# Conine Stream Restoration Project

## *Design and Implementation Report*

***Town of Prattsville, Greene County, New York***

***December, 2007***

# *Project Partners and Contacts*

***New York City Department of Environmental Protection-Stream Management Program***
*71 Smith Avenue*
*Kingston, New York 12401*
*845.340.7628*
*Contact: Dave Burns*
*mailto:DBurns@dep.nyc.gov*

***Greene County Soil and Water Conservation District***
*907 County Office Building*
*Cairo, New York 12413*
*518.622.3620*
*Contact: Rene' Van Schaack*
*mailto:rene@gcswcd.com*
*www.gcswcd.com*

***Kaaterskill Associates***
*24 Joel M. Austin Road*
*Cairo, New York 12473*
*518.622.9667*
*Contact: Ewald Schwarzenegger, PE*
*www.keaeng.com*

## TABLE OF CONTENTS

## LIST OF FIGURES



## LIST OF TABLES



## APPENDICES

# 1.0 Project Background

**Upstream supply reach "Red Falls" during an event on September 18, 2004.**

The New York City Department of Environmental Protection (NYCDEP) initiated a regional study of water quality in the spring of 1993. The study focused on sub-basins in the West of Hudson (WOH) watershed and included identifying areas of concern and developing a comprehensive understanding of the sources and fate of materials contributing to turbidity and total suspended solids (TSS). The results of the study ranked the Batavia Kill sub-basin as producing the highest levels of turbidity and TSS. In 1996, a pilot project was initiated between the NYCDEP and the Greene County Soil and Water Conservation District (GCSWCD) in the watershed. The Batavia Kill Stream Corridor Pilot Project focused on using fluvial geomorphic-based stream classification, assessment and restoration principles in an attempt to reduce turbidity and TSS loading in the watershed.

A primary goal of the Pilot Project was to demonstrate the effectiveness of using fluvial geomorphic restoration techniques for reducing turbidity & TSS loading from in-stream sources. Goals of the project were further developed and refined throughout the progression of the project, and are summarized below:

- Evaluate and improve the effectiveness of natural channel design techniques in the Catskills, based on assessments of the physical and biological characteristics of the restoration sites paired with water quality monitoring.

- Evaluate and improve the effectiveness of geomorphic assessment indices and techniques for the identification of stability problems for use in multi objective restoration and planning.

- Evaluate the effectiveness of using stable reference reaches and regional relationships in the development of restoration designs.

- Conduct performance evaluations of the restoration projects, through monitoring and inspection, to document the status and stability of the demonstration projects. The results of performance evaluations can then be used to improve the future use of the design techniques.

- Develop design standards, typical details, construction specifications, and construction sequencing procedures, and operation and maintenance protocols for geomorphic-based restoration projects.

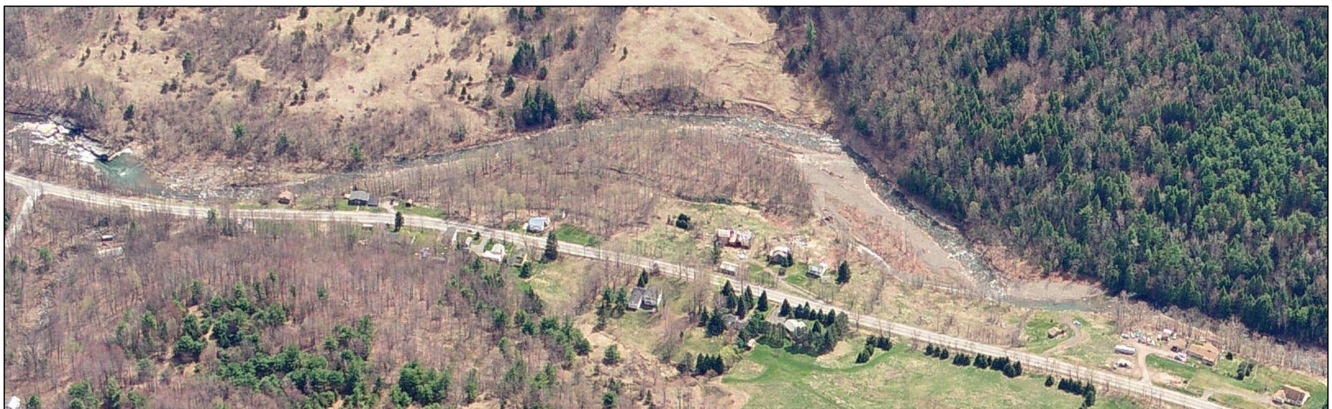
Three demonstration projects were implemented during the first phase of the project including the Big

Hollow, Brandywine and Maier Farm projects. The second phase of the project included the restoration of Ashland Connector reach in 2006, which joined the Maier and Brandywine reaches.

Inventories in 1997 identified sections of the Conine reach experiencing large-scale erosion and bank failure suspected to be negatively impacting water quality. The position of the channel and evidence of recent channel migration and excessive sedimentation through the reach indicated natural recovery was improbable in the near future. Annual surveys and assessments were initiated to quantify erosion risk, loading and characterize physical conditions in order to develop a trajectory for the reach. It is the intent of this report to summarize these assessments, and to document project objectives and constraints and propose a design to reduce channel and bank instability that ultimately will improve water quality.

## 2.0 Project Reach Setting

The Batavia Kill watershed is located in the northeastern limits of the Catskill Mountains located within the Appalachian Plateau physiographic province. The headwaters of the stream originate on the south slopes of Windham High Peak, Burnt Knob and Acra Point mountains, and the north slope of the Blackhead Range, which contains some of the highest elevations in the Catskills. The watershed is located entirely within Greene County in the Towns of Windham, Ashland and Prattsville. A portion of the watershed is located within the protected 700,000-acre Catskill State Park which includes a short section of the stream that carries a National Scenic River Designation from the United States Park Service.



**Aerial view looking south at Red Falls, upstream reach, and Conine project reach in 2006.**

The watershed is a sub-basin of the Schoharie Creek, and comprises approximately 30% of the Schoharie Reservoir drainage that is the northernmost reservoir in the Catskill/Delaware water supply system. Portions of flow from the Schoharie are diverted by means of a 19-mile underground tunnel discharging to the Esopus Creek near Phoenicia, and then flow naturally to the Ashokan Reservoir. The New York City water supply is unfiltered, and the NYCDEP operates its system under a Filtration Avoidance Determination (FAD) issued by the Environmental Protection Agency (EPA) and New York State Department of Heath (NYSDOH).

All waters of the State of New York are given a classification by New York State Department of Environmental Conservation (NYSDEC) based on the best usage of the waters. Streams with a use classification of C or higher may carry a sub-classification of (t) or (ts) to indicate the waters sustaining trout populations (t), and those which support trout spawning (ts). The main stem carries classifications ranging from A (ts) to C (t) indicating that the entire mainstem sustains trout populations and any activities in relation to the stream must be permitted. The NYSDEC Priority Waterbodies List (PWL) provides a broad assessment of water quality based on any known or suspected impacts to the best use classifications of state waters. The watershed is on the PWL, listed as impaired by sediment from erosion of streambanks, roads and construction that are impacting fish propagation.

The watershed contains three-flood control structures positioned on headwater streams in the upper watershed. These earthen structures were built in the late 1970’s to reduce water surface elevations through the hamlets in response to significant impact from the 1955 and 1960 storm events. These structures modify approximately 20 square miles of the project reaches 70 square mile drainage.

The project reach is located in the lower portion of the 23-mile long Batavia Kill mainstem in the Town of Prattsville. The project reach is located within a narrow "U" shaped valley containing steep side slopes with a moderately steep valley slope of approximately 1.3%. This morphology varies substantially from upstream sections of the Batavia Kill marked by a decrease in available valley bottom and floodplain, steeper valley and channel slopes, and reduced sinuosity. The Rosgen (1996) classification system uses geomorphic measurements including entrenchment, sinuosity, gradient, and width to depth ratio to classify and delineate river reaches for communication and comparison. Classification of project reach and upstream reaches indicate upstream segments are dominated by C4 type reaches, while the project reach classifies as F3, B3, and C3 types indicating a more entrenched channel form, dominated by larger cobble substrate. **Appendix A** contains a location map **(L-1)** containing topographic information and location along the profile Batavia Kill mainstem **(B-1)**.

Natural and cultural resources were inventoried as part of the assessment and design process including the presence of existing wetlands and historic resources in and near the project area. Field inventories in the fall of 2006 designated 1.2 acres of wetland within the area. These areas can be seen on **Map W-1 in Appendix A**, including a delineation report by Diversified Soil Services Inc. in **Appendix E.** Archeology investigations by Binghamton University were performed to inventory resources within the area and document any potential constraints on the stream restoration design. The inventory included a literature review and field investigation that determined a moderate prehistoric sensitivity and moderate historic sensitivity of the area. Field investigation identified no prehistoric materials and 19 pieces of historic material including a historic sawmill and tannery known as the B. Morss site. The site lies in the northern limits of the area near the Conine farm. A report including mapping has been provided in **Appendix C**.

### 2.1 Historic Aerial Photo Assessment and Channel Monitoring

Historic aerials from 1959, 1967, 1980, 1995 and 2004 were assessed to observe physical conditions of the reach including response and patterns in planform adjustment and trends in stream morphology. Historic storm events within the time period were evaluated to attempt to reveal trends in response to floods and major disturbances. Figure 1 displays the historic floods endured by the project reach in the last 100 years. Flows greater than the 10-year events are indicated by the red horizontal line and flow values corresponding with the time span of the aerial imagery are displayed. The figure describes significant events that occurred in 1960, 1980, 1987, 1996, 1999, and 2005. The aerial imagery is located in **Appendix A as Maps A-1-5**.

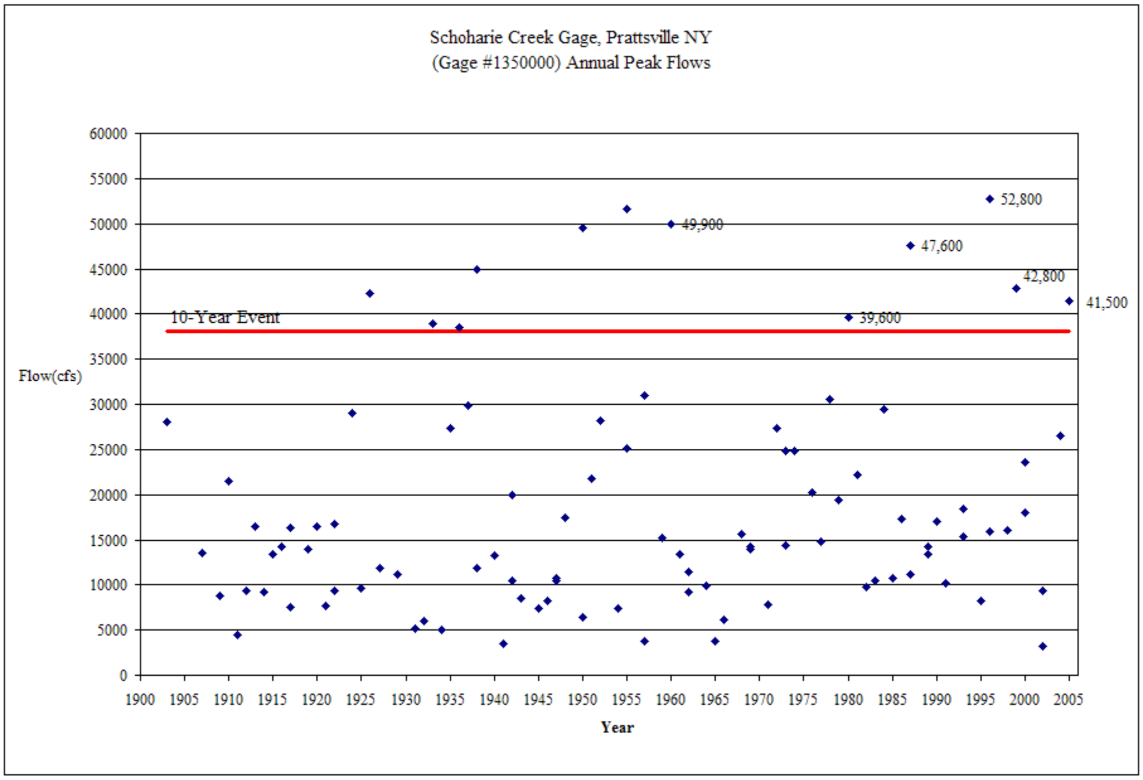



**Figure 1. Historic annual peak events at nearby Schoharie Creek at Prattsville (1903-2005).**

Annual monitoring from 1997-2000 of nine cross sections, streambed profile, and channel materials assisted in verifying more recent processes, erosion rates, and potential of the reach to naturally recover. Although the monitoring data provides a limited time span of 3 years, each year in the monitoring period an event above bankfull flow conditions occurred, as well as the major event associated with Hurricane Floyd in 1999 (16,800 cfs at the upstream Red Falls Gage).

