the sediment to deposit as gravel bars.

Mill Brook has a very narrow valley and appears in some locations to be up against the valley wall. However, with a valley as narrow as Mill Brook's, it is impossible to determine from 2001 aerial photographs and USGS topography maps whether the channel is in fact against the valley wall or what condition the stream is in.

Management Prescription for Mill Brook Sub-basin:

- A GPS walkover should be completed for this sub-basin
- A Rosgen Level II survey should be completed to verify stream type
- Eroded areas should be located and should be related to existing vegetation buffers or the lack thereof
- Instances where the stream is against the valley wall should be recorded during GPS data collection, along with any stream issues that may be occurring

Infrastructure

Mill Brook Road and Jim Alton Road run parallel to the Mill Brook mainstem, while Hinkley Road and Kittle Road are perpendicular to the mainstem. The roads have some adverse impacts on the stream health since the floodplain is restricted in these areas. Stormwater runoff from the road ditches adds excess water and pollution directly to the streams without allowing time for absorption into the ground. There are several locations where the stream is close to the road and revetment was placed along the banks in order to protect the road from channel migration. Further inspections will be required in order to document additional stream impacts.

Town Bridges #112, #100, #17, and some private bridges are located within this sub-basin. In the headwaters, the Mill Brook mainstem has a small drainage area and culverts are installed to convey the water under the road. According to windshield surveys, the impacts of these structures are deposition and log debris. The impacts of the culverts can be erosion or deposition upstream and/or downstream of the structure if the culvert is improperly sized. Further inspection of these structures is needed in order to determine the impacts on the stream.

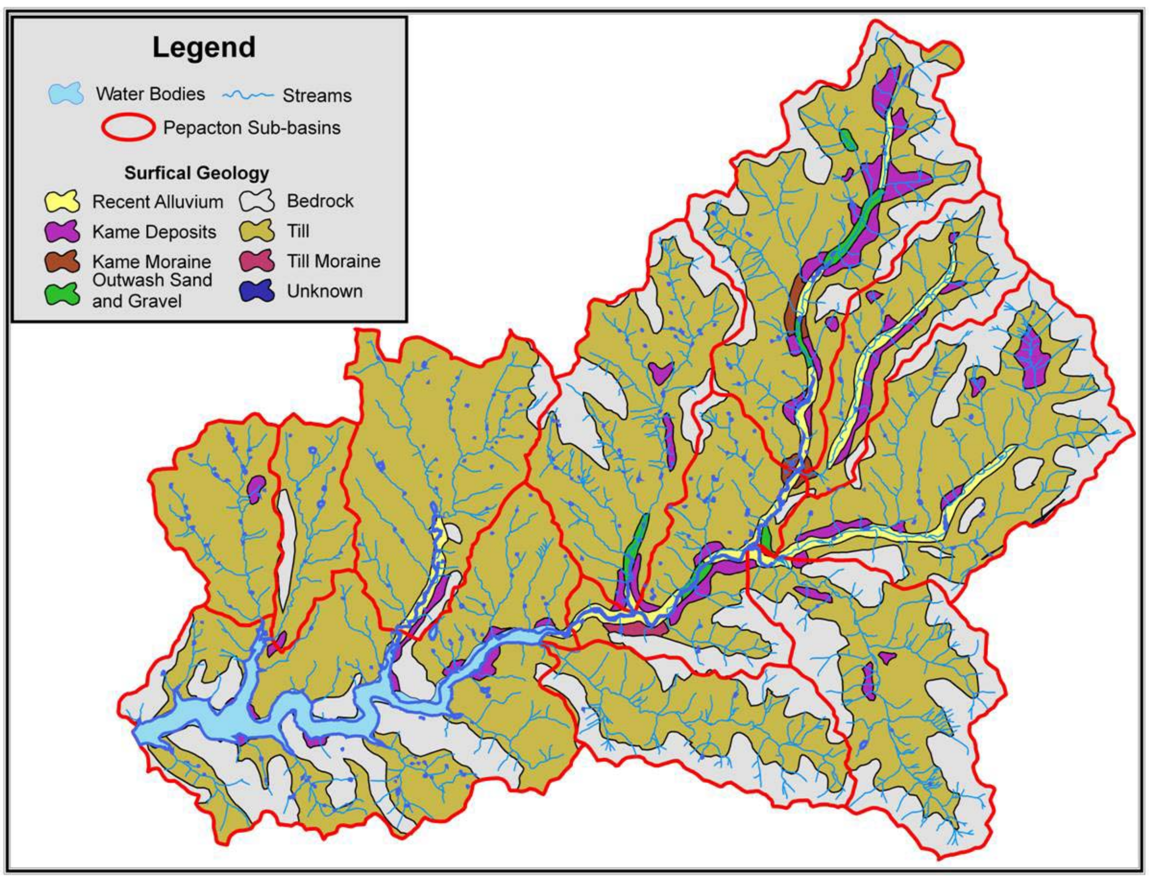
~ 2. Geology and Soils ~

GEOLOGY

The following section describes the basic geology of Delaware County and the East Branch Delaware River watershed, how this affects the stream channel form or fluvial morphology, and water quality of the 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.



Map 2.1 Surficial Geology

Eventually, long periods of pressure from overlying sediments and cementation by mineral-carrying waters lithified sands into sandstones, silts into siltstone and silty clays into shale. The thickest and most uniform beds of certain sandstones are now valuable for local "bluestone" quarries. As one travels from north to south across Delaware County, bedrock outcrops tend to expose progressively younger rocks. **Map 2.1**[3] shows the occurrence of bedrock types in the East Branch watershed (Fisher et al., 1971).

The regional dip of these relatively flat-lying rock layers is towards the south-southwest at angles less than 10 degrees, although thin zones of steeply sloping "crossbedding" within individual rock units also occurs. Rock colors are shades of red or bluish gray due to deposition in environments of high oxygen (terrestrial) or low oxygen (tidal or alluvial plain), respectively. Fossils are typically few, poorly preserved plant fragments, trace fossils, and some marine fauna; the dominance and abundance of each varies between locations and individual beds. Studies of bedrock types, layer sequences and fossil records indicate ancient delta-like and shallow marine environments within a tropical climate that was alternately wet and dry.

Important rock groups and some of their component rock formations in the East Branch watershed are shown in **Table 2.1**. 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 2.1. 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.

[3] Map 2.1 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 (1998) and Rich (1935) give more detailed descriptions of glacial landforms in the Catskills Region than the summary provided here.

Glacial Geology

A number of major glaciations have occurred in North America. Geologic age dating techniques imply that the most recent glaciation to leave this area (the Wisconsin glaciation) did so only some 10 to 12 thousand years ago. At its furthest advance, glaciers covered the county with moving ice nearly one mile thick, extending hundreds of miles northward. This caused tremendous amounts of erosion by abrasion and bedrock "plucking", the pressure-melting and refreezing of ice as the glaciers flowed over hills. The generally rounded and smoothed profile of hills and the U-shaped cross section of larger valleys resulted. The processes of glacial erosion also 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 2.1**). For example, about 95% of Dry Brook's watershed is covered by varying thicknesses of glacial till.

Because layers of sandstone and siltstone were continuously ripped up and incorporated into the till, our upland soils are commonly stony (or very stony) throughout their depth. On many hilltops and north-facing slopes, till was deposited as a relatively thin layer (less than 40 inches to bedrock), and in thicker layers over other areas. Certain south-facing hillsides received unusually massive accumulations of till (over 60 feet thick) where they were on the "lee" side of hills that obstructed the flow of advancing ice.

After long periods of glaciation, the climate warmed again and the glaciers melted back northward faster than they were flowing southward. This melting created tremendous amounts of sediment-laden water in rivers and lakes. However, tongues or flows of ice tended to remain in the larger valleys long after the uplands were relatively ice-free. Eventually these valley ice masses stopped flowing and melted away, creating landforms and deposits that are distinctly different from those in the uplands. Large amounts of meltwater flowed along the sides and beneath the stagnant valley ice masses, washing through the rocky and muddy debris. This tended to separate and remove the finer silt and clay from sand and gravel. 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 2.1**). 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 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).

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

An understanding of geology can be useful background to stream corridor management because bedrock and glacial deposits influence the stream system within its drainage basin. Dendritic stream patterns (having branches like those of a tree) that occur in this watershed tend to develop where horizontally-bedded, sedimentary bedrock had a gently sloping regional dip at the time the initial drainage channels began forming[4]. The bedrock's jointing pattern (system of deep, vertical fractures) also influence stream pattern formation.

The region's geologic history has favored the development of non-symmetric drainage basins in the East Branch, as it has in the West Branch basin, too. Notice in **Map 2.1** how stream sub-basins that slope to the south-southwest are more numerous and extensive than those that slope towards the north-northwest. The occurrence of bedrock also directly affects streams wherever the stream channel contacts bedrock instead of stream deposits. In such places, rates of stream channel downcutting, bank *stability* and lateral migration are dramatically reduced. Examples where the stream has cut down to bedrock occur in the middle and upper reaches of Dry Brook.

Thin soil materials typically cover fractured bedrock on the hilltops, while thicker deposits of glacial till occur at some distance downslope. As a result, precipitation is able to infiltrate bedrock fractures on upper hillsides and hilltops, creating and recharging the

[4] Ritter, 1978, p. 171

bedrock aquifer. Water stored in and released from the bedrock aquifer is relied on for individual drinking water wells and springs. Small springs are quite common throughout the basin, and often are the places where creeks originate. Springs and other groundwater sources comprise the majority of stream base flow in drier, summer months. In general, the quality and taste of this groundwater is excellent since it usually has low levels of dissolved solids and chloride, but may contain considerable iron.[5] A study in the Batavia Kill basin indicates that shallow groundwater has spent less than 10 years underground.[6]

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 base flow 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 2.1**).

The answer to this puzzle was first alluded to by a geologist from Binghamton University (Coates, 1971) and was more recently deduced by the 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 base flow — 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.

The glacial till deposits tend to be relatively coarse textured, often including a substantial amount (15 to 35% by volume) of gravel- to boulder-sized rock fragments. This reduces soil erodibility by providing a sort of "armoring" effect[7], and physical stability of stream beds and banks may similarly be increased, especially where the rock fragments are firmly held within firm till deposits. The pervasive sandstone layers in local bedrock tend to form relatively flat clasts (rock fragments) in the till. In stream deposits, such as gravel bars, point bars and alluvial fans, flowing water often arranges these flat stones into a shingled or imbricate form, where one clast rests on a slight angle on top of

[5] Soren, 1963
[6] Heisig, 1998
[7] McCormack and others, 1984.

another. Imbricated streambeds require a larger flow to move the bed material than do non-imbricated beds.

The streambanks of the mainstem of the East Branch are mostly made up of its own floodplain deposits (called "recent alluvium" on **Map 2.1**). In places, however, steep eroding streambanks have been created where the river has cut into kame, kame moraine or till moraine deposits. These loose materials tend to form unstable slopes, contributing excessive amounts of sediment that can de-stabilize downstream reaches as the streambed rises from added bedload. By contrast, upper reaches of tributaries to the mainstem are more likely to contact glacial till in the uplands, which tends to be more cohesive and therefore less erosive. Compared with, for example, the Schoharie Reservoir watershed, the East Branch, its tributaries, and the Pepacton Reservoir do not contain extensive deposits of glacial lake-deposited clays. The relatively rare occurrence of fine textured soils limits periods of high *turbidity* to times immediately bracketing high-flow events.

SOILS

In New York State, soils have been classified into four Hydrologic Soil Groups based on *runoff* potential and infiltration rates. These four runoff groups are defined as follows:[8]

> Group A soils exhibit low runoff and high infiltration even when thoroughly wetted. They are chiefly sands and gravels that are deep and well drained to excessively well drained.
>
> Group B soils exhibit moderate infiltration when thoroughly wetted. They are moderately deep to deep, moderately drained to well drained, and are moderately fine to coarse textured.
>
> Group C soils exhibit low infiltration rates when thoroughly wetted. They have a layer that impedes downward movement of water, such as hardpan subsoils or bedrock at 20 to 40 inch depths, and are moderately-fine to fine textured. This is the predominant hydrologic soil group, covering most of the basin. These soils can contribute substantially to runoff.
>
> Group D soils exhibit high runoff and very low infiltration when thoroughly wetted. They are chiefly shallow over nearly impervious material (bedrock).
>
> In many areas of the basin, dual hydrologic groups are also mapped. This fifth group of Group C/D soils generally is found where bedrock is close to the surface. If the bedrock is not fractured, the soils exhibit Group D characteristics (high runoff). Where the bedrock is fractured, allowing some infiltration, the soils exhibit Group C characteristics.[9]

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[8] National Engineer Handbook 649.00

[9] Personal communication with Laurence Day, Soil and Groundwater Specialist, Delaware County Soil & Water Conservation District.

In practical terms, the extensive areas of glacial till in the basin have thus developed permeable, upper soil layers, often 1 to 3 feet thick, that overlie relatively dense and slowly permeable subsoils. This would be typical of soils in Hydrologic Group C. Such abrupt changes in permeability with depth create saturated zones (perched water tables) at the contact between the two materials, particularly during the wetter seasons. On lower portions of hillslopes, the upper soil layers often become saturated to the surface from the accumulation of lateral flow of shallow groundwater. This in turn influences where erosive rills begin to form on a slope, and where new stream channels may begin to form.

Since approximately 90% of the soils in the East Branch basin are C and/or D, runoff potential is usually high. This is an important factor when performing stream assessments and developing mitigation protocols.

WETLANDS

Wetlands can greatly affect the way water travels through the landscape, and so it is important to describe what wetlands are, where and in what forms they occur, and the reasons they are important in the watershed.[10]

The term "wetlands" generally describes areas of the landscape that are periodically wet enough to limit uses of the land — farming is usually not possible in these areas without draining, and building is usually difficult without filling. Such areas include marshes, wet meadows, swamps (forested wetlands), bogs, the shallow margins surrounding ponds, lakes or reservoirs, and seasonally-flooded floodplains.

Because such areas were difficult to utilize for food or fiber production, wetlands used to be perceived more for what they were *not* (e.g., productive farmland) than valued for their ecological characteristics. 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. 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.

A number of laws have been created specifically to protect wetlands from being drastically harmed by human activities. These regulations are considered necessary because the U.S. has already filled or otherwise destroyed 30 to 50% of the wetlands that once existed in the lower 48 states.[11] Regulations usually require clear definitions of what is being regulated. For the purposes of conducting a nationwide inventory, the U.S. Fish and Wildlife Service developed a technical definition of wetlands:

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[10] Basic descriptions about wetlands in this section were paraphrased from a short publication by R. Tiner (1997); additional analyses and descriptions specific to the East Branch watershed provided by L. Day, Delaware Co. SWCD.
[11] Liebesman, 1993, p.10

> "Wetlands are lands transitional between terrestrial and aquatic systems where the water table is usually at or near the surface or the land is covered by shallow water. For purposes of this classification wetlands must have one or more of the following three attributes: (1) at least periodically, the land supports predominantly hydrophytes [wetland plants]; (2) the substrate is predominantly undrained hydric soil [usually grey-colored, with low oxygen content]; and (3) the substrate is nonsoil and is saturated with water or covered by shallow water at some time during the growing season of each year."[12]

The U.S. Fish & Wildlife Service used this definition and a wetland classification system to inventory wetlands (based largely on interpretation from color infrared aerial photography) within the NY City watershed. The result was a series of maps at 1:24000 scale that show where certain wetland types are likely to occur. A portion of one of these maps is shown in **Figure 2.1**. While it may appear that wetlands have been clearly defined, classified and mapped, proposed construction projects often require more precise delineations of wetland boundaries and types. These evaluations rely on onsite observations of plants, soils, and hydrology by trained professionals that use a more technical definition of wetlands than the one quoted above. It is the more technical definition that is followed by the U.S. Army Corps of Engineers.

[12] Cowardin, et al., 1979

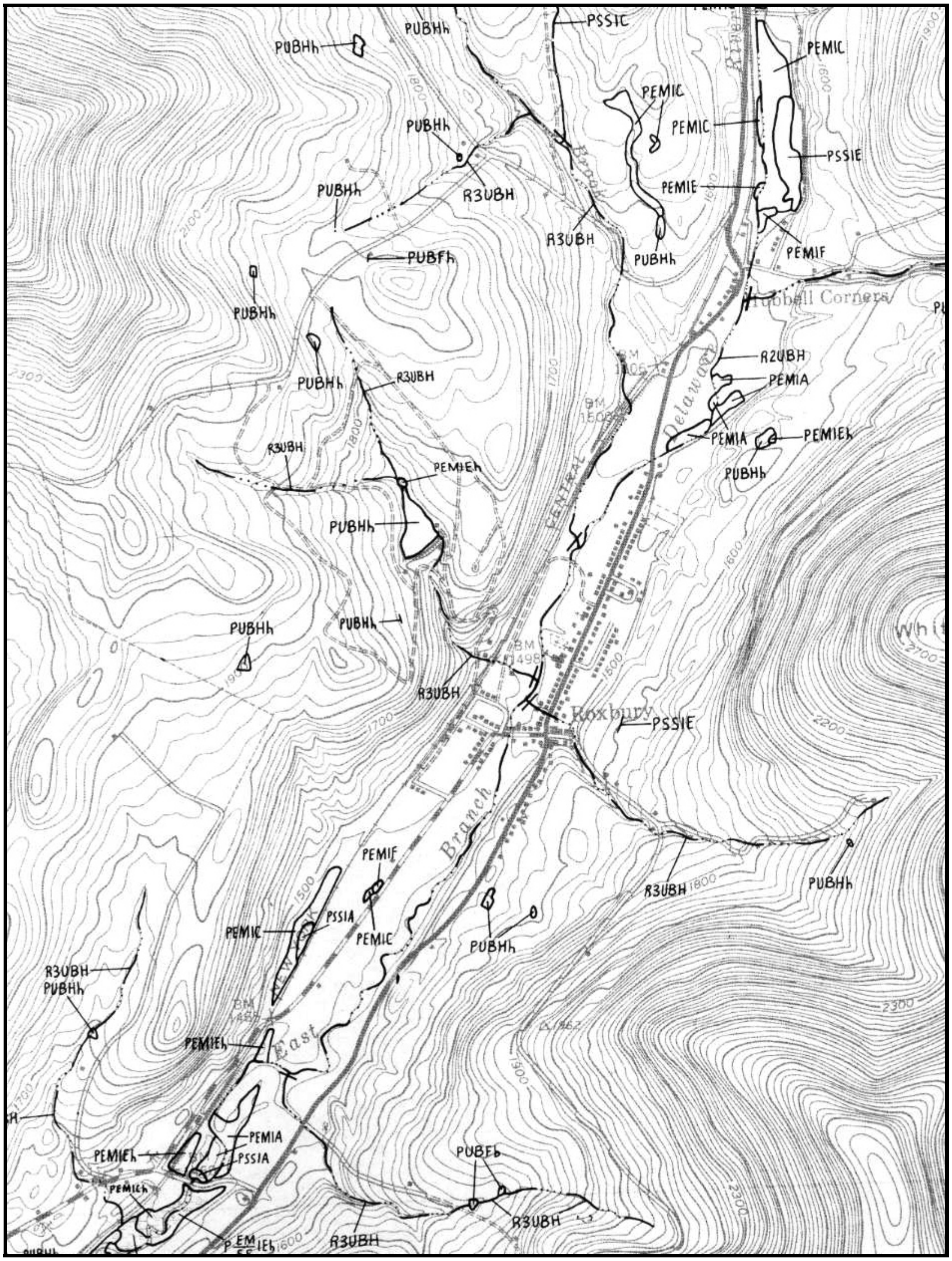


Figure 2.1 Wetlands around the Village of Roxbury as identified by the U.S. Fish & Wildlife Service in their National Wetland Inventory mapping (1995). The letter symbols (such as PUBHh) refer to wetland type.

Wetland Types

Considering the definition above, wetlands can take a variety of forms: shallow parts of a lake or pond, a wet marshy area just downslope from a hillside seep or spring, the low floodplain adjacent to a perennial stream, and so on. One can go into great detail when describing subtle traits that separate various wetland types. For the purposes of this SCMP, only the major types of wetlands will be described here.

One thing in common with all wetland types in the East Branch watershed is that they have freshwater hydrology; no salty marine or brackish water environments (which form another group of wetland types) exist. Freshwater wetlands are divided into three ecological systems – palustrine, lacustrine, and riverine. Palustrine wetlands, which are the most common general type in the East Branch watershed, are mostly vegetated wet areas such as cattail marshes, hemlock swamps and bogs, but they also include man-made ponds. Besides palustrine types, most of the other freshwater wetlands in the basin are associated with lakes and reservoirs. These are called lacustrine wetlands and are usually limited to aquatic beds (e.g., floating lily pads that grow in shallow water), wet marshes, and the shallow water zone (less than 6.6 feet deep) that may have no vegetation. Riverine wetlands are contained within the river channel (where water is usually flowing). Most of the riverine wetlands are non-vegetated, periodically-exposed shores, such as gravel bars.

While the above paragraph generally describes the three main ecological types of wetlands, the other major wetland subdivision considers the dominant kind of vegetation. Emergent wetlands (commonly called marshes or wet meadows) have mostly grasses, sedges, and other non-woody plants. Scrub-shrub wetlands (including alder or dogwood swamps and bogs) are represented by low- to medium-height (less than 20 feet tall) woody plants. Forested wetlands (mostly wooded swamps and bottomland forest) are dominated by trees over 20 feet tall. **Figure 2.2** illustrates where various types of palustrine wetlands occur in the landscape.

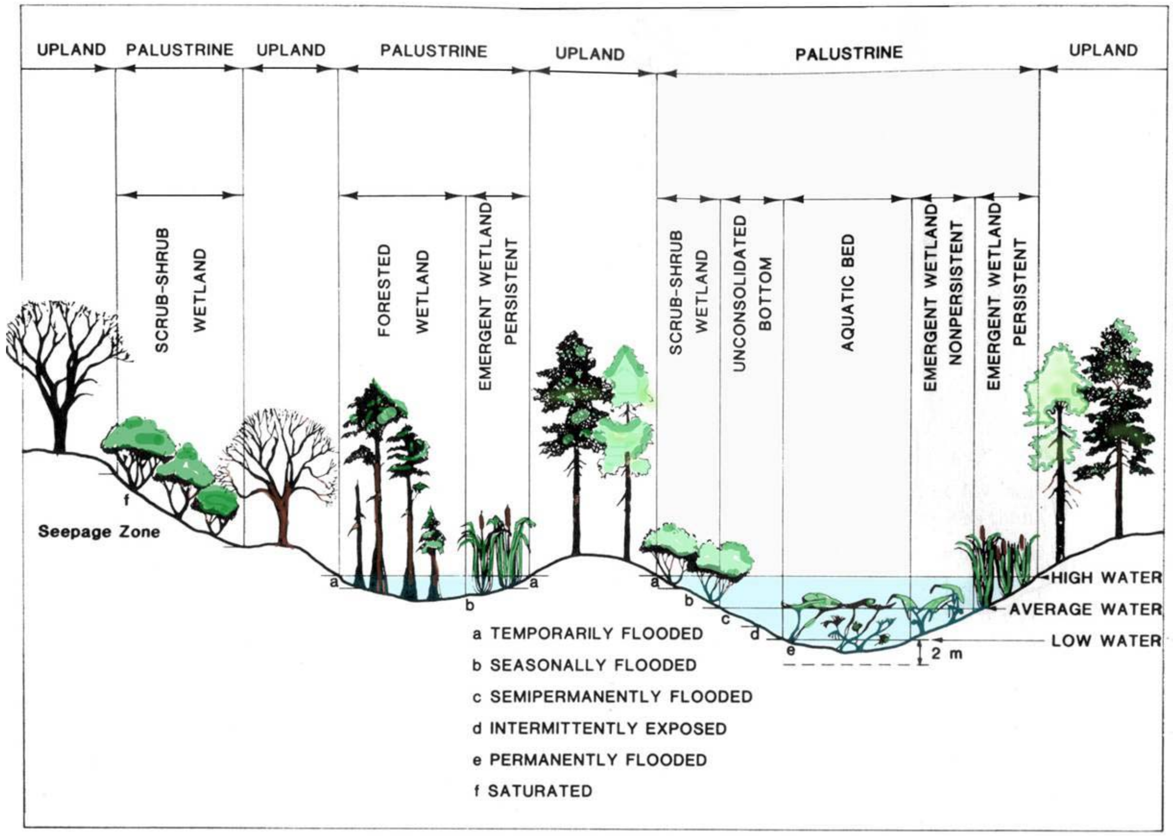


Figure 2.2: Diagram of palustrine system of wetlands (more commonly known as marshes and swamps) and their typical positions in the landscape.[10]

East Branch Watershed Wetlands Inventory

The U.S. Fish and Wildlife Service published their inventory of wetlands in the entire NY City watershed in 1996. Their data is available as printed maps, such as **Figure 2.1**, and also in digital format as a spatial and tabular database. Using GIS, the area of each sub-basin within the East Branch watershed was clipped from the NY City watershed-wide coverage of wetlands, and then rearranged in order to simplify comparison between sub-basins. This information is presented in **Table 2.2**.

As shown in the table, the largest sub-basin is the Pepacton Reservoir, which is 73.4 mi^2 or nearly 47,000 acres in size (column C). Because so much of this sub-basin is the Pepacton Reservoir itself, it has the largest amount of deepwater habitat (surface water bodies more than 6.6 feet deep) of any of the sub-basins (column E). (Because deepwater habitat is outside the definition of "wetlands," these areas were omitted from remaining calculations.)

The sub-basin with the most wetlands is the East Branch Headwaters. Its total of 359 acres of wetlands constitutes only 1.1% of this sub-basin, however (column F). This relatively small proportion is still near the maximum observed, since wetlands cover from

0.3% to 1.4% of all sub-basins. The East Branch Headwaters also has more individual wetlands (239) than the other sub-basins (column G).

Most wetlands in each sub-basin are relatively small, with median wetland size ranging from 0.64 to 1.48 acres (column H). The most extensive wetland type is small marshes with emergent vegetation (abbreviated as PEM in table – column I). The next most common wetland type is small ponds (abbreviated PUB in table – column J), followed by scrub-shrub swamps and lower portions of perennial streams (R2US).

Table 2.2 Summary of Wetland (WL) Information for East Branch Sub-basins

A	B	C	D	E	F	G	H	I	J	K
Sub-basin	**Sub-basin Size (sq. miles)**	**Sub-basin Size (acres)**	**WL Area in Sub-basin (acres)[1]**	**Deepwater Habitat (acres)**	**WL Area per Sub-basin (%)[1]**	**# of WLs in Sub-basin**	**Median WL size (acres)**	**Most Extensive WL Type[2]**	**2nd-most Extensive WL Type[2]**	**# of WLs per sq. mile**
Batavia Kill	19.3	12,352	66.2	–	0.536	85	0.64	PSS (34%)	PEM (34%)	4.4
Bush Kill	47.2	30,208	164.7	–	0.545	85	0.95	PEM (34%)	PUB (32%)	1.8
Dry Brook	35.2	22,528	116.3	–	0.516	76	1.25	PSS (30%)	PUB (26%)	2.2
E Branch Headwaters	50.0	32,000	*359.2*	28.73	1.123	239	1.23	PEM (59%)	PUB (23%)	4.8
E Branch Mainstem	25.8	16,512	*229.1*	221.82	1.387	141	1.19	R2US (25%)	PFO (22%)	5.5
Fall Clove	11.2	7,168	*71.2*	.01	0.993	44	1.30	PUB (48%)	PEM (26%)	3.9
Mill Brook	25.4	16,256	*42.5*	25.39	0.261	47	1.14	PEM (47%)	PUB (32%)	1.9
Pepacton Reservoir	73.4	46,976	*149.7*	5,379.11	0.319	181	1.16	PUB (50%)	PEM (27%)	2.5
Platte Kill	35.4	22,656	*91.0*	2.51	0.402	150	1.05	PEM (43%)	PUB (27%)	4.2
Terry Clove	15.1	9,664	68.5	–	0.709	62	0.95	PUB (40%)	PEM (36%)	4.1
Tremper Kill	33.5	21,440	252.0	–	1.175	164	1.48	PUB (43%)	PEM (31%)	4.9

[1]Omits deepwater habitat (water depth >6.6 ft) from calculations
[2]PEM = Palustrine, emergent (e.g. marshes, wet meadows)
PUB = Palustrine, unconsolidated bottom (e.g. small ponds)
PSS = Palustrine, scrub/shrub (e.g. alder marsh)
R2US = Riverine, lower perennial, unconsolidated shore (e.g. temporarily-flooded stream banks)
PFO = Palustrine, forested (e.g. hemlock or red maple swamp)

The geology section (see **Volume 2, Section 2** above) described the surface topography as asymmetric — sub-basins with slopes that largely drain southward tend to be longer and have gentler slopes than those sub-basins that drain northward. Consequently, it would not be surprising to find that sub-basins with steeper slopes have fewer wetlands than those that are less sloping, since water tends to run off more quickly from steeper slopes. **Table 2.3** shows that three sub-basins that largely slope northward (Dry Brook, Mill Brook and Pepacton Reservoir) have about half the density of wetlands compared to the other eight basins that mostly flow southward.

Table 2.3 Wetland Density in North-facing vs. South-facing Sub-basins

Sub-basin	# of Wetlands per sq. mile
North-facing Aspect	
Dry Brook	2.2
Mill Brook	1.9
Pepacton Reservoir[1]	2.5
Mean = 2.2 ± 0.31*	
South-facing Aspect	
Batavia Kill	4.4
Bush Kill	1.8
E Branch Headwaters[1]	4.8
E Branch Mainstem[1]	5.5
Fall Clove[1]	3.9
Platte Kill[1]	4.2
Terry Clove	4.1
Tremper Kill	4.9
Mean = 4.2 ± 1.10*	

[1] Omits deepwater habitat (water depth >2m) from calculations
* The two means are significantly different (.05 level)

Wetlands identified in the East Branch Mainstem sub-basin appear to differ from the wetlands typical to the other sub-basins. The East Branch Mainstem sub-basin contains the greatest density of wetlands per square mile (column K). The most extensive wetland type is the unconsolidated shores of lower perennial streams (R2US type, column I), and the second most common type is forested swamps (PFO type, column J). Neither of these wetland types is common in the other sub-basins.

Significance of Wetlands

As stated previously, wetlands provide important functions. Some functions may be more obvious than others, but they are all significant: flood control, erosion control, water quality protection, fish and wildlife habitats, and opportunities for recreation, aesthetic appreciation, and education. This section describes how wetlands affect these functions.

Flood Control — Wetlands have often been referred to as "natural sponges" that absorb flood waters, yet they actually function more like "natural tubs," storing flood waters that overflow streambanks or surface water that collects in isolated depressions. By temporarily storing flood waters, wetlands help protect adjacent and downstream property owners from flood damage. Trees and other wetland plants help slow the speed of flood waters. This action combined with water storage allows wetlands to lower flood heights and reduce the water's erosive force.

Erosion Control — Because wetlands are located between rivers and high ground, they are in a good position to slow the effects of soil erosion. Wetland plants are most important in this regard, since they increase the durability of the sediment through binding soil with their roots, and dampen wave action and current velocity through friction. Planting of wetland vegetation is being used to control streambank erosion in some places. Bioengineering techniques (such as biodegradable mats with wetland plants) are in many ways preferable to structural erosion control measures (such as rock rip-rap) because they provide habitat and aesthetic values while protecting the streambank.

