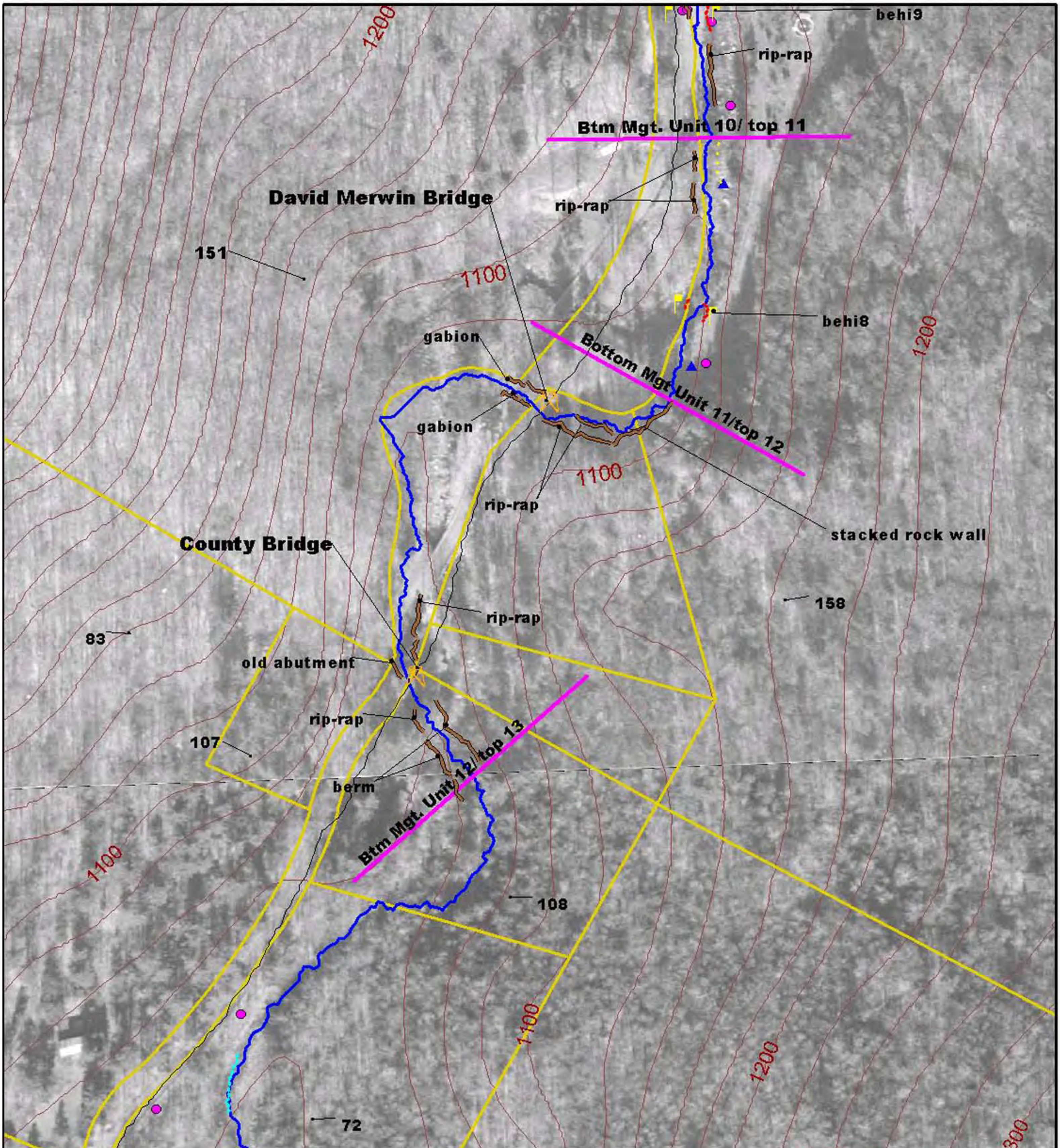

GIS Parcel and Wetland coverages are edited and provided by NYC DEP, 2000, UTM NAD 27, Zone 18 North, meters. Aerial Photography provided by UCSWCD & NYC DEP November 2001. All other coverages were developed using GPS in the UTM, Zone 18 North projection, NADCON (Conus), datum. GPS data collected 2001, by UCSWCD & NYC DEPSMP.

Note: G.I.S. data are approximate according to their scale and resolution. Data may be subject to error and are not a substitute for on-site inspection or survey. Parcel coverages are based on Ulster County Real Property tax maps 2000 and may not reflect actual surveyed property boundaries.