Most notable from the assessments was the relative stability of the upper portion of the reach. Evaluation of aerial photos over the last 45 years revealed minimal changes in planform, sediment deposition and vegetative character within the first 1,600 feet of the reach below Red Falls. Monitoring of three monumented cross sections confirmed stability, documenting minimal bank erosion and no apparent change in channel bed invert and channel material. Stream typing of the reach characterized the reach as predominately C3, with short isolated sections of F3 type related to localized areas confined by remnant floodplain berming.


**Upstream reach displaying general stability.**

The lower portion of the reach has been more active historically, with significant change in meander pattern. Historic processes include down valley channel migration, channel avulsion and bank erosion and channel and floodplain sedimentation. Historically (1959 and 1967 aerial photography) a private bridge crossed the stream connecting the Conine Farm and agricultural fields on the southern hill slope. The 1980 aerial imagery indicates that the bridge span had been removed during the time period between 1967 and 1980. Although it is unconfirmed that a storm event removed the structure, it is apparent that the reach experienced significant down valley migration of the upstream meander and avulsion around the left bridge abutment. The 1980 image documents that flow became divided into two main threads in the area of the remnant bridge abutments which remain in place today. These lateral processes removed numerous trees and vegetation through the southern floodplain of the lower reach.

Evaluation of the 1995 and 2004 imagery confirmed migration processes have slowed, however monitoring surveys indicate that erosion continues along the outside of meanders against the high banks leading to continued bank instability and failure. Most evident from the 2004 aerial imagery is scarping on the southern hill slope, estimated over 100 feet above the existing streambed elevation. Monitoring cross sections in the area confirmed processes including degradation and headcutting of the stream channel along the high bank toe. It is suspected that this process will continue and increase bank instability and slope failure. Further, monitoring documented sedimentation of the northern floodplain partially filling the 1959 relic channel. At the bottom of the reach, the stream meanders back across valley floor into a moraine generating erosion of the northern high bank

Aerial imagery confirmed the riparian condition is relatively good on both sides of the stream with a well-forested floodplain and slopes in the upper supply reach. The riparian condition is much poorer in the project reach, with little to no effective vegetation and buffer. It is suspected that natural vegetation reestablishment has been hampered by the continued erosion and sedimentation.

### 2.2 Channel Planform

Channel planform was evaluated to assess the condition of stream meanders and the future tendency of the channel to migrate laterally. Channel planform characteristics are most readily assessed using historic aerial photography as described in the previous section. Measurements and evaluation of physical characteristics commonly include sinuosity, meander amplitude or beltwidth, wavelength, radius of curvature, and feature spacing.

**Aerial View looking downstream through project reach.**

Sinuosity is the ratio of the length of the centerline of the channel to the length of a line defining the general trend of the valley and describes the amount of meandering in a stream. The pre-construction sinuosity of the project reach was 1.17, considered low within the Rosgen classification system for natural

“C” stream reaches. The average wavelength was 1,700 feet and measures of radius of curvatures were 324, 464, and 321 feet downstream respectively. The average meander beltwidth through the reach was 520 feet with a meander width ratio of 4.

In general the beltwidth was truncated through the lower reach due to impingement of the north and south valley walls. The condition caused the reach to be historically prone to bank erosion and failure as the channel has attempted to expand its beltwidth. The natural restriction of the valley has caused the channel to migrate down valley historically eroding both valley walls with a general trend of increasing planform dimensions.

### 2.3 Channel Profile

Channel profile data are commonly used in reach classification, hydraulic computations and to assess the tendency of the channel to vertically adjust. Monitoring reach profiles assist in quantifying erosion and sedimentation processes and the ecological potential of the reach. The pre-construction channel slope through the project reach was 1.1%. The presence of headcutting and confining geologic layers such as bedrock were also inventoried for use during the design process. **Map P-1 in Appendix A** represents the pre-construction streambed profile surveyed in summer of 2006.

Bedrock channel sections are located at Red Falls, and at the downstream extent of the project reach (Existing Profile Station 26+50). It is suspected that these sections isolate the reach with respect to watershed scale bed lowering processes, however local reach scale adjustment is evident from the dramatic changes in the channel alignment and sediment deposition.

Stream channel headcutting involves the initiation of channel incision at a nick point as the stream channel bed elevation adjusts to a natural or human induced disturbance. The nick point can be as subtle as an over-steepened riffle zone or as obvious as a cascade or "waterfall.” As the streambed erodes and the bed elevation lowers at the nick point, the active headcut will migrate upstream. The incision process will ultimately result in entrenched channel conditions. Most notable from the existing profile surveys of the project reach was the existence of potential headcutting at Station 17+00 and Station 24+00 illustrated in **Map P-1 of Appendix A**. Significant headcutting was inventoried at Station 17+00 measuring over 6 feet of channel bed elevation change. This formation was a concern due to its position in front of the large bank failure and potential to increase bank height and decrease stability of the slope.

Headcutting at Station 24+00 was less dramatic and took the form of an over-steepened riffle immediately upstream of a high bank at the downstream reach extent. Substantial narrowing of the floodplain in the downstream adjoining reach was suspected as the cause of this condition.

The majority of this bank is composed of glacial till which is durable material and not easily eroded by impinging flow, however the channel bottom at this bank is composed of more erodible clays allowing the channel to vertically erode. A potential cause of the formation is a backwater condition during major events causing sediment to deposit and aggrade the riffle feature.

### 2.4 Channel Cross Section

Channel cross section geometry affects the channel’s capacity for sediment conveyance and the hydraulic force exerted on the channel boundaries. Some common channel geometry parameters are flow area, width, hydraulic radius, depth of flow, and width/depth ratio. The analysis of cross section geometry of the project reach was performed using a recent HEC-RAS model developed for the production of flood insurance rate maps (FIRM's) for the reach. Modeled water surface elevations were calibrated to field identified bankfull indicators. **Table 1** summarizes the existing condition geometry during bankfull flow conditions and includes data from additional interpolated cross sections. The data are identified by stream stationing in both river mile from the original model, and feet referencing the downstream project extent as Station 0+00. The position of sections and extents of the 100-year floodplain can be seen on **Map H-1 in Appendix A**. **Figures 2, 3 and 4** illustrate bankfull area, width and width to depth ratios for the project reach.

Bankfull flow areas for the reach averaged 632 square feet, and are highly variable, ranging from 376 to 871. Bankfull average area is considered high varying considerably from adjoining reaches and other regional reference data. Bankfull width averaged 188 feet and hydraulic depth was 3.5 feet. Channel width to depth ratios averaged 59 indicating an over widened condition during this flow condition. It is suspected that these values are increased due to the general complexity of the reach containing multiple channels at bankfull stage and have historically led to the continued instability and sedimentation evident in the project reach.