Water Quality Protection — Wetlands can be effective filters by intercepting surface water runoff from higher land before it reaches open water, and at least partially removing nutrients, processing chemical and organic wastes, and reducing sediment loads to receiving waters. This function is important in both urban and agricultural settings. A vegetated buffer strip along a stream can significantly improve water quality in many areas, often at less cost than alternative measures. When streams are channelized and wetlands are eliminated, stormwater moves off the landscape more quickly; thus, streambank erosion can become accelerated, water in the stream becomes more turbid, and groundwater recharge can be diminished.

Aquatic Productivity — Wetlands are among the most productive natural ecosystems in the world, some rivaling our best cornfields in biomass production with over 10 tons per acre. The plant material produced in the form of dead leaves and twigs eventually fall and partially decompose to form small particles of "detritus", which serves as the principal food for many small invertebrates and forage fishes. These are food for larger predatory fishes, such as trout and bass, which are of course a favorite food for many people. Thus, wetlands provide a source of food for both people and aquatic animals.

Fish and Wildlife Habitats — Wetlands are critical habitats for various animals like the wood duck, muskrat, beaver, salamander and snake. Relatively rare animals like the bald eagle use wetlands for food, water, cover or reproduction. Almost all important recreational fishes, including bass, spawn in aquatic portions of wetlands. Streamside forests provide shade that keeps water temperatures cooler than if exposed directly to sunlight, which is important to trout habitat. A variety of birds including ducks, geese and redwinged blackbirds, along with a large number of songbirds, feed, nest and raise their young in these areas. White-tail deer use wetlands for food and shelter, especially evergreen forested wetlands in winter. The black bear also finds refuge and food in forested and shrub swamps of the Catskills.

Natural Products — Timber, fish, wildlife and wild berries are some examples of products that originate in wetlands. For agriculture, wetland grasses might be hayed for winter livestock feed, while livestock can also graze on wet meadow grasses during the spring and summer.

Quality of Life — Not many people take advantage of recreational activities in or adjacent to wetlands, but opportunities abound. Wetlands serve as habitat for waterfowl hunting, fishing and trapping, hiking, bird watching and photography. Many people simply enjoy the beauty and sounds of nature, the trilling of spring peepers, observing frogs and turtles, looking for marsh marigolds in spring or red maple leaves in fall.

Wetland Functions in the East Branch Watershed

While **Table 2.2** shows the most extensive types of wetlands in each sub-basin, it does not indicate where the wetlands occur in the landscape (except, by inference, the riverine wetlands that dominate in the East Branch Mainstem). Small areas (±1 acre each) of wet meadows might be expected to occur most anywhere except on steep hillsides, and the same could be said about small man-made ponds. Actually, most wetlands in this area tend to occur in recurring patterns.

While **Figure 2.1** shows the approximate location of individual wetlands on a base map of 20 ft. topographic contours around the Village of Roxbury, **Figure 2.3** covers a larger area of the same region in smaller scale. These maps illustrate the tendency of many wetlands to occur near natural drainage pathways — both in major valleys and their upland tributaries — in the East Branch watershed. This tendency is largely due to both stream corridors and wetlands developing where water naturally collects, and where surface slopes are flatter. Drainage patterns are, in turn, controlled by geologic history of the region, as discussed above in **Section 2 Geology and Soils**. Aside from the near-stream areas where wetlands occur, most of the uplands are relatively steeply sloping and well drained by comparison, and so wetlands typically form less than 1% of each sub-basin (**Table 2.2**).

While the majority of wetlands do occur in close association with streams (as opposed to being spread out evenly across the landscape), they do not have a strong tendency to reduce flooding due to their comprising a small proportion of the East Branch watershed. The limited ability of wetlands to help reduce flooding arises more from wetlands' ability to store surface runoff that would otherwise reach stream channels, thereby slowing the rise of stream waters. Stored runoff is released more gradually through small outlets (i.e., small in comparison to a stream channel), by allowing slow infiltration of stored water through upper soil layers, thus allowing time for evaporation and transpiration by plants. When wetlands are relatively dispersed across a drainage basin they also have the effect of de-synchronizing the pattern of surface runoff. This also slows the rise of stream waters during runoff events because an increased range of times is introduced into the storage, release and post-release travel-time of stored runoff. So, although the capacity of wetlands in the East Branch watershed to abate flooding is somewhat reduced by their small aerial extent and close association with streams, they still do provide this important function albeit to a limited degree. This function is especially important near developed areas along streams, such as upstream from the Villages of Roxbury or Margaretville.

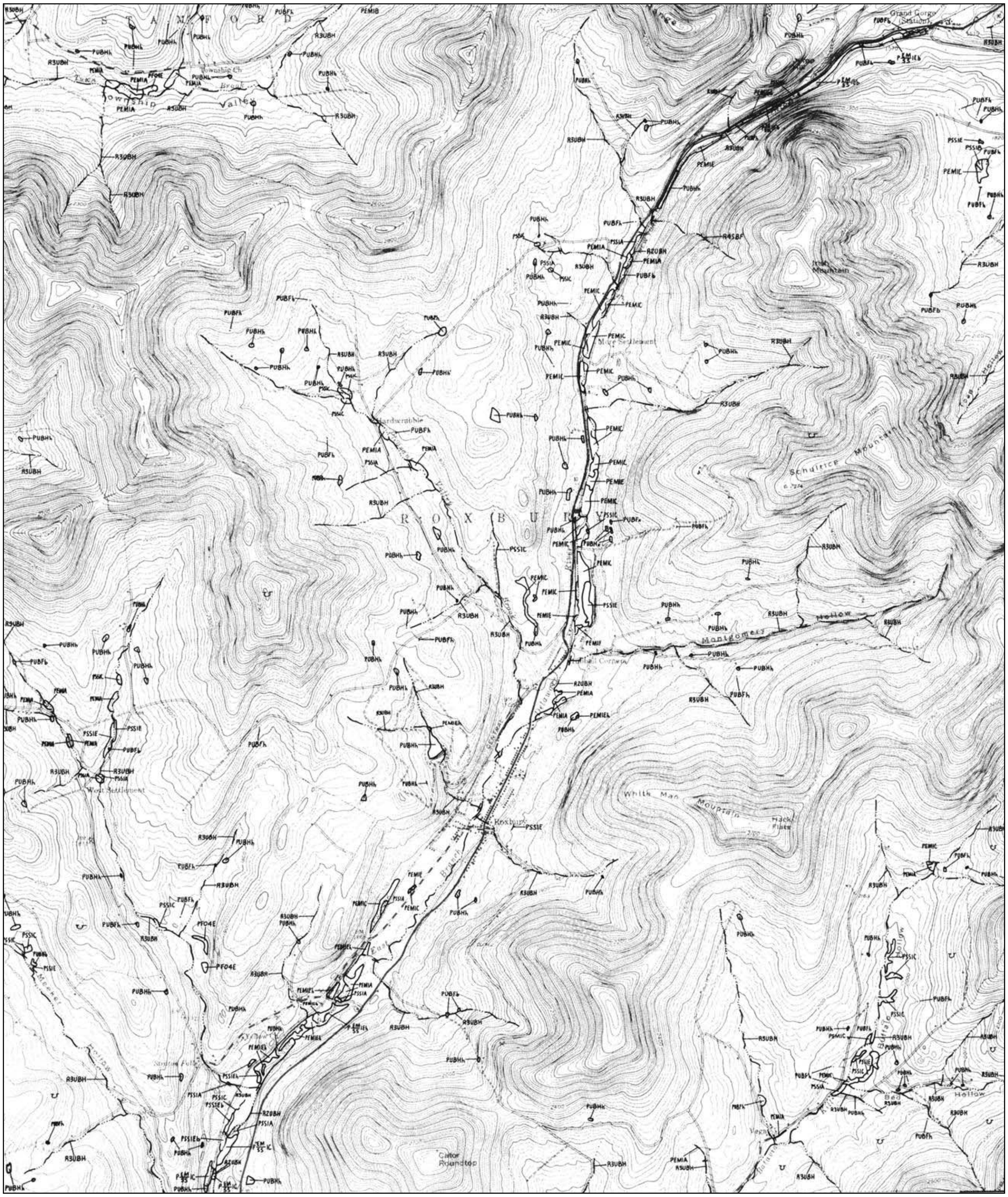


Figure 2.3 Small-scale portion of wetlands mapping, Roxbury quadrangle, by the U.S. Fish & Wildlife Service. Note how most wetlands occur in close association with the local stream network.

Across much of the Catskills, small springs and seeps commonly appear in places where slopes abruptly change from massive, steep hillsides to more gentle gradients. These groundwater discharge areas have long been favored for constructing livestock-watering ponds. Often, drainage from the spring forms the origin of streams, or the excess water draining from a pond flows a short distance before it reaches a nearby watercourse.

Wetland functions, as generally described in the previous paragraphs, can be more precisely evaluated using various "yardsticks" or methods of measurement. For example, the specific ability of a particular wetland to improve water quality is largely based on its capacity to promote: (1) sedimentation of particulate matter on its surface, before the sediment-laden water reaches a stream; (2) plant uptake of excess nutrients and/or contaminants; (3) leaf litter decomposition, slowly releasing sorbed nutrients for incorporation into the food web of the local biota; and (4) soil retention of dissolved and particulate matter into its near-surface or deep sediments.[13]

This type of science- or ecology-based approach is most often used to compare two wetlands' functional capacities rather than to measure the absolute values of such specific characteristics. In a much more general way, the tendency of wetlands to provide certain functions can be summarized based on wetland type. The types of wetlands that occur most commonly in the East Branch basin were listed in **Table 2.2**. Although detailed assessments of wetland functions require on-site review, a generalized evaluation of the principally occurring wetland types follows[14]. Other functions could be evaluated in addition to those discussed, depending on the approach used and opinions of what functions are more important.

Palustrine/Emergent (PEM): Many of these wetlands form in low spots or depressions on the landscape surface that accumulate surface runoff. Because they comprise a small proportion of the watershed, their effect on flooding is probably small, yet still of some significance in terms of runoff storage and flow desynchronization. Those emergent wetlands that are (1) adjacent to free-flowing streams or other water bodies, (2) are at least seasonally inundated with water, and (3) provide an abundance of cover, can provide fish habitat. Where vegetative cover is good and water flow is dispersed these areas can filter excess sediments from surface runoff. Dense stands of actively growing vegetative cover may help attenuate nutrients in runoff before it enters surface waters, and help stabilize shoreline against erosion (if adjacent to a water body). Where these wetlands are relatively large, in good condition and a there is a variety of cover in it and the surrounding terrain, these wetlands provide wildlife habitat for a variety of species. Recreational and aesthetics uses can be significant where these wetlands offer public access, are in relatively unpolluted condition, are physically accessible, and are regularly visited by wildlife.

Palustrine/Unconsolidated bottom (PUB): These small ponds tend to occur both within and above the floodplain. Because they comprise a small proportion of the watershed and may typically be near-full with groundwater discharge and surface runoff water

[13] Bartoldus, et al., 1994.
[14] Adapted from U.S. Army Corps of Engineers, 1999; Reschke, 1990; and Cowardin et al., 1990.

inputs, they provide limited capacity to store floodwater. They potentially provide fish habitat; however, unless there is a direct connection with a nearby stream this largely depends on fish-stocking history. Sediments and attached pollutants can be retained to the extent that sediments traveling in runoff can settle out in quiet water; similarly, excess nutrients can be filtered from surface runoff with sediments. These wetlands offer wildlife habitat, especially for amphibians, and also serve as a water source for mammals, especially if surrounded by brush or forest cover. Recreational and aesthetics uses can be significant where these wetlands offer public access, are in relatively unpolluted condition, are physically accessible, and are regularly visited by wildlife.

Palustrine/Scrub-Shrub (PSS): Comprising a very broadly-defined type, Scrub-Shrub wetlands may represent a successional stage leading to forested wetlands, or they may be relatively stable communities. Although they are one of the most widespread wetland types in the U.S.[15], these wetlands are not especially widespread in the East Branch basin. Functions are similar in many ways to those of PEM wetlands (described above), with certain functions being enhanced where there is a dense cover provided by shrub or sapling tree growth. These include shoreline erosion protection (where adjacent to water bodies), and wildlife habitat, especially when the vegetative cover is of diverse types. To the extent that these areas are difficult to physically walk through, they may offer limited recreational functions.

Riverine/lower perennial, unconsolidated shore (R2US): Characterized by flowing, non-tidal waters and a well developed floodplain, these areas along the margins of streams lack persistent and emergent vegetation. The substrate usually is composed of sand and gravel with mud. These wetlands are important as local fish habitat. Parts of wetlands associated with floodplain help retain sediments if in stable stream reaches; otherwise, excess nutrients and organic material tends to be "flushed" through this zone. Recreational uses of these areas are usually high if available to the public. Opportunities for wildlife can be high in healthy stream systems that offer adequate cover.

Palustrine/Forested (PFO): Dominated by trees over 20 ft. tall — such as hemlocks, red maples, poplars or willows — these wet woodlands are uncommon across most of the East Branch basin except some portions of the mainstem. Water levels often fluctuate seasonally, being flooded in spring and relatively dry by late summer. Sediments and attached pollutants can be retained to the extent that sediments traveling in runoff can settle out in quiet water; similarly, excess nutrients can be filtered from surface runoff with sediments. Ground cover may be fairly sparse, in which case these areas can be vulnerable to streambank erosion. These wetlands provide valuable wildlife habitat. When surrounded by upland forest, "vernal pools" are critical for amphibian spawning.

Deepwater habitat: These areas do not meet the definition of wetlands as defined at the beginning of this section, but rather can be described as other "aquatic systems." As seen in column E of **Table 2.2**, extensive areas exist in the Pepacton Reservoir sub-basin, with minor amounts in the East Branch Mainstem. The extent of deepwater habitat in these sub-basins varies widely depending on season, rainfall and consumptive use patterns.

[15] Cowardin et al., 1979.

Protecting Wetlands

The value of wetlands to perform functions described above has been recognized by federal, state and NY City governments, each of which have created their own methods of wetland protection.

The federal government regulates wetlands primarily by enforcing Sections 401 and 404 of the Clean Water Act by the U.S. Army Corps of Engineers. There are no publicly-available maps of where such wetlands occur, although maps produced by the U.S. Fish & Wildlife Service's National Wetland Inventory are often consulted as a good indicator of where such wetlands might occur. While each situation is unique, most disturbances over 1/10th acre in size require a permit. Permit questions should be directed to the Corps of Engineers' Troy office, 518-270-0589. In agricultural settings, the "Swampbuster" provision of the 1990 Farm Bill (administered by the USDA's Natural Resources Conservation Service) and Wetlands Reserve Program (administered by the Farm Service Agency) help protect wetlands from being converted into cropland or other agricultural uses.

Through Article 24 of the Freshwater Wetlands Act the NYS DEC primarily regulates activities in wetlands greater than 12.4 acres (5.0 hectares) in size, plus an adjacent area 100 ft. out from the wetlands' perimeter. All wetlands regulated by NY State are shown on an official Freshwater Wetlands Map. A portion of one map that covers the Roxbury area is shown in **Figure 2.4**. Compare this map to that of **Figure 2.1** to see how only the larger-sized wetlands are protected by NY State. A permit is required by the DEC if disturbing land within the 100 ft. buffer zone. Permit questions should be directed to the DEC's Schenectady office, 518-357-2234.

The NYC DEP uses a variety of tools to protect wetlands. DEP watershed Rules and Regulations define allowable setbacks from wetlands, defining wetlands as being only DEC-protected wetlands (12.4 acres or larger). However, because the DEP's field staff note the presence of all watercourses and wetlands on proposed project sites, and the DEP insists on compliance with other permitting agencies (such as the U.S. Army Corps of Engineers) before issuing their own permits, this has the effect of adding enforcement to all existing regulations. Other DEP programs include the Conservation Easement and Land Acquisition Programs, both of which remove land development opportunities and thus prevent wetland impacts that might affect wetlands. Permit questions should be directed to the DEP's Kingston office, 845-340-7500.

Public education is essential to increase awareness and understanding of the natural functions provided by wetlands, including the protection of local and regional water quality. This SCMP report is one part of this process. In addition, other state, regional and local agency staffs are available to assist interested local governments in developing local wetland protection strategies.

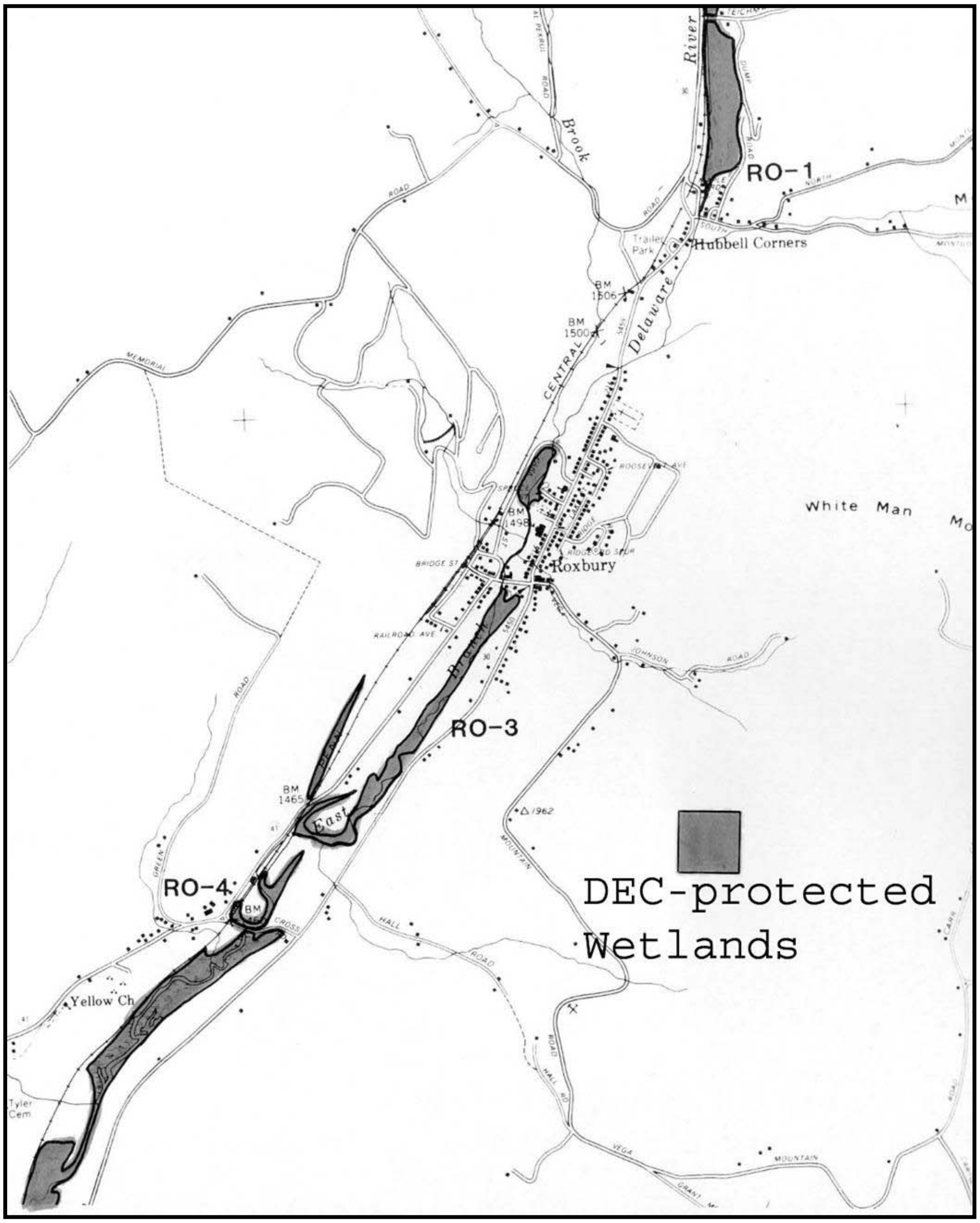


Figure 2.4: Location of DEC-protected wetlands around the Village of Roxbury (1974 edition, shading added). In contrast to Figure 2.1, only wetlands (or areas with wetland-upland complexes) greater than 12.4 acres in size are recognized for state protection.

~ 3. Principles of Stream Science ~

Fluvial Geomorphology: *the study of riverine landforms and the processes that create them*

Hydrology: *the science dealing with the properties, distribution, and circulation of water on and below the earth's surface and in the atmosphere (Merriam-Webster Online 09/12/07)*

An understanding of both hydrology and fluvial geomorphology is essential when approaching stream management at any level. This section is intended to serve as an overview of both aspects of stream science, as well as their relation to management practices past and present.

Figure 3.1 Stream Ordering (NRCS) and the Depiction of a Dendritic Stream System

Applied fluvial geomorphology utilizes the relationships and principles developed through the study of rivers and streams and how they function within their landscape to preserve and restore stream systems. In landscapes unchanged by human activities, streams reflect the regional climate, biology and geology. Bedrock and glacial deposits influence the stream system within its drainage basin. The "dendritic" (formed like the branches of a tree, **Figure 3.1**) stream pattern of the East Branch Delaware River watershed developed because horizontally bedded, sedimentary bedrock had a gently sloping regional dip at the time the initial drainage channels began forming[16]. The bedrock's jointing pattern (the pattern of deep, vertical fractures) also influence stream pattern formation. The region's geologic history has favored the development of non-symmetric drainage basins in the East Branch basin.

As rivers flow across the landscape, they generally increase in size, merging with other rivers. This increase in size brings about a concept known as stream order. Stream order identifies the position in a hierarchy of tributaries occupied by a stream segment. As described by Strahler (1964) and shown in **Figure 3.1**, any clearly defined (ephemeral)

[16] Ritter, 1978, p. 171.

channel without tributaries is designated as a 1st order channel; where two 1st order channels join they form a 2nd order channel; where two 2nd order channels join they form a 3rd order channel, and so on. The stream network thus formed is a drainage system and is often dendritic, but may adopt other patterns depending on the regional topography and underlying geology.

Watershed Characteristics

Stream flow patterns affect *aquatic habitat*, flood behavior, recreational use, and water supply and quality. Although it may not be obvious, the water flowing through the East Branch drainage system reflects the integrated net effect of all the watershed characteristics that influence the hydrologic cycle (**Figure 3.2**). These characteristics include the climate of the drainage basin (type and distribution patterns of precipitation and temperature regime), geology and land use/land cover (permeable vs. impermeable surfaces, materials affecting the timing and amount of runoff, constructed drainage systems), and vegetation (uptake of water by plants, protection against erosion, and influence on infiltration rates).

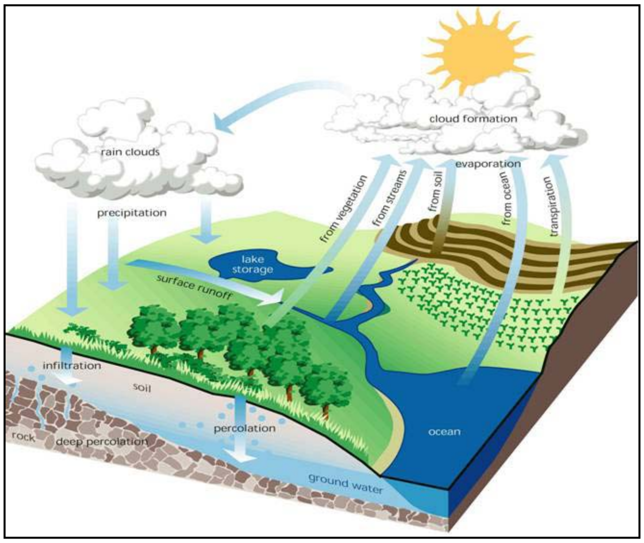


Figure 3.2 The Hydrologic Cycle

Climate conditions are variable both globally and in a given region. Climatic changes can noticeably affect seasonal rainfall and stream flow is derived from rainfall or snowmelt (Leopold, 1997). Varying rainfall amounts and soil moisture conditions prior to a rainfall event (or series of events) can have a direct effect on flooding frequency and magnitude. Therefore, it is necessary to have an understanding of climate to fully understand how stream systems function. For a basic description of climate in the East Branch Delaware River watershed and the surrounding area, refer to **Section II** in **Volume 1**.

Drainage area or watershed size is also part of the physical characteristics of the watershed. The size of the watershed is defined by the amount of land area that has the potential to drain stormwater runoff into the stream network. The shape of the watershed also plays a key role in the stream network; if two watersheds have the same size but different shapes, they will have different *peak discharges* and *times of concentration* resulting from the same storm event. Travel time for runoff to move through the stream network varies with watershed topography. A steep watershed typically exhibits a higher peak discharge than a flatter watershed.

The above factors (climate, geology, topography, vegetation, etc.) affect timing and amount of stream flow, referred to as the stream's hydrologic *regime*. Streams flow at many different levels over the course of a year, ranging from the small trickle of a dry summer to the raging torrent associated with the rapid thaw of a thick snowpack. There are essentially two basic types of stream flow: storm flow and base flow. Storm flow appears in the channel in direct response to precipitation and/or snowmelt. Base flow, on the other hand, sustains stream flow during inter-storm (between storms), subfreezing, or drought periods.

The graph below is an example of a *daily mean discharge curve* for the stream gage at Margaretville, NY for the period from September 2006 to August 2007. Note that the brown line indicates the average daily mean discharge (stream flow measured in cubic feet per second) for the 69 years of gage records, and the light blue line shows the daily mean discharge for the 2006-2007 period. This graph also 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 *evapotranspiration* from plants is low. The precipitation that falls during this period quickly runs off and the streams are full.

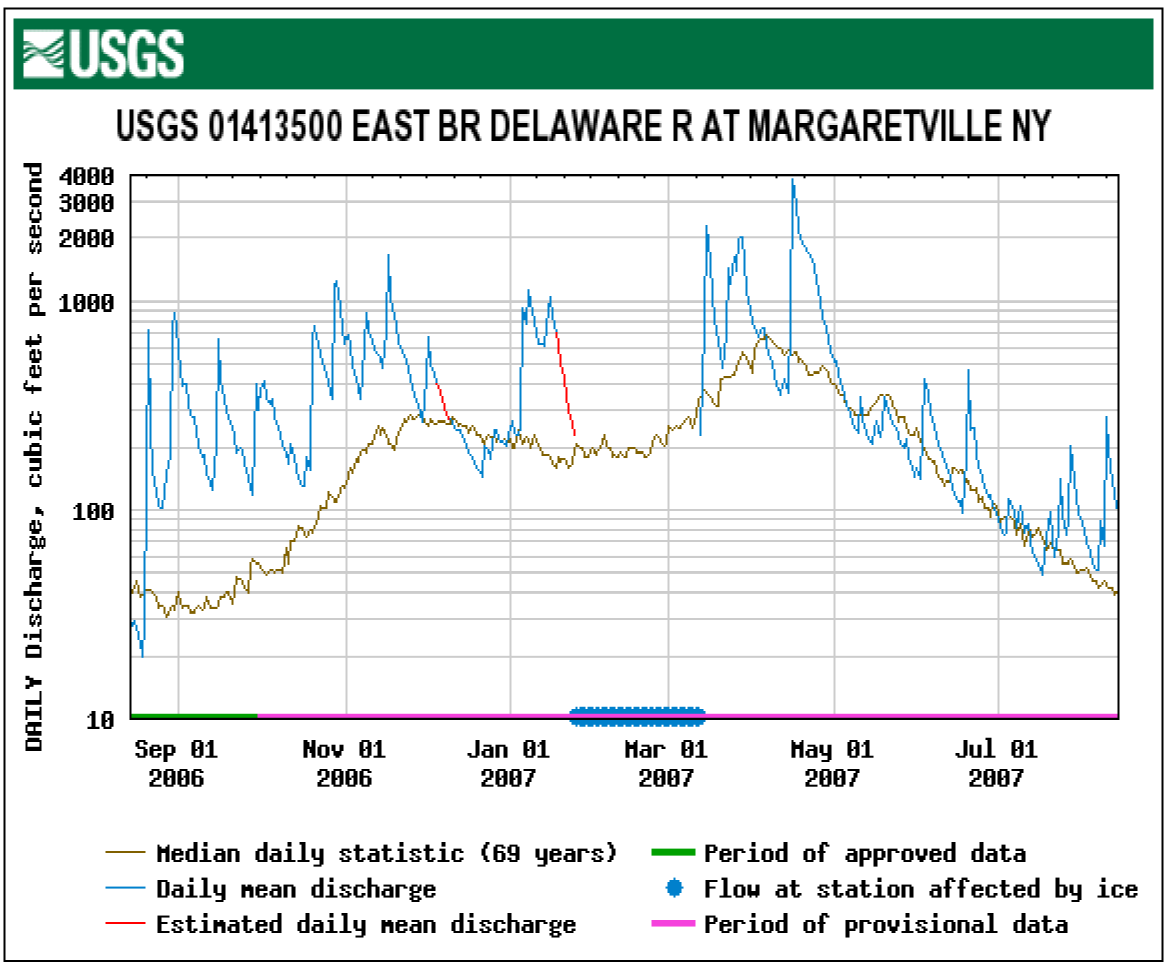


Figure 3.3 Daily Mean Discharge Curve

Because the climate, topography, geology and vegetation of a region usually change very slowly over time, the stream flow *regime* is fairly consistent at any given location.[17] This stream flow regime, in turn, defines when and how much bedload will move through the stream channel from year to year. Together, the movement of water and bedload carve the form of the stream channel into the landscape. Because the stream flow regime is fairly consistent year after year, the form of the stream channel changes relatively slowly, at least in the absence of human influence. Over the 120 centuries since glaciers covered the region, the stream and the landscape conditions have evolved into a dynamic balance.

Streams that are in dynamic balance with their landscape adapt a form that can pass the water and bedload associated with both small and large floods, regaining their previous form after the flood passes. This is the definition of stream stability. In many situations, however, stream reaches become unstable when some management activity has upset that balance, altering the stream's ability to move its water and bedload effectively.

The form of a stream that is considered "stable" varies with topography. When it is in balance with mountainous terrain, a stable stream will look different than one that is in balance with rolling hills or broad floodplains. Stable streams are less likely to experience bank erosion, water quality and habitat problems. The maintenance of a stable stream *morphology* and vigorous *riparian* (streamside) vegetation is essential to "healthy" streams. The condition and types of riparian vegetation play crucial roles in stream health, and thus are important to sound stream stewardship and management.