Broadstreet Hollow Management Unit 12

Contour Interval 20 feet

50 0 50 100 150 200 Feet

Scale 1:2,400

LEGEND

247 Street Address/911 code
Greene parcels
Ulster parcels
Land fills
Managment units
Stream Center (Thalweg)
Culvert
Wetland
Clay exposure
Revetment
Eroding bank
Tributary
Behi pin
Bridge
Broadstreet Hollow Road
Knotweed

Broadstreet Hollow Management Unit 12

General Description:

Management Unit 12 (MU12) begins about 200 feet upstream of the David Merwin bridge (County Bridge 2-22457-0) and extends approximately 1130 downstream, including the new County Bridge (3-34671-0, replaced in 2001) and about 170 feet of stream below it, just upstream of the property at 108 Broadstreet Hollow Road [1&2] (Photo 1). The bridges and associated stream bank stabilization and hardening work, or *revetments*, on both banks, dominate the character of the stream upstream and downstream ends of this unit. The middle portion runs away from Broadstreet Hollow road, and contains a section of split channel with center islands in fairly good condition, or *stable* (Photo 2).

Photo 1. Looking upstream into the top of MU12.

Photo 2. Looking upstream toward the split channel reach in MU12, note the well-vegetated center island, with large trees, and coarse boulder structure of the stream bed.

The structural shape, or *morphology*, of the stream (i.e., slope, width and depth) shifts in this unit, creating smaller sections, or *reaches*, with discrete morphologic character, or *stream type*[5]. The valley in MU12 is fairly narrow throughout compared with other units, with steep, close valley walls on the west side (the right bank looking downstream). In sections near the road, or where stream bank work has been done, the stream is somewhat confined, producing a predominantly *entrenched* stream shape, whereas the center section has more space in which to bend, or meander, inside the valley walls.

Photo 3. Looking upstream from the bottom of MU12, County Bridge 3-34671-0 in background.

This unit may be more vulnerable to disturbance in the vicinity of the bridges than a section of stream that is less crowded by its valley.

Typically stable stream types associated with this type of valley are relatively narrow, with riffles and pools, and stream banks formed into low benches, or *discontinuous floodplains*, that function as overflow areas during floods and provide areas for healthy streamside, or *riparian*, vegetation. Less steep areas with more floodplains have more space in which to maintain a stable shape, and better riparian vegetation to stabilize the banks and provide other habitat benefits[5&7]. MU12 maintains some of these discontinuous floodplain bench features, even in the entrenched sections, excepting in areas with intensive revetments [5] (Photo 3).

I. Flooding and Erosion Threats

A. Infrastructure, and Private Property

There are six properties (land parcels) associated with MU12; Five parcels contain or are bounded by the stream. There is one house between the road and the stream, at the bottom of the unit, and one house between the stream and the valley wall at the top of the unit. Both houses are accessed from the main Broadstreet Hollow road, with no private bridge crossings[1&2].

Stream assessment data for 2001 show the centerline of Broadstreet Hollow Road ranges from 0 (at bridge crossings) to 180 feet from the deepest part of the stream, or *thalweg*. Two bridges provide a road crossing in this unit, County Bridge 2-22457-0 (the "David Merwin" bridge) and County Bridge 3-34671-0[1&3].

<u>MU12 Bridges and Associated Stream Work:</u>

David Merwin Bridge 2-22457-0:

The span under the David Merwin Bridge appears to be appropriately sized to match the natural stream channel dimensions in this reach (Photo 4). The bridge span (measured in the field during the stream assessment in 2001) is approximately 40 feet between the old concrete abutments, and 48 feet between the newer abutments, compared to the average natural stream channel width upstream from the bridge location of approximately 42 feet.

Photo 4. Looking upstream toward County bridge 2-22457-0. Willows just downstream from the bridge (at the left) may help prevent further bank and stream bed erosion, while allowing the passage of water through them during floods.

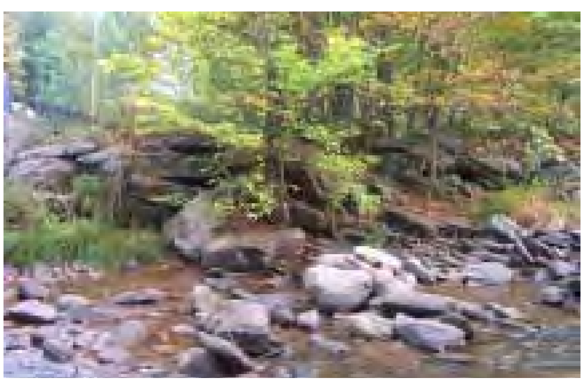

Photo 5. Boulder rip-rap on the right bank, just upstream from the David Merwin bridge. Stream flow is from right to left.