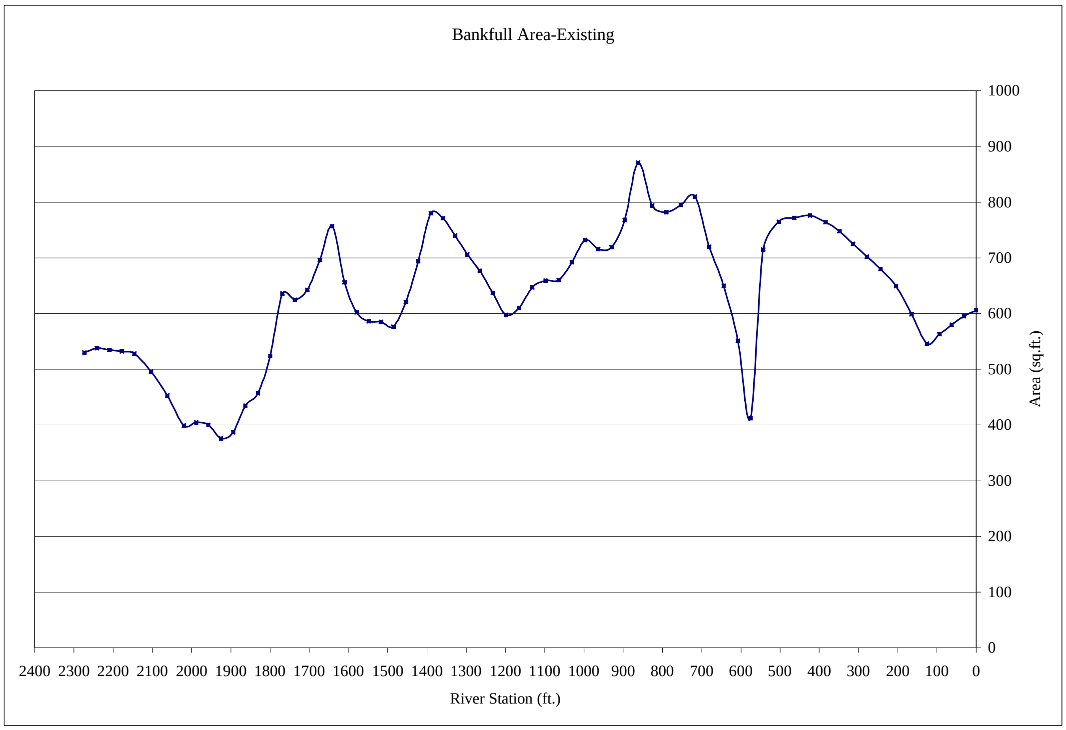



**Figure 2. Bankfull cross sectional area through the project reach.**

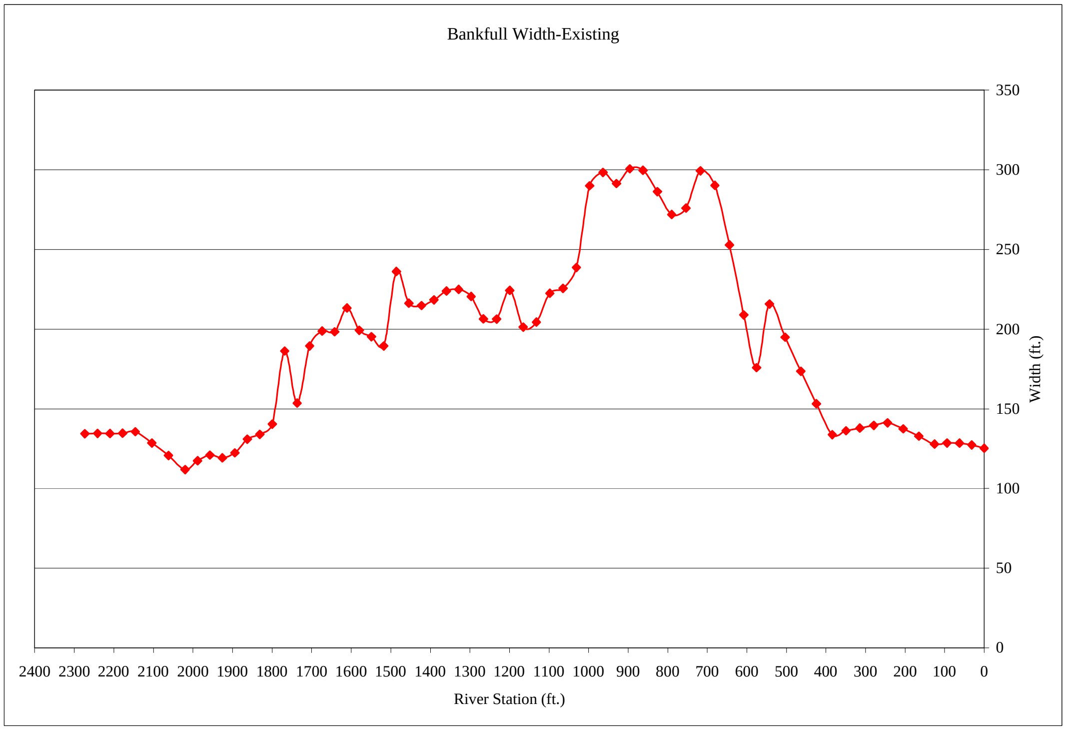



**Figure 3. Bankfull channel top width through the project reach.**

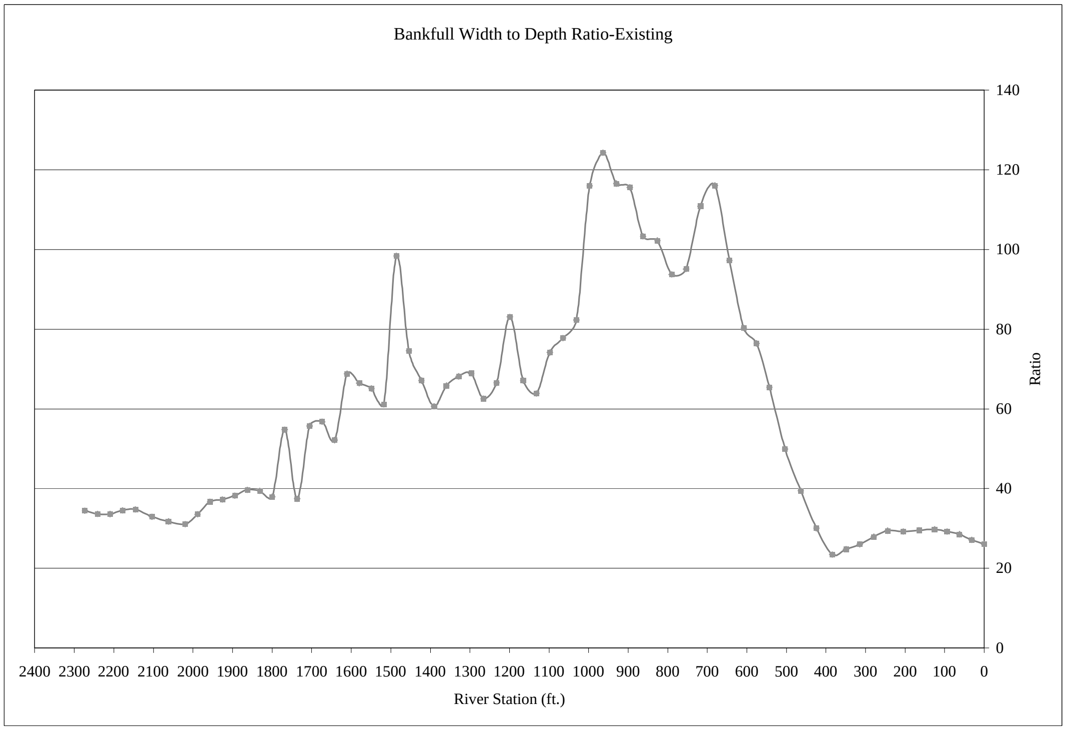



**Figure 4. Bankfull channel width to depth ratio through the project reach.**

**Table 1. Summary of HEC-RAS model output during bankfull flow for existing conditions.**

| River Sta | River Sta | Min Ch El | W.S. Elev | Hydr Depth | Bankfull Area | Top Width | Width/Depth | E.G. Slope |
|---|---|---|---|---|---|---|---|---|
| (*inter) | (ft) | (ft) | (ft) | (ft) | (sq ft) | (ft) | (Ratio) | (ft/ft) |
| 1.78559 | 2273.3 | 1239.9 | 1245.8 | 3.9 | 530 | 134.4 | 34.5 | 0.0026 |
| 1.77956* | 2241.4 | 1239.5 | 1245.7 | 4.0 | 538 | 134.6 | 33.7 | 0.0061 |
| 1.77353* | 2209.6 | 1239.1 | 1245.5 | 4.0 | 535 | 134.5 | 33.6 | 0.0060 |
| 1.76750* | 2177.7 | 1238.7 | 1245.3 | 3.9 | 532 | 134.7 | 34.5 | 0.0059 |
| 1.76148 | 2146.0 | 1238.3 | 1245.1 | 3.9 | 528 | 135.7 | 34.8 | 0.0062 |
| 1.75352* | 2103.9 | 1238.0 | 1244.8 | 3.9 | 496 | 128.5 | 32.9 | 0.0083 |
| 1.74556* | 2061.9 | 1237.6 | 1244.5 | 3.8 | 453 | 120.7 | 31.8 | 0.0095 |
| 1.73761 | 2019.9 | 1237.3 | 1244.1 | 3.6 | 399 | 111.9 | 31.1 | 0.0119 |
| 1.73165* | 1988.4 | 1237.0 | 1243.7 | 3.5 | 405 | 117.4 | 33.5 | 0.0133 |
| 1.72569* | 1957.0 | 1236.6 | 1243.2 | 3.3 | 400 | 121.0 | 36.7 | 0.0148 |
| 1.71973* | 1925.5 | 1236.2 | 1242.6 | 3.2 | 376 | 119.2 | 37.3 | 0.0186 |
| 1.71378 | 1894.1 | 1235.9 | 1242.3 | 3.2 | 387 | 122.4 | 38.3 | 0.0072 |
| 1.70782* | 1862.6 | 1235.5 | 1242.0 | 3.3 | 435 | 130.9 | 39.7 | 0.0182 |
| 1.70186* | 1831.2 | 1235.1 | 1241.6 | 3.4 | 457 | 134.0 | 39.4 | 0.0144 |
| 1.69590* | 1799.7 | 1234.8 | 1241.4 | 3.7 | 524 | 140.4 | 37.9 | 0.0045 |
| 1.68995 | 1768.3 | 1234.4 | 1241.4 | 3.4 | 636 | 186.3 | 54.8 | 0.0018 |
| 1.68394* | 1736.5 | 1234.0 | 1241.3 | 4.1 | 625 | 153.5 | 37.4 | 0.0065 |
| 1.67794* | 1704.9 | 1233.5 | 1241.1 | 3.4 | 643 | 189.5 | 55.7 | 0.0057 |
| 1.67193* | 1673.1 | 1233.1 | 1241.0 | 3.5 | 696 | 198.8 | 56.8 | 0.0051 |
| 1.66593 | 1641.4 | 1232.7 | 1240.8 | 3.8 | 757 | 198.3 | 52.2 | 0.0046 |
| 1.66006* | 1610.5 | 1232.6 | 1240.6 | 3.1 | 656 | 213.3 | 68.8 | 0.0093 |
| 1.65420* | 1579.5 | 1232.6 | 1240.2 | 3.0 | 602 | 199.3 | 66.4 | 0.0099 |
| 1.64834* | 1548.6 | 1232.5 | 1239.9 | 3.0 | 586 | 195.3 | 65.1 | 0.0099 |
| 1.64248 | 1517.6 | 1232.5 | 1239.6 | 3.1 | 585 | 189.5 | 61.1 | 0.0083 |
| 1.63647* | 1485.9 | 1232.5 | 1239.3 | 2.4 | 577 | 236.1 | 98.4 | 0.0101 |
| 1.63046* | 1454.2 | 1232.5 | 1239.0 | 2.9 | 621 | 216.2 | 74.6 | 0.0096 |
| 1.62445* | 1422.4 | 1232.5 | 1238.8 | 3.2 | 694 | 214.8 | 67.1 | 0.0080 |
| 1.61844 | 1390.7 | 1232.5 | 1238.6 | 3.6 | 780 | 218.4 | 60.7 | 0.0062 |
| 1.61252* | 1359.4 | 1232.3 | 1238.4 | 3.4 | 771 | 223.9 | 65.9 | 0.0102 |
| 1.60661* | 1328.2 | 1232.1 | 1238.1 | 3.3 | 740 | 224.9 | 68.2 | 0.0115 |
| 1.60070* | 1297.0 | 1231.8 | 1237.7 | 3.2 | 706 | 220.5 | 68.9 | 0.0130 |
| 1.59479 | 1265.8 | 1231.6 | 1237.3 | 3.3 | 677 | 206.4 | 62.5 | 0.0130 |
| 1.58844* | 1232.3 | 1231.0 | 1236.8 | 3.1 | 637 | 206.3 | 66.5 | 0.0113 |
| 1.58210* | 1198.8 | 1230.3 | 1236.4 | 2.7 | 598 | 224.3 | 83.1 | 0.0094 |
| 1.57576* | 1165.3 | 1229.7 | 1236.1 | 3.0 | 610 | 201.3 | 67.1 | 0.0068 |
| 1.56942 | 1131.9 | 1229.0 | 1235.9 | 3.2 | 647 | 204.4 | 63.9 | 0.0059 |
| 1.56303* | 1098.1 | 1228.7 | 1235.7 | 3.0 | 659 | 222.5 | 74.2 | 0.0118 |
| 1.55665* | 1064.4 | 1228.4 | 1235.4 | 2.9 | 660 | 225.6 | 77.8 | 0.0110 |
| 1.55027* | 1030.8 | 1228.0 | 1235.0 | 2.9 | 692 | 238.6 | 82.3 | 0.0105 |
| 1.54389 | 997.1 | 1227.7 | 1234.7 | 2.5 | 732 | 289.9 | 116.0 | 0.0114 |
| 1.5375* | 963.3 | 1227.2 | 1234.2 | 2.4 | 716 | 298.3 | 124.3 | 0.0135 |
| 1.53111* | 929.6 | 1226.8 | 1233.8 | 2.5 | 719 | 291.3 | 116.5 | 0.0114 |
| 1.52472* | 895.9 | 1226.4 | 1233.5 | 2.6 | 768 | 300.6 | 115.6 | 0.0087 |
| 1.51833 | 862.1 | 1226.0 | 1233.3 | 2.9 | 871 | 299.6 | 103.3 | 0.0059 |
| 1.51146* | 825.8 | 1226.0 | 1233.1 | 2.8 | 794 | 286.2 | 102.2 | 0.0070 |
| 1.50460* | 789.6 | 1226.0 | 1232.9 | 2.9 | 782 | 271.9 | 93.8 | 0.0081 |
| 1.49774* | 753.4 | 1226.0 | 1232.6 | 2.9 | 795 | 275.9 | 95.1 | 0.0093 |
| 1.49088 | 717.2 | 1226.0 | 1232.2 | 2.7 | 810 | 299.3 | 110.9 | 0.0113 |
| 1.48396* | 680.6 | 1225.8 | 1231.7 | 2.5 | 720 | 290.2 | 116.1 | 0.0129 |
| 1.47704* | 644.1 | 1225.6 | 1231.1 | 2.6 | 650 | 252.9 | 97.3 | 0.0175 |
| 1.47012 | 607.6 | 1225.4 | 1230.2 | 2.6 | 551 | 208.9 | 80.3 | 0.0255 |
| 1.46399* | 575.2 | 1223.9 | 1228.7 | 2.3 | 412 | 175.8 | 76.4 | 0.0509 |
| 1.45787 | 542.9 | 1222.5 | 1228.7 | 3.3 | 715 | 215.8 | 65.4 | 0.0040 |
| 1.45035* | 503.2 | 1221.7 | 1228.4 | 3.9 | 765 | 194.9 | 50.0 | 0.0102 |
| 1.44284* | 463.5 | 1220.8 | 1228.1 | 4.4 | 772 | 173.6 | 39.5 | 0.0069 |
| 1.43532* | 423.8 | 1220.0 | 1227.9 | 5.1 | 776 | 153.2 | 30.0 | 0.0048 |
| 1.42781 | 384.2 | 1219.1 | 1227.7 | 5.7 | 764 | 133.8 | 23.5 | 0.0037 |
| 1.42118* | 349.2 | 1219.2 | 1227.5 | 5.5 | 748 | 136.2 | 24.8 | 0.0068 |
| 1.41455* | 314.2 | 1219.3 | 1227.3 | 5.3 | 725 | 137.9 | 26.0 | 0.0067 |
| 1.40792* | 279.2 | 1219.4 | 1227.0 | 5.0 | 702 | 139.6 | 27.9 | 0.0067 |
| 1.4013 | 244.2 | 1219.5 | 1226.8 | 4.8 | 680 | 141.2 | 29.4 | 0.0069 |
| 1.39379* | 204.5 | 1219.3 | 1226.4 | 4.7 | 649 | 137.5 | 29.3 | 0.0125 |
| 1.38629* | 164.9 | 1219.2 | 1225.9 | 4.5 | 599 | 132.8 | 29.5 | 0.0129 |
| 1.37879 | 125.3 | 1219.0 | 1225.3 | 4.3 | 546 | 127.9 | 29.7 | 0.0144 |
| 1.37285* | 94.0 | 1218.4 | 1224.8 | 4.4 | 563 | 128.6 | 29.2 | 0.0128 |
| 1.36692* | 62.7 | 1217.8 | 1224.5 | 4.5 | 580 | 128.4 | 28.5 | 0.0106 |
| 1.36098* | 31.3 | 1217.2 | 1224.2 | 4.7 | 595 | 127.4 | 27.1 | 0.0090 |
| 1.35505 | 0.0 | 1216.6 | 1223.9 | 4.8 | 606 | 125.2 | 26.1 | 0.0080 |
| Average | | | | 3.5 | 632 | 188.3 | 58.7 | 0.0101 |

## 2.4 Bank Stability

The type of material and stratigraphy in a channel bank affects its erosion potential. Bank statigraphy is identified and measured in the field. Geotechnical analyses are performed to quantify the strength characteristics of the bank materials. Many channels are comprised of composite channel banks with bedrock, clay, alluvium and soils.