Sediment Balance

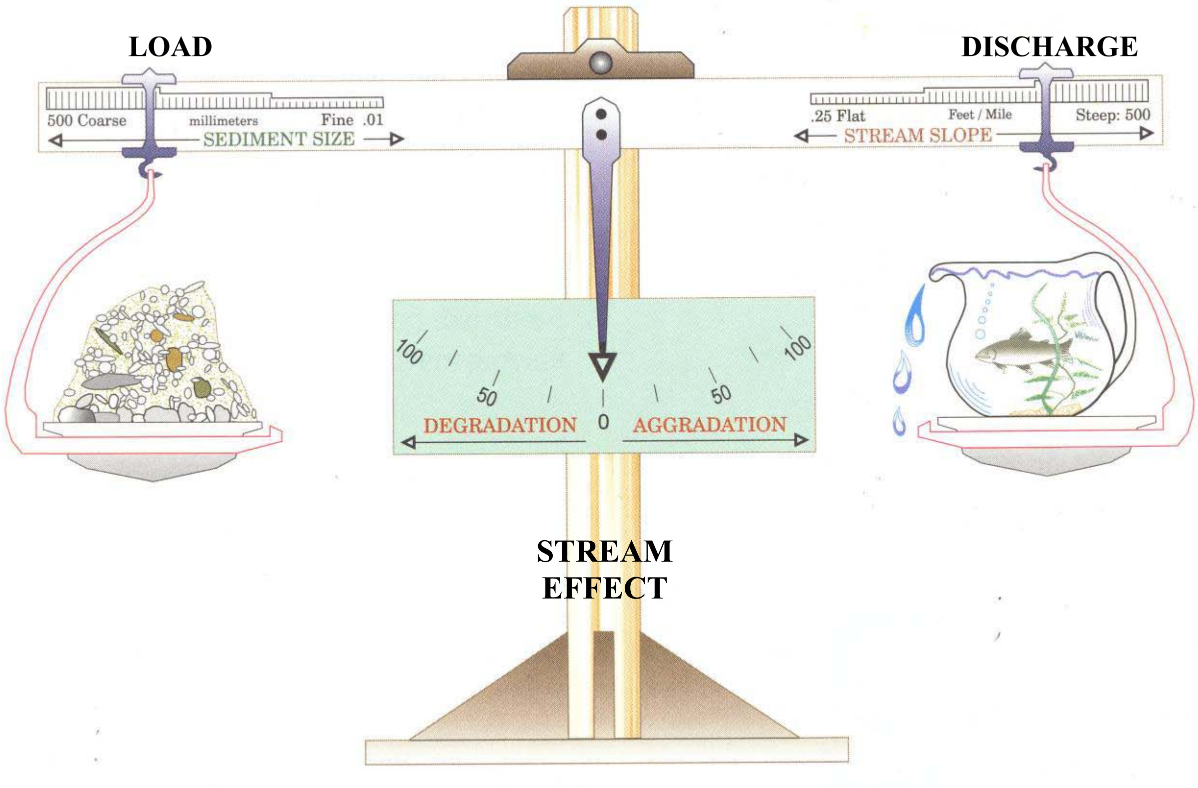
Essential to the maintenance of a stable stream is the preservation of a "sediment balance." The following paragraph sums up the importance of sediment transport in the formation of rivers:

> "Sediment transport processes have a major control on channel morphology since rivers can only develop if sediment is eroded and transported. Not only are the overall dimensions of the river influenced by sediment transport, but local temporal and spatial variations in transport capacity within a reach result in the formation and maintenance of *pools*, *riffles* and bar forms which are so characteristic of alluvial channels"
> (R. D. Hey, 2003).

Sediment discharge has long been recognized as one of the primary variables that determine the characteristics of a stream. **Figure 3.4** below illustrates the inversely proportional relationship between a set of four primary physical variables (sediment size, sediment load, stream discharge and stream slope) and two opposing processes (stream bed aggradation and *degradation*) that determine stream sediment and channel characteristics and balance. The figure suggests that a change in one of four physical

[17]One exception is when the vegetation changes quickly, such as can happen during forest fires, catastrophic geologic events, or rapid commercial or residential development.

variables will trigger a response in the two process variables. This in turn creates changes in river characteristics.



(Sediment LOAD) x (Sediment SIZE) is proportional to (Stream SLOPE) x (Stream DISCHARGE)

Figure 3.4 Sediment Balance (Rosgen, 1996)

If the supply of sediment decreases (for example, an impoundment leading to reduced sediment load downstream) or the supply of water increases (for example, increase in impervious area or decrease in vegetative cover in the watershed leading to increased runoff), the stream will begin to erode downward or *degrade*. The most noticeable manifestations of this will be incision (the stream depth will increase), and the stream slope will become less steep. Incision could lead to undermining of the streambanks as they become over-steepened and bank height ratio increases. As banks fail, this feedback mechanism provides additional sediment and results in a widening of the stream channel, bringing sediment transport capacity and sediment supply back into equilibrium. An increase in sediment transport capacity by increasing slope or decreasing width will have similar effects as increasing discharge or decreasing sediment supply (**Figure 3.4**).

Conversely, if the supply of sediment increases (for example, due to removal of bank vegetation causing increased erosion) or the supply of water decreases (for example due to water diversions or increasing vegetation on floodplain or watershed areas) the stream will begin to *aggrade* or fill in. Noticeable manifestations of this include a localized increase in stream slope and a reduction in stream depth often followed by further increase in stream width. Frequently the supply of sediment increases while the supply of water remains constant. This leads to a stream becoming too shallow from increased deposition, which can cause greater frequency of flooding due to a lack of channel capacity for its available water. Alternatively, the stream may erode its banks to become wider and achieve the necessary cross-sectional area to transport its available water. This process is temporary, because the increase in width encourages additional deposition. Eventually, the stream channel will develop a flow concentration between deposits, and a new channel will develop within the over-widened channel.

Stable streams can be considered to be "operating at their full potential." A number of factors can change the stability of streams such as changes in flow input, sediment, and land use. Channelization of the stream, berms, culverts and bridges can also have a negative impact on stream stability (potential). Departure from potential —stream potential is defined as the best channel condition, based on quantifiable morphological characteristics, for each stream type (Rosgen, 1996) — can be measured at different sections of a stream and can be compared to stable reaches (reference reaches). This comparison allows us to determine the departure from potential, understand causes, predict and plan future changes.

Stream Features

The features of a stream are described in terms of their cross-section dimension, their planform dimensions and their longitudinal dimensions.

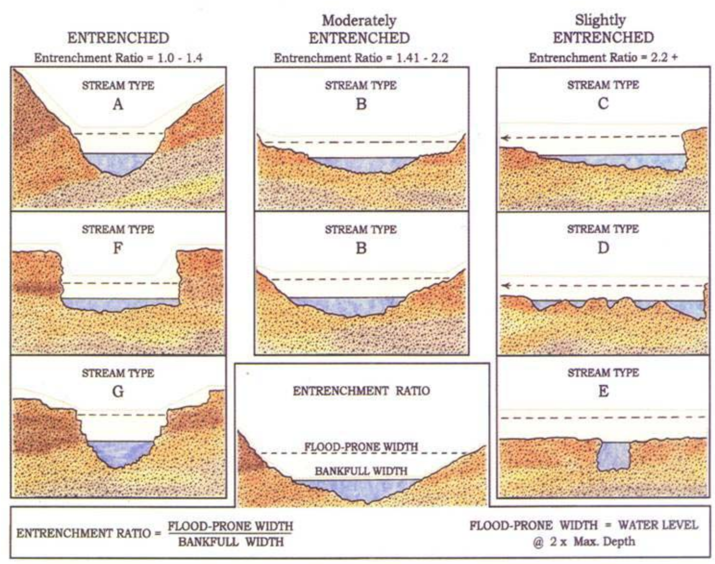


Figure 3.5 Entrenchment of Various Stream Types

In terms of its cross-sectional dimension, a stream has a primary channel that conveys most of the flow throughout the year. Another feature of the stream that moves flow is the floodplain. Floodplains are the flat area of a stream system located above the top of the stream bank that is inundated with flowing water during and following storm events. Streams can have split or multiple channels that may move flood flows. If a stream has more than three channels, it is commonly referred to as a "braided" stream. Storm flows in some streams may not rise over the top of the banks and therefore may lack or are disconnected from their historic floodplain. Such stream channels are commonly called entrenched channels (**Figure 3.5**).

DCSWCD and NYCDEP have developed Regional Hydraulic Relationship Curves (see page 150) to aid in determining a stream's cross-sectional area, width and depth for a give drainage area. This information is used during assessments to determine if a stream's dimensions are within an acceptable range of values. As shown, stream dimensions and flow usually change significantly below a tributary confluence.

Consequently, it is important to know when two or more stream orders occur in an impacted or study stream reach as there are impacts on its hydraulic function and how we interpret our Regional Hydraulic Relationship Curve data.

Longitudinal dimensions of a stream are used to describe how the stream changes from the top of the watershed to the mouth of the stream. The most important factor is the slope of the stream. Slope is a critical contributor to the energy of the stream. The energy of water flowing down a slope is needed to move sediment. A stream's slope can vary from high gradient (slope greater than 4%) to medium gradient (2%-4%) to low gradient (less than 2%). The slope of the stream typically is greatest at the top of the watershed (high gradient stream) and gradually declines as the stream flows down the valley (medium gradient stream) and makes its way to the bottom of the watershed (low gradient streams). Within a reach, the slope of the stream can vary as the water moves through riffles (steep sections), runs (steepest sections), pools (flat sections), and glides (transition sections from flat to steep). The illustration below (**Figure 3.6**) shows a profile of the stream through one riffle – pool sequence. Pools are important features in stream since their low slope acts to slow the velocity (hence reduce the energy of the stream). Typically a stable stream reach will maintain a balance in the ratio of the length of riffles to the length of pools.

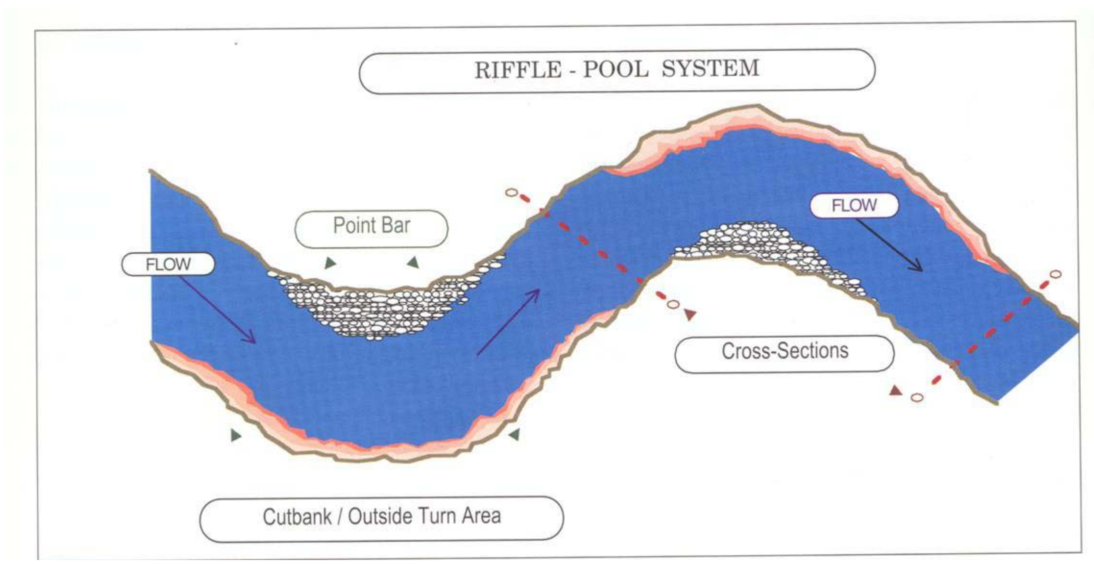


Figure 3.6 Typical Riffle-Pool Sequence

The overhead or "planform" view of the stream focuses at the winding nature of the stream within its valley. Stream managers speak of a stream's *sinuosity* as they describe the extent the stream meanders across the valley. Sinuosity is related to slope and energy. A sinuous stream is longer than the straight line distance between an upstream and downstream set of points and associated elevations. Therefore the greater the sinuosity the lower the average slope. The sinuosity of a stream is generally greater at the lower end of the valley closer to the mouth of the watershed. Additional information on stream features and the relevance of their dimensions is provided in "Stream Morphology and Classification".

Stream Morphology and Classification

"The river is the carpenter of its own edifice" - Luna Leopold, 1994

One useful tool for stream managers, developed by Dave Rosgen (1996), is a system for classification of different stream reaches based on their form. Rosgen's system gives letter and number designations to different stream types, depending on their combination of five *bankfull* channel characteristics:

1) Entrenchment ratio
2) Ratio of width to depth
3) Slope
4) Sinuosity
5) Bed material size (D_{50})

Different combinations of these characteristics result in a great number of different stream types, from A1 through G6 (see **Figure 3.7**; read letter designation across the top, particle size number down the left side). These letter/number designations provide a sort of shorthand for summing up the form of a stream reach. By classifying the different types of streams in a watershed different management strategies can be targeted to each section of stream. These and other characteristics come together to influence how a stream "makes itself" and whether is it stable or unstable in a given setting. These include[18]:

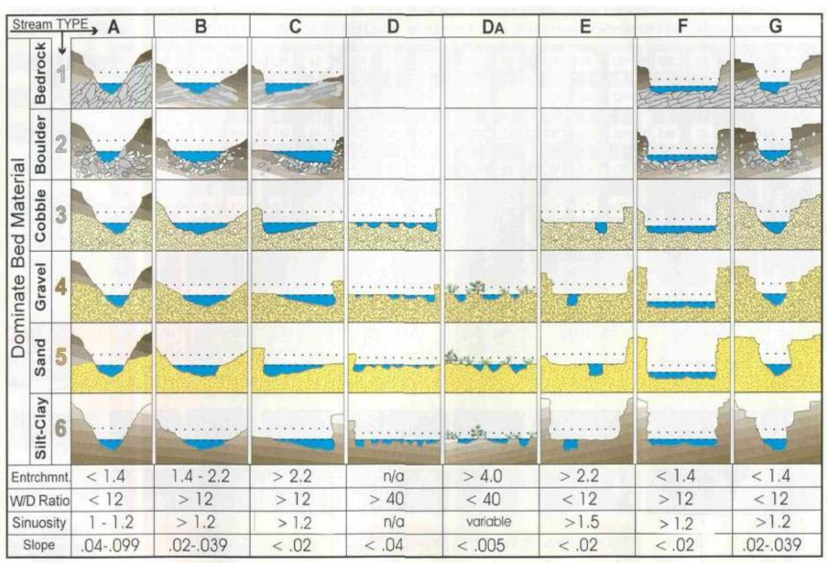


Figure 3.7 Stream Type Delineative Criteria (Rosgen, 1996)

Stream flow (Q) – Usually represented as cubic feet or cubic meters per second, stream flow is also called stream *discharge*. Stream flow changes from hour to hour, from day to day, from season to season, and from year to year.

[18] Each characteristic is followed (in parentheses) by the symbol commonly used to represent it in hydraulic equations.

Some stream flows play a more significant role than others in determining the shape of the stream. The bankfull flow is considered most responsible for defining the stream form. For this reason, bankfull flow is also sometimes called the *channel-forming flow*. This flow typically recurs every 1-2 years. It may seem surprising that very large floods aren't more important in forming the channel. While they may induce catastrophic changes in a stream—severely eroding banks and washing countless trees into the channel—these major floods are rarer, occurring on the average every decade or so. The flows that have the most effect on channel shape are those that come more frequently (**Figure 3.8**), but which are still powerful enough to mobilize the gravel and cobble on the streambed: the smaller, bankfull flows.

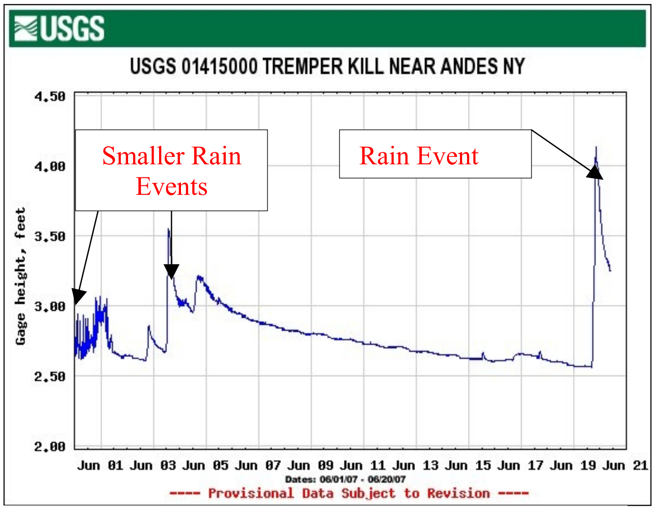


Figure 3.8 Flow Responses to Precipitation

The height of the water in the channel is called the *stage*. When a stream overtops its banks, it is in *floodstage*. *Bankfull stage* — when the stream is just about to top its banks — is used as a benchmark for measuring stream dimensions for classifying different *stream types*.

Slope (S) – The distance that the stream channel drops divided by the distance over which that drop occurs. Slope is one of the two main determinants of a stream's potential force for erosion of the streambed and banks. The slope of a stream usually refers to the average slope of the water surface when the stream is running at bankfull flow, though can be measured as a low flow water surface slope for use in stream classification.

Bankfull depth (d) – The depth from the elevation of water surface at the *bankfull discharge* to the deepest point in the channel. ***Depth*** is the other primary determinant of potential force, and is measured from the streambed to the water's surface at the bankfull stage elevation. Again, this will depend on the level of the stream flow. When used to compare one stream reach to another in *stream classification systems* (see above), the average depth of the stream during a bankfull flow is used.

Bankfull width (W) – The width of the water surface at the bankfull discharge. Together with average depth, channel *width* determines the *cross-sectional area* (Area (A) = width x depth). Channel width is measured from bank to bank at the bankfull elevation. One principle important to understanding stream morphology is that whenever outside influences change a stream's channel dimensions, the stream usually adjusts itself to maintain a cross-sectional area that will pass normal bankfull flows.

From the above two measurements, the following two ratios are calculated:

Entrenchment ratio – Entrenchment ratio is equal to the floodplain width at two times the bankfull depth divided by bankfull depth. When a reach of stream is either straightened or narrowed, the power of the stream flow is increased. The stream may then cut down into its bed, so that flood flows are less likely to spill out into the floodplain. When this happens, we say that the reach has incised, and that the channel has become *entrenched*, which can occur to varying degrees of severity. When large flood flows are confined to the narrow channel of an incised stream, the water becomes very deep and erosive; the stream may gully down even deeper into its bed. Eventually the banks may become so high and steep that they erode away on one or both sides, widening the channel. This in turn can change previously stable areas downstream, having a significant impact on road and bridge infrastructure.

Width/depth ratio – Bankfull width divided by bankfull depth. Stream channel morphology is often described in terms of a width/depth ratio related to the bankfull stage cross-section. Width/depth ratio varies primarily with the dimension of the channel cross-section for a given slope; the boundary roughness as a function of the stream flow and sediment regime; bank erodibility factors including the nature of streambank materials; degree of entrenchment; and the distribution of energy in the stream channel (Rosgen, 1996).

Sinuosity (k) – The ratio of the linear valley floor length to the stream length measured along the *thalweg*. A different kind of roughness that slows water flow has to do with whether the channel runs straight, or curves. The flow of a stream is slowed as it moves around a bend as a result of *form roughness*. The overall "curviness" of a stream is called its *sinuosity*. In natural channels, as a rule of thumb, lower slopes produce more sinuous streams.

Name	Particle Size	
Silt	< 0.062mm	< 0.002 in
Sand	0.062mm - 2mm	0.002 in - 0.08 in
Gravel	2mm - 64mm	0.08 in - 2.52 in
Cobble	64mm - 256 mm	2.25 in - 10.08 in
Boulder	256mm - 2048 mm	10.08 in - 80.63 in

Particle size distribution (Dxx) – The statistical distribution of stream bottom material sizes measured in the stream channel below the bankfull depth. It takes more force for a stream to move material on the streambed if it consists of large cobbles than if it is sand or silt; the smaller the particles, the more easily they will be moved. To characterize the sediment in a stream reach, 100-300 particles are randomly selected and measured, and the median size particle determined. Although a time-consuming task, this procedure determines the D_{50} of the reach: meaning that 50% of the particles in the stream are smaller, and 50% are larger. The D_{50} is used in overall stream reach classification while the D_{84} is used for hydraulic calculations.

Channel roughness (n) – Although flowing water develops potential to erode streambeds and banks, other stream characteristics combine to slow the water down. One of these is the channel roughness: there is more resistance to flow where a stream reach contains boulders and cobbles than through a reach with a smooth, silt-bottomed bed and no obstructions. Similarly, water flows more slowly across a floodplain filled with trees and dense brush, and so is less likely to cause erosion, than it does across a smooth, newly mown lawn or parking lot. This characteristic is also referred to as *bed roughness*.

Sediment discharge (Qs) – In general, the term "sediment" is used to describe the silt, sand, gravel, cobbles and even boulders that are moved by stream flow. Sediment discharge is the amount of sediment moving past a particular point over some interval of time, usually measured in tons per year. Bedload is sediment that moves along the bottom of the channel, while washload is sediment that is suspended within the water. Measuring sediment discharge helps determine if a stream reach is stable. If the amount of sediment entering a reach doesn't roughly equal the amount leaving it, the form of the reach is changing or unstable.

Bed and Bank Cohesiveness – Some soil types hold together better than others, or are more *cohesive*. Some streambeds have their gravel and cobbles bound together in a *matrix* of finer material that resists movement by stream flow; those that do not can erode more easily. The roots of trees and shrubs can reach deep into streambanks, and the web of fine root fibers can add much strength to otherwise erosive soils. This creates a balance between water forces the bed and banks to resist erosive power. When changes in streambank vegetation affect soil erosivity, stream morphology will change in response until a new *equilibrium* is reached.

Radius of curvature (Rc*)* – *Radius of curvature* describes the "curviness" of the stream at a single curve, and is measured as shown in **Figure 3.9**.

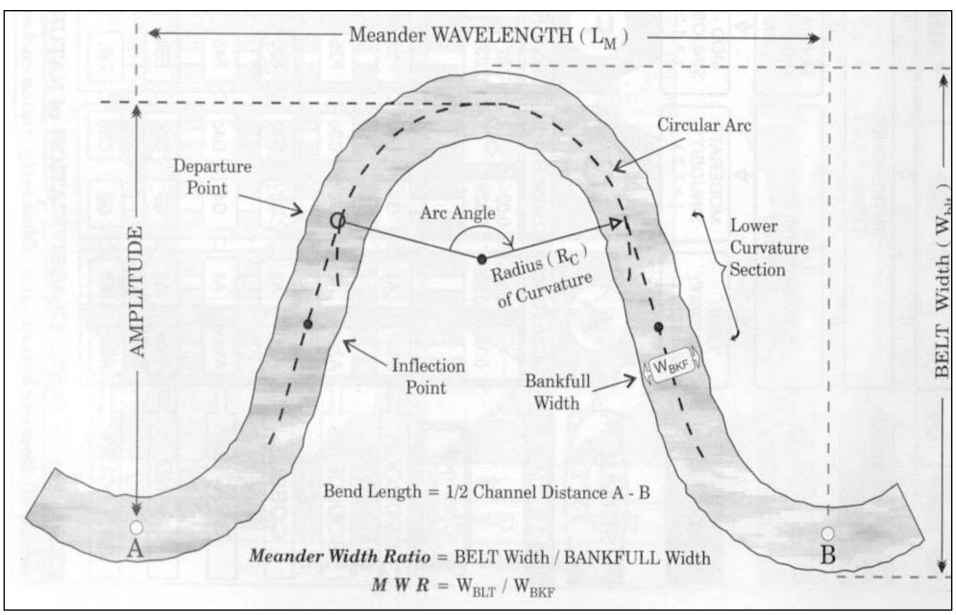


Figure 3.9 Radius of Curvature (Adapted from The Reference Reach Field Book, D. Rosgen.)

Channel Disturbance and Evolution

Channels that have been disturbed by dredging, incision, or channelization follow a systematic path to recovery. This process has been documented by Simon and Hupp (1992), and is illustrated in **Figure 3.10**.

- Class I, is the channel in its natural pre-disturbed state.
- Class II, is the channel immediately after being disturbed (in this case, channelized, presumably straightened and steepened in addition to over-widened).
- Class III, is the channel eroding down (degrading) due to the flood waters being confined because channel is lower and out of contact with the former floodplain.
- Class IV, the channel continues to degrade, the banks become unstable, and the channel erodes laterally.
- Class V, the channel begins to deposit eroded material in the over-wide channel, and the newly developing floodplain continues to widen.
- Class VI, and a new channel is established and becomes relatively stable. A new floodplain is established within the original channel, and the former floodplain becomes a *terrace* (abandoned or inactive floodplain).

The six classes would temporarily occur at a single cross-section, but they can be seen to occur spatially as well when viewed along the stream profile, most typically in the downstream direction from Class I at the headwaters to Class VI at the mouth.

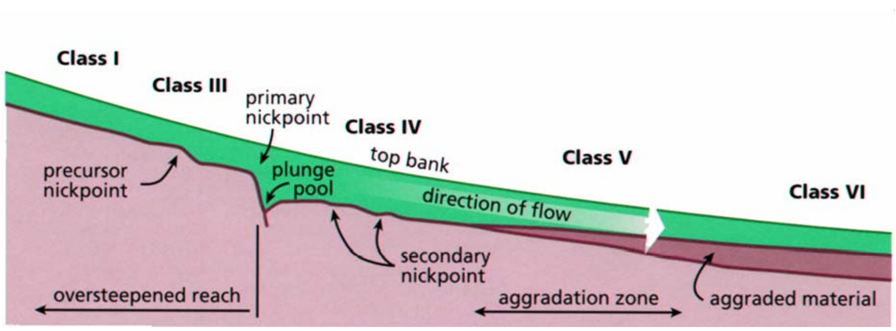


Figure 3.10 Profile View of Channel Evolution Sequence (Simon and Hupp, 1992)

Figure 3.10 shows this process occurring along the stream profile. The profile view illustrates the changes a stream goes through in adjustment to disturbance or to natural stream processes over geologic time. Bank erosion is a symptom of change within the watershed. Focusing on stabilizing short reaches of eroding bank (*rip rap*) does not address the issue of change within the watershed. It ignores the effect that excess sediment form upstream will be deposited, and that this in turn triggers rapid channel migration and additional bank erosion. The causes of erosion must be addressed and this requires looking at the watershed as a whole.

Dave Rosgen (2001) has described nine evolutionary scenarios using his stream types which are illustrated below in **Figure 3.11** (below). These are not theoretical evolutionary scenarios; each has been observed by Rosgen in the field. A common evolutionary sequence in this region is number nine. A C type stream degrades to a G, then widens to an F. Eventually a new C is formed inside the wide F channel. Note that in this case a new floodplain has been created. The old floodplain is at a higher elevation relative to the streambed, and becomes a terrace.

The evolutionary sequence can be used on any particular stream to tell scientists, engineers, or hydrologists something about the stream's former and present state, or to determine what the stream's former condition (type) and what it should be to be in balance with the current setting.

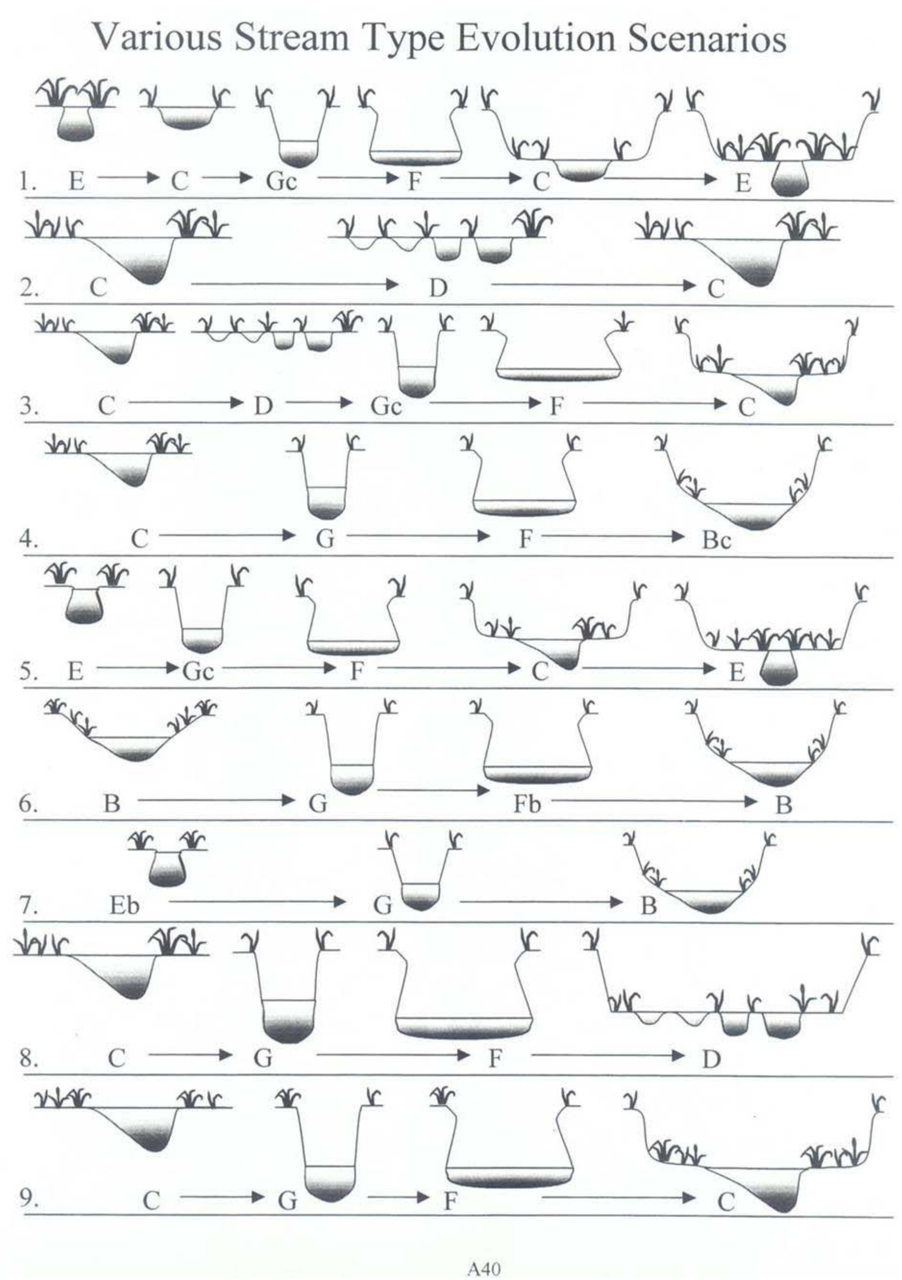


Figure 3.11 Stream Evolutionary Sequence (Rosgen, 2001)

Human Activities and Impacts on Stream Health

The distinction between natural and human disturbances is important to understand. The effects of ice floes, pests, and disease can cause widespread damage to riparian vegetation but these effects are usually temporary (see **Volume 2, Section 5**). Human disturbances, however, often significantly alter natural conditions and can have a longer lasting impact on the capability of riparian vegetation to survive and function. These disturbances can include logging practices, livestock overgrazing, cropping practices, construction and maintenance of highway infrastructure, real estate development, gravel mining, dredging, channelization, berming, and introduction of non-native species in the riparian corridor. All of these practices have impacted stream stability on a watershed scale.