Rip-rap on both banks upstream from the David Merwin Bridge is in fairly good condition, showing little evidence of undercutting or potential failure, partially owing to the low slope and short banks they protect, as well as the presence of large trees between the rocks, which help maintain stability (Photos 5 and 6).

Additionally, both of these areas were constructed by stacking the boulders in addition to piling them along the bank, which lends structural stability to the rip-rap and lengthens its design life, perhaps even creating stable enough conditions to encourage the development and growth of some riparian shrubs and trees in the structure[7].

Photo 6. Large boulder rip-rap on left bank, just upstream from the David Merwin bridge. Stream flow is from left to right. Note partially stacked structure increases rip-rap stability.

The section of stream just downstream from the bridge, however, is too narrow compared to the natural sustainable width of the stream, at approximately 26 feet, creating an unstable stream type.

Additionally, there is a short waterfall, or "step", just below the bridge as the stream enters this artificially narrow section. This type of step feature has the tendency to continue to erode, moving the step upstream, or *headcutting*, as the stream cuts into its bed. In this particular reach, the step is associated with an overly narrow section of stream channel, creating constriction of flow during floods, which artificially raises the flood level, or stage, creating even greater erosive potential[3&5]. Shrub willows in this reach, just downstream from the bridge (Photo 7, and see Photo 4), may help prevent further erosion by breaking up stream energy. Small willows such as these also allow floodwaters to pass through them easily, being quite flexible, and do not typically allow large wood to hang up in them causing debris jams. Small, low-growing shrub willow species should be used in settings such as this to improve stream bank and bed stability without causing undue flood flow constriction[7].

Photo 7. Gabion basket stream bank revetment, with willows upstream on right bank just downstream from the David Merwin Bridge, with minor "eddy erosion" on the downstream edge. Stream flow is from right to left.

Sixty feet (3%) of bank below the bridge, in two sections (one on each bank), has been reinforced by large wire-mesh baskets filled with rock material or *gabions* [2&3] (see Photos 7 and 8). Unfortunately, gabion revetment is not typically recommended in a stream setting like the Broadstreet Hollow, especially where stream energy is high, because the action of cobbles and boulders in transport, or *bedload*, can

Photo 8. Looking upstream, gabions on left bank, downstream of David Merwin County Bridge 2-22457-0.

destroy the baskets, smashing and breaking the wires, releasing rock material inside.

Broadstreet Hollow stream can transport very large rocks, or *sediment*, along the stream bed. The size of sediment used to fill the wire baskets is often smaller than the bedload, so when they break open, the sediment simply washes downstream, providing no bank protection[3&8].

County Bridge 3-34671-0:
The span under County Bridge 3-34671-0, just upstream from 108 Broadstreet Hollow Road and rebuilt in 2000, is less than 30 feet, compared to the average natural stream channel width both upstream and downstream from the bridge location of between 40 and 50 feet (see Photo 3). Additionally, due to the valley and road configuration, this bridge was built at an angle to accommodate the road direction. The result is that the stream is directed into the right abutment (looking downstream) during high flow, possibly increasing potential for bridge structural instability and stream bed scour over time. Because sheet piling was used primarily in bridge abutments and wing walls (extending along the stream banks upstream and downstream from the primary bridge structure), the bridge is probably not threatened. Stream banks at the margins of sheet piling may be at greater risk for increased erosion. Though sheet piling may be necessary where space is limited.

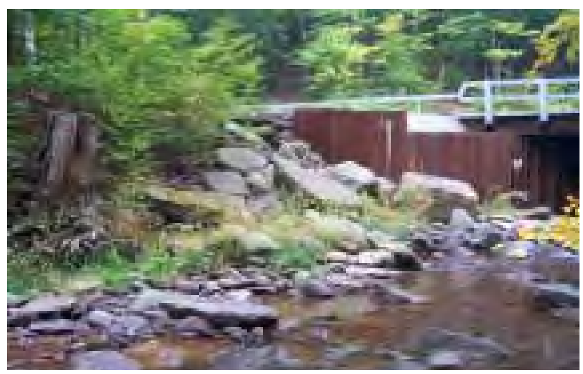

Photo 9. Looking upstream toward rip-rap and sheetpiling (bridge wing wall) along downstream from County Bridge #3346710. Stream flow is from right to left.