**Erosion and failure of upstream high bank in 2001.**

Geotechnical analyses are used to determine existing bank stability, anticipate bank failures and to provide design parameters for embankment construction. Bank failure can occur in various modes depending on the bank soil properties and the morphology of the stream. Bank failure modes include shallow, planar, and rotational and cantilever type failures. The most common type of bank failure results from removal of soil from the channel toe (undermining) and subsequent slope failure.

External stability refers to the acting and resisting forces adjacent to stream that influence stability of the slope. External stability analysis evaluates forces related to bearing capacity, base sliding, and overturning moments. Internal stability refers to forces within the channel bank that affect the stability of reinforcements (internal sliding, tensile overstress, and pullout). Local stability is related to the surficial facing of a channel bank. This also relates to the connection strength between the facing and internal reinforcements in a constructed slope. Global Stability relates to deep-seated rotational failures that are generally outside the limits of a constructed slope.

Two high stream banks within the project reach were identified as unstable during the assessment. Due to the scale and condition of the upstream large bank, a geotechnical investigation was initiated in 2005 to evaluate bank mechanics, and risk for future failure and provide recommendations for any necessary monitoring and stabilization. The Geotechnical Report is attached as **Appendix B**.

Historic bank erosion and failure along a second bank near a private residence was also identified during the reach assessment process. This bank is smaller in scale compared to the upstream bank. However, it is a concern due to its proximity to a nearby structure and conditions of the existing channel near the bank. Both banks are experiencing erosion of the bank toe and failure of the upper banks. Vertical streambed erosion and head cutting were inventoried near the bank toes, increasing instability of the banks and exposing underlying clays which threaten water quality.

## 2.5 Channel and Bar Material Characteristics

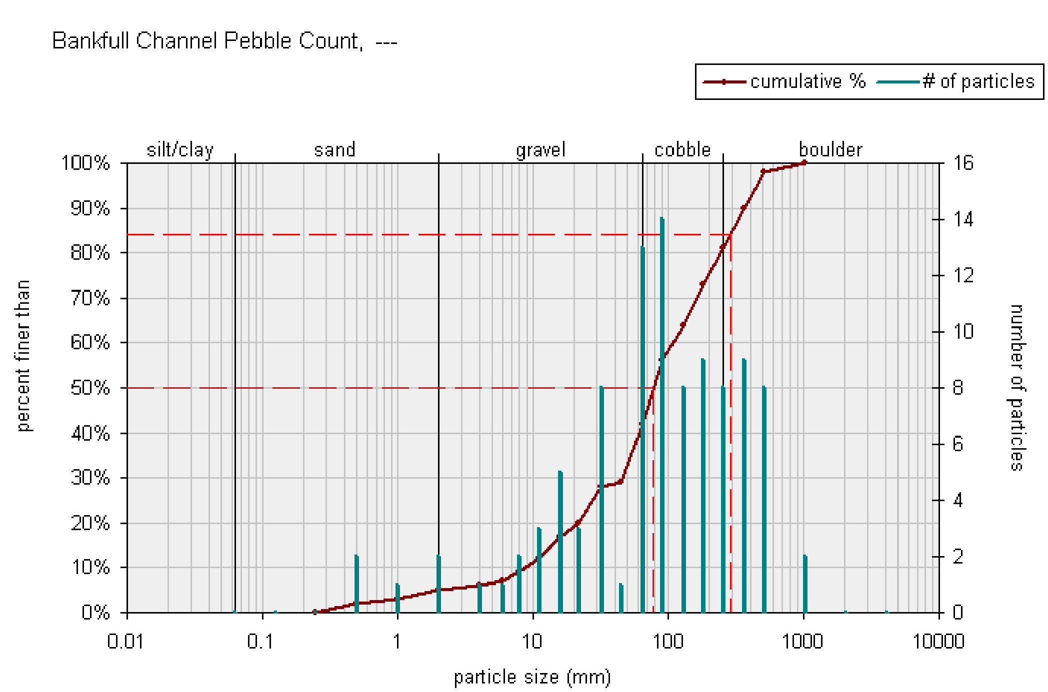
**View looking downstream from upstream bank failure.**

The size, shape, composition and distribution of material in the channel bed are important to the channel stability. These characteristics are used to determine the mobility of the channel bed and subsequently the erosion potential. In general, larger sediment sizes (cobbles/boulders) act to stabilize the channel bed, where smaller particles (sand/silt) are more readily erodible. The distribution of particle sizes in bed material mixtures affects the ability of water to mobilize these sediments. The characteristics of the bed material are analyzed through visual observation and gradations developed from standard sieve and pebble count procedures.

A well-sorted sediment mixture consists of grains that are of uniform size and a poorly sorted sample contains particles of many sizes and may be indicative of a high energy/flashy system. A poorly sorted stream may also include large particles that armor the channel bed. The shape of the bed material affects its stability where angular particles provide more stability than rounded particles because of the interlocking and friction characteristics.

Sediment samples were collected from the stream channel pavement and point bar and were used for classification, and hydraulic analysis to evaluate the sediment entrainment and competence characteristics of the existing condition. Representative distributions are included in **Figure 5** and **Figure 6**.

The pebble count distribution in **Figure 5** reveals the predominant material found in the riffle is in the small cobble size range (D50=78mm) with large portion of the sample in the gravel class. Nearly 20% of materials were boulders and 84% of the sample is estimated to be smaller than 290 mm. The gradation of materials is "poorly sorted" containing a wide range of grain size (dispersion 4.5) considered normal and negatively skewed with a geometric mean of 66 mm and a D50 of 78 mm. Sample materials were generally well rounded and not well imbricated.



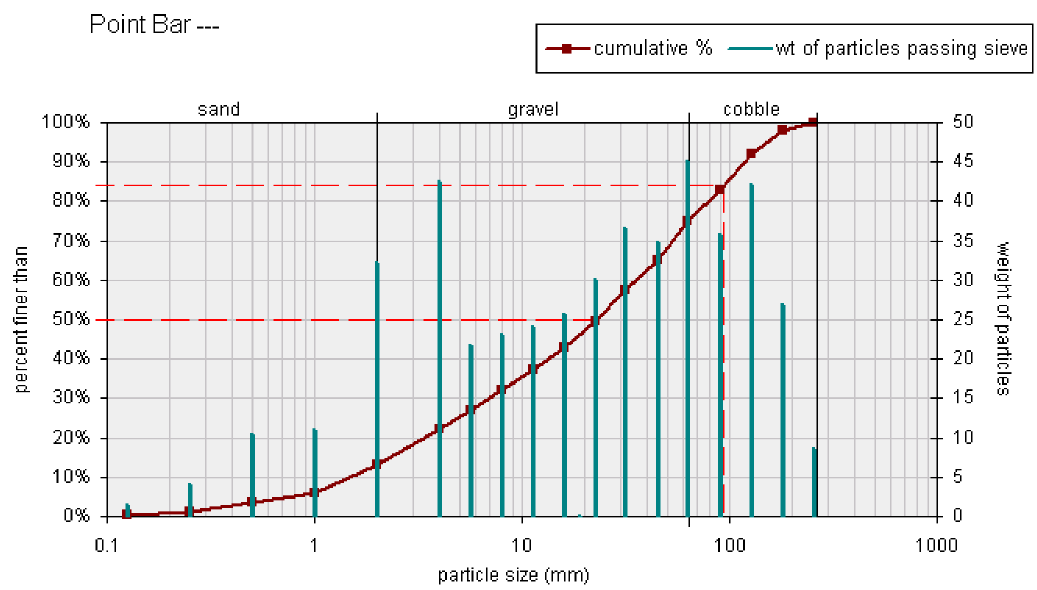

| Size (mm) | |
|---|---|
| D16 | 15 |
| D35 | 53 |
| D50 | 78 |
| D65 | 130 |
| D84 | 290 |
| D95 | 450 |

| Size Distribution | |
|---|---|
| mean | 66.0 |
| dispersion | 4.5 |
| skewness | -0.06 |

| Type | |
|---|---|
| silt/clay | 0% |
| sand | 5% |
| gravel | 37% |
| cobble | 39% |
| boulder | 19% |

**Figure 5. Representative bankfull sediment distribution at a riffle section.**

Point bar sampling was performed at a bar formation at the downstream project extent. **Figure 6** represents the sieve analysis distribution depicting consistently smaller materials than the pavement sample, dominated by gravels and small cobble. These materials were well embedded by finer gravel and sand material. Several larger materials were found on the bar near the sample site characterized as small boulders measuring approximately 300 mm and greater.




| | Size (mm) | | |
|---|---|---|---|
| D16 | 2.5 | D65 | 45 |
| D35 | 9.6 | D84 | 94 |
| D50 | 23 | D95 | 150 |

**Figure 6. Point bar sediment distribution sampled near the bottom of the project reach.**

## 2.6 Hydrologic and Hydraulic Assessment

Hydrologic and hydraulic models for estimating runoff quantities, rates and the hydraulic force are commonly used in the assessment and design of stream channels. Results from these analyses are used to estimate channel boundary shear stresses and sediment transport capacities, which allow for prediction of future short- and long-term channel erosion and provide data for design of channel stabilization measures.

Several sources of data were used in the assessment of the project reach including USGS gage data, regression equations, regional curves, and hydraulic modeling. Due to the modification of the flows by three upstream flood control structures, available gage data from the Batavia Kill basin were considered more relevant for estimations.

### *2.6.1 Flood Frequency Analysis*

Analysis of flood frequencies was performed on three USGS gages within the basin as well as a nearby downstream gage on the Schoharie Creek in Prattsville. The Schoharie Creek data was used in the analysis due to its long period of record, and the large contribution of the Batavia Kill to its drainage (30%) and the downstream position of the project reach in relation to the flood control structures. Annual peak flow data used in the analysis were limited to post flood control structures construction providing approximately 20 years of record. **Table 2** displays the discharge estimates and the corresponding frequency of the nearby gages.

**Table 2. Flood frequencies and discharge estimation of USGS gages.**

| Gage # | USGS Gage | DA | 1 | 1.5 | 2 | 5 | 10 | 25 | 50 | 100 |
|---|---|---|---|---|---|---|---|---|---|---|
| 1349850 | Hensonville (1978-2005) | 13.5 | 215 | 729 | 881 | 1452 | 1886 | 2493 | 2984 | 3508 |
| 1349900 | Near Ashland (1987-2005) | 51.2 | 420 | 2396 | 3627 | 8145 | 12511 | 19868 | 26857 | 35284 |
| 1349950 | Redfalls (1996-2006) | 68.6 | 424 | 3081 | 4827 | 11342 | 17633 | 28114 | 37920 | 49557 |
| 1350000 | Schoharie Creek Prattsville (1982-2005) | 237 | 3888 | 12381 | 16399 | 28393 | 38059 | 52258 | 64300 | 77618 |

An analysis that normalized discharge estimates by drainage area for each gage was used to estimate project reach discharges. Although the Red falls gage is located immediately upstream of the project reach, it is assumed that utilizing multiple gages would provide better discharge estimation due to the short period of record at the Red Falls gage, the confluence of Dent Road tributary immediately downstream of the gage, and significant storms in recent gage history. Discharge estimates for the project reach for specific frequencies up to the 100-year event can be seen in **Table 3**.