Agricultural Influence

Continuous access to streams by livestock has a significant impact on the vigor, mortality and diversity of riparian vegetation. Grazing can reach an intensity that will keep grasses and forbs at a height too low to effectively uptake nutrients and impede storm runoff, which increases environmental contamination and streambank erosion (see Figure 3.12). Intensive riparian grazing also inhibits the growth, establishment and/or regeneration of shrubs and trees while hoof shear (cattle-eroded stream access points) on streambanks exacerbates erosion. Cultivating row crops and mowing haylands to the stream's edge or the top of the streambank also result in decreased species diversity and riparian buffer width. These practices significantly increase runoff and associated nutrient contamination and streambank erosion.

Figure 3.12 Streambank Impacted by Cattle

Agriculture is a notable 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 United States Department of Agriculture's (USDA) Conservation Reserve Enhancement Program (CREP) is a voluntary program that protects environmentally sensitive agriculture land with vegetative riparian buffers often associated with exclusionary livestock fencing. This program provides numerous environmental benefits and has met with great success in the West Branch Delaware River watershed and is expanding into the East Branch watershed. More information on CREP is included in the Watershed Programs section at the end of this volume.

Highway/Public Utility Infrastructure Influence

Some of the most easily visible impacts to stream stability result from the construction or maintenance of highway infrastructure. Use and maintenance of state and local highways impacts the vigor of riparian vegetation where narrow buffers exist between roads and streams. These areas receive runoff containing sediment and road chemicals that stunt vegetative growth or increase stress and mortality. Highway maintenance activities that regularly disturb the soil along shoulders and cut banks can welcome undesirable *invasive plants*. In areas where public utility lines parallel or cross streams, riparian areas are disturbed by the practice of keeping vegetation trimmed to near ground level. This is another contributor to accelerated runoff and increased streambank erosion.

Figure 3.13 Dry Brook Road Culvert

Roads are commonly located close to streams, especially in the Catskill region with its narrow and winding valleys. Road encroachment has narrowed and deepened many streams, resulting in increased velocity. This causes the bed of the stream to *degrade* and, ultimately, to become *incised,* like a gully in its valley. This means that the stream reach has become unstable, which can lead to rapid streambank erosion as well as impairment of water quality and stream health. Worse yet, these local changes can spread upstream and downstream, causing great lengths of stream to become unstable. Roads near streams can also introduce pollutants or garbage to the stream system from stormwater runoff which effects aquatic habitat. Stormwater runoff is recognized as a significant water quality concern in Delaware County. As overland flow from impervious surfaces, such as roads and parking areas, stormwater runoff contains contaminants and nutrients that are delivered directly into stream system. A good streamside buffer along roads could help minimize excess pollutants and garbage from entering the stream system.

Roadside ditches collect stormwater runoff, carrying it away from the road and sometimes directly into streams. Without retention and/or filtration, resulting stream issues are often contamination, excess sediment, and excess nutrients in the stream. Ditch maintenance without re-seeding can increase sediment (turbidity) in the stream system. This can exacerbate gravel deposition problems. Proper culvert installation and sizing is also important for stream stability. Culvert installation that utilizes improper size, slope, and headwall can lead to streambank erosion and/or gravel deposition both upstream and downstream of the culvert.

In addition to roads and ditches, bridges have had a considerable impact on stream system stability. Bridges built wider than the stream's natural dimensions will lead to the deposition of sediment under and near the structure during periods of low or base stream flow. Localized scour may also be present. Sediment that deposits under the bridge will affect the flow capacity of the channel beneath the bridge. In many instances, the sediment is dredged out to maintain design capacity. Bridges built narrower than the stream's natural dimensions will exhibit a depositional wedge upstream of the structure. This can lead to water backup behind the bridge, resulting in local flooding upstream. Bridge approaches are sometimes built across floodplains in order to have a gradual rise unto the bridge. These become floodplain encroachments. Bridges can force water that would normally be on the floodplain through a narrow opening, concentrating energy that can cause problems downstream of the bridge, such as streambank and stream bed erosion.

Figure 3.14 Bridge at Erpf Road

Residential Development Influence

Residential land use and development of new homes can have a significant impact on the watershed and ecology of the riparian area. Houses require access roads and utility lines that often have to cross streams. Homeowners who enjoy their stream and desire to be close to it may clear all the trees and shrubs along it to provide views and access. They may replace natural conditions with an un-natural mowed lawn that provides little benefit to stream health or local wildlife. These practices can lead to new streambank erosion or increase existing erosion issues.

Many people live close to a stream and have access to the water without destabilizing the bank. Careful selection of a route to the stream and locating access where the water's force on the bank is lower, a landowner can minimize disturbance to riparian vegetation and the streambank. Minimizing disturbance in the flood prone area and promoting a dense natural buffer provide property protection, aesthetic value and wildlife habitat. Riparian gardeners must know which riparian species are appropriate for planting. More information can be obtained by contacting the Delaware County Soil & Water Conservation District, 44 West Street, Suite 1, Walton, New York, 13856, (607) 865-7162. The following websites also offer information on riparian buffers:

USDA Natural Resources Conservation Service backyard tree planting -
http://www.nrcs.usda.gov/feature/backyard/TreePtg.html (Verified September 27, 2007)

USDA Natural Resources Conservation Service wildlife habitat - http://www.nrcs.usda.gov/feature/backyard/WildHab.html (Verified September 27, 2007)

Connecticut River Joint Commission, Inc. - http://www.crjc.org/riparianbuffers.htm (Verified September 27, 2007)

The National Wildlife Federation – http://www.nwf.org/backyardwildlifehabitat/ (Verified September 27, 2007)

A Look to the Future

Many past and current human attempts at fixing streams have been "band-aid solutions" for spot problems and these attempts often create additional problems downstream. To combat stream problems, fluvial geomorphology techniques can help stream managers understand natural and human-induced stream problems on a larger (watershed) scale and prioritize severely unstable stream reaches for treatment. By carefully measuring the characteristics of stream form described in the preceding sections, stream managers can get a fairly good idea about the relative stability of a stream, reach by reach, over its whole length. Stable stream reaches *(reference reaches*) are identified and surveyed, and the stable form characteristics are used as a design template for restoration projects. A variety of management strategy options can then be provided to address these problems on both short and long-term bases.

Practices consistent with fluvial geomorphology (natural stream channel design) include:

- **Proper sizing of channels when undertaking stream work**.
  - As previously mentioned, the DCSWCD and NYCDEP have put considerable effort into the development of Regional Hydraulic Relationship Curves. This has been accomplished through the calibration of USGS Stream Gaging Stations to bankfull parameters. These curves are extremely useful for determining if a stream's bankfull dimensions are within an accepted range of values for a given drainage area. As an example, picture a stream reach with a 25 square mile drainage area, a bankfull width of 80 feet, and an average depth of 1.3 feet. By interpolating from the Regional Hydraulic Relationship Curves or by using the formulas, the chart below (**Figure 3.15**) indicates that the average width should be 56 feet and the average depth should be 2.5 feet. This means that the reach in question is both too wide and too shallow, and it will likely aggrade, widen, and become shallower. More frequent flooding is also likely. The stream will probably become multi-channeled at some point, creating the potential to relocate itself during a major flood. Such a reach would be noted as being "impacted" and, as part of developing a mitigation plan, DCSWCD staff would further examine the watershed to determine the cause of these issues.

    Conversely, DCSWCD staff can determine whether a stream reach is functioning well. A reach that is functioning really well can be used as a "reference reach" for future mitigation projects. (See "Using Stable Stream Feature Dimensions" later in this section.) In a case where recent floods totally destroyed the stream, DCSWCD staff were able to reconstruct streams using the Regional Curves. The curves are also useful in performing emergency stream mitigation. In emergency situations, streams can be returned to a somewhat natural dimension so they have a chance to recover naturally until more permanent work can be planned and implemented.

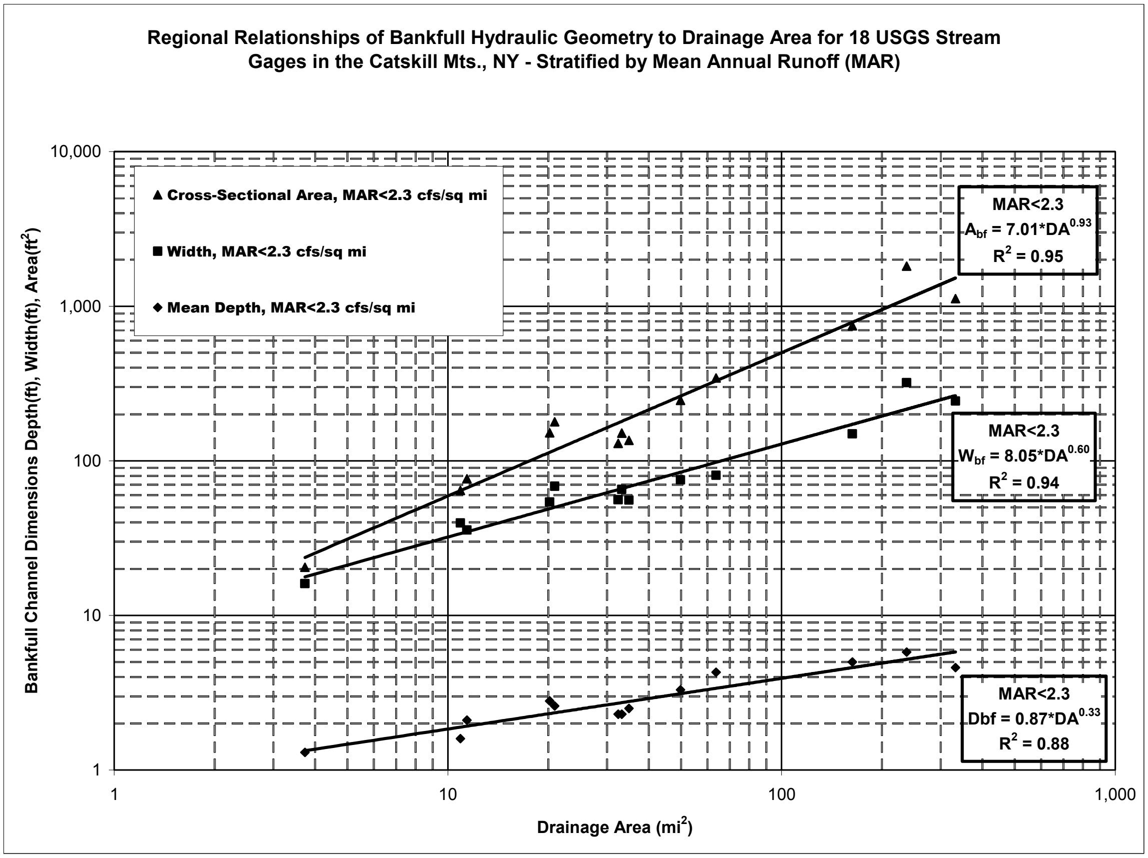


Figure 3.15 Regional Hydraulic Relationship Curves

- **Identifying the desired stream type as part of a project design process**
  - Part of stream classification involves determining the stream type of a given stream reach. Stream type is often dependant on the type of valley through which it flows. For example, headwater streams in the Catskills are typically in steep narrow valleys and tumble from one pool to the next. These are commonly called an "A" or "Aa+" type stream (**see Figure 3.16**). As the stream continues to descend down the valley, it flattens out and becomes a "B" type stream ending in a "C" stream in the valley bottom. The occasional "E" stream type is a very stable stream. Other stream types that may be encountered in the Catskills are "D", "F", and "G". These stream types are usually unstable.

    Knowing the stream type helps stream managers in determining stream stability. When planning a restoration project, it is important to restore a stream to the correct stream type. As depicted in **Figure 3.16**, A and B type streams are fairly straight while the C type stream exhibits some sinuosity. Sinuosity plays a role in energy reduction. If a straighter B type stream were constructed where a C type stream should be, the stream would be over-steepened and would crash and thrash about until the correct stream slope is attained.

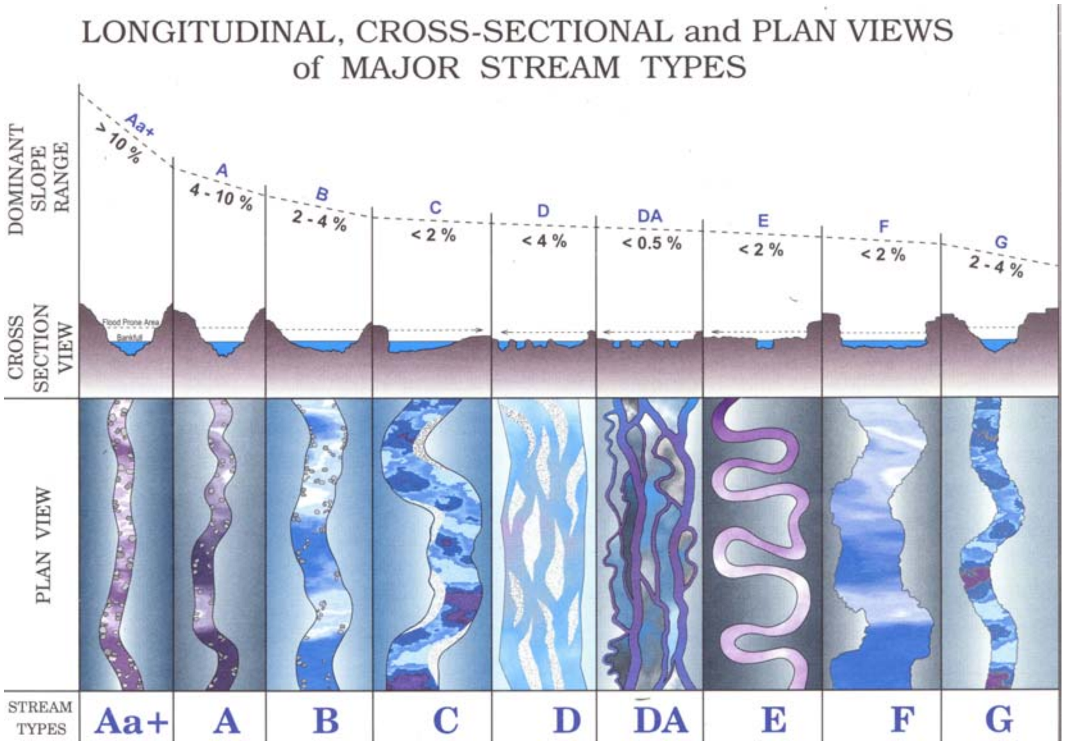


Figure 3.16 Stream Types

Another look at **Figure 3.11** on page 145 shows stream evolutionary scenarios. Scenario 9 is fairly common in Delaware County. If a stream in a valley bottom is a G or F type, and it is known that the stream was once a C type, it is reasonably certain that it will eventually build another C type stream at a lower elevation. While the stream is lowering its elevation, excessive erosion and deposition patterns and loss of property can be expected. This evolutionary sequence can migrate upstream and/or downstream and create the same effect in the stream's tributaries. This information must also be taken into consideration when planning and designing a stream restoration project.

- **Re-connecting floodplains**
  - "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). The floodplain is a critical component of stream function. The floodplain serves as an energy dissipater and depository of finer sediments during high flows. When streams are disconnected from floodplains by berming, dredging or other means, this natural balance is disrupted – often with undesirable impacts. Additionally, floodplain obstructions like bridge approaches and buildings can restrict floodplain flow or concentrate flow elsewhere – again with undesirable impacts. It is, therefore, an important component of any restoration project to give prioritization to floodplain re-connection.

- **Using stable stream feature dimensions**
  - As previously mentioned, a stream reach that is functioning well (stable) can be used as a "reference reach". Every aspect of a reference reach is accurately surveyed and measured and data compiled with specialized computer software. Data collected and compiled include all the features and information described in the "Stream Morphology and Classification" on pages 106. The watershed drainage area is also documented. The drainage area is important because as a rule-of-thumb, stream managers do not extrapolate more than ten percent above or below the reference drainage area for design. For example, if the drainage area of a reference reach is 60 square miles, that data is only good for projects between 54 and 66 square miles. However, replicating "reference dimensions" in a stream restoration project reach helps ensure project success.

Figure 3.17 Functioning Floodplain Along NYS 30 North of Margaretville, September 18, 2004

- **Consideration of upstream and downstream impacts**
  - Impacts upstream and downstream of a stream restoration project always need to be considered. For example, if a stream bank is armored with riprap or other hard material, consideration is given to increased velocities and erosion potential on an opposing downstream bank. Likewise, if a restoration project is designed to improve sediment transport through a reach, deposition potential downstream must be assessed. It is a goal with fluvial geomorphological design to not only improve an impacted reach but to *not* create undue stress elsewhere in the stream system. This also includes not creating any situation that may increase upstream deposition or negatively alter flood flows.

Figure 3.18 Root wad Installation Taken After the September 18, 2004 Storm

- **Using vegetation and natural channel design structures**
  - Re-establishing or enhancing streamside vegetation is a crucial component of a natural stream channel design restoration project. A planting plan can range from simple to complex. However, it is important to plant wet-adapted plants near the water and phase to dryer-adapted species from the top of the bank back. Streamside vegetation serves to help stabilize the stream bank with their root masses, slow down higher flows and trap sediments, regulate water temperatures, and provide habitat for both aquatic and upland fauna.

Figure 3.19 Rock Cross-Vane

  - Natural channel structures are designed to reduce stress on the stream bank by re-directing stream flow toward the center of the stream. These typically include single arm rock vanes, rock cross-vanes and root wad structures. Rock vane structures are built with large rock, well-footed below the stream bed, and well-tied into the stream bank. The vane arm slopes from the top of the stream bank to the stream bed. A rock cross-vane is simply two single arm vanes with a throat in the center (**Figure 3.19**). Root wads are similarly used. A root wad is a large tree devoid of limbs but with the entire root system attached. They have typically been used in Delaware County for post-flood mitigation to take advantage of the large woody debris left on floodplains. There is, however, a standard design for using them in restoration projects. Plantings are done around both at the ends of the vane arms (where they are tied into the stream bank) and all around a root wad. **Figure 3.18** shows a typical root wad installation prior to stream bank plantings (which are done in the fall during their dormancy).

- **Limiting gravel removal**
  - Gravel removal at a project site should be given careful consideration. Generally, only deleterious gravel bars, such as transverse bars (those bars across a stream that direct flow toward a stream bank), center bars (those in the center of a stream with flow on both sides) or deposition near or around drainage structures should be considered for removal. Point bars (those on the inside of a bend) actually serve a hydraulic function primarily by providing a definable stream channel during lower flows. They are actually formed by lack of stream energy on the inside of a bend and are partially eroded away during flood events, being re-deposited as flood flows subside. Removing point bars will reduce stream energy at low flows, thereby creating potential for increased deposition.

- Point bars are formed in the following manner. "As a flowing stream enters a bend in its channel (see **Figure 3.20**), the water surface, being swifter than that near the bottom, moves toward the concave bank and tends to erode it. Continuity requires, then, that the surface water plunge downward near the concave bank and that some bed water emerge at the surface near the convex bank (point bar). This circulatory motion in the cross-sectional plane of a channel, which was first observed and explained by Thomson in 1879, is a result of the larger centrifugal force that is exerted on fast-moving surface parcels than on slower-moving ones near the bed. The motion gives to an individual water parcel a path resembling a helix." (Leopold, 1997).

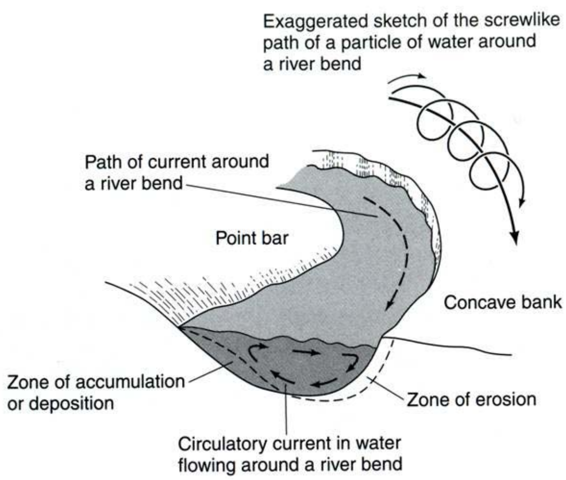


Figure 3.20 Effect of a curved channel on water flow creating point bars

Figure 3.21 Looking upstream at a point bar in the Tremper Kill Sub-basin

~ 4. Fisheries and Wildlife ~

Stream and upland conditions in the East Branch Delaware River watershed support numerous species of fish and wildlife. Their presence is an indicator of land cover types, land uses, and ecosystem health. This section briefly describes fish and wildlife species that are present.

FISH SPECIES

Brown trout (*Salmo trutta*) and wild brook trout (*Salvelinus fontinalis*) are the primary species found in the East Branch Delaware River and its tributaries. Brook trout do not grow as large as the brown trout in the basin. Chain pickerel (*Esox niger*) are occasionally caught by anglers. The riverine system also includes a variety of minnows including the closely related white sucker (*Catostomus commersoni*).

Figure 4.1 Brown trout (*Salmo trutta*)

Species common in the Pepacton Reservoir include brown trout, smallmouth bass (*Micropterus dolomieu*), yellow perch (*Perca flavescens*), brown bullhead (*Ameiurus nebulosus*) and rock bass (*Ambloplites rupestris*). On rare occasions rainbow trout (*Oncorhynchus mykiss*) are noted. The alewife (*Alosa pseudoharengus*), a herring native to the lower mainstem Delaware and its tributaries, was introduced into the Pepacton Reservoir by bait pail and is very common.

The American eel's (*Anguilla rostrata*) migratory passage upriver was impeded by the Pepacton Reservoir. Eels do inhabit the East Branch Delaware River downstream of the reservoir, as do sea lamprey (*Petromyzon marinus*).

These fish are managed with statewide fishing regulations. No non-trout species are stocked in the river or reservoir.

Public Use and Angling

The New York State Department of Environmental Conservation (NYSDEC) routinely purchases public fishing rights along streams inhabited by trout but the number of access points and reaches with fishing rights are extremely limited in the Pepacton watershed. Fishing is permitted on State land within the Catskill Park with a valid New York State fishing license.

The Pepacton Reservoir is well known fishery and fishing is allowed by obtaining a permit from the New York City Department of Environmental Protection. NYC DEP Recreation Permits can be obtained on-line at:

http://www.nyc.gov/html/dep/html/watershed_protection/html/wsrecreation.html
(Verified on September 27, 2007)

Permits can be requested by mail from NYCDEP Land Management – Access Permits, 71 Smith Avenue, Kingston, NY 12401, or by telephone (800) 575-5263. A New York State fishing license is required to fish on New York City lands.

The following web sites have information about fishing in Delaware County and on the East Branch of the Delaware. Please note that much of the information on these sites is specific to the waters below the Pepacton. Nonetheless, the information can be helpful to anglers fishing above the reservoir.

Delaware County Chamber of Commerce: Lists local fish tackle shops and contains a map of public fishing access points http://www.delawarecounty.org/fishing/ (Verified on September 27, 2007)

Catskill Flies Inc: Provides information on current river conditions for the Catskills http://www.catskillflies.com/stream.html (Verified on September 27, 2007)

Upper Delaware Chapter of Trout Unlimited: http://www.hancock.net/~udtu/ (Verified on September 27, 2007)

Fish Habitat Protection

Laws are currently in effect that provide some protection to the bed and banks of the East Branch Delaware River and its tributaries, and also to its water quality. Permits are required for any work on the banks or in the bed of the stream, and for any discharge from a point source. Those laws do not change the fact that some land use patterns have altered the physical form of the river system. Protection and enhancement of the streamside vegetation helps to regulate temperature and provides important cover for the aquatic life. Stormwater controls, such as detention basins and environmentally engineered storm water outfalls, limit and mitigate the direct input of turbidity and pollutants from work sites and highways, and warm water from impervious surfaces. Restricting floodplain development can reduce the strain on aquatic habitat as well as protect homes, businesses and lives. Habitat protection also ensures that recreational and business opportunities are not compromised while maintaining a quality water supply and a good quality of life for watershed residents.

Please refer to **Recommendation #14** of **Volume 1** for suggested actions and research.

Wildlife

Riparian corridors in the East Branch basin support a diverse community of wildlife species. Species mix ranges from predator to prey and commonly includes: white-tailed deer (*Odocoileus virginanus*), eastern wild turkey (*Meleagris gallopavo*), ruffed grouse (*Bonasa unbellus*), eastern coyote (*Canis latrans*), red and gray foxes (*Vulpes vulpes* and *Urocyon cinereoargenteus*), eastern cottontailed rabbit (*Sylvilagus floridanus*), muskrat (*Ondatra zibethicus*), beaver (*Castor canadensis*), porcupine (*Erethizon dorsatum*), mink (*Mustela vison*), striped skunk (*Mephitis mephitis*), raccoon (*Procyon lotor*), Great blue heron (*Ardea herodias*), turkey vulture (*Cathartes aura*), American crow (*Corvus brachyrhynchos*), Canada goose (*Branta canadensis*), and various ducks, songbirds, hawks, owls, gulls, snakes, frogs, toads, salamanders, turtles, squirrels, chipmunks, mice, voles, bats, weasels, shrews, woodchucks, and black bear (*Ursus americanus*), bobcat (*Lynx rufus*) and bald eagle (*Haliaeetus leucocephalus*). The bald eagle population has been on the increase, particularly around the Pepacton Reservoir, during the past few years.

All these species depend on the stream and/or the floodplain and adjacent uplands for food, cover and shelter. Many of these species are managed as game species under jurisdiction of the NYSDEC Division of Fish, Wildlife and Marine Resources, while others are permanently protected by state and federal legislation. On equal par with fish habitat protection is protection of streams and their adjacent floodplains. Again, habitat protection equates to good quality of life for watershed residents and enhances business and recreation opportunities.

~ 5. Riparian Vegetation ~

Riparian vegetation plays a crucial role in stream health, and thus is important to sound stream stewardship and management. This section discusses riparian vegetation in terms of general ecology, forest history of the East Branch Delaware River basin, natural and human disturbances, and the effects of invasive plants on riparian vegetation. A separate subsection focuses particularly Japanese knotweed (*Fallopia japonica*), an ecologically harmful invasive plant that has gained a significant foothold in the watershed.

General Concepts of Riparian Vegetation Ecology

Riparian vegetation provides numerous benefits to water quality, aquatic and terrestrial plants and animals, and local landowners. Vegetated *riparian zones, also frequently referred to as riparian buffers,* facilitate stream bank stability by providing root structure to protect against bank erosion and flood damage. Riparian vegetation buffers the stream against non point source pollution, such as nutrient and sediment runoff, and the adverse impacts of human activities. Streamside forests and shrublands also provide food and shelter for aquatic and upland wildlife, and moderate fluctuations in stream temperature. Streamside vegetation also improves the aesthetic quality of the riparian landscape.

Figure 5.1 A Healthy Riparian Community

The extent of benefits of a riparian buffer is proportional to the width of the riparian zone and its species diversity. For example, a narrow 25 foot buffer zone may offer only bank stabilization as a benefit while a buffer over 200 feet wide includes a diverse range of water quality and ecological benefits. A buffer containing a diverse community of plant species and forms (trees, shrubs, grasses and forbs) offers the best protection **(Figure 5.1)**. A buffer composed of a diverse mix of native species of different ages - including adequate regeneration - will function better than a community dominated by only one or two species. Diverse native plant communities are better suited to the local growing conditions, provide great occupation of the rooting zone and have the ability to resist or recover from disturbance, such as flooding, disease or pest outbreaks.

The riparian forest community can be more extensive where a floodplain exists and valley walls are gently sloping. Where valley side slopes are steeper, the riparian community may occupy only a narrow corridor along a stream and quickly transition to an upland forest community. Soils, ground water and solar aspect may create conditions allowing the riparian forest species to occupy steeper slopes along a stream, as in the case where Eastern hemlock (*Tsuga canadensis*) which commonly inhabits steep, north facing slopes along a watercourse.

Changes in the composition, vigor and density of riparian vegetation produce corresponding changes in rooting depth and density, shading, water temperature, physical protection from bank erosion processes, terrestrial insect habitat and contribution of detritus to the channel. The decline or destruction of the riparian vegetation generally results in the destabilization of the stream system. The loss of vegetation opens the system up to the potential for radical channel adjustments which cause bank erosion, sedimentation, and the degradation of aquatic habitat. Eventually the stream alignment may change and problem may migrate up or down stream to other landowners (Rosgen, 1996).

Previous stream management planning efforts in neighboring watersheds have undertaken a riparian land cover mapping exercise designed to provide more accurate information on the extent of each land cover within the stream corridor. This exercise was delayed for this basin and will be initiated as a follow-up activity for the watershed. The results of this effort will be instrumental in prioritizing riparian buffer protection efforts. Information is available within this plan on the average width of the riparian buffer for each management unit discussed in the Stream Assessment Section.

Natural Disturbance and its Effects on Riparian Vegetation

Natural disturbances can greatly affect the vigor of riparian vegetation. These disturbances include floods, ice or debris floes, and to a lesser extent, high winds, pest and disease epidemics, drought and fire. Deer herds can also alter the composition and structure of vegetation due to their specific browse preferences.

Figure 5.2 Channel-wide Debris Jam

The effect of flooding on healthy streamside vegetation is generally short term and the recovery/ disturbance regime can be cyclical. Following a large flood, the channel and adjacent floodplains can be littered with everything from woody debris to downed live trees. In following years, much of the vegetation recovers. Trees and shrubs flattened by floodwaters re-establish their form. In stable streams, gravel bars and sites disturbed in previous flood events become seedbeds for natural regeneration of grasses and forbs. However, if significant flood or ice floe events occur too frequently to allow adequate vegetation re-establishment, large trees do not have the opportunity to establish.

Springtime ice break-up, like floods, can damage established vegetation along streambanks and increase mortality of young tree and shrub regeneration. Ice floes can also cause channel blockages **(Figure 5.2)**, which result in erosion and scour associated with high flow channels and over-bank flow. This type of disturbance generally has a short recovery period.

When stream managers seek to expedite or augment the recovery process, the following local geology and stream morphology factors are important to consider before attempting restoration: hydraulics of flowing water, morphological evolution of the stream channel, geology of the streambank, and the requirements and growth capabilities of vegetation.

Pests and diseases that attack vegetation also impact the riparian area. In portions of the eastern United States, the hemlock wooly adelgid (*Adelges tsugae*) attacks eastern hemlock and can ravage a stand. Currently, the adelgid is known to exist in 20 counties in New York State[19], including a population in the Town of Middletown[20]. According to the NYSDEC Region 4 Forester, the adelgid has migrated from Ulster County. Natural resource managers are aware of its potential to expand its impacted range.