Sheet piling, or other bank hardening materials, tends to act to accelerate water over its relatively smooth surface (compared to a bank covered with trees and small shrubs). A transition between a hardened area of stream bank and a "softer" area tends to produce erosion, especially if the banks are disturbed or unprotected by vegetation, which is often the case following stream bank or bridge work. Stream banks on both sides, both upstream and downstream from the bridge, have some combination of additional hardening, primarily in the form of boulder rip-rap (Photo 9, and see photos and further discussion below). Despite this, these banks and bank areas flanking the rip-rap, would at a minimum benefit from additional vegetation[7], or *bioengineering*, to increase and preserve bank stability and other benefits of a healthy streamside, or *riparian* area[3& 8].

Approximately 280 feet, or 13% of the stream banks in MU12, have been rip-rapped with a mix of dumped and partially stacked boulders and concrete blocks, primarily along the banks associated with both bridges. This type of revetment comprises the greatest length of hardened stream bank MU12. Generally, this type of revetment in MU12 is low gradient and typically on low banks, so it doesn't have to hold a high, steep slope and may be more resistant to slumping or failure. However, these areas often do not have toe rocks (at the base of the slope in the stream bed) that are "keyed in", or anchored with additional boulders buried into the stream bed. The result is a higher potential for the stream to cut into the finer sediments below these boulders, causing them to be undermined and potentially leading to failure of individual boulders or entire sections of rip-rap.

This appears to be occurring in the rip-rap section on the left just upstream from County bridge 3-34671-0, where much of the slope above and behind the rip-rap boulders is falling into the stream, and the rocks at the toe (base) of the slope are sliding downward out from under the rest, *destabilizing* the entire wall (Photo 10). This slope is also the highest and steepest in the unit, so would experience the greatest potential for erosion.

Photo 10. Partially failing rip-rap along left bank, just upstream of County Bridge 3-34671-0. Stream flow is from left to right.

Photo 11. Looking upstream from just above County Bridge 3-34671-0. Steep valley wall to the left, Broadstreet Hollow Road fill and rip-rap bank to the right.

Additionally, this reach of stream in MU12 runs against the steep valley wall opposite the road, so greater stream energy will be focused in this section during flood events (Photo 11).

The combination of flow constriction at the bridge and similar rip-rap configuration against the bank downstream of the bridge may make this section of rip-rap vulnerable to the same undercutting process, though this section isn't constructed on such a steep angle, and appears to contain much larger boulders, so this area may be able to resist eddy scour on the bank and rip-rap failure into the stream bed [3&8] (see Photo 9).

In addition to bank hardening, constriction at a bridge can cause water to back up during floods, which can lead to increased erosion both upstream and downstream of the bridge. Constriction raises flood stage upstream of the bridge, increasing the risk of inundation of the road, and producing conditions, which cause water to swirl, or *eddy*, behind it. As water then rushes through the bridge opening, under increased pressure due to the increased elevation of the water surface upstream, it can also eddy around the banks just downstream causing similar bank erosion conditions[3&5].

The *berm* on the left bank just downstream from the bridge, appears to be material pushed up onto the banks in response to 1996 flood damages in the vicinity of County bridge 3-34671-0 [3] (Photo 12). This practice of "cleaning" the gravel out of a stream in this way is thought to increase flood capacity by creating a larger stream channel, but in this case acts to further constrict flow and potentially increase eddy scour bank erosion downstream from the bridge. Unfortunately, berms such as these also generally do not offer any protection from flooding (inundation) due to their short length, and can cause stream

Photo 12. Looking upstream at cobble berm along left bank, downstream of County Bridge #3346710. Stream is to the left.

entrenchment and higher flood stage locally by preventing floodwaters from flowing over the floodplain, cutting off an important function of these flat areas. In addition, increased flood stage and flow concentration, with higher banks formed by the berm, can encourage erosion of berm material, delivering it back into the stream channel to wash downstream.

Floodplains reduce flood velocity, increase absorption of floodwaters, encourage deposition of silt and fine sediments (keeping them from being washed further downstream) and decrease flood stage, or height, in downstream areas. The majority of Broadstreet Hollow stream floodplains consist of small, low, discontinuous floodplain benches that perform the important floodplain functions in small mountain streams. Because MU12 is particularly entrenched and confined in the vicinity of both bridges, with little floodplain storage in these areas, removal or restructuring of this berm should be considered to add floodplain function to this area[3].