**Table 3. Normalized discharge estimates for the Conine Project Reach.**

| USGS Gage | DA | 1 | 1.5 | 2 | 5 | 10 | 25 | 50 | 100 |
|---|---|---|---|---|---|---|---|---|---|
| Hensonville (1978-2005) | 13.5 | 15.9 | 54.0 | 65.3 | 107.6 | 139.7 | 184.7 | 221.0 | 259.9 |
| Near Ashland (1987-2005) | 51.2 | 8.2 | 46.8 | 70.8 | 159.1 | 244.4 | 388.0 | 524.6 | 689.1 |
| Redfalls (1996-2006) | 68.6 | 6.2 | 44.9 | 70.4 | 165.3 | 257.0 | 409.8 | 552.8 | 722.4 |
| Schoharie Creek Prattsville (1982-2005) | 237.0 | 16.4 | 52.2 | 69.2 | 119.8 | 160.6 | 220.5 | 271.3 | 327.5 |
| Average | | 11.7 | 49.5 | 68.9 | 137.9 | 200.4 | 300.8 | 392.4 | 499.7 |
| Conine Project Reach Discharges | 70 | 818 | 3464 | 4824 | 9656 | 14030 | 21053 | 27469 | 34981 |

### *2.6.2 Bankfull Discharge Analysis*

An evaluation and understanding of the flow corresponding to the bankfull discharge is central to the application of natural channel design and stream restoration. The channel forming discharge is commonly assumed as a flow that transports the most sediment over time and determines the principal dimensions and characteristics of natural channels. Based on observations of numerous researchers across the country, bankfull flow, assumed as the dominant discharge, has been proven to approximate the 1-and 2-year event. A combination of several methods for determining bankfull discharge was performed for the development of the proposed design, including flood frequency analysis of gages, evaluation NYCDEP regional curves (Miller and Davis 2003), USGS regression equations (Lumia 1991), and the calibration of field identification of bankfull indicators and water surface elevations developed from a hydraulic model of the project reach.

The gage analysis and average of the normalized data in **Table 3** estimate the 1.5-year storm at approximately 50 cfs/sq mi or 3500 cfs. The evaluation of NYCDEP regional curves of unmodified watersheds suggest that bankfull discharge should approximate 3200 cfs. Calibration of the existing HEC-RAS model produced water surface elevations estimating bankfull discharge as 2500 cfs. Modeled values are suspected to be low due to the general complexity of the reach containing several channels at bankfull stage, and high values used for resistance coefficients for the floodplain. Regional relations for New York presented by USGS estimated 2-year event discharge at approximately 3500 cfs. It is estimated from the flood frequency analysis of gages, NYCDEP curves and USGS regression equations that bankfull discharge is approximately 3100 cfs, which was used for preliminary design.

### *2.6.3 Hydraulic Analysis*

Hydraulic Analysis of the project reach was performed using an existing model. Model data was evaluated for general applicability and accuracy. Channel and floodplain resistance coefficients were verified using field collected sediment data and aerial imagery, and geometry data was compared with topographic data collected for the design. The addition of interpolated cross sections through the reach was necessary to model smaller discharges through the existing channel. **Table 4** provides a summary of the model output.

**Table 4. Summary of existing HEC-RAS model for bankfull flow conditions.**

| River Sta (mi) | River Sta (ft) | Q Total (cfs) | Min Ch El (ft) | W.S. Elev (ft) | Vel Chnl (ft/s) | Froude # | Power Chan (lb/ft s) | Shear Chan (lb/sq ft) |
|---|---|---|---|---|---|---|---|---|
| 1.78559 | 2273.3 | 2500 | 1239.9 | 1245.8 | 4.7 | 0.42 | 3.1 | 0.7 |
| 1.77956* | 2241.4 | 2500 | 1239.5 | 1245.7 | 4.7 | 0.41 | 7.0 | 1.5 |
| 1.77353* | 2209.6 | 2500 | 1239.1 | 1245.5 | 4.7 | 0.41 | 7.0 | 1.5 |
| 1.76750* | 2177.7 | 2500 | 1238.7 | 1245.3 | 4.7 | 0.42 | 6.8 | 1.5 |
| 1.76148 | 2146.0 | 2500 | 1238.3 | 1245.1 | 4.7 | 0.42 | 7.0 | 1.5 |
| 1.75352* | 2103.9 | 2500 | 1238.0 | 1244.8 | 5.0 | 0.45 | 10.0 | 2.0 |
| 1.74556* | 2061.9 | 2500 | 1237.6 | 1244.5 | 5.5 | 0.5 | 12.1 | 2.2 |
| 1.73761 | 2019.9 | 2500 | 1237.3 | 1244.1 | 6.3 | 0.58 | 16.3 | 2.6 |
| 1.73165* | 1988.4 | 2500 | 1237.0 | 1243.7 | 6.2 | 0.58 | 17.5 | 2.8 |
| 1.72569* | 1957.0 | 2500 | 1236.6 | 1243.2 | 6.2 | 0.61 | 18.8 | 3.0 |
| 1.71973* | 1925.5 | 2500 | 1236.2 | 1242.6 | 6.6 | 0.66 | 24.1 | 3.6 |
| 1.71378 | 1894.1 | 2500 | 1235.9 | 1242.3 | 6.5 | 0.64 | 9.1 | 1.4 |
| 1.70782* | 1862.6 | 2500 | 1235.5 | 1242.1 | 5.7 | 0.56 | 21.5 | 3.8 |
| 1.70186* | 1831.2 | 2500 | 1235.1 | 1241.6 | 5.5 | 0.52 | 16.6 | 3.0 |
| 1.69590* | 1799.7 | 2500 | 1234.8 | 1241.4 | 4.8 | 0.44 | 4.9 | 1.0 |
| 1.68995 | 1768.3 | 2500 | 1234.4 | 1241.4 | 4.1 | 0.34 | 1.5 | 0.5 |
| 1.68394* | 1736.5 | 2500 | 1234.0 | 1241.3 | 4.0 | 0.33 | 6.5 | 1.8 |
| 1.67794* | 1704.9 | 2500 | 1233.5 | 1241.1 | 4.0 | 0.32 | 4.7 | 1.7 |
| 1.67193* | 1673.1 | 2500 | 1233.1 | 1241.0 | 3.9 | 0.3 | 3.9 | 1.6 |
| 1.66593 | 1641.4 | 2500 | 1232.7 | 1240.8 | 3.8 | 0.29 | 3.5 | 1.5 |
| 1.66006* | 1610.5 | 2500 | 1232.6 | 1240.6 | 4.1 | 0.32 | 6.7 | 2.9 |
| 1.65420* | 1579.5 | 2500 | 1232.6 | 1240.2 | 4.5 | 0.37 | 7.7 | 2.9 |
| 1.64834* | 1548.6 | 2500 | 1232.5 | 1239.9 | 4.8 | 0.4 | 7.9 | 2.7 |
| 1.64248 | 1517.6 | 2500 | 1232.5 | 1239.6 | 5.1 | 0.43 | 6.8 | 2.2 |
| 1.63647* | 1485.9 | 2500 | 1232.5 | 1239.3 | 5.2 | 0.45 | 6.7 | 2.6 |
| 1.63046* | 1454.2 | 2500 | 1232.5 | 1239.0 | 4.9 | 0.43 | 6.9 | 2.4 |
| 1.62445* | 1422.4 | 2500 | 1232.5 | 1238.8 | 4.3 | 0.38 | 5.7 | 2.0 |
| 1.61844 | 1390.7 | 2500 | 1232.5 | 1238.6 | 3.7 | 0.32 | 4.4 | 1.6 |
| 1.61252* | 1359.4 | 2500 | 1232.3 | 1238.4 | 3.4 | 0.31 | 7.1 | 2.5 |
| 1.60661* | 1328.2 | 2500 | 1232.1 | 1238.1 | 3.6 | 0.34 | 7.9 | 2.6 |
| 1.60070* | 1297.0 | 2500 | 1231.8 | 1237.7 | 3.8 | 0.36 | 9.1 | 2.7 |
| 1.59479 | 1265.8 | 2500 | 1231.6 | 1237.3 | 4.0 | 0.39 | 9.7 | 2.7 |
| 1.58844* | 1232.3 | 2500 | 1231.0 | 1236.8 | 4.7 | 0.43 | 8.5 | 2.5 |
| 1.58210* | 1198.8 | 2500 | 1230.3 | 1236.4 | 5.2 | 0.44 | 6.5 | 2.5 |
| 1.57576* | 1165.3 | 2500 | 1229.7 | 1236.1 | 5.2 | 0.41 | 5.2 | 2.1 |
| 1.56942 | 1131.9 | 2500 | 1229.0 | 1235.9 | 5.3 | 0.39 | 4.4 | 2.0 |
| 1.56303* | 1098.1 | 2500 | 1228.7 | 1235.7 | 4.5 | 0.34 | 8.2 | 3.9 |
| 1.55665* | 1064.4 | 2500 | 1228.4 | 1235.4 | 4.3 | 0.34 | 7.5 | 3.3 |
| 1.55027* | 1030.8 | 2500 | 1228.0 | 1235.0 | 4.0 | 0.33 | 6.8 | 2.9 |
| 1.54389 | 997.1 | 2500 | 1227.7 | 1234.7 | 3.8 | 0.34 | 6.1 | 2.8 |
| 1.5375* | 963.3 | 2500 | 1227.2 | 1234.2 | 4.0 | 0.35 | 7.0 | 3.4 |
| 1.53111* | 929.6 | 2500 | 1226.8 | 1233.8 | 4.2 | 0.35 | 6.1 | 3.0 |
| 1.52472* | 895.9 | 2500 | 1226.4 | 1233.5 | 4.2 | 0.34 | 4.5 | 2.5 |
| 1.51833 | 862.1 | 2500 | 1226.0 | 1233.3 | 4.0 | 0.3 | 3.1 | 1.9 |
| 1.51146* | 825.8 | 2500 | 1226.0 | 1233.1 | 3.7 | 0.31 | 3.8 | 2.0 |
| 1.50460* | 789.6 | 2500 | 1226.0 | 1232.9 | 3.5 | 0.31 | 4.6 | 2.0 |
| 1.49774* | 753.4 | 2500 | 1226.0 | 1232.6 | 3.3 | 0.3 | 5.2 | 2.1 |
| 1.49088 | 717.2 | 2500 | 1226.0 | 1232.2 | 3.1 | 0.31 | 5.8 | 2.3 |
| 1.48396* | 680.6 | 2500 | 1225.8 | 1231.7 | 3.7 | 0.37 | 6.9 | 2.5 |
| 1.47704* | 644.1 | 2500 | 1225.6 | 1231.1 | 4.2 | 0.43 | 10.8 | 3.3 |
| 1.47012 | 607.6 | 2500 | 1225.4 | 1230.3 | 5.2 | 0.53 | 18.9 | 4.7 |
| 1.46399* | 575.2 | 2500 | 1223.9 | 1228.7 | 6.1 | 0.7 | 45.1 | 7.4 |
| 1.45787 | 542.9 | 2500 | 1222.5 | 1228.7 | 3.5 | 0.34 | 2.9 | 0.8 |
| 1.45035* | 503.2 | 2500 | 1221.7 | 1228.4 | 3.3 | 0.29 | 8.1 | 2.5 |
| 1.44284* | 463.5 | 2500 | 1220.8 | 1228.1 | 3.2 | 0.27 | 6.2 | 1.9 |
| 1.43532* | 423.8 | 2500 | 1220.0 | 1227.9 | 3.2 | 0.25 | 4.9 | 1.5 |
| 1.42781 | 384.2 | 2500 | 1219.1 | 1227.7 | 3.3 | 0.24 | 4.3 | 1.3 |
| 1.42118* | 349.2 | 2500 | 1219.2 | 1227.5 | 3.3 | 0.25 | 7.6 | 2.3 |
| 1.41455* | 314.2 | 2500 | 1219.3 | 1227.3 | 3.5 | 0.27 | 7.4 | 2.2 |
| 1.40792* | 279.2 | 2500 | 1219.4 | 1227.0 | 3.6 | 0.28 | 7.4 | 2.1 |
| 1.4013 | 244.2 | 2500 | 1219.5 | 1226.8 | 3.7 | 0.3 | 7.5 | 2.1 |
| 1.39379* | 204.5 | 2500 | 1219.3 | 1226.4 | 3.9 | 0.31 | 14.0 | 3.6 |
| 1.38629* | 164.9 | 2500 | 1219.2 | 1225.9 | 4.2 | 0.35 | 15.0 | 3.6 |
| 1.37879 | 125.3 | 2500 | 1219.0 | 1225.3 | 4.6 | 0.39 | 17.4 | 3.8 |
| 1.37285* | 94.0 | 2500 | 1218.4 | 1224.8 | 4.4 | 0.37 | 15.4 | 3.5 |
| 1.36692* | 62.7 | 2500 | 1217.8 | 1224.5 | 4.3 | 0.36 | 12.7 | 3.0 |
| 1.36098* | 31.3 | 2500 | 1217.2 | 1224.2 | 4.2 | 0.34 | 10.9 | 2.6 |
| 1.35505 | 0.0 | 2500 | 1216.6 | 1223.9 | 4.1 | 0.33 | 9.9 | 2.4 |
| Average | | | | | 4.4 | 0.39 | 9.0 | 2.5 |

### *2.6.4 Shear Stress and Sediment Transport*

Shear stress is a function of slope and depth and is commonly used to describe a reaches hydraulic condition. The initial step in a sediment transport analysis is evaluation of the mobility of the channel bed material. Commonly this is accomplished through comparison of the hydraulic shear stress and the critical shear stress of the bed material. It should be noted that there are many paradigms for sediment and channel armor mobility. **Figure 7** displays the average shear stress through the reach during bankfull flow and limiting shear stress values corresponding with the bed material D50 and D84. The model indicates that D50 (78 mm) is typically mobile during bankfull condition, and D84 (280 mm) would generally remain stable through the reach.