Forest Land Cover

Catskill region forests have evolved since the last ice age, reflecting changes in climate, competition and human land use. As ice melted, plants adapted to warmer temperatures and migrated north, replacing species with a colder climate preference. The forests of the East Branch Delaware basin gradually re-established and evolved from boreal spruce-fir dominated forests (examples of which can presently be found in Canada) to maple-beech-birch forests (typical northern hardwood forests of the Adirondacks and northern New England) with a final transition in some areas to oak-hickory-ash dominated southern hardwood forests typical of the northern Appalachians (Kudish, 2000). The forests of the western Catskills and East Branch of the Delaware River basin are the eastern most extension of the Allegany Highlands forests, a broadleaf, temperate, mixed forest ecozone. The pre-settlement forests in this ecozone consisted largely of American beech (*Fagus grandifolia*) and Eastern hemlock (*Tsuga canadensis*). Sugar maple (*Acer saccharum*) later replaced hemlock as a major component of the forest on drier sites as fire controlled hemlock. Red maple (*Acer rubrum*), white ash (*Fraxinus americana*), black cherry (*Prunus serotina*), yellow birch (*Betula alleghaniensis*) and black birch (*Betula lenta*) were and continue to be associates of the beech-maple and beech-hemlock forests. Eastern white pine (*Pinus strobus*) established nearly pure stands after fire or wind impacted the previous stands. One of the earliest recorded natural disturbances was the March 20th blowdown in 1797. Regional high winds felled trees around Delaware and surrounding counties (Kudish, 2000). There have also been several significant floods that have altered the landscape over the years. Hemlock has remained an important species in riparian forests along the north facing slopes of the East Branch Delaware River. Because of its dense overstory and allelopathic characteristics, hemlock may have been

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[19] NYS DEC website - http://www.dec.ny.gov/animals/7250.html (verified September 27, 2007).
[20] Email from NYS DEC Regional Forester, Stamford, New York, dated May 7, 2007.

able to preserve its dominance by regulating the diversity and abundance of ground cover vegetation in riparian zones (Williams and Moriarity, 1999).

The activities of people have affected forests through manipulation of regeneration for desirable species maintenance, exploitation for wood and wood products and through clearing for development. Native American land management practices included the use of prescribed burning as a means of enabling nut bearing oaks to remain dominant in the forest. In response to a rising industrial economy, European settlers altered the landscape and forest cover through land clearing for agriculture, harvesting for construction materials, and hemlock bark harvesting for tannin extraction. These activities may have allowed the migration of some southern hardwood species (e.g. American sycamore (*Platanus occidentalis*) and shagbark hickory (*Carya ovata*)). Land cover in the basin began to revert back to forest with the local collapse of these economies in the 20th century (Kudish, 2000).

Continued evolution of the forest cover should be anticipated with changes in climate. Although the expected increase in rainfall predicted Catskills by global change scientists (see Volume 1 – Climate on page 4) will continue to support a moist-temperate forest cover, the potential for more frequent summer droughts and warmer average temperatures may lead to an accelerated loss of sugar maples and coincided with an increased presence of southern species such as oak and hickory. Additionally, the continued invasion of exotic species in the woodland may be exacerbated with further climate change.

Invasive Plants and Riparian Vegetation

Sometimes attempts to beautify a property with new and different plants will introduce a plant that aggressively spreads out of control. These "invasive" plants present a threat when they alter the ecology of the native plant community. Their impact may even alter the landscape should the invasive plant destabilize the geomorphology of the watershed (Malanson, 1993). Japanese knotweed, an invasive plant gaining a foothold in the East Branch basin, is an example of a plant capable of causing such a disruption. Although others exist, additional invasive plants of note along the East Branch corridor include common reed (*Phragmites australis*), purple loosestrife (*Lythrum salicaria*) and garlic mustard (*Alliaria petiolata*)[21].

All three of these plants are not native to the United States and are termed "exotic species". Because exotic species are often transported without the associated plants and animals that normally keep them in check, they can become *invasive* species. Invasive species earn this categorization by out-competing local, native species and may alter the ecosystem and its functions. Invasive plants can often survive under less than perfect conditions – from high and low soil pH levels, full sun to much shade, or wet to dry soils. The following text briefly describes common reed and purple loosestrife, followed by an in-depth description of Japanese knotweed, its traits as an invasive species, what people can do about it and resources for additional information.

[21] The Nature Conservancy, 2006

It should be noted that only a cursory plant inventory was taken by staff working on this plan and that the northern bounds of The Nature Conservancy study was New York State Route 28 and the Pepacton Reservoir. It is reasonable to assume that these species also inhabit parts of the East Branch watershed north of this demarcation but further study will be required to validate this.

Common Reed

Common reed is a large grass native to wetland sites throughout temperate and tropical regions of the world. It is generally regarded as the sole species of the genus *Phragmites*, though some botanists divide the genus into three or four species.

Figure 5.3 *Phragmites australis*

It commonly forms extensive stands, up to a square kilometre or more (known as reedbeds); where conditions are suitable, it can spread at up to 5 m or more per year by horizontal 'runner' stems, which put down roots at regular intervals. The erect stems grow to 2–6 m tall, with the taller plants growing in areas with hot summers and fertile growing conditions. The leaves are broad for a grass, 20–50 cm long and 2–3 cm broad. The flowers are produced in a dense, dark purple panicle 20–50 cm long.

Common Reed is a very important plant for wildlife and conservation, particularly in Europe and Asia, where several species of birds are strongly tied to large *Phragmites* stands[22]. Common reed can occur in undisturbed habitats, but is most common in roadside ditches, disturbed wetlands and disturbed soil. It can reproduce vegetatively and from seed. Once a new population takes hold, it spreads vegetatively, forming dense monolithic stands, changing vegetation structure, composition, and altering wildlife habitat (paraphrased)[23].

Purple Loosestrife

Figure 5.4 Purple Loosestrife

Purple loosestrife is native to Eurasia and was introduced to the northeastern United States and Canada in the 1800's for ornamental and medicinal uses. It is still widely sold as an ornamental. Purple loosestrife adapts readily to natural and disturbed areas and is capable of invading wetlands, river and stream banks, pond edges, reservoirs and ditches. Under favorable conditions, loosestrife is able to rapidly establish and replace native

[22] http://en.wikipedia.org/wiki/Common_reed, (verified May 16, 2007)
[23] The Nature Conservancy, 2006

vegetation with a dense, homogenous stand that reduces local biodiversity, endangers rare species, and provides little value to wildlife.

Small infestations of purple loosestrife plants may be pulled by hand, preferably before seed set. For older plants, spot treatment with a glyphosate herbicide may be effective. Biological control using USDA approved beetle species is probably the most effective method for long-term control of large infestations[24].

Garlic Mustard

Figure 5.5 Garlic Mustard

Garlic mustard is an herbaceous biennial native to Europe, Asia and other parts of the world but invasive in North America. A single plant can produce hundreds of seeds, which scatter as much as several meters from the parent plant. Depending upon conditions, garlic mustard flowers either self-fertilize or are cross-pollinated by a variety of insects [25].

It can tolerate a wide range of moisture and light levels, invading a forest understories and out-competing native vegetation. The rapid spread of garlic mustard is primarily associated with small scale disturbances that expose mineral soil. Its importance to stream corridor management is that it has been found in high densities on floodplains where flood disturbance is frequent, out-competing some native plants[26].

Other Invasive Species

Other invasive species noted in The Nature Conservancy study that have potential to occur in Catskill Mountains forest ecosystems include: Norway maple (*Acer platanoides*), Japanese barberry (*Berberis thunbergii*), Asiatic bittersweet (*Celastrus orbiculatus*), autumn olive (*Elaeagnus umbellata*), bush honeysuckle (*Lonicera* spp.), buckthorn (*Rhamnus spp.*), multiflora rose (*Rosa multiflora*), and black swallow-wort (*Vincetoxicum nigrum*)[27]. Their impact on stream corridor management has not been evaluated.

[24] National Park Service, 2004
[25] http://en.wikipedia.org/wiki/Garlic_Mustard (verified September 27, 2007)
[26] The Nature Conservancy, 2006
[27] Ibid, page iv.

Japanese Knotweed

Figure 5.6 Japanese Knotweed in the Town of Halcott, June 2006

A plant whose presence within the Catskill region has become much more prevalent in the last few years, Japanese knotweed (*Fallopia japonica*) is an invasive plant that is often referred to by Catskill residents as bamboo or Japanese bamboo. Although bamboo and Japanese knotweed are two different plants, they do have a couple of similarities. Both have tall, hollow stems, but more importantly, neither belong in the United States. As implied by its name, Japanese knotweed originates from Asia. This categorizes knotweed as an *exotic* plant, one that evolved in another area of the world with different plants and animals.

Characteristics of Japanese knotweed

Fortunately, Japanese knotweed is quite recognizable throughout the year. The photographs to the left illustrate different stages of Japanese knotweed's growth throughout each season. This herbaceous, or non-woody, perennial goes through these cycles every year.

In the spring (generally late April, early May), new red, asparagus-like shoots sprout from last year's crown or from underground roots (*rhizomes*).

By July individual stems may reach as tall as 11 feet. Many thick, hollow stems are based at a crown. The upper areas of the stems form a few branches that reach out like an umbrella from the crown. Each mainstem and branch holds several large, nearly-triangular leaves that shade out most of summer's sunlight.

In August knotweed dons abundant clusters of small, white flowers that attract several pollinators, such as bees, wasps and Japanese beetles.

The numerous flowers turn into buckwheat-like seeds by late September, early October. Although some seeds may create small seedlings, knotweed spreads more by their *rhizomes*.

Cold weather halts the growth of knotweed; once frost covers the land, knotweed drops its leaves and turns an auburn hue. These dead stems often remain standing for one or two years and then cover the ground, decaying slowly.

Problems associated with Japanese knotweed

As previously mentioned, knotweed is an exotic, invasive species. Some texts explain that knotweed was brought to Great Britain as early as 1825 where it won accolades as an ornamental plant. By the late 1800s immigrants to the United States brought their prized garden plant. Knotweed has escaped personal gardens and spread into lawns, farm fields (**Figure 5.7**), along roadsides and railroads, along streambanks and onto floodplains. It is found in five Canadian provinces and all but ten states in the US.

Figure 5.7 Knotweed Growing Amongst Corn

Knotweed spreads vegetatively from portions of the roots or shoots. This vegetative propagation characteristic explains how it has expanded into such a wide variety of environments. The rhizomes begin new colonies of knotweed by spreading up to 20 feet from an existing plant. For this reason people may transport knotweed unknowingly by digging up rhizome-contaminated soils and dumping them elsewhere. Even a very small piece of this rhizome can sprout a new plant.

When kept moist, other plant parts, such as the stem, can also sprout new plants. Stems and rhizomes float downstream after breaking off from floods (knotweed is actually a very brittle plant and breaks easily) or from beaver damage. These fragments then come into contact with disturbed or eroded soils lacking vegetation and begin more new colonies. This is why streams host such dense stands of knotweed.

Knotweed can also be unwittingly introduced to new areas by highway departments and contractors through soil transported from gravel and sand pits contaminated with knotweed. *Stream assessment* teams have noted several instances where knotweed stands have developed in the new soil where a *culvert* or bridge has been renovated. Once established near the waterway, the knotweed is able to spread downstream after disturbance associated with a storm event.

Figure 5.8 From left to right:
Knotweed flattened by a high flow event
A stream bank *slump* where only grass and knotweed bordered the streambank
The shade created by the dense canopy of broad knotweed leaves.

Why is this rapid invasion such a concern? Knotweed's traits pose a broad array of concerns. Some of these concerns include:

- Knotweed appears to be less effective at stabilizing streambanks than deeper-rooted shrubs and trees, possibly resulting in more rapid bank erosion (**Figure 5.8**).
- The shade of its broad leaves and the cover by its dead litter limit the growth of native plants that provide food and shelter for associated native animals (**Figure 5.8**).
- Dead knotweed leaves (*detritus*) may alter food webs and impact the food supply for terrestrial and aquatic life.
- Large stands of knotweed impede access to waterways for fishing.

In spring 2006, a group of concerned people recognized that Japanese knotweed was starting to invade the headwaters of the Bush Kill sub-basin. Working together with Delaware County Soil and Water Conservation District SCMPr staff, the group found a demonstration project site on West Settlement Creek tributary at the intersection of Greene County Route 3 and Greene County Route 1. There are few knotweed patches along Vly Creek and this site was a good candidate for a project. The group has dubbed the project site "Knot-A-Lot". The research obtained from the demonstration project will be used for education and outreach to the local area in the hope to inspire community awareness and involvement for future projects.

What to know before treating knotweed

Besides understanding key characteristics about knotweed (e.g. how it spreads, what environments it prefers), it is also essential to recognize a few key concepts that actually apply to most invasive species.

First and foremost,

Prevention is the best policy

No knotweed is the best knotweed.

Preventing its spread is the best, most cost effective, and time efficient approach to take.

Prevention may be in the form of:

1). Telling others about knotweed and warning them of its associated problems
2). Keeping stream banks stable by allowing native trees and shrubs to grow
3). Testing transported soil and sources for any knotweed colonies and plant fragments

Unfortunately, the East Branch Delaware River has a knotweed problem and some level of treatment is necessary. It is critical to recognize that knotweed grows under diverse conditions and in varying locations, so there are different ways to approach its control. Before simply mowing down all the knotweed or spraying herbicides everywhere, one should first ask:

- How large is the stand of knotweed?
- Is it located near a waterway?
- What native plants exist nearby?

With answers to the above questions, a customized approach may be taken, saving time and money by applying the most appropriate techniques.

Finally, someone wanting to control knotweed should understand that:

- A disposal plan for all knotweed material is a must; otherwise a new colony will just sprout somewhere else. This might include burning the material, burying it more than 6 ft. deep or letting it completely dry out.
- Most treatments require multiple applications. A one-time cutting or mowing of knotweed will not do anything except stunt it temporarily and cause the rhizomes to extend underground faster towards more nutrients, possibly causing a higher rate of spread. Be prepared to make follow-up visits to past treatment sites to ensure complete control of knotweed.
- Re-vegetation with native species after treatment is necessary. Leaving bare ground only promotes the reinvasion of knotweed. Rapid-growing, native trees and shrubs must be planted soon after removing knotweed in order to affect the most beneficial change.

What to do about knotweed

Getting involved is as simple as 1, 2, 3:

1. Check your property. Locate any knotweed or areas of bare soil to know where you may need to remove knotweed or add more native trees or shrubs.
2. Become informed & spread the word. Since knotweed can travel anywhere, via stream or dump truck, let your neighbors know about it. *Spread the word, not the weed.*
3. Ask for help. Contact the Delaware County Soil & Water Conservation District for assistance with assessment or control.

Below are various treatment prescriptions depending on size of the knotweed stand, its proximity to a waterway, and amount of surrounding vegetation. Please note that where bare ground exists after removing knotweed stems and roots, it is essential to re-vegetate the area with competitive (fast-growing) native trees and shrubs. This is especially critical if surrounding vegetation is limited or nonexistent. Otherwise, reestablishment of knotweed is likely and control efforts may be futile.

For *small* stands (less than $3ft^2$):

Cover with dark plastic.
Frequent cutting, grubbing or pulling with safe disposal of knotweed stems.
Herbicide injection of stems. **PLEASE READ CAUTION BELOW**.

For *medium* stands ($3ft^2$ to $25ft^2$):

Frequent mowing (do not allow cut material to leave site).

For *large* stands ($25ft^2$+):
In some cases, the extent of a knotweed colony is so extensive that more harm (e.g. damage to soils) would be done in trying to eliminate the entire stand. For this reason control of expansion is the appropriate action.

Frequent mowing around edges of stand (do not allow cut material to leave site).
Herbicide injection of stems in edges of stand. **PLEASE READ CAUTION BELOW**.

Herbicide Caution: Glyphosate (e.g. Rodeo, Roundup, and Aquamaster) is the recommended active agent. When used with care and according to product labels, this herbicide does NOT negatively affect *un*touched plants and animals. Using an injection method is highly recommended, because knotweed material is not cut therefore requiring no disposal. Also this method eliminates drift and targets only injected stems. Only certain herbicides, such as Rodeo and Aquamaster, can be safely used near a waterway.

Please take care to wear appropriate protective equipment. Check with Cornell Cooperative Extension of Delaware County at (607) 865-6531 for information about the proper, safe and legal use of herbicides.

Delaware River, Delaware & Sullivan Counties
The Delaware River Invasive Plant Partnership (DRIPP) was formed to increase public awareness and understanding of invasive plants and their impacts, facilitate the exchange of information regarding invasive plant management, and help coordinate public and private efforts to control these weeds in the Delaware River watershed. Recently the director of DRIPP, in partnership with the National Park Service, established a Knotweed Initiative working group that meets periodically to coordinate efforts to address knotweed management.

Catskill Region, Delaware, Greene, Sullivan & Ulster Counties
Through matching funds from the WAC Forestry Program, The Nature Conservancy's Catskill Mountain Chapter began a study in summer 2004 of the distribution of nine exotic, invasive species, including Japanese knotweed, in seven forest matrix blocks in the Catskills – Beaverkill, Cannonsville, Panther Mountain, Sugarloaf, Catskill Escarpment, Westkill and Bear Pen Vly.

Catskill Regional Invasive Species Partnership
The Catskill Regional Invasive Species Partnership (CRISP), formed following the rise in interest from numerous groups and agencies within the region about the issues related to invasive species. CRISP is a voluntary, cooperative partnership that promotes prevention, early detection and rapid response, and in limited areas/cases, broader control of invasive species to protect natural resources. In addition to conducting public outreach and management activities, CRISP seeks to support research about ecological impact and effective controls of invasive species. The Catskills Streams (see table below) website contains a link to contact information and a membership form for the group.

Resources for more information

While scientists and resource managers throughout the U.S. and the United Kingdom are conducting useful research and experiments on knotweed, various agencies within the Catskill region are making their own efforts to address this problem plant. Learning from the experience of others has greatly informed the above text and will continue to inform future practices. **Table 5.1** below shows summaries of these local efforts, including contact information.

Table 5.1 Regional Agencies and Organizations for Additional Information (Verified September 27, 2007)

Regional Agencies & Organizations		
Catskill Regional Invasive Species Partnership CRISP		http://www.catskillstreams.org/stewardship_streamside_is.html
NYCDEP Stream Management Program	845-340-7515	http://www.ci.nyc.ny.us/html/dep/watershed/html/streams.html
Greene County Soil & Water Conservation District	518-622-3620	www.gcswcd.com
Hudsonia, Ltd.	845-758-7053	www.hudsonia.org
Delaware River Invasive Plant Partnership (DRIPP)	570-643-7922 x12	http://www.paflora.org/DRIPP%20Brochure%202004.pdf
Adirondack Park Invasive Plant Partnership (APIPP)	518-576-2082 x 131	http://www.adkinvasives.com/terrestrial/Program/Program.html
The Nature Conservancy-Catskill Mountain Program	845-586-1002	
National Park Service-Upper Delaware Scenic & Recreational River	570-729-7842	
Other Japanese Knotweed resources		
The Nature Conservancy-UC Davis		http://tncweeds.ucdavis.edu/esadocs/polycusp.html
The Nature Conservancy-Oregon	503-230-1221	http://tncweeds.ucdavis.edu/success/or002.html
The Knotweed Page		http://www.knottybits.com/Knotweed/
Japanese Knotweed Control Forum of Cornwall		http://www.ex.ac.uk/knotweed
The Invasive Plant Council of New York State	518-271-0346	http://www.ipcnys.org/default.aspx

~ 6. Land Use ~

The East Branch Delaware River watershed is defined by a scenic mix of forested hills, agricultural valleys, and small hamlets set in the valley flats. The trend in the last 40 years has been one of fewer agricultural operations and the subdivision of farm lands. This has enabled parcelization of the abandoned agricultural lands for residential development. This trend, supported by demand for second homes and difficult economic times for the dairy industry, is expected to continue for the foreseeable future. However, the agricultural economy is diversifying and seeking different niches, with an increase in specialty crop production and greater emphasis in horse ranching and small stock husbandry. One example of niche-filling is Mountainside Farms, a creamery in the town of Roxbury that is currently catering to the demand for antibiotic and added hormone-free milk.

The urban economy of the villages and hamlets is also changing, with a visual presence of more shops, businesses and eateries catering to tourists and seasonal residents.

A snapshot of land use and land cover is provided below for the Pepacton Reservoir watershed. This classification was produced in 2001 and used a supervised classification of remotely sensed imagery for the mapping of the area. The pie chart (**Figure 6.1**) shows that the overwhelming majority of land (82.3%) is under forest cover with another 7.7 % occupied by brushland – frequently a transitional stage before becoming forested. Grassland (commonly hayland and pasture) together with agricultural land (cropland), make up only 4.2% of the watershed area. In contrast to the more heavily developed portions of other NYC water supply basins, only 1.6% of the watershed is residential.

In terms of water quality protection, it should be noted that approximately 17% of the stream length within the Pepacton basin flows through land that is conserved under ownership by the NYSDEC, NYCDEP, or under a conservation easement program (**Table 6.1**).

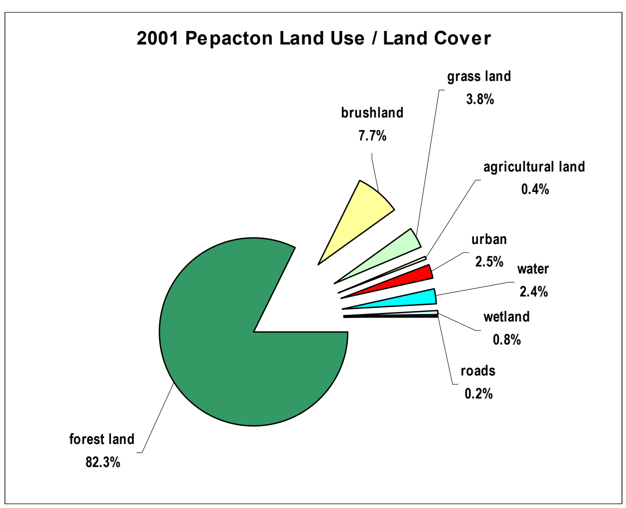

Figure 6.1 Pepacton Land Use / Land Cover

Table 6.1 Land Ownership By Category (stream miles)*

	NYS	NYC Pre-MOA Fee Simple	NYC Newly-Acquired Fee Simple	NYC Conservation Easements	WAC Easements	Other Open Space	Subtotal Protected	Private	TOTAL STREAM MILES	Percent Protected
Stream Miles w/in Pepacton Basin	**57.67**	**21.32**	**27.30**	**4.21**	**1.54**	**0.66**	**112.70**	**552.81**	**665.51**	**16.9%**

**As of 12/31/2003, under contract or closed*

Major Economic Land Uses of the East Branch Delaware River Watershed

Forestry

According to the Delaware County Agricultural and Farmland Protection Plan (2000), "Delaware County has an established forest industry that contributes to the economic well-being of the county, the Catskill region, and New York State. Loggers, foresters, sawmills, and agribusinesses producing value-added wood products abound, with approximately **$7 million** in timber sales generated annually. Non-timber or agro-forestry crops, such as ginseng and maple syrup, are prominent agro-forestry crops in the county."

The increasing abundance of wood that supplies the forest economy results from abandoned agricultural land reverting to forest land. This trend began in the late 1800s and is still occurring. The majority of the watershed is dominated by red and sugar maple (*Acer rubrum* and A. saccharum), beech (Fagus grandifolia), and yellow birch (*Betula alleghaniensis*) – a composition referred to as "northern hardwoods." Frequently encountered species also include hemlock (*Tsuga canadensis*), white pine (*Pinus strobus*), red oak (*Quercus rubra*), black cherry (*Prunus serotina*), and white ash (*Fraxinus americana*).

While management of forest stands for hardwood veneer and softwood pulpwood/saw timber may be a principal economic objective of landowners, wildlife habitat management and associated recreational benefits are also of interest to landowners. A report from the late 1990s estimated that the amount of wood removed was less than one third of the wood grown on an annual basis[28]. Information for this economic sector is often aggregated for the state or region and is difficult to apply to local areas. The Watershed Forestry Program's and the Catskill Forestry Association's support for best forest management practices are discussed in **Section 10, Volume 2**.

[28] Low-grade Wood Products Market Feasibility and Forestry Economic Development Strategy, prepared by the Beck Group for the Watershed Agricultural Council, December 1999.

Agricultural

As of 2000, the towns in **Table 6.2** contained 72 dairy farms (not all within the NYC watershed). This is in significant contrast to the 117 dairies that – in 1890 – existed in Bovina alone. Between 1982 and 1997, the entirety of Delaware County lost 353 farms, 267 of which were full-time. According to the Delaware County Agriculture and Farmland Protection Plan (2000), "Characteristics and types of farms have changed, the trend being towards more part-time farmers (11% more) and less dairy farmers (11% less). Correspondingly, the market value of agricultural products declined $7.7 million dollars from 1992 to 1997, with individual farms averaging $10,791 less per year in products sold."

Table 6.2 Dairy Farms of the East Branch Delaware River Watershed

TOWN	% OF TOWN IN EB WATERSHED	# OF DAIRY FARMS
Andes	89.4	13
Bovina	13.4	10
Delhi	1.6	24
Hamden	19.3	13
Middletown	99.8	4
Roxbury	72.4	8
TOTAL	**---**	**72**

The Conservation Reserve Enhancement Program and the Watershed Agricultural Council's Watershed Forestry Program (see **Section 10, Volume 2)** are two programs that implement managed riparian forest buffers along streams for land under agricultural and forestry production, respectively. **Recommendation #3, Volume 1** outlines the need for riparian management on non-agricultural and non-forestry land.

"Additionally, there is a Purchase of Agricultural Conservation Easement (PACE) Program, a Forestry Management Program, and an Economic Development/Marketing Program offered to farms located within the NYC Watershed through the Watershed Agricultural Program. The implementation of these voluntary whole farm planning programs has greatly enhanced the viability of participating Delaware County farms…*Protection of the New York City water supply has benefited Delaware County farmers by providing many resources that would have been very difficult or impossible for individual farmers to implement"* (Delaware County Agriculture and Farmland Protection Plan).

Bluestone

Quality bluestone, one of the most durable quarried stones, is found solely in south-central New York, northeast Pennsylvania, and Africa. Bluestone operations in NY and PA represent the only commercial source in the Americas. Whereas many stone quarry operations remove masses of solid deposits of material (e.g. limestone and salt strip mines), bluestone quarries affect relatively little surface area. Most quarries (more than 85%) affect less than three acres of land and are operated by 1-4 people. Bluestone is found in thin veins ranging in thickness from 3-20 feet (Delaware County Agriculture and Farmland Protection Plan).

As of 2006, the bluestone industry of Delaware County employed over 700 people and generated $75-$100 million in annual sales. The majority of bluestone businesses are locally owned and operated, and many farmers take advantage of the opportunity to mine bluestone on their property. This often bolsters the economic viability of the farm.

According to the New York State 2005 Mineral Fact Sheet for bluestone, "While bluestone is a strongly cemented rock, it splits easily into smooth thin slabs that are ideal for outdoor patios, building exteriors and indoor floors. Bluestone's current popularity has lead to exploration for new deposits and reopening of old mines. In addition, bluestone's recent high prices are enabling mine operators to switch from old-fashioned hand mining to more modern techniques. As an aid to exploration, bluestone miners have the option of applying for a simplified one-year Exploration Authorization (EA) instead the full mining permit. When the EA expires, the operator must apply for a regular mining permit if the site is commercially viable or reclaim the land."

~ 7. Water Quality ~

Water Quality of the East Branch Delaware River and its Tributaries

Perhaps one of the greatest attributes of the East Branch Delaware River is its excellent water quality. Good water quality is of interest to all people and is the product of a healthy environment. The magnitude of human impact on the environment determines whether or not a clean water source will be available in the future. Whether drinking water comes from a well, spring, or stream via a water supply system, human actions regarding land, air, and waterways will determine the quality of both surface and groundwater. To ensure that water – and all who rely on it – are not negatively impacted, laws have been established to regulate land use practices, air emissions, discharge of waste, and the diversion of stream flow (see **Volume 2**, **Section 3**). In addition, best management practices and technologies are adopted to avoid negatively impacting surface and ground water resources. Examples include forest and agricultural conservation practices, stormwater controls, and engineered septic/wastewater treatment systems. Monitoring the quality of the water ensures that the water is suitable for human consumption and the sustenance of other life. Surface water quality is monitored by several government agencies, including the NYS DEC, NYC DEP, and the USGS. The goal of this monitoring is to ensure that the water is safe for human consumption and recreation, and suitable for the needs of fish and wildlife.

The excellent quality of water within this watershed can most likely be attributed to the watershed's high percentage of forest cover (see **Volume 2**, **Section 6**). There have been many studies that demonstrate the effects of land use/land cover on water quality. For example, there has been a vast array of research demonstrating that as land use becomes more urbanized, biotic communities decline in health (Schueler and Holland, 2000; Limburg and Schmidt, 2000; May et al., 2000; Wang et al., 2001; Potter et al. 2005 and Kratzer et al. 2006).

Ground Water Quality

Protecting and monitoring ground water quality is the responsibility of local communities and the NYS Department of Health under the Wellhead Protection Program of the Source Water Assessment Program. Under these programs, local communities typically study their ground water aquifer to determine the areas contributing to the public water supply, inventory potential sources of contamination, then define a course of action to protect the supply. Upon completing the assessments, a community typically amends their local land use laws to protect the public wells and aquifer from activities which could result in contamination. Within the East Branch Delaware River watershed, the Villages of Fleischmanns and Margaretville have established wellhead protection programs. The Village of Roxbury's source water protection plan is currently in progress.

For individual household wells, the protection of the source for the water through proper land use and the safe siting of septic systems are important for maintaining clean drinking water. In the higher elevations of the East Branch Delaware River watershed, springs result from the surface contact of confining shale layers at the base of permeable sandstone layers. These springs have historically been a major source of drinking water for households and some communities. The water flowing from springs typically has a shorter subsurface resident time and travel a shorter distance than the ground water acquired from deep wells near the valley floor. Proper land management of the areas that are the source for these springs is critical due to the limited natural filtration that would correspond with shorter travel distances and resident times. Since ground water is also the principle contributor to summer stream base flow, the protection of ground water also provides protection to surface waters in streams.

Surface Waters

All waters in the State of New York are assigned a letter classification by the NYSDEC that denotes their "best usages". "Best usage" means the best acceptable use of these waters. These are:

- AA and A – source of drinking water, culinary or food processing purposes (reservoirs, direct tributaries to reservoirs)
- B – swimming and other contact recreation and fishing (ponds, lakes, and some streams)
- C – waters supporting fisheries and fish propagation
- D – waters supporting fishing, but not fish propagation

Waters may also have a standard designation or specification. These are: (T) – supports a trout population or (TS) – supports trout spawning.[29] For example, the Bush Kill (Dry Brook) tributary in Arkville is designated C (TS), indicating that it supports fisheries, fish propagation, and is a designated trout spawning stream.

The following table indicates the classifications for streams within the East Branch Delaware River basin from the NYS Priority Waterbodies List. The table indicates that much of the basin has fairly high water quality and is capable of supporting trout spawning.

Table 7.1 Stream Classifications

Waterbody/Segment Name	Segment Size (miles)	Class
Fall Clove Brook and Tribs	25.0	C(TS)
Terry Clove Brook	25.0	C(TS)
Tremper Kill and Tribs	52.6	A(T)
Mill Brook and Tribs	40.7	A(TS)
Platte Kill and Tribs	44.3	C(T)
Bush Kill, Lower, and Tribs	9.1	C(TS)
Dry Brook and Tribs	50.1	C(TS)
Batavia Kill and Tribs	25.5	B(TS)

[29] Official Compilation of Codes, Rules and Regulations of the State of New York, Title 6, Chapter X, Parts 701, 703 and 815 (6 NYCRR Parts 701, 703 and 815)

Water Quality Record

In the United States (USEPA, 2005) and New York State (NYSDEC, 2004), nonpoint sources of pollution are the cause of the majority of water quality impairments. In New York State, nonpoint sources of pollution accounted for 90% of impacts on the water quality of rivers and streams and 92% for lakes and reservoirs, including the Pepacton (NYSDEC, 2004). There are many ways to measure water quality, from direct laboratory analysis of water samples to indirect measures such as surveys of aquatic insects as indicators of water quality. Water samples collected from the stream and analyzed for a suite of chemical, biological, and physical parameters provide us with a good picture of all the components that are carried by the East Branch Delaware River's waters. The NYCDEP, USGS, NYSDEC, and other researchers, make available the large quantity of water quality data necessary to draw conclusions. Biological indicators, such as fish and macroinvertebrates, are also monitored to determine surface water quality and nonpoint source pollution impacts (Barbour et al., 1999; Murray et al., 2002). For example, biological assessment models have been tested with field data. The results suggested that macroinvertebrate data collected for establishing the degree of water quality impairment can also be used to identify the impairment source with reasonable accuracy (Murray et al., 2002). There is a relatively extensive set of data for both direct and indirect measures on the East Branch Delaware River.