This bridge and/or the stream channel upstream and downstream, will likely have maintenance problems over time, unless it is reconstructed to accommodate the natural width of the stream[8]. Addressing stream bank stability separate from amending the bridge will likely only offer a temporary fix, though increased vegetative stabilization may reduce ongoing maintenance problems.

B. History of Stream Work

Landowners for this reach have expressed concerns about flooding, flood damage to homes and property, and streambank erosion. Infrastructure maintenance of Broadstreet Hollow Road and the bridges in MU12 have included a variety of bank hardening techniques, resulting in approximately 730 feet, or 34%, of altered or hardened stream banks in MU12 [3] (Table 1). Most of this work is associated with bridge construction or maintenance, discussed above.

Table 1. Altered Banks*Broadstreet Hollow MU12[2].
*based on linear feet of both sides of stream bank.

Revetment Type	Length (feet)	Percent of Unit
rip-rap	280	13
berm	205	9
stacked rock wall	115	5
gabions	60	3
cemented rock wall	35	2
sheet pile	35	2
Total Revetment	**730**	**34%**

Photo 13. Looking upstream at right bank boulder berm, just downstream from County Bridge 3-34671-0.

The berm area directly across the stream from the berm associated with County Bridge 3-34671-0, on the right bank downstream from the rip-rap area just below the bridge, is at 108 Broadstreet Hollow Rd, and was not constructed in association with the bridge [1] (Photos 13 and 14 also see rip-rap in Photo 9).

The house is up on the hillside, between the road and the stream. The stream splits just above this property, and one of the side channels has eroded into the hillside, threatening streamside improvements constructed by the landowner. This berm is constructed primarily of boulders and cobble material, with some large wood, for the purpose of prevention of flood inundation and erosion protection for this property at the base of the hillside below the house and lawn area. The berm is designed to deflect water away from this side channel, downstream in the main channel, away from the hillside.

During low flow and some low magnitude floods, the berm is probably effective, keeping water from flowing over the surface and into the side channel along the toe (base) of the hillside. Unfortunately, during higher floods the berm will inevitably overtop. Flood waters cascading down the other side of the berm will be falling from a much greater height than they would have done without the berm present, and will therefore have much greater erosive power. In this way, this berm may cause even greater damage to both the hillside and the berm itself in larger floods.

Photo 14. Back side of boulder/debris berm at 108 Broadstreet Hollow Road property, stream to the right.

The solution to the flood damage problems in this reach may not be simply to build a taller berm – conceivably, eventually there would be a large enough flood to overtop it. Rather, remediation in this reach should include an assessment of the stream channel pattern and evolution, the function of the split channels, and provision for some way to allow water to flow near the hillside without eroding or scouring at the toe (base) of the hillside and threatening structures or property values. This could be accomplished with a combination of some stream channel reconstruction, including removal or restructuring of berms on both banks below the bridge, provision of additional floodplain bench areas along stream banks on the hillside, and intensive re-vegetation, or bioengineering, to improve longer-term structural stability of the hillside [3,5,7 & 8].

A stacked rock wall has been constructed along 115 feet, or 5%, of the stream bank in MU12, in one section on the left bank at the top of the unit, around the outside of a meander bend [1] (Photo 15). The embankment above this revetment is very steep, though appears not to be slumping or eroding, and has dense grass and small shrub vegetation. By using a stacked rock wall, existing stream morphology has been preserved, and road width maintained, with a minimum of disturbance to the stream bed in this area.

Photo 15. Looking upstream at left bank stacked rock wall, at the top of MU12. Private drive at the top of the bank.

Augmenting stacked rock walls with *bioengineering*, or re-vegetation, should be considered to enhance riparian functions in these areas. Bare banks and un-vegetated rocks store heat from the sun, and can increase stream temperature by contact with stream flow and rain runoff. Though stacked rock walls produce less of a heating effect because they contain less surface area for the same degree of slope stabilization (i.e., they can hold an almost vertical slope), they still do not afford any shading to the stream or stream banks that keeps water temperatures low. Elevated aquatic temperatures may adversely affect water quality and stream ecology. Un-vegetated stacked rock wall in this reach should be "inter-planted" (planting small shrub species with small root systems between the rocks to provide some vegetative cover without compromising the structural integrity of the wall) with a mixture of native riparian species to improve shade and cover conditions for aquatic habitat, as well as to improve bank stability on the slope above the wall, and reduce the need for further bank stabilization work that causes stream ecosystem disturbances[7].