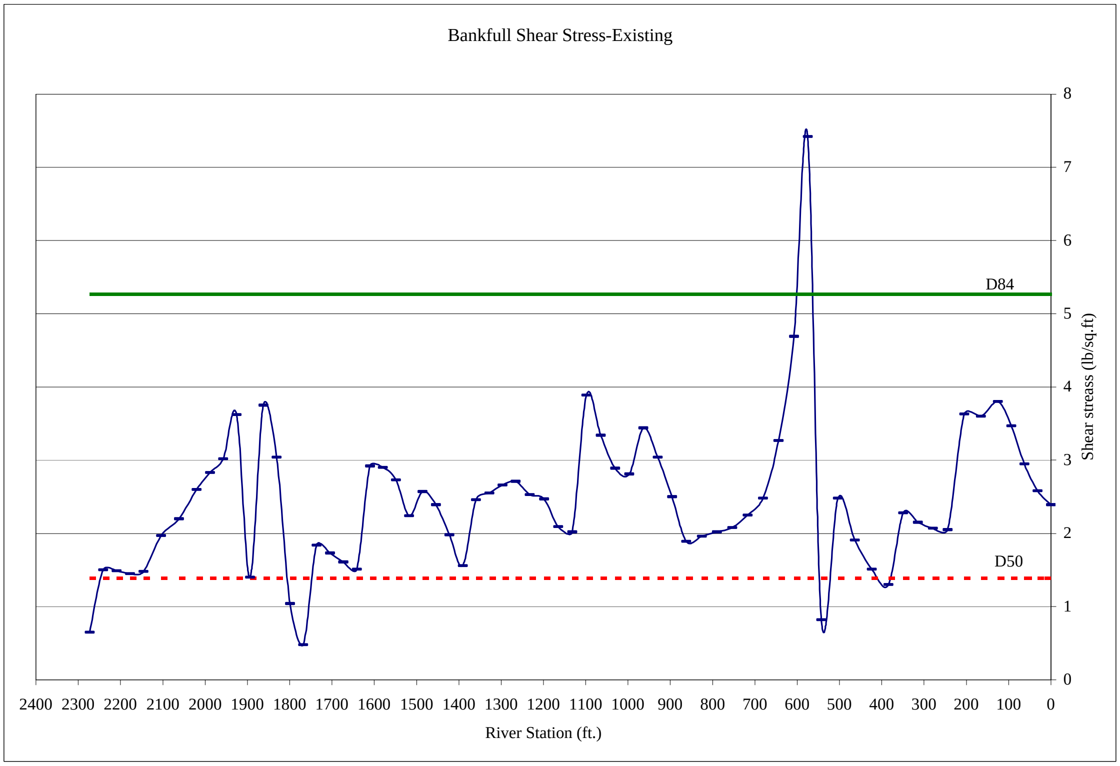



**Figure 7. Average shear stress and channel armor threshold values.**

In mobile bed systems the erodibility of the channel is dependent on the sediment supply from upstream sources and the ability of the channel to transport the incoming load. Sediment supply for the project reach was not modeled as part of the design process. It is suspected the Red Falls reach located upstream of the project reach has historically supplied an inconsistent sediment regime to the project reach. The eroded sediments are generally finer than bedload material, composed of fine clay and silt; however, they do have the potential to affect the stability of the project reach.

Generally there are three cases related to the equilibrium condition of the stream. Dynamic equilibrium indicates the channel can transport the incoming sediment load without excessive erosion or deposition. A transport-limited channel cannot sufficiently pass the incoming sediment load and aggradation results. In a supply-limited channel transport capacity exceeds the incoming load and erosion and degradation may occur.

Computing critical dimensionless shear stress combined with entrainment analysis provides information on the channels capacity to transport its bed load. Critical dimensionless shear stress for the existing project condition was determined through a regression relationship developed by Andrews (1983). Entrainment analysis estimated that a mean depth of 6.3 feet would be required to transport the larger material found on the bar formations. The average existing mean channel depth averaged 4.4 feet, indicating the reach is transport limited, and a potential for sedimentation during bankfull conditions exists. That finding was supported by site monitoring data and the historic aerial imagery.

**Upstream bank erosion and failure in reach above Red Falls.**

Sediment transport capacity was further evaluated using the hydraulic model to compute stream power, a function of discharge and slope, and bedload transport capacity, using Meyer-Peter Muller Equation (1948). **Figures 8 and 9** display the output of this analysis under bankfull flow conditions. Both techniques indicate a high degree of variability suggesting the potential for future instability.

In general, upstream and downstream reaches demonstrate greater sediment transport capacities and exhibit more typical stable channel morphology such as lower width/depth ratio than that observed through the project reach and less active historic processes such as channel braiding and excessive gravel deposition.

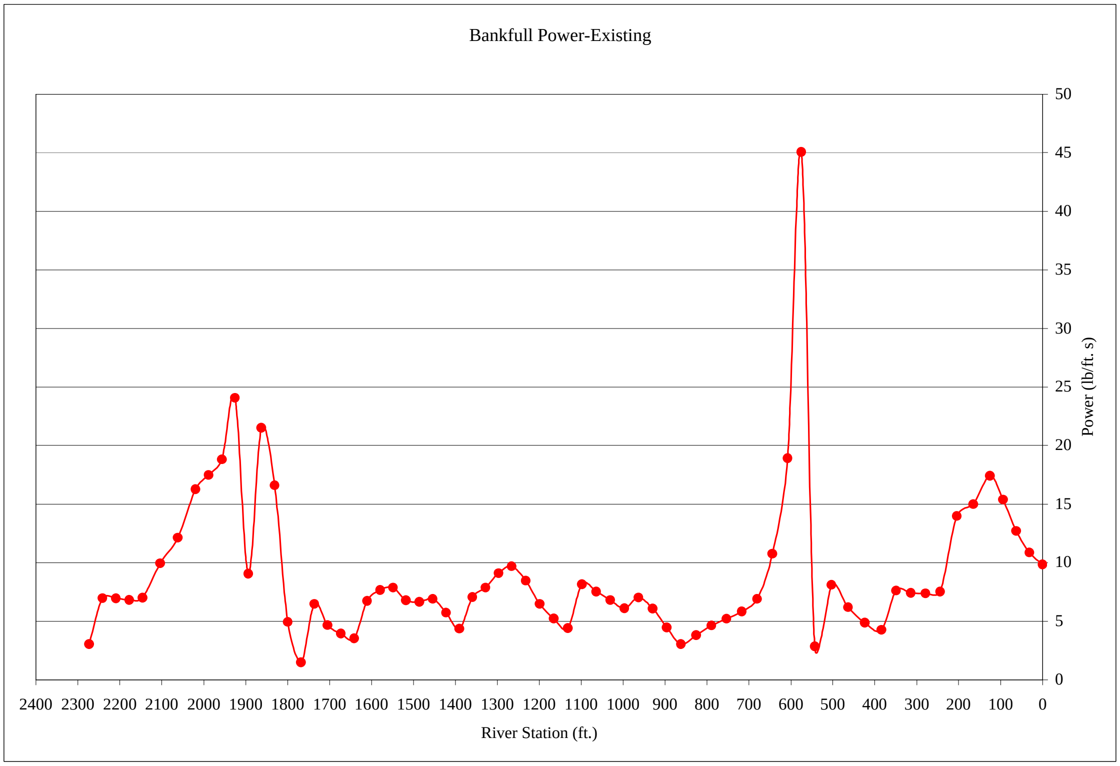



**Figure 8. Stream power during bankfull conditions.**

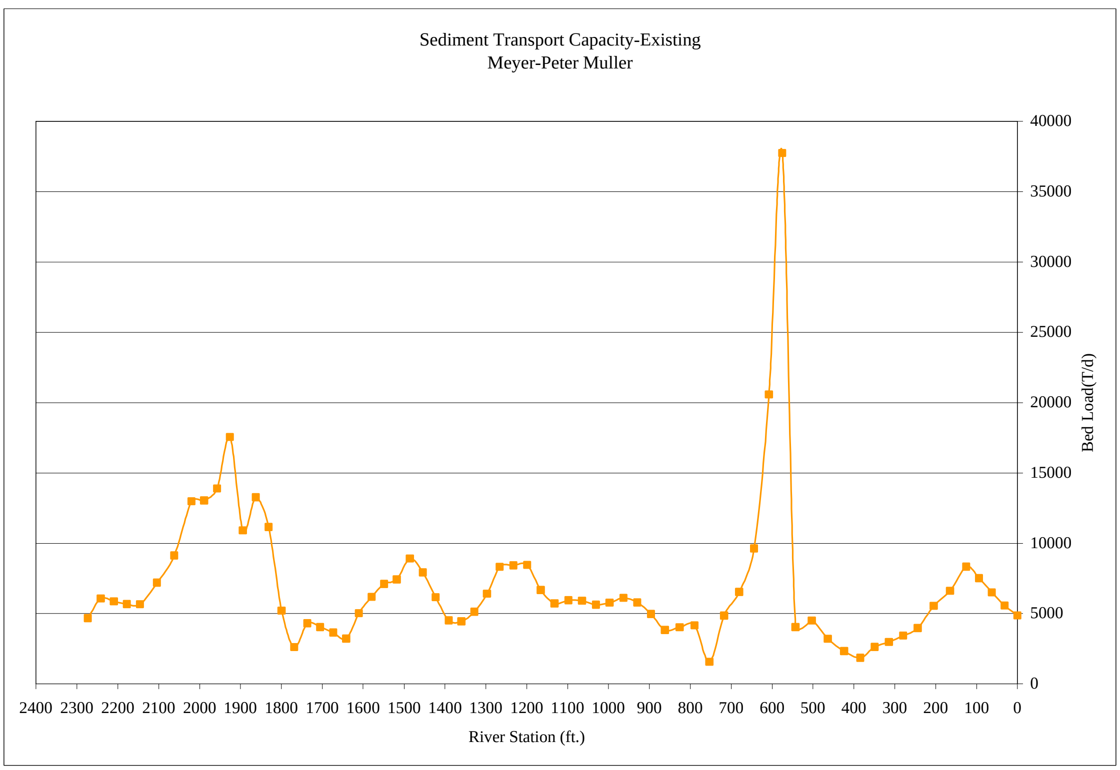



**Figure 9. Bedload transport capacity using Meyer-Peter Muller equation through the project rea**

## 3.0 Proposed Design


Image of downstream bank erosion and failure.