Direct Water Quality Measurements

There are several sources of direct water quality measurements for the East Branch Delaware River. The following sources provide the bulk of available information:

- The most extensive and comprehensive set of available data is from NYCDEP as part of its long-term water quality monitoring of the NYC drinking water supply (NYCDEP, 2006). NYCDEP has been sampling and analyzing the East Branch Delaware and its tributaries since the construction of the dam at Downsville.
- The United States Geological Survey (USGS) collected water quality data, which is available within the East Branch Delaware watershed website: http://nwis.waterdata.usgs.gov/ny/nwis/qwdata/
- In 2000, Stroud Water Research Center located in Pennsylvania was awarded a Safe Drinking Water Act (SDWA) grant funded by the New York State Department of Environmental Conservation and the USEPA to conduct a six-year study to monitor and evaluate water quality and sources of pollution in the streams, rivers, and reservoirs that provide New York City's (NYC) drinking water. There were 15 sites in the East Branch Delaware River watershed that have been variably sampled since 2000. Reports for the first five years can be found at: http://www.stroudcenter.org/research/newyorkproject.htm
- The NYSDEC Routine Statewide Monitoring Program provides for the routine monitoring of the waters of the State to allow for the determination of the overall quality of waters, trends in water quality, and identification of

water quality problems and issues. This monitoring effort is coordinated through the Rotating Integrated Basin Studies (RIBS) Program, which typically operates on a 5-year cycle. Contacts for the program staff, which can provide relevant reports, are available at their website: http://www.dec.state.ny.us/website/dow/bwam/rsm.html

NYCDEP Monitoring Efforts

The NYCDEP has a long-term water quality sampling program of streams in the NYC water supply watersheds. Water quality samples are collected at a fixed frequency from a network of sampling sites throughout the watershed. Grab samples are generally collected once a month (twice a month at selected sites). Storm event sampling is also performed at selected sites. While the analyses performed on samples from a specific site vary somewhat based on the objectives for the site, in general, samples are tested for temperature, pH, alkalinity, specific conductivity, dissolved oxygen, turbidity, nutrients, dissolved organic carbon, total organic carbon, silica, chloride, suspended solids (selected sites), major cations (Ca, Mg, Na, K, Fe, Mn, Al, Cu – analyzed monthly), trace metals (Ag, As, Ba, Cd. Also included here are Cr, Hg, Pb, Se, Zn – collected at selected sites quarterly), and total and fecal coliform (most sites). The current monitoring system was re-designed in 2002 and was based on multiple objectives (NYCDEP, 2002), with several sampling sites located in the Pepacton Basin. Results are presented in annual water quality monitoring reports (e.g. NYCDEP, 2006).

NYSDEC Monitoring Efforts

Approximately every five years, the NYS DEC Division of Water regularly reports on the quality of the state's waters through the Rotating Integrated Basin Studies (RIBS) of the Statewide Water Monitoring Program. The program integrates sampling, testing, watershed characterization, and narratives of monitoring efforts to establish the baseline condition and water quality trends for each of the state's major drainage basins. The Delaware drainage basin was last reported on in 2004 and most recently scheduled for sampling in 2004-2006. Information from the RIBS program is used to maintain the List of Impaired Waters of the State, the Priority Waterbody List, and prepare the NYS Water Quality Report for the USEPA. The following link directs you to a copy of the report for 2004: New York State Water Quality (Section 305b Report 2004) - NYS Dept. of Environmental Conservation http://www.dec.ny.gov/chemical/23837.html.

In the 2004 report, the NYS DEC found that most of the streams in the planning basin (above the Pepacton dam) for the East Branch Delaware River had "no known impact". While seven sites are "screened" (monitored at a lesser intensity) by the DEC within the planning area, only two sites are intensively monitored. These include the Bush Kill at the NYS Rt. 28 bridge and East Branch Delaware River at the County Rt. 38 bridge in Arkville. Samples from the Bush Kill site found the levels of lead (Pb) to be a parameter of concern in the water column and arsenic in the sediments above the Threshold Effect

Concentration[30]. All other parameters were within acceptable ranges for both intensively sampled sites and screened sites.

Constituents of East Branch Delaware Water

The following section provides a summary of the major parameters that are tracked by NYCDEP in the East Branch Delaware River and its tributaries. Combined, these parameters provide a basic overview of water quality while potentially allowing for a general understanding of human-induced changes to water quality. The NYCDEP data reported here are annual medians for selected water quality variables. The median is a statistic that expresses the "typical" condition of something. The median is simply the value in the center of a data set, i.e. half of the samples are equal to or higher, and half are equal to or lower. One characteristic of the median is that it is not overly influenced by data from extreme events. Also, the results are based on routine grab samples and do not specifically target extreme events.

Turbidity and Total Suspended Solids

Turbidity, an index of water clarity, is a concern for drinking water supplies because it has the potential to mask pathogens and interfere with disinfection agents such as chlorine. In the natural system, turbidity is a concern for the ecologic, recreational, and aesthetic use of the water.

Turbidity is an optical measurement of the light-scattering at 90^{o} caused by particles suspended in water (**Figure 7.1**). Turbidity is measured in arbitrary "nephelometric turbidity units" (NTUs) by a "nephelometer". The higher the NTU value, the lower the water clarity. Turbidity can be influenced not only by the amount of particles in suspension, but also by the shape and size of the particles. There is no single, fixed relationship between turbidity and total suspended solids. Total suspended solids are a measure of suspended solids concentration, expressed as a mass per volume (mg/L), obtained by physically separating the liquid and solid phases by filtration. Further, it is important to note that there is no universal, usable, fixed turbidity/clarity relationship.

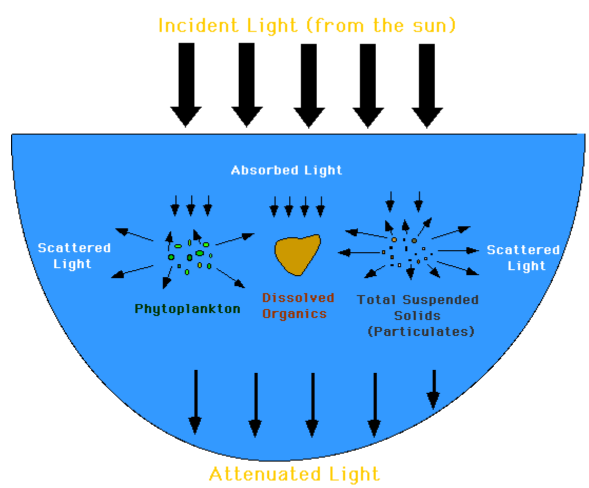

Figure 7.1 Light Scattering Caused by Suspended Particles in Water.

Suspended solids in Catskill streams are predominantly fine sediment. It does not take much of the fine suspended sediment to reduce water clarity. Water clarity can range

[30] Rotating Integrated Basin Studies- Delaware River Drainage Basin – Sampling Years 1999/2000, NYS DEC, October 2004, page 180.

from clear to an opalescent red-brown following a significant high water event. Sediment gets in the stream primarily from two sources: (1) runoff from the landscape carries fine sediment (silt and clay) into the stream through ditches and culverts; and (2) from entrainment in the stream. Due to the large amount of forested landscape in the Delaware system, it is safe to speculate that the main source of sediment is erosion within the stream channel and banks, and not the landscape. Exposed “clays” that the stream has cut into and the mobilization of fine sediment mixed in the stream bed deposits are the major sources of turbidity at times when turbidity reaches levels of concern for drinking water purposes (NYCDEP, 2006). Landscape sources of turbidity should not be ignored, however. Left untreated, they may cause further instability within the bed and banks. The development of a watershed stewardship ethic would aid in mitigating these sources.

The regulatory water quality standard for turbidity in New York State is a narrative standard: “no increase that will cause a substantial visible contrast to natural conditions” (NYCRR, Title 6, Section 703.2). There is also a narrative water quality standard for suspended, colloidal, and settleable solids: “None from sewage, industrial wastes or other wastes that will cause deposition or impair the waters for their best usages.” Although there are no numerical standards for turbidity or suspended sediment, these constituents are of concern in streams because the presence of suspended fine-grain sediments such as clay particles can affect stream biota. These fine sediments can settle on substrates used by colonizing algae and invertebrates and can fill the small spaces between gravel where fish lay their eggs. Transmission of light through the water can be reduced, which can affect stream productivity through decreased photosynthesis. Turbid waters also become warmer as suspended particles absorb heat from sunlight, which can also cause oxygen levels to fall.

While turbidity in Catskills is a major concern within the stream systems of the neighboring Esopus and Schoharie Creek watersheds due to the extensive streamside exposures of glacial lake clays, there are only limited similar exposures in the East Branch Delaware system. Therefore the frequency and duration of turbidity events are much more limited within the Pepacton basin. It remains to be seen what the effects of global climate change will be on the frequency of large storms and the related spikes in turbidity. In its 2005 Annual Watershed Water Quality Report, the NYCDEP reported that median turbidity for all of its reservoirs increased in all Delaware and Catskill system reservoirs as compared to their annual medians for the previous 10 years. Turbidity in the Delaware system (including the Pepacton Reservoir) was 20-50 percent higher than the previous 10 year median, while it was 2.5 to 15 times the median for the Catskill system. The bulk of the turbidity increase was caused by the surface runoff generated by rain – on – snow events in the spring storm of April 2005 and the fall storm of October 2005. **Figure 7.2** provides a box plot of annual medians (1995-2004) for turbidity, total phosphorus, and fecal coliform measurements for the Pepacton and other NYC water supply reservoirs.

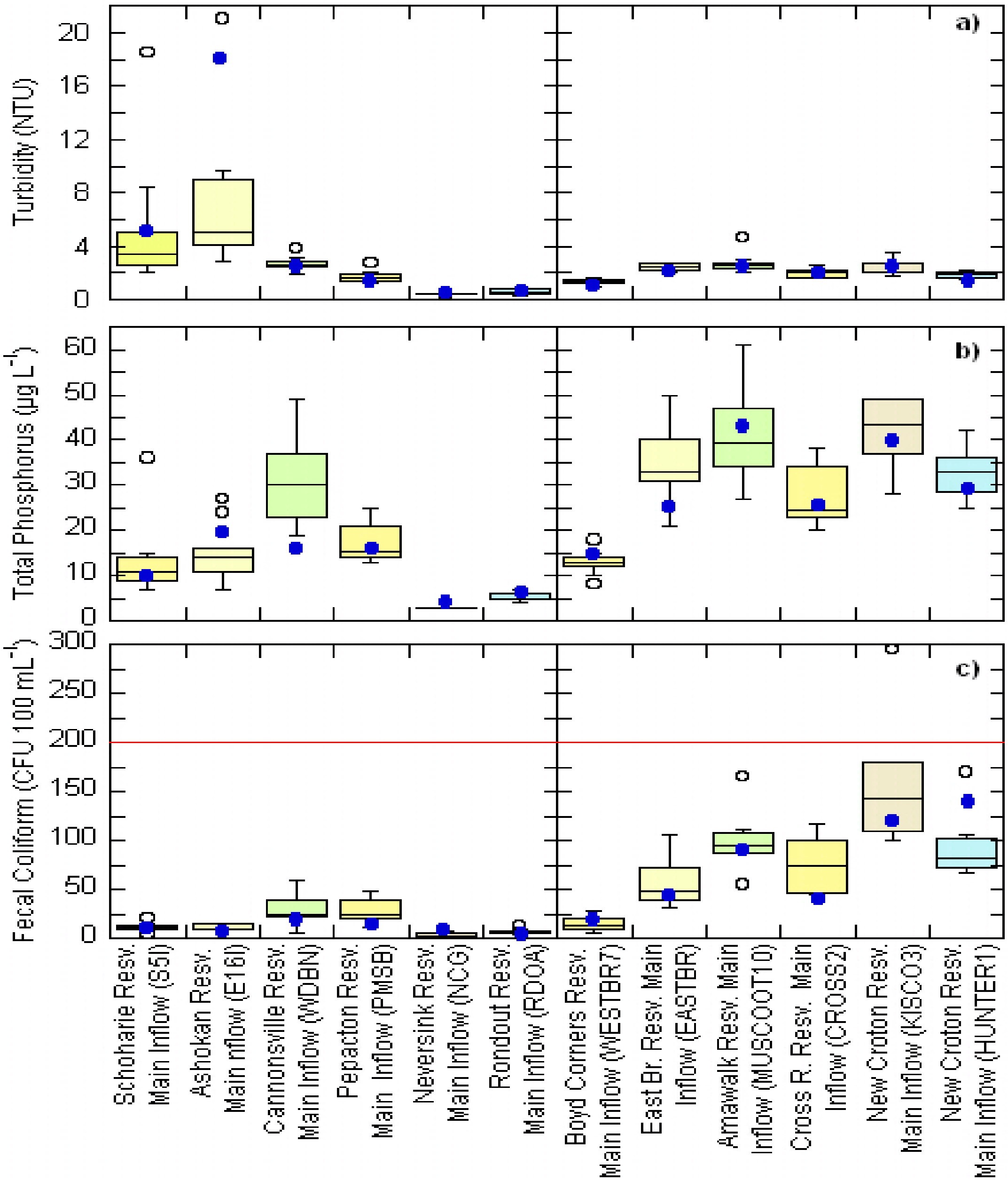

Figure 7.2 Annual Median Box Plot for Selected Stream (reservoir inflow) Sites

Pathogens

The NYCDEP monitors for pathogens, specifically giardia and cryptosporidium, in a large number of Catskill mountain streams. Specifically, NYCDEP's Pathogen Program monitors sampling location sites within the East Branch Delaware River watershed for many water quality parameters, including protozoa, *Cryptosporidium spp.* oocysts, and *Giardia spp*. cysts. While there are no regulatory thresholds for these protozoa in surface waters, the NYCDEP maintains a monitoring program for them due to their potential negative effects on public health. These protozoa are of concern to public health for two reasons: 1) if consumed, certain strains of these protozoa can cause disease in humans, and 2) the presence of these protozoa indicates that the water has been contaminated with fecal matter (animal or human). The water therefore may be carrying other pathogens that have the potential to cause disease in humans.

The NYCDEP's monitoring data has shown the presence of these (oo)cysts in ambient water and during high flow conditions related to runoff events. However, their concentrations have been at low levels. In any event, since certain strains have the potential to cause disease in humans, determining their source, transport properties, and fate are of utmost importance to the NYCDEP. The NYCDEP maintains a surveillance program designed to narrow down source locations and trends of (oo)cysts throughout New York City's water supply watersheds. Additional tools used by DEP to ultimately assess the public health risk associated with these protozoa in the watershed include: 1) PCR (polymerase chain reaction) source tracking to identify anthropogenic (human) and autochthonous (natural) sources, 2) land use/land cover analyses which also indirectly identifies potential human sources such as failing septic systems and wildlife sources, and 3) watershed physiographic characteristics analysis such as percent area of contribution to a site, slope, and elevation, which may affect transport and fate.

NYCDEP scientists analyzed storm water from streams East-of-Hudson in an attempt to identify the sources of *Cryptosporidium* oocysts. Samples were analyzed using a small-subunit rRNA based diagnostic tool utilizing polymerase chain reaction technology to identify the genetic patterns of the oocysts. Results indicated that all of the oocysts genotyped in 2003 originated primarily from non-human sources. Deer, muskrat, and skunks topped the list of sources (NYCDEP, 2004). This does not mean that these results automatically translate to streams West-of-Hudson, but the results offer a glimpse into potential sources.

Temperature

Water temperature is one of the most important variables in aquatic ecology. Temperature affects movement of molecules, fluid dynamics, and metabolic rates of organisms as well as a host of other processes. In addition to having its own potential "toxic" effect (i.e. when temperature is too high), temperature can also affect the solubility and, in turn, the toxicity of many other parameters. Generally, the solubility of solids increases with increasing temperature, while gases tend to be more soluble in cold water (i.e. available O_2 to fish).

In densely wooded areas where the majority of the streambed is shaded, heat transferred from the air and groundwater inputs drive in-stream temperature dynamics. However, in areas that are not shaded, the water temperatures can rise much more quickly due to the direct exposure to the sun's radiation. Rock and blacktop also hold heat and can transfer the heat to the water (like hot coals in a grill). Annual fluctuation of temperature in a stream may drive many biological processes, for example, the emergence of aquatic insects and spawning of fish. Even at a given air temperature, stream temperature may be variable over short distances depending on plant cover, stream flow dynamics, stream depth, and groundwater inflow. Water temperatures exceeding 77˚ Fahrenheit cannot be tolerated by brook trout, which prefer water temperatures less than 68˚ Fahrenheit (TU, 2006).

Phosphorus

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

Phosphate binds to soil particles, which act to slow its transport. The soil-attached phosphate will often settle out in standing water (ponds/lakes/reservoirs), which once disturbed and resuspended, or due to anoxic conditions, can lead to excessive vegetation growth. The most likely sources of phosphate inputs include animal wastes, human wastes, fertilizer, detergents, disturbed land, road salts (anticaking agent), and stormwater runoff. Based upon the average concentrations found in water samples from 85 sites across the United States in relatively undeveloped watersheds, the median concentrations of total phosphorus (P) and orthophosphate were 0.022 and 0.010 mg/L respectively (Clark et al., 2000). In general, any concentration over 0.05 mg/L of phosphate will likely have an impact on surface waters (Behar, 1996). However, in many streams and lakes, concentrations of phosphate as low as 0.01 mg/L can have a significant impact on water resources by causing a proliferation of aquatic vegetation and phytoplankton. In order to control eutrophication, the USEPA recommended limiting phosphate concentrations to 0.05 mg/L in waters that drain to lakes, ponds and reservoirs, and 0.1 mg/L in free flowing rivers and streams (USEPA, 1996). The NYCDEP considers the 0.05 mg/L as a guidance value for streams.

In the USGS study of water quality within the Pepacton basin, the USGS found that phosphorus levels were within the acceptable range as defined above, but were highest in Terry Clove and the East Branch Delaware mainstem. These results were based on limited sampling in the base flow period of the summer of 2001 and were largely thought to be attributable to dairy farming and septic waste disposal inputs (Heisig 2004, Part 4, pg 17 and 22-23). The Stroud Center results for the sites on the Tremper Kill, East Branch Delaware River mainstem, and Bush Kill were all below the 0.05 mg/L concentration for the years 2000 – 2002. NYC water supply measurements for phosphorus can be found in **Figure 7.2** above.

Nitrogen

Nitrogen is found in various forms in ecosystems including organic forms, nitrate (NO_{3-}), nitrite (NO_{2-}), and ammonium (NH_4+). The majority of nitrogen is in the form of a gas

(N_2), which makes up approximately 80% of our air. It is converted into inorganic forms by some types of terrestrial plants (legumes) with nitrogen-fixing bacteria, lightning, and microbes in the water and soil. Nitrate, the most mobile form of nitrogen, can either be assimilated by vegetation to make protein, leached into groundwater or surface water, or converted to nitrogen gas in the process of denitrification (Welsch et al. 1995). Nitrites, ammonia, and ammonium are intermediate forms of nitrogen in aquatic systems and are quickly removed from the system by being converted to another form of nitrogen (NO_{3-} or N_2) (Behar, 1996). Ammonium is released into the system during animal or plant decomposition or when animals excrete their wastes. Through the process of nitrification, ammonium is oxidized to nitrates by nitrifying bacteria. Nitrate concentrations in water can serve as an indicator of sewage or fertilizer in surface or groundwater.

Based upon average concentrations found in water samples from 85 sites across the United States in relatively undeveloped watersheds, the median concentrations of nitrate-nitrogen and total nitrogen were 0.087 and 0.26 mg/L respectively (Clark et al., 2000). Due to land uses and atmospheric deposition, the undeveloped watershed concentrations (below 0.087 mg/L) of in-stream NO_{3-} rarely occur in the Catskills. Major sources of nitrate (most mobile form of nitrogen) in streams are municipal and industrial wastewater discharges and agricultural and urban runoff. Deposition from the atmosphere of the nitrogenous material in automobile exhaust and industrial emissions are also a source (Smith et al., 1991).

Nitrate in excessive amounts can accelerate eutrophication of surface waters and can present a human health concern in drinking water. Any water that contains nitrate concentrations of 44 mg/L (equivalent to 10 mg/L nitrate-nitrogen for EPA and NYSDOH standards) or higher has the potential to cause methemoglobinemia or "blue baby" disease in children, and the excess nitrate can indicate serious residential or agricultural contaminants (McCasland et al., 1998). Although the human health standard for nitrate consumption has little correlation with stream health, high levels of nitrate in both surface and groundwater typically indicate widespread nonpoint source pollution.

When compared with forested and previously farmed areas, actively farmed areas contained the highest concentration of nitrate and organic nitrogen throughout the year. These concentrations were highest in the winter months. The East Branch Delaware had low nitrate concentrations during the growing season, when uptake by plants was greatest, and highest concentrations during the nongrowing season (Heisig, 2004). Since nitrogen is often storm-driven, the annual medians should not be compared to the guidance values for rivers and reservoirs. The USGS found that nitrate-nitrogen values in low flow conditions of July and August 2001 ranged between 0.057 to 0.615 mg/L for various East Branch Delaware watershed streams (Heisig, 2004, pg. 22-23)

Fecal Coliform

Fecal coliform bacteria are used as an indicator of possible sewage contamination because they are commonly found in human and animal feces. Although coliform bacteria are generally not harmful themselves, they indicate the possible presence of pathogenic bacteria, viruses, and protozoa that also live in the digestive tract. Therefore, the greater the numbers of fecal coliform bacteria colonies present, the greater the human health risk for other pathogens. In addition to the human health risk, excess fecal coliform bacteria can cause increased oxygen demand, cloudy water, and unpleasant odors. Common sources of fecal coliform bacteria in waterways include poorly functioning sewage treatment plants, on-site septic systems, domestic and wild animal manure, and stormwater runoff. Because coliform attaches itself to soil particles, storm events can produce erosion and stir up sediments, leading to higher than normal coliform counts. Fortunately, the Delaware basin soils are less susceptible to erosion than neighboring Catskill watersheds, therefore the coliform counts for the East Branch Delaware tend to be lower than in the Esopus and Schoharie basins.

Testing for all bacteria, viruses, and protozoa is very costly and time consuming. Therefore it is common practice to test for fecal coliform bacteria as an indicator of pathogens. The New York State Department of Health standard for contact recreation (swimming) is as follows: the fecal coliform bacteria density should not exceed 200 colonies per 100 ml, based on a logarithmic mean from a series of five or more samples over a thirty-day period. The annual median total coliform for the Pepacton reservoir was less than 50 colonies per 100 ml for the period 1996-2005 (see **Figure 7.2**).

Specific Conductivity

Specific conductivity describes the ability of water to conduct an electric current and is an index of the concentration of chemical ions in solution. An ion is an atom of an element that has gained or lost an electron, which will create a negative or positive state. High conductivity is created by the presence of anions such as chloride, nitrate, sulfate, and phosphate, or cations such as sodium, magnesium, calcium, iron, and aluminum. The natural conductivity in streams and rivers is affected primarily by the geology of the area through which the water flows. Conductivity is often used to compare different streams because it is a cheap and easy measurement that can indicate when and where a site is being influenced by a source of contamination. Often when wastewater treatment plant effluent constitutes the majority of flow in a stream, it can be seen in water quality data due to its higher conductivity signature. Road salting practices can also significantly impact conductivity.

Dissolved Oxygen

Dissolved oxygen refers to oxygen gas (O_2) molecules in the water. The molecules are naturally consumed and produced in aquatic systems and necessary for almost all aquatic organisms. If dissolved oxygen levels fall below a certain threshold, biologic integrity will be compromised. For example, on a scale of 0 to 14 mg/L, a concentration of 7 mg/L to 11 mg/L is ideal for most stream fish (Behar, 1996). Dissolved oxygen can be measured as the concentration of milligrams O_2 per liter (mg/L) or as percent saturation of O_2. Percent saturation is the amount of oxygen in a liter of water relative to the total amount of oxygen the water can hold at a given temperature. In cold water systems, a percent saturation of 60% to 79% is acceptable for most stream animals (Behar, 1996). The New York State regulations for a stream designated as supporting trout spawning states that the dissolved oxygen should not be less than 7.0 mg/L from other than natural conditions.

Sulfur

Sulfur in natural waters is essential to the life processes of plants and animals. Although the largest Earth fraction of sulfur occurs in reduced form in igneous and metamorphic rock, there is significant sulfur in sedimentary rock as well. When sulfide minerals undergo weathering through contact with oxygenated water, the sulfur is oxidized to yield stable sulfate ions that become mobile in solution. Another major source of sulfate in the environment is the combustion of coal, petroleum, and other industrial processes such as smelting of sulfide ores. Atmospheric deposition both as dry particulates and entrained in precipitation can cause acid rain that can alter stream chemistry. Sulfate is highly mobile and often ends up in our local streams, lakes, and reservoirs. Sulfate is classified under the EPA secondary maximum contaminant level (SMCL) standards. The SMCL for sulfate in drinking water is 250 milligrams per liter (mg/l). Sulfate was not monitored by the NYCDEP until 1994. Sulfate values basin-wide have dropped since 1994, and despite a brief rise in 2002, have remained at a lower level, possibly due to reduced sulfur emissions throughout the US. The USGS samples for sulfate from various East Branch Delaware River watershed streams ranged between 3.7 to 6.7 mg/L during July and August of 2001 (Heisig, 2004 pg.22-23).

pH

For optimal growth, most species of aquatic organisms require a pH in the range of 6.5 to 8.0, and variance outside of this range can stress or kill organisms. Due to the acidity of rainfall in the northeast, maintaining this range is of concern. According to the NYSDEC (2004a), the average pH of rainfall in New York ranges from 4.0 to 4.5.

Chloride

Chlorides are salts resulting from the combination of chlorine gas with a metal. Chlorine as a gas is highly toxic, but in combination with a metal such as sodium it becomes useful to plants and animals. Small amounts of chlorides are required for normal cell function in plants and animals. Common chlorides include sodium chloride (NaCl), calcium chloride ($CaCl_2$), and magnesium chloride ($MgCl_2$). Chlorides can get into surface water from several sources, including geologic formations containing chlorides, agricultural runoff, industrial wastewater, effluent from wastewater treatment plants, and the salting of roads. Excess chloride can contaminate fresh water streams and lakes, negatively affecting aquatic communities.

Concentrations of chloride of approximately 140 mg/L should be protective of freshwater organisms for short-term exposure; concentrations less than 35 mg/L are likely protective during long-term exposures (Environment Canada, 2001). Overall, approximately 5 percent of species would experience effects from chronic exposure to concentrations of chloride of 210 mg/L, while 10 percent of species would be affected at concentrations of 240 mg/L (Environment Canada, 2001). According to the United States Environmental Protection Agency, biota on average should not be affected if the four-day average concentration of chloride does not exceed 230 mg/L more than once every three years. Biotic impacts would be minimal if the one-hour average chloride concentration did not exceed 860 mg/L more than once every three years (USEPA, 2005a).

The USGS study of chloride and sodium in base flow on the East Branch Delaware River found that chloride concentrations in May discharges exceeded December discharge concentrations in sub-basins with high salt applications, but in basins with low salt applications the May and December concentrations were similar. Chloride concentrations from stream basins with high salt application rates were higher in May than December because recharge of water containing road salt near streams is likely saltier after the winter period (May) due to spring runoff (Heisig et. al., 2004). Groundwater discharge is also impacted by road salt application with estimated chloride concentrations in valleys along state or county roads averaging 5 times higher than naturally occurring chloride levels. These levels of 8-13 mg/L are still well below the NYS drinking water maximum contaminant levels for chloride of 250 mg/L. Typically the groundwater in the area between the road and stream is the most affected by road salt applications (Heisig et. Al., 2004).

Biomonitoring

Benthic macroinvertebrates (BMI) can be simply defined as animals without backbones that are larger than 1 millimeter and live at least a portion of their life cycles in or on the bottom of a body of water. In freshwater systems, these animals may live on rocks, logs, sediments, debris, and aquatic plants during their various life stages. A few common examples of BMIs include crustaceans such as crayfish, mollusks such as clams and snails, aquatic worms, and the immature forms of aquatic insects such as stonefly, caddisfly, and mayfly nymphs.

BMIs function at the lower levels of the aquatic food chain, with many feeding on algae, detritus, and bacteria. Some shred and eat leaves and other organic matter that enters the water, and others are predators. Because of their abundance and position in the aquatic food chain, BMIs play a critical role in the natural flow of energy and nutrients through the aquatic system (Covich et al., 1997). For example, Sweeney (1993) demonstrated in a second order stream that leaf litter and woody debris were primarily consumed in the forested woodlot where the debris originated. Also, as benthos die, they decay, leaving behind nutrients that are reused by aquatic plants and other animals in the food chain. Insects fill the roles of predators, parasites, herbivores, saprophages, and pollinators, among others, which indicate the pervasive ecological and economic importance of this group of animals in both aquatic and terrestrial ecosystems (Rosenberg et al., 1986).

Biological assessments have been used by many states to evaluate the effectiveness of water quality programs, particularly for nonpoint source impact determinations (USEPA, 2002). For example, biological assessment models have been tested with field data and the results suggested that macroinvertebrate data collected for establishing the degree of water quality impairment can also be used to identify the impairment source with reasonable accuracy (Murray et al., 2002). In addition, it has been suggested that the percentage of chironomids in samples may be a useful index of heavy metal pollution (Winner et al., 1980). Furthermore, the Ohio EPA employs biological response signatures – based on biological, chemical, physical, bioassay, pollution source, and watershed characteristics – that consist of key response components of the biological data that consistently indicate one type of impact over another (Yoder, 1991). In New York State, the first recorded biological monitoring effort dates from 1926-1939, but the regulatory role of stream biomonitoring did not begin in New York until after the passage of the Federal Water Pollution Control Act Amendments of 1972 (Clean Water Act). The primary objective of New York State's program was to evaluate the relative biological health of the state's streams and rivers through the collection and analysis of macroinvertebrate communities (Bode et al, 2002).

Biological monitoring appears to be an attractive methodology for documenting water quality for several reasons. First, the community collected at a given site reflects the water quality at that site over several weeks, months, or years. The alternative methodology of grabbing a water sample reflects the water quality at the instant the sample is collected (i.e. a snapshot image). Second, the community-based approach focuses on the biological integrity of the water body instead of a limited number of chemical parameters. Third, samples can be preserved in reference collections for future application; this provides a convenient routine of summer collection and winter analysis. Finally, biological assessments tend to be much more cost effective than chemical analysis. **Table 7.2** lists the rationale for biomonitoring in New York State (Bode et al, 2002).