C. Exposed Banks

Stream assessment conducted in 2001 did not reveal any significant eroding or exposed banks that currently warrant extensive stabilization or monitoring. However, areas of localized bank erosion were noted associated with the ends of gabion-hardened banks and rip-rapped areas, as discussed above (Photo 16, and see Photos 7 and 10). Larger-scale erosion associated with the rip-rap on the left bank upstream from County Bridge 3-34671-0 could threaten the road, so should be visually inspected annually to detect any changes or ongoing instability. A section of stacked rock wall may be considered in this area, particularly with the close proximity

Photo 16. Left bank rip-rap and road fill erosion, upstream from County Bridge 3-34671-0, Broadstreet Hollow Road at the top of the bank. Stream flow is from left to right.

between the stream and the road, and the fact that this already narrow reach may put additional pressure on the bridge and adjacent stream banks. No monumented monitoring cross-sections have been installed to document the extent or rate of potential erosion[4].

II. Water Quality

A. Sediment

The stream assessment conducted in 2001 did not reveal any significant areas of bank erosion or *clay exposures* in MU12 that could contribute to water quality impairment from clay and silt, or *sediment*, sources. Localized eroding banks in the vicinity of rip-rap or other hardened bank areas could contribute amounts of silts and other sediment.

B. Landfills/Dumping Sites

Stream assessment conducted in 2001 did not reveal any current dumping sites in or near the stream in MU12 that could contribute to water quality impairment from leaching of toxic materials.

C. Other Water Quality Issues

Investigation of other possible sources of contamination was not part of the stream assessment conducted in 2001. However, no evidence was found for *nutrient* or *pathogen* contamination in the stream (i.e., odors or discolored water). Any runoff of water from the road or culverts (no culverts were documented in MU12 in 2001) that may contain salts or other pollutants was not specifically investigated. Compromised riparian buffer areas, particularly along rip-rap, gabions, stacked rock wall and bermed areas, could reduce the capacity of the stream banks to assimilate, or slow the input of, contaminants to the stream[7].

III. Stream Ecology

A. Aquatic habitat and populations

No specific aquatic habitat or population monitoring was conducted in MU12 as part of the stream assessment survey in 2001. However, as part of the stream restoration demonstration project completed in MU3 in 2000, fish and aquatic insect population data have been gathered yearly since 1998 within the stable reference reach (MU1), the project site (MU3) and the control reach (MU17). These data show the Broadstreet Hollow self-supports, without stocking, populations of all three common trout species (rainbow, brook and brown) as well as a healthy and diverse community of aquatic insects[9]. The impact that stream bed and/or bank instability has on these aquatic organisms or their communities in this unit is unknown.

B. Riparian Vegetation

Stream assessment conducted in 2001 did not investigate specific streamside (riparian) plant species or density condition, other than to note areas of insufficient or stressed vegetation that could affect stream stability, flooding or erosion threats, water quality or aquatic habitat for trout species. Based on these general observations, riparian vegetation throughout most of the middle portion of MU12 appears to be in good condition. Riparian vegetation in the vicinity of the bridges at the upstream and downstream ends of MU12, however, is insufficient to provide the full benefits of a healthy riparian zone. Under-vegetated areas discussed above should be vegetated with a mixture of native riparian species to improve shade, cover and water temperature conditions for aquatic habitat[7&9]. Vegetation will also improve bank stability and reduce the need for ongoing or future bank stabilization work that could cause or increase stream ecosystem disturbances[3].

No *Japanese Knotweed* [7], a non-native, *invasive* plant was noted in this unit at the time of the assessment survey, though source populations of this plant have been documented upstream, increasing the potential for colonization of any disturbed or under-vegetated areas in MU12.

[1]Broadstreet Hollow Management Unit 12 Map
[2] Volume II Appendix 3.1.5 Management Unit 12 Workbook.
[3] Volume II Section 2.2 Watershed Management Recommendations
[4] Volume II Section 2.2.1-Monitoring Cross Section and Summary Tables
[5] Volume I Sections 3.2.1&2 Stream Processes, Morphology and Classification
[6] Volume I Section 3.5 Fisheries and Wildlife
[7] Volume I Sections 3.4 & Volume II 2.2.2 Riparian Vegetation Issues and Recommendations
[8] Volume II 2.0 Stream Stability Restoration Projects, Techniques and Contact Information & Appendices
[9] Volume I Sections 3.4 & Volume II 2.2.2 Riparian Vegetation Issues and Recommendations
[10] Section 3.2.4.2 Broadstreet Hollow Geology