The morphology of a stream consists of its shape, pattern, and position in the landscape. The forces resisting movement in relation to those imposed by water and sediment moving in the channel largely dictate the channel morphology. Physical factors influence morphology including valley structure, soil type and cohesion factor of the bed and bank material. Successful channel design and implementation account for these factors.

An important part of any restoration project is predicting stable channel dimensions for the project reach. The geomorphic approach to channel restoration embraces the notion of dynamic equilibrium allowing some degree of freedom to erode and deposit sediment, while maintaining the general character and stability of the system. Naturally occurring stream channels have a "most probable state" for hydraulic geometry variables that result from the variable flow and sediment regime paired with the channel boundary conditions. The general approach to natural stream channel design is to estimate the "most probable state" and determine how to best achieve the channel form within the project constraints, and realize that state with the minimum possible intervention.

### 3.1 Project Goals and Objectives

As project partners reviewed the condition of the reach and its potential for restoration, a number of goals and objectives were identified. Water quality is negatively affected by excessive streambank and bed erosion. The restoration of the reach presents the opportunity to minimize erosion, while providing a number of environmental benefits. The primary goal of the project can be summarized as follows:

> ***To mitigate excessive turbidity and total suspended solids impact on water quality by addressing excessive erosion in areas with glacial lake clay and clay rich lodgment till exposures by restoring a self sustaining stream form and function through the reach.***

To accomplish the improved water quality goal it was determined that the design needed to address the existing condition of the stream channels bed and banks, conveyance of water and sediment, and riparian vegetation condition. Further, it is suspected that restoring stream form and function within the project reach would reduce the safety hazard and property losses, improve aquatic and fisheries habitat as well as recreational and aesthetic values.

### 3.2 Project Constraints

A number of potential constraints for the project were identified during the design process including physical site constraints, landowner approval and access, project permitting and data needs and limitations. The project design addressed channel stability and processes while working within the existing physical site constraints. The design needed to modify planform, channel profile and cross sectional parameters in order to achieve the goals and objectives of the project which include long-term channel stability. Physical site constraints were identified that could impact various design alternatives, making an analysis of the costs and risks involved with each design alternative critical to the development of an appropriate restoration strategy.

The most significant challenge to design development was to identify a channel planform alignment meeting appropriate channel morphology conditions and bank stability objectives in light of the physical site constraints. The alignment is constrained by a naturally narrow valley morphology, existing wetlands, vegetation, and archeological resources located in the northern floodplain.

A wetland inventory identified 1.2 acres of wetland located in and around the project site (**Map W-1 in Appendix A)**. Substantial effort was made to limit disturbance to these areas during the design and planning for construction and project implementation. The designers proposed 0.4 acres of wetland disturbance within the project grading extent **(Map WD-1 in Appendix A)**. As proposed, wetland mitigation will include a 0.3 acre constructed wetland near Station 8+00 and approximately 0.2 acres of wetland along the channel boundary between Station 6+00 and 9+00. Detailed mitigation planning information is available on construction drawings **CR-3** and **CR-4** in **Appendix I** as well as in sections 3.4.5 and 5.2 of this report.

Archeological inventories documented a sawmill and tannery known as the B. Morss site located in the northern floodplain near the Conine farm. The recommendation was made by Binghamton University to avoid and protect the site during design and construction activity. The proposed project grading extent was several hundred feet away from the site and protective measures utilizing fencing and signage was proposed during construction. The location site and protective measure can be seen on construction drawing **CR-10** in **Appendix I.**

As proposed the project requires the clearing and grubbing of approximately one acre of forested floodplain in the upper portion of the project reach. This cover type has been identified as potential habitat of the Indiana bat (*Myotis sodalis*), which is a federally and state protected endangered species. Investigation was performed to determine any potential affect the project may have on the bats habitat. Communications with Alan Hicks, a Mammal Specialist with the Endangered Species Unit of NYSDEC confirmed that there has been no record of Indiana bats inventoried near the project area, nor have any known maternity colonies been discovered at elevations above 1,000 ft anywhere in the state (project reach elevation approximately 1,220 feet), and further, that in the unlikely event the bats are present, they would most likely benefit from the stream restoration project due to the ecological enhancements expected from the project.

Landowner approval of the project is prerequisite to project construction. Implementation of the project requires formal approval to be obtained in the form of Landowner Project Agreements. These agreements contain a ten year easement where attainable for protection of the project and to facilitate project maintenance when necessary. Education of the multiple primary and secondary landowners within the project area included information about stream instability, need for action, project benefits and long term maintenance and management. Initial planning and design for this project incorporated landowner knowledge of the site and addressed owner concerns where appropriate. The provisions of landowner approval were set forth via the Landowner Project Agreement, which is a temporary license between the landowner and the GCSWCD. Long term operation and maintenance agreement is discussed in ensuing sections.

Construction of the project required ACOE, NYSDEC and NYCDEP permits. Project design and construction requires close coordination with these agencies. The NYSDEC has authorized similar projects under Article 15 of ECL, while the ACOE utilizes Nationwide 27 permits. NYCDEP requires the preparation and approval of stormwater pollution prevention plan outlining erosion and sediment controls to be used during construction.

## 3.3 Design Approach

Several approaches were used to develop the proposed channel to achieve equilibrium channel conditions. These include analog and reference reach, empirical, and analytical techniques applied at various times through the design process. Typically, the analog design approach utilizes historic site data or field collected data from reaches exhibiting desirable physical forms from areas assessed to be in sediment and hydrological equilibrium. The project reach design utilized this approach incorporating data from the upstream reach as a reference reach as a starting point for design. Empirical relations including regional curves and suitable regime equations were also used to validate the initial channel dimensioning. Analytical techniques were used to refine and validate equilibrium channel conditions for the proposed channel. These techniques make use of the continuity equation, roughness equations, hydraulic modeling and various sediment transport functions.

## 3.4 Design Components

The proposed channel design includes the complete realignment of 1,650 linear feet of the stream channel. Channel reconstruction includes modification of the channel geometry and stream channel profile, floodplain and adjoining banks and terraces. The design includes two primary types of rock structures including vanes and cross vanes to promote channel stability during vegetation reestablishment. Construction specifications are located in **Appendix H** and construction drawings can be found in **Appendix I**.

### *3.4.1 Channel Reconstruction*

During the design process, channel sizing was used to promote channel equilibrium and to provide long-term self-sustainability. The project reach design utilized regime, reference reach and analytical techniques to develop the channel design. The channel was designed to provide for sediment transport and passage of the base, bankfull and flood flows, with considerations for future channel boundary conditions. Unlike traditional channel sizing, the design channel continually transforms between riffle and pools, which change in shape, length and spacing as the channel meanders through the reach.

Empirical relationships that relate channel geometry to hydrology are termed “regime equations” and are based on observations of groups of streams and commonly used for comparative purposes. **Table 5** summarizes the bankfull channel width and depth in relation to discharges estimated for the site. The average top widths determined by regime equations indicate an average width of 150 feet and depths of 4.2 feet for the project reach. Several regional curves developed by NYCDEP SMP relating drainage area to width and depth estimate a width 115 feet and depth of 4 feet which correlated well with bankfull morphology of the upstream adjoining reach.

**Table 5. Regime relations for bankfull channel width and depth.**

| Investigator/Source | Formula | Bankfull Width | Bankfull Depth |
|---|---|---|---|
| Bray (1982) | W=2.38 *Q2^.53 | 188 | 3.4 |
| (General) | d=.226*Q2^.33 | | |
| | | | |
| Emmett (1972) | W=2.39*Qbf^.5 | 133 | 4.3 |
| (Alaska Meander Streams) | d=.26*Qbf^.35 | | |
| | | | |
| Drage & Carlson (1977) | W=4.66*Qbf^.47 | 204 | 2.8 |
| (Braided Streams) | d=.13*Qbf^.38 | | |
| | | | |
| USGS Channel Width | W=(Q2/.4)^1/1.82) | 153 | 3.9 |
| (Used Williams (1986) W/d Relationship) | d=0.12*W^0.69 | | |
| | | | |
| Lacey (1948) | W=2.67*Qbf^0.5 | 149 | 4.5 |
| | d=(Qbf/(13.5*((D50*25.4)^.5)))^.333 | | |
| | | | |
| Yukon Placer 1990 DFO W/D Charts | W=2.73*Qbf^0.5 | 152 | 3.1 |
| (converted from metric) | d=0.22*Qbf^0.33 | | |
| | | | |
| Leopold et al. (1956) | W=5*Qbf^.5 | 278 | 1.4 |
| | d=0.1*Qbf^.0.33 | | |
| | | | |
| Simons & Albertson (1971) | W=2.5*Qbf^.51 | 151 | 7.8 |
| | d approx R= 0.43*Qbf^0.43) | | |
| | | | |
| Nixon (1959) | W=1.67*Qbf^.5 | 93 | 7.8 |
| | d=0.55*Qbf^0.33 | | |
| | | | |
| Nash (1959) | W=1.32*Qbf^.54 | 101 | 8.1 |
| (for clays) | d=0.93*Qbf^0.27 | | |
| | | | |
| Chang (1988) | W=[1.905+0.249*ln(0.0001065*D50^1.15)/(S*Qbf^0.42))]*Qbf^0.47 | 80 | 6.4 |
| | d=[.2077-0.0418*ln(0.000442*D50^1.15)/(S*Qbf^0.42))]*Qbf^0.42 | | |
| | | | |
| Miller & Davis (2003) | W=17.07*DA^.46 | 120 | 4.1 |
| NYCDEP Regional Curves (Region 4) | d=1.05*DA^0.32 | | |
| | Average | 150 | 4.8 |
| *Source: FischenIck (2000), Esopus Creek Asessment & Conceptual Design Report* | | | |

The existing channel is considered inefficient and sediment deposition has amplified bank erosion and channel instability. Improving the width-depth dimensions of the over-widened sections and creating a single channel in the braided area of the reach will provide for proper transport of sediment through the reach.

The initial step in evaluating sediment transport competency and capacity was to evaluate mobility of the channel bed and bar material and develop a proposed depth and slope for the channel. This is accomplished through comparison of the hydraulic shear stress and the critical shear stress of the proposed bed material utilizing proposed planform data, sediment characteristics of the upstream supply reach and the project reach. Utilizing regression equations for competency analysis developed by Rosgen (2006) it was determined that a required mean depth within a riffle feature should approximate 4.3 feet for the proposed slope of 1.2% and produce a bankfull shear stress of approximately 3.2 lbs/ft$^2$. These dimensions verify that the proposed 84$^{th}$ percentile bed pavement particle size (D84) of approximately 320 mm would be mobile during bankfull conditions, however D95 and D100 of the bed pavement would be immobile promoting stability of the channel bed during bankfull flows. Sediment transport competency and capacity was further evaluated during design review by Buck Engineering PC. Their evaluation included the use of HECRAS modeling of the proposed channel which further agreed with the proposed channel design dimensions. These findings have been provided as **Appendix G**.

Base flow channel dynamics were enhanced through the creation of pools at the outside of meander bends and behind proposed in-stream structures. These pools will improve base flow conditions by increasing storage, enhancing bedform diversity and restoring floodplain connectivity during larger storm events.

After review of historic trends of channel migration, it was determined the channel has attempted to expand its belt width through erosion of streambanks throughout the reach. The design called for realignment of the majority of the existing stream channel in order to meet bank stability project objectives.

Temporary boundary lines were generated along the toe of high banks and large floodplain terraces through the reach using the topographic survey prepared for the project reach. The boundary lines were offset in order to allow adequate floodplain area between the active channel and the high banks for construction, bank protection and flood water conveyance. The proposed plan form dimensions were drafted and incorporated into a design template, which was transposed onto the existing topographic survey of the project site. Modifications to the alignment were made to achieve the best feasible alignment through the project area in order to connect upstream and downstream reaches and avoid existing high banks, terraces, wetlands and archeological resources. The proposed channel pattern results in a consistent slope through the project reach, suitable for the valley setting. Substantial effort was also made to minimize the disturbance to the existing floodplain vegetation and to use the existing vegetation as bank protection where applicable.