Table 7.2 Rationale for Macroinvertebrate Community Analysis

1. BMIs are sensitive to environmental impacts;
2. BMIs are less mobile than fish, and thus can avoid discharges;
3. They can indicate the effects of spills, intermittent discharges, and lapses in treatment;
4. They are indicators of overall, integrated water quality, including synergistic effects and substances lower than detectable limits;
5. They are abundant in most streams, and are relatively easy and inexpensive to sample;
6. They are able to detect non-chemical impacts to the habitat, such as siltation or thermal change;
7. They are readily perceived by the public as tangible indicators of water quality;
8. They can often provide an on-site estimate of water quality;
9. They bioaccumulate many contaminants to concentrations that analysis of their tissues is a good monitor of toxic substances in the aquatic food chain;
10. They provide a suitable endpoint to water quality objectives.

Standardized protocols for benthic macroinvertebrate monitoring were developed in the mid-1980s due to the need for cost-effective habitat and biological survey techniques (Plafkin et al., 1989). The primary driver of the development was limited economic resources available to states with miles of unassessed streams. It was also recognized that it was crucial to collect, compile, analyze, and interpret environmental data rapidly to facilitate management decisions and resulting actions for control and/or mitigation of impairment. Therefore, the conceptual principles of rapid bioassessment protocols (RBPs) were as follows: cost-effective, yet scientifically valid procedures; provisions for multiple site investigations in a field season; quick turn-around of results for management decisions, easily translated to management and the public; and environmentally benign procedures (Barbour et al. 1999). Finally, in order to save time, it was recognized that a certain degree of accuracy would need to be sacrificed, and a field-based assessment would be necessary (Hisenhoff, 1988). Therefore, a field-based assessment was developed that could be calculated in the field by professionals (Hilsenhoff, 1988). This field-based assessment allows professionals to focus their time and efforts on the more in-depth analysis of areas that indicated degradation in the rapid field assessment.

For the most part, the East Branch Delaware River and its tributaries exhibit good water quality based on BMI community structure. Two sites sampled 1994 and 2005 on the East Branch Delaware River are consistently designated as non-impaired, while one site on the Bush Kill has been designated as slightly impaired in 2000 and 2002 (NYCDEP, 2006). See **Figures 7.3** and **7.4**.

The Stroud Center's evaluations from the summers of 2003 and 2004 of the sample sites within the Pepacton Reservoir basin are consistent with the NYCDEP reported results. The Water Quality Scores, a value derived from multiple analyses of the macroinvertibrate community sample, were largely within the non-impaired range of values. The values of one or two sites occasionally dipped into the slightly impacted range (Stroud Center, 2003, 2004).

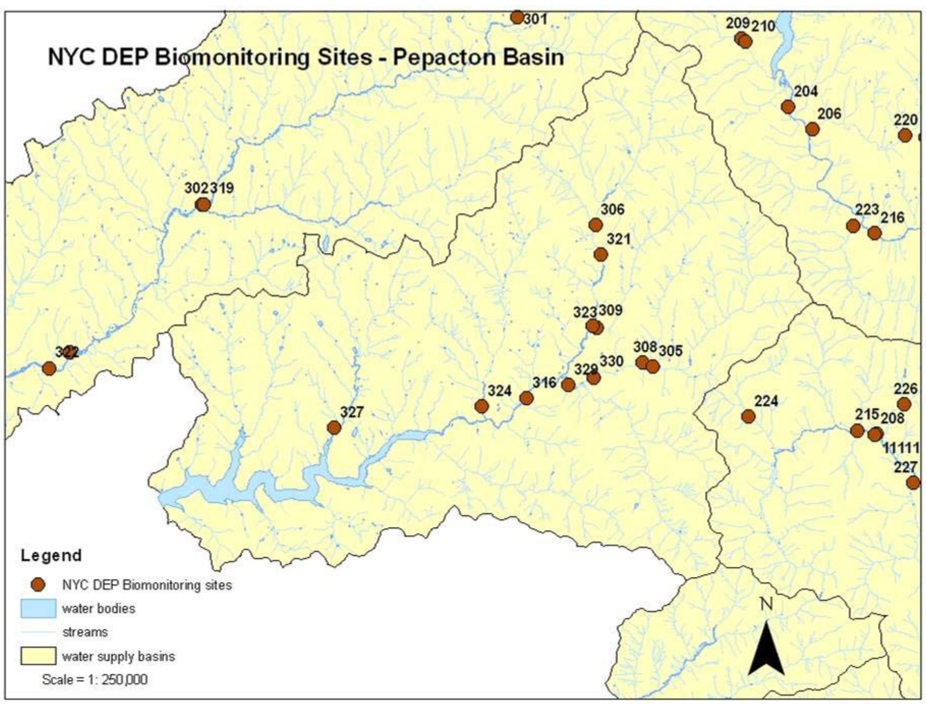

Figure 7.3 NYCDEP Biomonitoring Sites

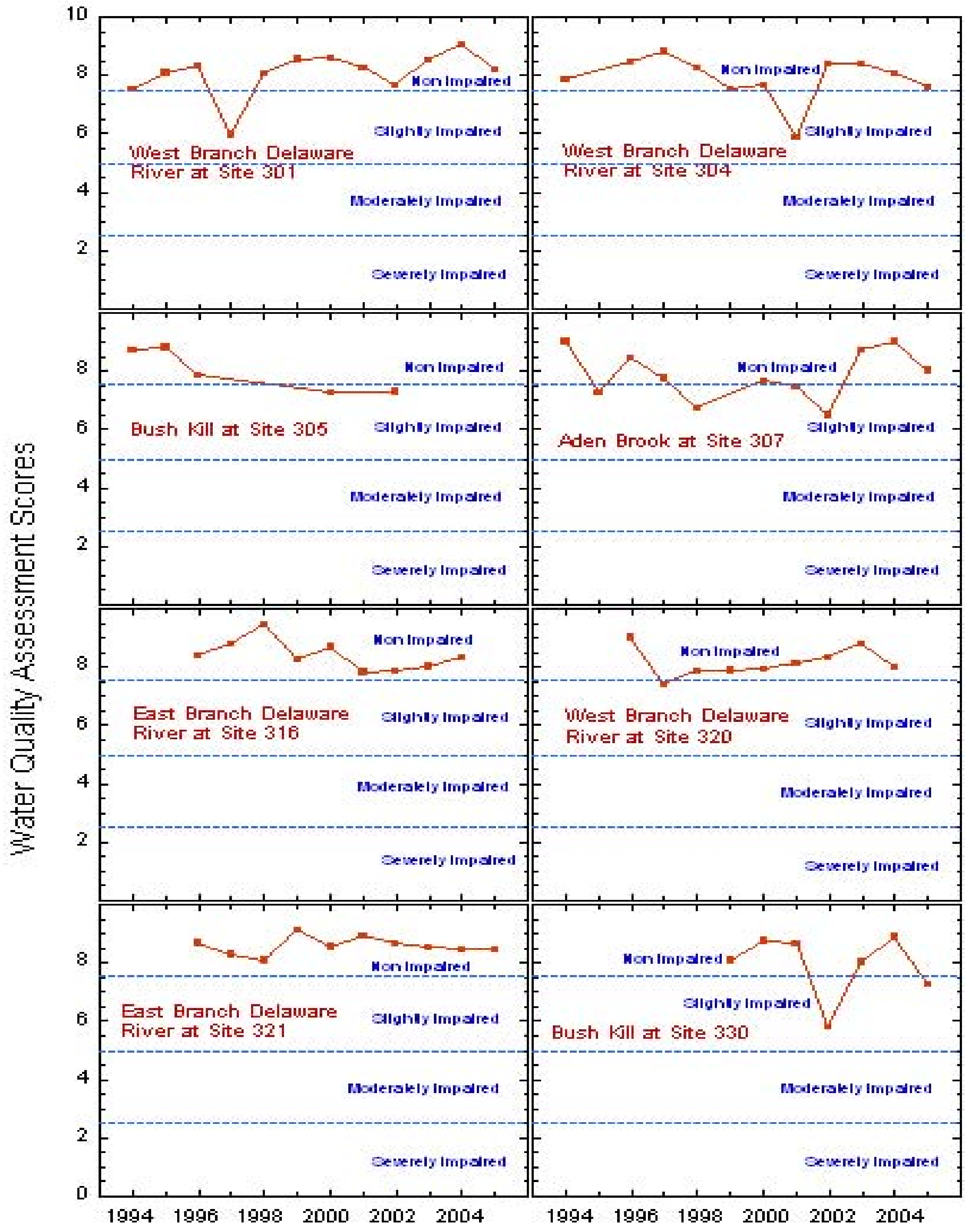

Figure 7.4 Water Quality Assessment Scores Based on Stream Biomonitoring Data for Delaware Streams With 3 Year Record or More

Stream Management Implications

Determining whether a stream has good or bad water quality often depends largely upon the observer. For the purposes of the NYC water supply, the East Branch Delaware River watershed supplies good quality water. Streams in the Catskills have moved large amounts of suspended sediment during storms for thousands of years and will continue to do so for thousands more. That being said, watershed landowners do have direct influence over land uses in the watershed and there are other, more local reasons for watershed protections measures to be implemented. For example, protecting and enhancing the fishery could also benefit the economy and aesthetic values of the region. Proper watershed management can also assist in protecting infrastructure, reducing flood damages, and helping to develop a stream stewardship ethic. Taken together, all these benefits can increase the quality of life of watershed residents, while providing high quality drinking water to the residents of New York City into the future.

Although, in general, water quality appears to be pretty good, there also seems to be specific areas where water quality may be impacted and late summer water temperatures are high for a cold-water fishery. Future development in the stream corridor, with a resulting increase in impervious surface, may increase runoff and impair water quality. While approximately 85% of the East Branch Delaware River basin is forested, this is somewhat deceptive since much of the developed land and roads are on the gentle slopes adjacent to the stream. Therefore, management efforts should be focused on preventing further human-induced degradation through implementation of best management practices designed to reduce/minimize impacts in the developed area. These efforts should be both direct measures such as remediating failing septic systems and upgrading sewer treatment plants (point sources of pollution); and indirect measures such as reducing stormwater inputs, properly installing new infrastructure, and planting riparian buffers. In areas where existing infrastructure is acting to destabilize the stream or is threatened by erosion, stabilization techniques incorporating natural channel design should be employed. Enhance streamside vegetation along the banks of the East Branch Delaware River and its tributaries, coupled with the protection of cold groundwater seeps, may help to lower summer water temperatures, reduce nutrient inputs, minimize turbidity, and enhance the fishery.

~ 8. Permitting Requirements ~

Work in any stream in New York State requires a permit or series of permits, depending on the nature of the project. This section briefly describes the requirements of the permitting agencies, and Stormwater Pollution Prevention Plans (SPPP) that are typically required in order to receive these permits.

NYSDEC Permit Requirements

The NYSDEC regulates activities in and around the water resources of New York State pursuant to the Environmental Conservation Law (ECL) Article 15, Title 5, Protection of Waters Program. This is known as an Article 15 Permit, and is issued to applicants at no charge.

A Protection of Waters Permit is required for temporary or permanent disturbances to the bed or banks of a stream with a classification and standard of C(T) or higher. Examples of activities requiring this permit are:

- Placement of structures in or across a stream (i.e., bridges, culverts or pipelines);
- Fill placement for bank stabilization or to isolate a work area (i.e., riprap or other forms of *revetment*);
- Excavations for gravel removal or as part of a construction activity;
- Lowering streambanks to establish a stream crossing;
- Use of heavy equipment in a stream to remove debris or to assist in-stream construction.

Some stream disturbance activities are exempt from the requirements of an Article 15 Permit. The most common of these are:

- Disturbance of a protected stream by a town or county government that enters into a written agreement with NYSDEC for specified categories of work, undertaken in compliance with performance criteria that are protective of stream resources.
- Agricultural activities involving the crossing and re-crossing of a stream by livestock or farm equipment at an established crossing.
- Removal of fallen tree limbs or tree trunks where material can be cabled and pulled from the stream without disruption of the streambed or banks, utilizing equipment placed on or above the streambank.

Projects are classified as minor or major for the purposes of review by NYSDEC. Maximum allowable review periods are different for “minor” and “major” projects under the Uniform Procedures Act requirements (6 New York Code of Rules and Regulation (NYCRR) Part 621). Minor projects include: 1) repair or in-kind replacement of existing structures; and 2) disturbances of less than 50 linear feet along any 1,000 feet of watercourse. All other activities are considered major projects for the purposes of review and public notice, as required by the Uniform Procedures Act. For minor projects, NYSDEC must make a permit decision within 45 days of determining the application complete. For major projects: 1) if no hearing is held, NYSDEC makes its final decision on the application within 90 days of its determination that the application is complete; and 2) if a hearing is held, NYSDEC notifies the applicant and the public of a hearing within 60 days of the completeness of determination. The hearing must commence within 90 days of the completeness determination. Once the hearing ends, NYSDEC must issue a final decision on the application within 60 days after receiving the final hearing record.

For permit applications and any questions regarding the permit process contact the Deputy Regional Permit Administrator at:

NYS Department of Environmental Conservation
Division of Environmental Permits, Region 4
65561 State Highway 10, Suite 1
Stamford, NY 12167-9503
(607) 652-7141

Protection of Waters permit information is also available on the NYSDEC website: http://www.dec.ny.gov/permits/6042.html (Verified September 27, 2007).

U. S. Army Corps of Engineers (USACOE) Permit Requirements

Under Section 404 of the Clean Water Act, any activities where placing fill or undertaking activities resulting in a discharge to *waters of the United States* also require a Nationwide permit from the U. S. Army Corps of Engineers (USACOE). Minor projects include those projects that will not exceed the minor project thresholds for NYSDEC Article 15 permits, and which do not involve the approval of construction and operation of hydroelectric generating facilities. All other projects are major projects and require USACOE review.

Currently, applications are a one form joint application available from the NYSDEC, which forwards a copy of the application package to the regional USACOE office. USACOE will contact the applicant if additional information is required. Information is also available from the regional USACOE office at:

Department of the Army
New York District, Corps of Engineers
Albany Field Office
1 Bond Street
Troy, NY 12180
(518) 270-0588

Erosion and Sediment Control

Stormwater Pollution Prevention Plan

A Stormwater Pollution Prevention Plan (SPPP) documents how erosion will be controlled during construction, and the project's likely effects on the rate and quality of stormwater leaving the site. An SPPP consists of a narrative report, plans, details and specifications.

NYSDEC Requirements

Generally, construction activities in the East Branch watershed that involve one acre or more of land disturbance must obtain a State Pollutant Discharge Elimination System (SPDES) permit, which includes the development of an Erosion and Sediment Control Plan and an SPPP. Operators of potential construction activities should contact the local NYSDEC office in Stamford for a determination whether or not a SPDES permit is required. Additional information is available from the NYSDEC website: http://www.dec.ny.gov/permits/6054.html (Verified September 27, 2007).

Implementation of certain agricultural Best Management Practices are exempt from SPDES permitting requirements pursuant to a Memorandum of Understanding (MOU) between the NYSDEC, NYS Department of Agriculture and Markets and the NYS Soil and Water Conservation Committee dated March 25, 2004.

New York City Requirements

The New York City Department of Environmental Protection (NYCDEP) requires an SPPP to be submitted and approved prior to implementation of any of the following activities:

- Development or sale of land that will result in the disturbance of five or more acres of land.
- Construction of a subdivision.
- Construction of a new industrial, municipal, commercial or multi-family residential project that will result in creation of an impervious surface totaling over 40,000 square feet in size.
- A land clearing or land grading project, involving two or more acres, located at least in part within the limiting distance of 100 feet of a watercourse or *wetland*, or within the limiting distance of 300 feet of a reservoir, reservoir stem or controlled lake or on a slope exceeding 15%.
- Construction or alteration of a solid waste management facility within 300 feet of a watercourse or wetland or within 500 feet of a reservoir, reservoir stem or controlled lake.
- Construction of a gasoline station.
- Construction of an impervious surface for a new road within certain limiting distances from various watercourses.

- Construction of an impervious surface within a village, hamlet, village extension or area zoned for commercial or industrial uses.
- Up to a 25% expansion of an existing impervious surface at an existing commercial or industrial facility which is within the limiting distance of 100 feet of a watercourse or wetland.

Generally, installation of culverts, stream diversions and bridges or stream crossings within 100 feet of a stream or wetland, or within 300 feet of a reservoir , reservoir stem or controlled lake also require NYCDEP approval. For applications and any questions regarding this process contact the Deputy Chief, Engineering Section at:

NYCDEP
71 Smith Avenue
Kingston, NY 12401
(845) 657-2390

Local Requirements

It should be recognized that since New York is a "home rule" state, the authority to regulate development rests with the local municipalities. Communities that participate in the National Flood Insurance Program (NFIP) have adopted local laws for Flood Damage Prevention that incorporates Federal Emergency Management Agency (FEMA) minimum standards for development in a Special Flood Hazard Area. Participating communities appoint a local floodplain administrator, typically the Building Inspector or Code Enforcement Officer, to administer the program within the community. The intent of the program is, at least in part, to reduce flood risk to new development, and to prevent an increase in flood risk to the existing community from development proposed in the future. It should be noted that development as defined in the local law is: "… any man-made change to improved or unimproved real estate, including but not limited to, buildings or other structures, mining, dredging, filling, paving, excavation or drilling operations, or storage of equipment or materials." As such, proposed stream corridor management projects should be assessed by the affected communities, and floodplain development permits should be issued or denied as appropriate.

~ 9. Flood Protection and Recovery ~

As protection is a principal function of government, and floods and the potential resulting loss of life and property are a serious threat to those living along the East Branch Delaware River, it is the role of all levels of government to assist the public in securing itself from the threats associated with flooding. Policy for protecting the public from flooding and programs for assisting the public in the event of a flood, flow from the federal level to the state and local levels of government. FEMA, within the Department of Homeland Security, establishes flood programs enabling communities to plan and respond to flood events, minimize or mitigate against flood hazards, and recover from flood disasters. The State Emergency Management Office (SEMO) generally mirrors FEMA policies and programs and helps to administer flood planning, mitigation and coordinate state resources for recovery efforts. Within Delaware County, the Director of Emergency Services coordinates emergency response and recovery, while efforts to plan for mitigating against flood hazards is shared across county agencies such as the Department of Public Works, Planning Department and other Delaware County Action Plan (DCAP) partners under the supervision of the County Hazard Mitigation Coordinator. As a tool for individuals and communities living along the river, this Stream Corridor Management Plan provides a general background on the programs and policies that will enable the community to avoid, mitigate against, or recover from a flood. This section is written for home owners, local leaders and the general public to help increase their knowledge of steps they can take to reduce flood losses and facilitate disaster recovery.

Avoiding Flood Losses

Flood waters are very destructive and while losses in terms of property or life cannot be totally avoided, with good information and wise decisions, individuals and communities can reduce their losses. Information is the most important tool available. Local knowledge, timely communications and accurate maps of where flood waters are likely to have their greatest impact are only some of the information that can help the community with decisions as they seek to avoid flood losses.

Communicating with local experts is critical to avoiding flood losses. A very important and often overlooked individual is the local *floodplain administrator* or floodplain regulation enforcement officer. Many municipalities employ a person in this position to inform the public about floodplain regulations and help landowners make wise decisions about their development projects. The floodplain administrator develops an understanding of the regulations, the best practices and the location of flood-prone areas for their community. Making use of their knowledge can save time and money by avoiding red tape and otherwise avoidable flood damages. Often, the floodplain administrator is also the building/code enforcement officer, so it is likely to meet this person in more than one capacity when a construction project be undertaken in or around a floodplain. Training courses are available through NYSDEC and FEMA to keep the local floodplain administrator current with the latest best management practices and regulations.

Flood Insurance Rate Maps (FIRMs) are available for most communities in the United States and provide a guide to where flood waters of larger floods are likely to inundate the lands surrounding a water body. Before buying or building a house or buying property near a body of water, whether stream, river, lake or wetland[31], an individual should consult their floodplain map or FIRM "community panel" to find out where the waters will be likely to rise during a major storm event. FIRMs are produced and maintained as part of the National Flood Insurance Program, which provides flood insurance to home owners and businesses living in a participating community. Because properties located outside of Special Flood Hazard Areas are assumed to have a lower risk, they benefit by qualifying for lower insurance premiums. The most recently updated FIRMs for Delaware County were created through engineering studies which based the estimated extent of the floodplain on local topography, channel shape and slope, hydrology and hydraulic conditions for a range of flood return probabilities. Typically, the maps show the one percent annual chance flood (also called the base flood or 100 year flood) extent or the Special Flood Hazard Area. An example of this generation of maps includes the Village of Margaretville. These maps are of reasonable accuracy but could be improved with current mapping technologies. Older maps, such as the FIRM map for the Town of Andes, created in the early 1970's at the start of the NFIP, only show the "flood hazard boundary" based on approximate studies of the floodprone area for the 100 year flood event. Care should be exercised in using these maps if one is considering a development anywhere near this map zone. When an area is suspected as being within the floodplain, but the limits and depth of the base flood are not known for a location, a flood study should be required of the applicant by the local code officer or planning board. Not all areas at risk of flooding have been mapped by FEMA, so at a minimum, each property owner should evaluate the flood risk for themselves and decide whether they need to purchase flood insurance.

Should an older map be of questionable accuracy, the individual should obtain an engineer's estimate of the floodprone area or the Base Flood Elevation (BFE) for the development site prior to any construction. Before securing financing to purchase or build a home within a known floodprone area with an established Base Flood Elevation (BFE) a lender will require the purchase of flood insurance and have a surveyor define the elevation of the structure's first floor for use in estimating your flood insurance premium. Building in a floodplain can result in thousands of dollars of losses, especially if the construction is not compliant with the NYS Building Code and NFIP requirements (per DEC). Not only does the individual risk personal losses, but building within the floodplain or floodway can seriously impact the neighboring property owners by causing flood elevations to rise or flood routes and velocities to change. The local Floodplain Administrator can inform individual of the requirements before they begin planning a project. Individuals that are buying land with the intent to build should avoid floodprone areas. FIRM maps are available for inspection at each of the Town or Village Halls. Copies of the maps can also be purchased from FEMA through their website or by mail.

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[31] The National Wetland Inventory (NWI) maps produced by the U.S. Fish and Wildlife Service provide a good reference for the location of wetlands. These maps are available for inspection through the local planning board, the Delaware County Planning Department or the DCSWCD.

Recent advances in remote sensing, hydraulic modeling and computer mapping technology have greatly improved the ability of engineers to accurately estimate the flood extent and elevation for a range of floods. FEMA, together with the NYSDEC have established procedures for revising the current flood studies around New York State. NYSDEC and Schoharie County have completed a new flood study and set of revised paper floodplain maps and Digital FIRMs (DFIRMs) for the entire county. Similar efforts in Delaware County should improve the information available to landowners about the development potential of their property, their risk of flood losses, and help prevent future threats to life and property throughout the area. This information should also improve the community's rating and minimize the need for individuals to bear the expense of site specific flood studies.

NFIP was established by Congress in 1968 to reduce the cost of taxpayer funded disaster relief. The Mitigation Division, within FEMA, manages the NFIP, and oversees the floodplain management and mapping components of the Program.

Nearly 20,000 communities across the United States, (including all municipalities within Delaware County), participate in the NFIP by adopting and enforcing floodplain management ordinances to reduce future flood damage. In exchange, the NFIP makes Federally backed flood insurance available to homeowners, renters, and business owners in these communities. Flood insurance can be purchased through a local insurance agent and covers the cost of structural damage to a home. If an insurance agent is unable to write a flood policy, call 1-800-638-6620 for information. The contents of a home, such as appliances, furniture and clothing are typically insured at additional cost. There is a 30 day waiting period for new policies.

Flood damage is reduced by nearly $1 billion a year through partnerships with communities and the insurance and lending industries. Further, buildings constructed in compliance with NFIP building standards suffer approximately 80 percent less damage annually than those not built in compliance. And, every $3 paid in flood insurance claims saves $1 in disaster assistance payments (FEMA, 2004). Flood Insurance rates for individual policyholders of a community can be reduced if the community improves its "*community rating*" by participating in flood disaster planning efforts and takes action to reduce or avoid flood losses. The NYSDEC Flood Bureau within the Division of Water, together with SEMO can help the community identify ways to improve the community's rating under the Community Rating System (CRS). Additional information is available at: http://www.fema.gov/business/nfip/ (Verified September 27, 2007) and http://www.fema.gov/pdf/nfip/alt_elevations/elevations_appt.pdf (Verified September 27 2007).

Flood Recovery

Following a flood that has been an officially declared disaster, several forms of assistance become available to individuals and communities. There can be both Public Assistance and Individual Assistance programs depending upon the severity of the flood event. Declarations are made on a county by county basis. Less severe events may only trigger a declaration enacting Public Assistance programs to assist with infrastructure recovery, such as the repair of roads and public facilities. If a disaster is declared for Individual Assistance, then programs are deployed to address the property losses of individuals, farmers and other businesses.

Public Assistance is managed by the state through the Emergency Services Coordinator and local government representatives. A SEMO team will organize initial contact meetings to inform local government representatives of the assistance process and initiate project identification. It is important to document all actions taken to repair damages to a flood and carefully track the use of materials, equipment and labor for later reimbursement. Attendance at these meetings is critical especially if local leadership has changed and the new leadership has not experienced a flood event. Documents regarding flood recovery efforts should be held and shared with those considering flood hazard mitigation planning. The SEMO website is an excellent resource for obtaining the latest information on the status of a disaster recovery effort or finding out who to contact for more information: http://www.semo.state.ny.us/ (Verified September 27, 2007).

Individual Assistance is typically made available following a flood where there has been widespread damage to homes and businesses. The American Red Cross is a first responder helping flood victims with their immediate needs for food, shelter, medical attention and cleanup provisions. Within 12-36 hours of an event, FEMA deploys its staff of inspectors to assess the damage and meet with state and local officials. Once the declaration is made, FEMA will announce an 800 telephone number for individuals to seek assistance and file claims. One of the primary forms of individual assistance is the Assistance for Individuals and Households Program which can help with lodging or temporary housing, home repair grants, and other personal needs. The Small Business Administration (SBA) offers low interest loans to eligible individuals, farmers and businesses to repair or replace damaged property and belongings not covered by insurance. Other assistance is available as tax rebates, veterans benefits and unemployment benefits. 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. If individuals have flood insurance they should initiate a claim immediately.

Flood Hazard Mitigation

Hazard Mitigation is any sustained action taken to reduce or eliminate long-term risk to people and property from natural hazards and their effects. Examples of hazard mitigation are the acquisition and removal of hazard prone property, retrofitting of existing buildings and facilities, elevation of floodprone structures, and infrastructure protection measures. The federal government provides funding for hazard mitigation following disasters through two programs; the 404 Hazard Mitigation Program and the 406 Hazard Mitigation Program.

FEMA provides funding to States under section 404 of the Stafford Act for the Hazard Mitigation Grant Program (HMGP). The funds are to provide state and local government, certain private non-profit organizations and Native American tribes with the incentive and capacity to take critical mitigation measures during the flood recovery and reconstruction process to protect life and property from future disasters (FEMA, 2001). The eligibility of a community requires a community to have prepared and filed with the SEMO, a Hazard Mitigation Plan which describes the local priorities for mitigation. Funding is competitive with other communities around the State, and will be ranked by the results of a benefit-cost analysis with others possible projects for having the greatest potential to reduce future losses. Delaware County received significant levels of funding through this program following the January 1996 flood disaster for the Flood Property Buyout Program and other mitigation projects.

The Delaware County Planning Department has prepared an All-Hazards Mitigation Plan for the county and all 28 municipalities to enable any community within the county to apply for funding under this program. The Plan was completed in 2006 and Delaware County and each of the municipalities adopted the Plan and filed it with New York State in early 2007. The Plan reflects all potential hazards that could affect the county and ranked each for their potential. Flooding was by far the most significant threat to the county and both public and private property. The Plan also requires all hazard mitigation efforts must be coordinated through the Delaware County Planning Department as the Hazard Mitigation Coordinator is the County Planning Director. HMGP funds require a 25 percent local commitment in cash or in kind for total project costs. For more information about this program contact the Delaware County Planning Department or the Hazard Mitigation Program Director within SEMO. The website for the state program is: http://www.semo.state.ny.us/programs/mitigation/ (Verified September 27, 2007).

The Section 406 Hazard Mitigation Program is available for public assistance projects (those dedicated to the recovery and reconstruction efforts of local government) for the reduction or elimination of future damages to a facility damaged during a disaster. Hazard mitigation funding can be sought for infrastructure damage where the funds would enable the applicant to upgrade the structure to a standard that will avoid future flood damages. Undamaged structures would not be eligible under this program. 406 Hazard mitigation funds are added to the reconstruction costs normally used to return a structure to its pre-flood condition. Typically, there is a 25% local cost share for the mitigation activity. This program is not cost competitive and can be very useful in preventing future flood damages, especially where recurrent flood losses are avoidable through a retrofit. Questions about this and other flood recovery programs should be directed to:

New York State Emergency Management Office
1220 Washington Avenue
Suite 101, Building 22
Albany, New York 12226-2251
Region II Office: Telephone: (845) 454-0430
Fax: (845) 454-4620
E-mail: SEMORegion2@semo.state.ny.us
24 Hour Emergency Coordination Center
Telephone: (518) 292-2200

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 9.1** below).

<u>Holliday Brook</u>

Along Holliday Brook, one house was completely washed away, one private bridge was obliterated, another bridge disabled, and several vehicles were washed downstream. Approximately three quarters of one mile of road – both Town of Colchester and New York City jurisdictions – was completely washed out, making 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.

Figure 9.1 Flood aftermath on Holliday Brook on City Property

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's flood response protocol involved assessment of the stream reach, removal of large woody debris from the channel, and where necessary returning the stream to its original channel as well as re-establishing an adequate channel cross-sectional area. Approximate cross-sectional area was calculated from the DCSWCD Regional Hydraulic Relationship Curves (see **Volume 2, Section 3**). DCSWCD

Figure 9.2 NYS DOT Post Flood Recovery of Holliday Brook

staff provided channel alignment, stream grade, and cross-section stakeout to guide National Guard operators. **Figure 9.1** shows flood damage on Holliday Brook on the NYC DEP property. **Figure 9.2** NYS DOT post flood recovery triage on Holliday Brook - note that the floodplain elevation is near preflood state

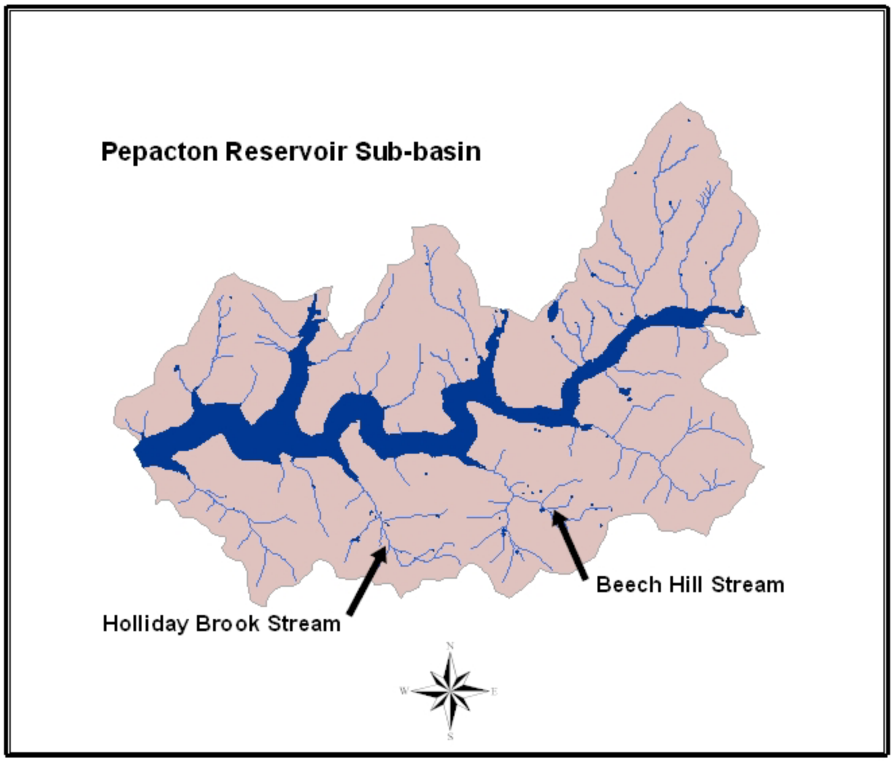
Figure 9.3 Holliday Brook After Construction with Cross Vane Structure

The flood event resulted in a sustained discharge of turbidity from Holliday Brook and posed a continuing threat to water quality in the Pepacton Reservoir, even after the NYS DOT/National Guard response efforts. The flood's disturbance to the stream on the City property threatened to continue to destabilize the upstream reaches with future bed and bank erosion. After the Commissioner of the NYCDEP issued an emergency declaration, the NYCDEP dedicated staff, consulting engineering, and funding in order to restore the lower 1300 feet of channel. The intent of the restoration was to address issues of channel instability and road protection. Beginning within 45 days of the event, a multi-million dollar stream restoration/road reconstruction project was designed, bid and contracted out by the NYCDEP. Construction was initiated in late August, with stream restoration efforts completed by early October. At the direction of the NYCDEP Stream Management Program, the design incorporated natural channel design structures to stabilize the channel slope and alignment and reconnect the stream with its floodplain. These structures were also designed to protect the realigned, reconstructed road way during future storm events. This effort provides an example for future recovery efforts where long term instability is likely due to flood induced geomorphic changes to the stream system. **Figure 9.3** shows the restored reach on City property (same location as shown in **Figure 9.1**). Note that the cross vanes limit the potential for headward bed degradation (head-cuts) and the floodplain is restored. Additional vegetation will be planted in the Spring of 2008. **Figure 9.4** shows Holliday Brook restored reach and the cross vane (at upstream plunge pool). The cross vane will prevent future migration of head-cuts and a series of straight vanes protect the base of this stacked rock wall.

Figure 9.4 Holliday BrookAfter Construction

<u>Beech Hill</u>

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 9.1 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.[32]

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.

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

~ 10. Watershed Programs ~

Watershed Agricultural Council

The Watershed Agricultural Council (WAC) was formed in 1992 to assist the NYCDEP in the development and implementation of voluntary watershed protection programs that include agriculture and forestry, with the overall objective of safeguarding and improving source water quality in the New York City watershed region through various conversation programs. Two programs pertinent to stream management are the Watershed Agricultural Program (WAP) and the Watershed Forestry Program, further described below. Further information is available on the WAC website: www.nycwatershed.org (Verified September 27, 2007)

Watershed Agricultural Program

WAP is a contractual partnership between WAC and the following agencies: Delaware County Soil & Water Conservation District, USDA Natural Resources Conservation Service (NRCS) and Cornell Cooperative Extension (CCE). These partner agencies develop and implement Whole Farm Plans (WFP) that address goals documented in the United States Environmental Protection Agency's Filtration Avoidance Determination and the WAC contract with New York City. WAP program staff consists of NRCS planners, agronomists and engineers, DCSWCD civil engineering technicians and technicians, and CCE crop, livestock, and nutrient management specialists.

WAP teams work collectively to plan and implement agricultural Best Management Practices (BMPs) as an integrated system on each participating farm in both large and small farm programs in the Catskill/Delaware Watersheds. These water quality BMPs are designed and constructed to NRCS standards and specifications and include: barnyard management systems, manure storage, roof runoff management, grazing systems, livestock water systems, livestock trails, comprehensive nutrient management, diversions, and crop rotation, to name a few. The Conservation Reserve Enhancement Program (CREP), implemented by USDA through WAP, is a very important riparian buffer program for land under agricultural production. Other practices not covered by NRCS standards are designed and implemented by a team of WAC engineers and technicians.

Watershed Forestry Program

WAC administers the Watershed Forestry Program with funding from the U. S. Forest Service and NYCDEP to address forestry needs within the Catskill/Delaware Watersheds. Community-based forestry groups and foresters provide technical support with the New York State Department of Environmental Conservation. The program encourages private forest landowners to actively manage their forests using sustainable best management practices and offers information and technical assistance to help them reach their goals, while observing practices that ensure the preservation of water quality.

The program offers training for consulting foresters and loggers and partners with the New York Logger Training's "Trained Logger Certification" program to help timber harvesters learn about a range of topics from safety and first aid to sustainable forestry to BMPs for water quality. The program also encourages forest land owners to develop and implement Forest Management Plans and provides technical assistance and some cost-sharing for implementation of forest management and riparian forest BMPs. In addition, the Watershed Forestry Program also coordinates four model forests throughout the watershed that integrate research, demonstration, continuing education and public outreach.

With funding from the USDA Forest Service Economic Action Program, eligible wood-based businesses in the NYC Watershed regions East and West of the Hudson River are awarded grants through the Forestry Grants Program to assist in a variety of projects ranging from website design and marketing to apprenticeship programs and new equipment. The results are improved safety and efficiency, cutting-edge wood technology and innovative marketing campaigns, all of which emphasize WAC's goal that forestry remain a viable enterprise to protect water and to bolster economic vitality in watershed communities.

Delaware County Action Plan

The Delaware County Action Plan (DCAP) was formulated in 1999 to address water quality issues in the New York City watershed. DCAP is a comprehensive strategy developed to meet the needs of Delaware County as a result of the Cannonsville basin being designated a phosphorus-restricted basin. DCAP coordinates with public and private agencies (listed below) to develop water quality initiatives and seek funding for implementation.

DCAP lead agencies include the DCSWCD and the following Delaware County Governmental Departments: Planning, Public Works, Watershed Affairs and Economic Development, and the New York State Water Resources Institute (WRI). Other DCAP participants include: Delaware County: Industrial Development Agency, Chamber of Commerce, and Cornell Cooperative Extension; Regional: Catskill Watershed Corporation, Watershed Agricultural Council and NYCDEP; New York State Departments: Environmental Conservation, Health, State, Agriculture and Markets, Soil and Water Conservation Committee, and Cornell University researchers. Federal Agencies: Environmental Protection Agency, Department of Agriculture, Natural Resources Conservation Service, and Army Corps of Engineers.

DCAP adopted a multiple barrier approach to address potential pollutants, particularly phosphorus. The barriers utilized are called the Initial Source Barrier, the Transport Barrier and the Stream Corridor Barrier. Current components of DCAP include management programs for stormwater and flooding, highway runoff, on-site septic systems, precision livestock feeding, forage management, SCMPr, and monitoring and modeling of best management practices to assess phosphorus reduction. By coordinating all water quality efforts under the DCAP umbrella, these programs are working together to collectively reduce pollutants entering watercourses and to improve overall water quality. The following categories demonstrate DCAP effectiveness to date:

Stream Corridor Management

Data has been gathered in the watershed for development of this Plan. This information will be useful for residents and municipalities to aid in making stream management decisions. This information is also being integrated with other DCAP efforts, particularly with stormwater management and highway maintenance programs, to further enhance the effectiveness of these local water quality initiatives, further described below:

Stormwater Management

The Delaware County Planning Department (DCPD) has developed the following long-term management programs:

- Inventory, Assessment and Evaluation of Stormwater Sources and Infrastructure

  Goal: to identify all point and non-point sources of stormwater in village and hamlet areas and manage them to reduce their impact on water quality.

  Work Completed:
  - A detailed evaluation of stormwater sources and conveyance systems is underway in the Pepacton basin using GPS to locate stormwater infrastructure and culvert outfalls in hamlets and villages. A Geographic Information Systems (GIS) database has been created combining this information with soils, land use and topographic datasets.
  - Pilot projects of stormwater collection, conveyance and treatment methods have been implemented in the Cannonsville Basin through stormwater retrofit projects in the Village of Walton and the Village of Hobart.
  - Stormwater assessments have been completed in the Village of Margaretville and a Stormwater Management Plan has been prepared and accepted by both the Village of Margaretville and the Town of Middletown.
  - With the use of grant moneys from New York State all stormwater outfalls have been located in the Pepacton and Cannonsville Basins as part of an on going inventory project to understand and improve stormwater management and reduce flooding and pollution from inadequate stormwater infrastructure.

- Local Implementation and Municipal Plan Development

  Goals: to work with each municipality to develop local initiatives for water quality protection through stormwater management and demonstrate the role of water quality to community economic development; also, to develop Stormwater Management Plans consistent with the NYCDEP Watershed Regulations and Phase II EPA Stormwater Regulations.

Work Completed:

- DCPD developed a Stormwater Management Plan for the Village of Margaretville in 2002. The Plan inventoried the existing infrastructure and developed strategies to improve the village stormwater system as well as made recommendations for changes in the Local Laws regulating land use, to include stormwater practices as part of the local review process.
- Source Water Protection Plans have been completed for the Villages of Margaretville and Fleischamnns as well as the hamlet of Roxbury in the East Branch corridor and a plan is being prepared for the Village of Walton currently. These plans delineate sensitive areas surrounding the community water supplies and recommends more restrictive land use policies within these areas.

Highway Management Activities

The Delaware County Department of Public Works (DCDPW) completed an inventory and assessment of storm drainage infrastructure along county highways in 1999 and continues to maintain a comprehensive inventory and assessment program for all pipes and their conditions. DCDPW has since evaluated alternative repair strategies for culverts that have reached the end of their useful life. These alternatives include culvert cut and cover practices; line inverts of existing pipes with concrete; slip line existing pipes and fill interstitial space; as well as the use of natural bottom square culverts.

Ongoing management practices include: 1) Sediment removal from culverts and catch basins with a vacuum truck; 2) In-place road culvert stabilization, which includes slip lining failed culverts (when feasible) to minimize sedimentation caused by traditional excavation and replacement. 3) De-icing material control, which includes installation of modern control equipment on material spreaders to facilitate precise metering of de-icing materials. 4) All new structures (drop inlets) installed by DCDPW include sumps. These new structures are part of routine maintenance practices and capital improvement projects.

DCDPW along with the assistance of DCPD has inventoried and cataloged all major drainage features on county highways using GPS and a GIS database. The databases are kept up to date with continual updates from DCDPW crews after maintenance and repairs to any infrastructure. DCPD maintains and houses the databases and provides continuous support to DCDPW on this program.

As a result of Delaware County's efforts to improve stormwater, DCPD along with DCDPW developed a town highway management program. DCPD has been successful at securing moneys from the New York State Department of State (NYSDOS), New York State Department of Environmental Conservation (NYSDEC) and the CWC to inventory town highways and all associated infrastructure and drainage systems. Data has been collected using GPS in the towns of Davenport, Andes, Kortright, Roxbury, Walton, Bovina, Colchester, Deposit and Meredith. Through grant programs from NYSDEC moneys have been secured to complete the inventories in all Delaware County communities by the year 2010. The inventories have been cataloged through a GIS database and all infrastructure has been mapped along with a connection to pictures of each item. DCPD along with DCDPW has continued to seek funding to continue phase two of developing the town highway management plans. Phase two requires an engineer assessment and evaluation of the infrastructure and the development of a multi-year capital investment plan.

Other activities include creation of wetlands towards the establishment of a mitigation bank on county-owned property in Walton, and research investigating the use of chipped passenger car tire chips as a medium to remove dissolved phosphorus from stormwater.

Additional information is available on the DCAP website:
http://www.co.delaware.ny.us/depts/h2o/dcap.htm (Verified September 27, 2007)

Catskill Watershed Corporation

The Catskill Watershed Corporation (CWC) is a not-for-profit local development corporation with a dual goal: to protect the water resources of the New York City watershed west of the Hudson River, while preserving and strengthening communities located in the region. The CWC was formed in January 1997 with the signing of the New York City Memorandum of Agreement between City, State, federal, local and environmental entities. To help offset the costs and restrictions of increased regulations and land purchases by the city, CWC is charged with developing and implementing several city-funded programs including residential septic rehabilitation, replacement and maintenance, community wastewater management, planning and installation of stormwater controls, road salt storage, public education and economic development. CWC also consults on recreational uses of city lands, tax assessment issues, and wastewater treatment plants planned for several watershed communities. These programs are intended to protect the quality of the water which sustains 9 million residents of New York City and its suburbs, while at the same time preserving and strengthening the rural communities within the 5-county Catskill and Delaware Watersheds. Further information is available on the CWC website: www.cwconline.org (Verified September 27, 2007).

Conservation Reserve Enhancement Program

On August 26, 1998, New York City entered into a Memorandum of Agreement (MOA) with the United States Department of Agriculture (USDA) and New York State to implement a Conservation Reserve Enhancement Program in the Catskill and Delaware Watersheds. This MOA allows watershed landowners to enter into 10 to 15 year contracts with the USDA to retire environmentally-sensitive agricultural lands from production. CREP helps establish forested or grass riparian buffers adjacent to watercourses and provides for fencing watercourses to exclude livestock. New York City helps offset costs for participating farms, technical and administrative assistance through its agreement with the Watershed Agricultural Council (WAC) located in Walton, New York. Most CREP implementation in the East Branch watershed consists of the establishment of riparian forest buffers through tree and shrub plantings and exclusionary livestock fencing, both of which are CREP priorities.

~ Glossary ~

NOTE: Italicized words within a definition are defined elsewhere within this glossary.

aggradation (aggrading) – A progressive build-up or raising of the channel bed and *floodplain* due to *sediment* deposition. The geologic process by which streambeds are raised in elevation and *floodplains* are formed. Aggradation indicates that stream *discharge* and/or *bedload* characteristics are changing.

aquatic habitat – Physical attributes of the stream channel and *riparian area* that are important to the health of all or some life stages of fish, aquatic insects and other stream organisms. Attributes include water quality (temperature, pH), *riparian* vegetation characteristics (shade, cover, density, species), stream bed *sediment* characteristics, and *pool/riffle* spacing**.**

bankfull depth – The depth from the elevation of water surface at the *bankfull discharge* to the deepest point in the channel.

bankfull discharge – The discharge (or flow) that occurs, on average, every 1.2 to 2.0 years. This discharge, from relatively frequent storms, is largely responsible for the shape of the stream channel within the *floodplain*.

bankfull width – The width of the water surface at the *bankfull discharge*.

base flood elevation – The height of the base flood, usually in feet, in relation to the National Geodetic Vertical Datum of 1929, the North American Vertical Datum of 1988, or other datum referenced in the Flood Insurance Study report, or average depth of the base flood, above the ground surface.

bedload – *Sediment* moving on or near the streambed and transported by jumping, rolling or sliding on the bed layer of a stream.

berm – A mound of earth or other materials, usually linear, constructed along streams, roads, *embankments* or other areas. Berms are often constructed to protect land from flooding or eroding, or to control water drainage (as along a road-side ditch). Some berms are constructed as a byproduct of a stream management practice whereby stream bed *sediment* is pushed out of the channel and mounded on (and along the length of) the stream bank - these berms may or may not be constructed for flood control purposes; some are simply piles of excess material. These berms often interfere with other stream processes such as *floodplain* function, and can exacerbate flood-related *erosion* or stream *instability*.

boulder – In the context of *stream assessment surveys*, a boulder is stream *sediment* that measures between 256 mm and 4096 mm (about 10 inches to 13.3 feet).

braided – A stream form in which the channel splits into 3 or more separate sub-channels, often crisscrossing to produce a "braided" pattern of connected channel with large or small islands between them. Islands formed between the channels can be either bare *gravel* or *cobble* materials, or contain mature forest vegetation.

channel-forming flow – see *bankfull discharge*

clay – Clay is the smallest *sediment* size present in a stream, measuring less than 0.0039mm in size. Clay can be identified by its smooth and slippery texture. Clay deposits can be seen in sections of the stream, and can produce *turbidity* in stream water when it is disturbed either during floods or by activity in the stream.

cobble – In the context of *stream assessment surveys*, cobble material is *sediment* that measures between 64 mm and 256 mm (about 2.5 inches to 10 inches).

cohesive - Soil types such as *clays* and *silts* that are held together owning to attraction between like molecules.

confluence – The location of the joining of two separate streams, each with its own *watershed*.

cross-section (see also monitoring cross-section) – In the context of *stream assessment surveys*, a *cross-section* is a location on a stream channel where stream *morphology* is measured perpendicular to the *stream flow* direction (as if taking a slice through the stream), including width, depth, height of banks and/or *terraces*, and area of flow.

culvert – A closed conduit for the free passage of surface drainage water (Lo, 1992). Culverts are typically used by the Town and County to control water running along and under the road, and to provide a crossing point for water from road side drainage ditches to the stream, as well as for routing *tributary* streams under the roads. Culverts are also used by landowners to route roadside drainage ditch water under their driveways to reduce or prevent *erosion*.

degradation (degrading) – The process by which a stream *reach* or channel becomes deeper by eroding downward into its bed over time, also called "downcutting", either by periodic episodes of bed scouring without filling, or by longer term transport of *sediment* out of a *reach* without replacement.

demonstration stream restoration project, (demonstration project) – A *stream (stability) restoration* project that is designed and located to maximize opportunities for *monitoring* of project success, public and agency education about different *stream restoration* techniques, and interagency partnerships for funding and cooperation.

discharge (stream flow) – The amount of water flowing in a stream, measured as a volume per unit time, usually cubic feet per second (cfs).

embankment – A linear structure, usually of earth or *gravel*, constructed so as to extend above the natural ground surface (Lo, 1992). Similar to a *berm*, but usually associated with *road fill* areas, and extending up the hillside from the road, or from the stream up to the road surface.

emergent (wetlands) – A type of wetland dominated by erect, rooted, herbaceous, water-loving plants. Examples of emergent wetland plants include certain grasses, sedges, rushes and cattails. Such areas are also known as "marshes," or sometimes called "swamp pasture" by the farming community.

entrenched – In stream classification (see s*tream type*), entrenchment (or entrenchment ratio) is defined by stream *cross-sectional* shape in relation to its *floodplain* and valley shape, and has a specific numerical value that in part determines *stream type*. For example, if this number is less than 1.4, the stream is said to be highly entrenched, if between 1.4 and 2.2 it is mildly entrenched, and greater than 2.2 it is not entrenched. Entrenchment ratio is used with other stream shape data to determine *stream type*, and define baseline data for future *monitoring* (Rosgen, 1996).

equilibrium (see also "stable") – The degree to which a stream has achieved a balance in transporting its water and *sediment* loads over time without *aggrading* (building up), *degrading* (cutting down), or migrating laterally (eroding its banks and changing course).

erosion – The wearing away, detachment, and movement of the land surface (*sediment*), by running water, wind, ice, or other geological agents, including such processes as gravitational creep or *slumping* (New York Guidelines for Urban Erosion and Sediment Control, 1972). In streams, erosion is a natural process, but can be accelerated by poor stream management practices.

evapotranspiration – the process of transferring moisture from the earth to the atmosphere by evaporation of water and transpiration from plants. **(**http://dictionary.reference.com/browse/evapotranspiration**,Verified September 27, 2007)**

exotic plant – see *invasive plants*

floodplain – The portion of a river valley, adjacent to river channel, which is covered with water when river overflows its banks at flood *stage*. The floodplain usually consists of *sediment* deposited by the stream, in addition to *riparian* vegetation (Rosgen, 1996). The floodplain acts to reduce the *velocity* of floodwaters, increase infiltration (water sinking into the ground rather than running straight to the stream - this reduces the height of the flood for downstream areas), reduce stream bank *erosion* and encourage deposition of *sediment*. Vegetation on floodplains greatly improves their functions.

Geographic Information System (GIS) – Desktop software with a graphical user interface that allows loading and querying, analysis and presentation of spatial and tabular data that can be displayed as maps, tables and charts (ArcView GIS, 1996). The maps in the East Branch Delaware River Stream Corridor Management Plan were produced with GIS, and can be updated as new information becomes available.

Global Positioning System (GPS) – A satellite–based positioning system operated by the U.S. Department of Defense (DoD). When fully deployed, GPS will provide all-weather, worldwide, 24-hour position and time information (GPS Pathfinder Office: Getting Started Guide, 1999). The *stream assessment survey* done for the East Branch Delaware River Stream Corridor Management Plan included the use of a GPS unit to document the locations of all mapped stream features. This information was added to the *GIS* to produce the maps.

gravel – In the context of *stream assessment survey*, *gravel* is *sediment* that measures between 2 mm and 64 mm (about 0.08 inches to 2.5 inches).

head-cut – A marked change in stream bed slope, as in a "step" or waterfall, that is unprotected or of greater height than the stream can maintain. This location also referred to as a "knick point", moves upstream, eventually reaching an *equilibrium* slope.

imbricate - Having the edges of bed material overlapping in a regular arrangement like roof tiles or the scales of a fish. Rocks in a riverbed often end up leaning on each other, their tips pointing downstream in an imbricated pattern.

instability (see also "unstable") – An imbalance in a stream's capacity to transport *sediment* and maintain its channel shape, pattern and profile.

incised – *Erosion* of the channel by the process of *degradation* to a lower base level than existed previously or is consistent with the current hydrology.

invasive plants – Non-native species that are able to compete with and replace native species in natural habitats, also referred to as "exotic" plants.

Japanese knotweed (see also invasive plants) – An *invasive plant*, not native to the Catskill region, that colonizes disturbed or wet areas, especially stream banks, road-side ditches and *floodplains*. This plant out-competes natives and other beneficial plants, and may contribute to *unstable* stream conditions.

left bank – The left stream bank as looking or navigating downstream. This is a standard used in *stream assessment surveys*.

matrix – The framework material within which other materials are lodged or included. For example, *cobbles* could be embedded in a matrix of *sand* and fine *gravel*.

meander – Refers both to a location on a stream channel that is curved (a "meander bend"), and to the process by which a stream curves as it passes through the landscape (a "meandering stream").

monitoring – The practice of taking similar measurements at the same site, or under the same conditions, to document changes over time.

monitoring cross-section – For the purposes of the East Branch Delaware River Stream Corridor Management Plan, this is a location where metal rebar rods have been used to permanently locate an actively eroding stream bank. At this site, detailed data have been gathered to document the stream condition. The site is permanently marked to enable future measurements that, when compared to the existing condition, provide information about the stream's change. Measuring change over time is considered '*monitoring*,' and this information provides early warning to stream managers about important but perhaps visually imperceptible changes in the stream.

monumented – Refers to a location, usually a *cross-section*, that is marked with a permanent or semi-permanent marker, or "monument", to enable future *monitoring* at the same place.

morphology, stream morphology – The physical shape, or form, of a landscape or stream channel, that can be measured and used to analyze stream or landscape condition, type or behavior.

morphometry - The quantitative measurement of the form especially of living systems, such as watershed and its stream network.

nutrient – The term "nutrients" refers broadly to those chemical elements essential to life on earth, but more specifically to nitrogen and phosphorus in a water pollution context. In a water quality sense nutrients really deals with those elements that are necessary for plant growth, but are likely to be limiting – that is, where used up or absent, plant growth stops.

physiography – The physical features of the earth's surface, including landforms, currents of the atmosphere and climate, ocean and distribution of flora and fauna or the general "look" of the land.

planform – The general shape and layout of the river as viewed from above.

pool – A small section of stream characterized by having a flat or nearly flat water surface compared to the average *reach* slope (at low flow), and deep and often asymmetrical *cross-sectional* shape.

reach – A section of stream with consistent or distinctive *morphological* characteristics (New York Guidelines for Urban Erosion and Sediment Control, 1972).

reference reach, stable reference reach – A *stable* portion of a stream that is used to model restoration on an *unstable* portion of stream. Stream *morphology* in the reference reach is documented in detail, and that *morphology* is used as a blueprint for design of a *stream stability restoration* project.

revetment – Any structural measure undertaken to stabilize a road *embankment*, stream bank or hillside.

riffle – A small section of stream characterized by having a steep water surface slope compared to the average *reach* slope (at low flow), and a shallow and often uniform *cross-sectional* shape.

right bank – The right stream bank as looking or navigating downstream. This is a standard used in *stream assessment surveys*.

riparian (area, buffer, vegetation, zone) – The area of land along stream channels, within the valley walls, where vegetation and other land uses directly influence stream processes, including flooding behavior, *erosion*, *aquatic habitat* condition, and certain water quality parameters.

rip-rap – Broken rock, *cobbles*, or *boulders* placed on earth surfaces, such as a road *embankment* or the bank of a stream, for protection against the action of water; materials used for soil *erosion* control (New York Guidelines for Urban Erosion and Sediment Control, 1972).

rotational failure (translational failure) – A geotechnical term referring to the shape and mechanism of a hillslope failure that results in a section of land surface that falls, or "fails", by rotating out of place along a curved plane surface (as opposed to sliding along a straight line or flat plane surface). This type of failure is common in the East Branch Delaware River valley, easily recognized by "back leaning" trees on displaced sections of the slope, separated by fault scarps (cracks in the ground surface perpendicular to the failure direction, also often curved) as these blocks of land rotate downward and outward.

runoff – The portion of precipitation (i.e., rainfall) that reaches the stream channel over the land surface.

sand – In the context of *stream assessment surveys*, sand material is *sediment* that measures between 0.063 mm and 2 mm (up to 0.08 inches).

sediment, stream bed sediment – Material such as *clay*, *sand*, *gravel* and *cobble* that is transported by water from the place of origin (stream banks or hillsides) to the place of deposition (in the stream bed or on the *floodplain*) (Lo, 1992).

sediment discharge – The combination of *washload* plus *bedload* material.

silt – In the context of *stream assessment surveys*, silt material is *sediment* that measures between 0.0039 mm and 0.063 mm.

sinuosity – The ratio of channel length to direct down-valley distance. Also may be expressed as the ratio of down-valley slope to channel slope.

slump – The product or process of mass-wasting when a portion of hillslope slips or collapses downslope, with a backward rotation (also a rotational failure).

stable (see also equilibrium) – A stable stream is defined as maintaining the capacity to transport water and *sediment* loads over time without *aggrading* (building up), *degrading* (cutting down), or migrating laterally (eroding its banks and changing course). Stable streams resist flood damage and *erosion*, and provide beneficial *aquatic habitat* and good water quality for the particular setting.

stability – In stream channels, the relative condition of the stream on a continuum between *stable* (in *equilibrium* or balance) and *unstable* (out of *equilibrium* or balance). Stream stability assessment seeks to quantify the relative *stability* of stream *reaches*, and can be used to rank or prioritize sections of streams for management.

stacked rock wall – A *boulder revetment* used to line stream banks for stabilization. Stacked rock walls can be constructed on a steeper angle that *rip-rap*, so they take up less of the stream *cross-section*, provide a wider road surface, and provide less surface area for solar heating, allowing stream temperature to remain cooler relative to banks lined with *rip-rap*. These features can be augmented with bioengineering to enhance *aquatic habitat* and *stability* functions.

stage – In streams, stage refers to the level or height of the water surface, either at the current condition (i.e., current stage), or referring to another specific water level (i.e., flood stage).

stream assessment, stream assessment survey – The methods and summary information gathered in a stream *reach* or series of *reaches*, primarily focused on stream *morphology*. Stream assessment for the East Branch Delaware River included detailed characterization and mapping of stream channel patterns, *cross-section* shapes and slope.

stream flow (*discharge*) – The amount of water flowing in a stream, measured as a volume per unit time, usually cubic feet per second (cfs).

stream stability restoration (design, project) – An *unstable* portion of stream that has been reconstructed, using *morphology* characteristics obtained from a *stable reference reach* in a similar valley setting, that returns the stream to a *stable* form (that is, to a shape that may allow the stream to transport its water and *sediment* load over time without dramatic changes in its overall shape).

stream type – As defined by Rosgen (1996), one of several categories defined in a stream classification system, based on a set of delineative criteria in which measurements of channel parameters are used to group similar *reaches*.

terrace – A level area in a stream valley, above the active *floodplain*, that was deposited by the stream but has been abandoned as the stream has cut downward into the landscape.

These areas may be inundated (submerged) in higher floods, but are typically not at risk in more common floods.

thalweg – The line followed by the majority of the *stream flow* (New York Guidelines for Urban Erosion and Sediment Control, 1972). In *stream assessment*, this location is used as a reference location for surveys and other measurements, and is most often associated with the deepest point in the stream *cross-section* (i.e., the stream channel that would still have water flowing in it at even the lowest flow conditions).

toe – The bottom, or base, of a stream bank or *embankment*.

tributary – A stream that feeds into another stream; usually the tributary is smaller in size than the main stream (also called "mainstem"). The location of the joining of the two streams is the *confluence*.

turbidity – A measure of opacity of a substance; the degree to which light is scattered or absorbed by a fluid. Streams with high turbidity are often referred to as being "turbid".

unstable (see also instability) – Describing a stream that is out of balance in its capacity to transport *sediment* and maintain its channel shape, pattern and profile over time.

washload – The finest-grained fraction of the total *sediment* load, consisting of particles whose settling *velocity* are so low that they are transported in suspension at approximately the same speed as the flow and only settle out when flow *velocity* are much reduced.

watershed – A unit of land on which all the water that falls (or emanates from springs) collects by gravity and runs off via a common outlet (stream) (Black, 1991).

waters of the United States

1. All waters which are currently used, or were used in the past, or may be susceptible to use in interstate or foreign commerce, including all waters which are subject to the ebb and flow of the tide;
2. All interstate waters including interstate wetlands
3. All other waters such as intrastate lakes, rivers, streams (including intermittent streams), mudflats, sandflats, wetlands, sloughs, prairie potholes, wet meadows, playa lakes, or natural ponds, the use, degradation or destruction of which could affect interstate or foreign commerce including any such waters:

    - Which are or could be used by interstate or foreign travelers for recreational or other purposes; or
    - From which fish or shellfish are or could be taken and sold in interstate or foreign commerce; or
    - Which are used or could be used for industrial purpose by industries in interstate commerce;

1. All impoundments of waters otherwise defined as waters of the United States under the definition;
2. Tributaries of waters identified in paragraphs (1)-(4) of this definition;
3. The territorial seas;
4. Wetlands adjacent to waters (other than waters that are themselves wetlands) identified in paragraphs (1)-(6) of this section.

wetland – An area that is saturated by surface water or ground water with vegetation adapted for life under those soil conditions, as in swamps, bogs, fens, and marshes.

velocity – In streams, the speed at which water is flowing, usually measured in feet per second.

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