Field assessment determined that the channel was vertically unstable through the reach due to the dramatic planform adjustments and localized degradation and aggradation. The stream channel profile was created using slope characteristics of the valley, the existing channel and floodplain terraces, as well as regime and reference conditions to match proper geometry with the existing floodplain. The channel profile is constrained vertically through the reach by underlying glacial clay layers that exist in close proximity to the channel invert. The profile design included re-elevating portions of the channel invert in order to properly utilize the adjacent floodplain, decrease entrenchment and to prevent future scour into the clay layers. Consideration was given to the cost associated with elevating portions of the stream channel and were weighed against the potential benefits of decreased suspended sediment loading and the multiple ecological benefits of enhanced channel and floodplain interaction. The channel profile was also designed to provide for bed feature variation, simulating a more natural riffle/pool complex, in order to provide for increased channel habitat diversity and energy dissipation. The existing grade of the floodplain was used to target the proposed bankfull elevation of the project throughout the majority of the channel length.

It was estimated that channel reconstruction would require approximately 22,700 cubic yards of fill material generating a material deficit of 2,600 cubic yards after channel and floodplain cuts were made. Borrow areas within the project area were created to generate the additional material required to complete the channel excavation.

Exposures of glacial clay materials were inventoried in the bottom of the pools. To mitigate the water quality impacts of the clays during channel reconstruction, the design provided specifications for over excavation of the clay materials and replacement with clean gravel/cobble materials in the channel area. Construction specification for clay over-excavation and replacement are detailed in specification **SR-07** in **Appendix H** and can be seen on drawing **CR-9** detail **SR-07c** in **Appendix I**.

The nature of this project required critical attention to the size of the materials used in various sections of the stream channel. As proposed, various materials were to be preserved during construction for use in specific areas of the channel as directed by the contracting officer during construction. Construction drawing **CR-3** displays the channel between Station 6+00 and 9+00 designated as a riffle feature. Coarser materials used in the construction of this feature are specified on detail **SR-07b** on sheet **CR-9** in **Appendix I,** remaining pool areas will utilize detail **SR-07a** in regards to the levels and locations of materials within a typical cross section.

**Table 6. Summary of existing, reference, and proposed conditions during bankfull flow.**

| Morphological Value | Existing Reach | Reference Reach | Proposed Reach |
|---|---|---|---|
| Rosgen Stream Type | C3 | C3 | C3 |
| Drainage Area (sq mi) | 70 | 68 | 70 |
| Bankfull Width (ft) | 188 | 128 | 110 |
| Bankfull Mean Depth (ft) | 3.4 | 3.8 | 4.3 |
| Width to Depth Ratio | 56 | 34 | 26 |
| Bankfull Flow Area (ft) | 632 | 486 | 470 |
| Pavement D50 (ft) | 0.21 | 0.24 | 0.26 |
| Pavement D84 (ft) | 1.37 | 0.92 | 0.94 |
| Wetted Perimeter (ft) | 190 | 133 | 112 |
| Hydraulic Radius (ft) | 3.3 | 3.7 | 4.2 |
| Manning's coefficient | 0.059 | 0.049 | 0.048 |
| Mean Velocity (ft/sec) | 5.9 | 7.1 | 8.8 |
| Discharge (cfs) | 2500 | 3100 | 3100 |
| Max Depth (ft) | 6.8 | 6.5 | 5.5 |
| Floodplain Width (ft) | 438 | 400 | 438 |
| Entrenchment Ratio | 2 | 3 | 4 |
| Radius of Curvature (ft) | 321 | 324 | 350 |
| Mean Channel Slope (ft/ft) | 0.011 | 0.0096 | 0.012 |
| Pool Max Depth (ft) | 8.6 | 10 | 8.6 |
| Pool Width (ft) | 141 | 118 | 120 |

### *3.4.4 In-Stream Structures*

The design incorporated three general types of in stream structures to promote reach stability including; rock vanes, cross vanes, and root wads. The structures will provide significant benefits by enhancing fisheries habitat through the reach, while generating a bed and bank form suitable for the proposed stream type.

The use of rock vanes will impede bank erosion within the reach. These structures reduce shear stress along the streambanks in order to allow for the establishment of vegetation.

Rock vanes will create scour pools downstream of the arms, thus enhancing fisheries habitat. The design may incorporate the use of available root wads in high stress areas along the streambanks. These structures would assist the vanes to ensure bank protection and habitat enhancement. Several rock vanes will be installed along the proposed channel meander bends in order to re-direct channel currents and reduce the potential for excessive channel migration and erosion. The vanes will be constructed of large diameter rock, and will be oriented in an upstream fashion with an interior acute angle of 20 – 30 degrees. The length of the rock vanes will average 100 feet and key into the streambanks at an elevation approximately one foot below the bankfull stage. The vanes will be keyed into the streambanks a minimum of 20 feet to prevent scour and flanking of the structures in the event of a large flood.

Two rock cross vanes will be installed through the project length to provide stream bank protection along with grade control for the channel bottom. The cross vane structures will re-direct channel currents and provide energy dissipation, while maintaining transitions between physical bed features. The cross vanes will be constructed of large diameter rock oriented in an upstream fashion with two vane arms protruding from both the right and left streambank, connected in the center of the stream channel by a rock sill. Each cross vane arm will be constructed with an interior acute angle of 20 – 30 degrees. The length of the rock cross vanes will average 100 feet and key into the streambank at an elevation approximately one foot below the bankfull stage. The cross vanes will be keyed into the streambank a minimum of 20 feet to prevent scour and flanking of the structure. The typical detail drawings illustrating configuration of the rock and cross vanes can be found in the accompanying project drawings in **Appendix I on CR-3** and details on **CR-9**. **Table 7** summarizes the types of structures proposed for the project, their locations and the estimated material necessary to construct them.

**Table 7. In stream structure details.**

| Structure | Type | Station (Approx. feet) | Rock Volume (cuyd) | Weight (ton) |
|---|---|---|---|---|
| 1 | Cross Vane | 1+00 | 409 | 817 |
| 2 | Rock Vane | 3+00 | 179 | 358 |
| 3 | Rock Vane | 4+50 | 194 | 387 |
| 4 | Rock Vane | 5+50 | 180 | 360 |
| 5 | Cross Vane | 9+00 | 462 | 925 |
| 6 | Rock Vane | 10+50 | 184 | 368 |
| 7 | Rock Vane | 12+00 | 183 | 366 |
| | | Total | 1,791 | 3,582 |

### *3.4.5 Project Site Re Vegetation*

Establishment of an effective riparian buffer zone is critical to the success of a stream stabilization design. A combination of dormant plant materials, conservation seed mixtures, and plantings of live trees and shrubs will be employed to initiate the development of a functioning riparian community. Native willow and dogwood species will be planted on the streambanks. Single or double rows of live fascines will be applied to flood plain benches, along side each vane, on outside bends and to other areas of special concern. All other areas of disturbance will be treated with conservation seed mixtures and mulched to minimize soil losses. Various species of woody trees and shrubs, appropriate for the riparian zone, shall be planted in the disturbed upland areas.

Wetlands and improved riparian buffer will be constructed to mitigate the disturbance of approximately 0.4 acres of wetland within the grading extent. Wetland will be developed totaling 0.5 acres in addition to the reestablishment of 4.2 acres of riparian buffer. A single wetland will be developed on the northern floodplain near Station 8+00 measuring 0.3 acres in size, and 0.2 acres of wetland will be developed along the margin of the newly constructed channel between Stations 6+00 and 9+00. The attached project drawings **(CR-3-4)** further clarify the proposed location of the constructed wetlands and riparian buffer re vegetation plan. Wetland vegetation will be established by use of a wet meadow seed mixture, with species selected for known wetland and wildlife values **(Table 8)**. The emergent species selected for this area would be tolerant of irregular surface inundation and are expected to survive in saturated soil conditions. The wetland seed mixture would encourage the establishment of a uniform herbaceous cover. Seed mix's to be used will include "New England Wetmix" marketed by New England Wetland plants, Inc. as well as "Northeast Wetland Grass Mix" marketed by Southern Tier Consulting.

**Table 8. Proposed wetland seed mixture.**

| Percent | Common Name | Scientific Name |
|---|---|---|
| 37.3% | Canada Mannagrass | Glyceria Canadensis |
| 29.3% | Reed Meadowgrass | Glyceria grandis |
| 7.5% | Blue Joint | Calamagrostis canadensis |
| 7.3% | Smooth Panic Grass | Panicum dichotomiflorum |
| 4.9% | Rice Cut Grass | Leersia oryzoides |
| 3.9% | Japanese Millet | Echinochloa crusgalli |
| 3.0% | Blue Verbain | Verbena hastata |
| 1.7% | Canada Wildrice | Elymus Canadensis |
| 1.5% | Water Plaintain | Alisma plantago-aquatica |
| 0.9% | Pennsylvania Smartweed | Polugomum pensylvanicum |
| 0.8% | Nodding Bur Marigold | Bidens cernua |
| 0.7% | Stout Wood Reedgrass | Cinna arundinacea |
| 0.7% | Spotted Water Hemlock | Cicuta maculata |
| 0.3% | BeggersTick | Bidensfrondosa |
| 0.2% | Swamp Dock | Rumex verticillatus |
| *Note:Percentage is based on number of seeds, not proportion by weight.* | | |

# 4.0 Project Construction Sequence

This project included disturbance of approximately 8 acres of riparian lands. The major construction activities were performed in two phases intended to minimize the total area vulnerable to erosion at any time.

## 4.1 Construction Phasing

### *4.1.1 Phase I*

Phase I included the installation of project erosion and sediment controls and the construction of stream restoration measures beginning at Station 0+00 and continuing to Station 10+00. Phase I construction sequencing progressed as follows:

1. Installed access road and staging area.
2. Commenced Clearing and Grubbing.
3. Installed phase I coffer dams and de-watering pump and pipeline.
4. Installed turbidity pumps and pipe lines.
5. Installed dewatering outlet controls.
6. Installed turbidity pump outlet controls.
7. Performed stream channel excavation.
8. Constructed rock structures.
9. Installed vegetative measures of seed & mulch as specified.

### *4.1.2 Phase II*

Phase II included the installation of project erosion and sediment controls and the construction of stream restoration measures beginning at Station 10+00 and continuing to Station 16+50. Phase II construction sequencing progressed as follows:

1. Commenced Clearing and Grubbing.
2. Installed phase II coffer dam and de-watering pump and pipeline.
3. Installed turbidity pumps and pipe lines.
4. Installed dewatering outlet controls.
5. Installed turbidity pump outlet controls.
6. Performed stream channel excavation.
7. Constructed rock structures.
8. Installed vegetative measures of seed & mulch as specified.

# 5.0 Project Bidding

### 5.1 Bidding Process

The contractor used for construction of this project was selected through a public sealed bid process. Bidders were required to attend a mandatory pre-bid site meeting prior to submission of a sealed bid. Bidders were asked to prepare bids on the basis of nine Primary Bid Items and seven Alternate Bid Items (see table 9). Bidders were also instructed to provide a pricing schedule of equipment and labor rates to be applied to any work required outside the scope of the bid. The bids were evaluated and awarded on the basis of the aggregate costs of all of the Primary Bid Items for the provided estimated quantities. Alternate bid items were not used for the purpose of evaluating the bids and determining the low bidder.

### 5.2 Contract Award

Six sealed bids were received for the project. The bidding contractors, aggregate costs of all of the Primary Bid Items for the respective bids as well as the Engineer's Estimate for the project are presented below:

| | |
|---|---|
| Evergreen Mountain Contracting, Inc. | $ 717,925.00 |
| Kingston Equipment Rentals | $ 789,900.00 |
| Fastracs Rentals, Inc. | $1,014,650.00 |
| T.C. Briggs Contracting & Supply, Inc. | $1,115,400.00 |
| Grant Street Construction | $1,244,586.00 |
| CFI Construction | $1,395,500.00 |
| **Engineer's Estimate** | **$1,254,027.20** |

The contract was awarded to Evergreen Mountain Contracting, Inc. by the GCSWCD Board of Directors at their June 7, 2007 board meeting. The bid forms received are on file and available for further review at the GCSWCD office.

# 6.0 Project Contract Activities

Phase I stream channel excavation.

Project construction commenced on July 30, 2007 with clearing and grubbing activities in Phase I of the project sequence. Project dewatering began on August 6, 2006, and continued through August 29, 2007. Project dewatering was sustained for a total of 23 days. Planting of containerized material was conducted by GCSWCD and volunteers outside of this primary construction time frame. Bioengineering activities completed by Evergreen Mountain Contracting, Inc. were also conducted outside of the primary construction window in order to allow sufficient time for plant materials to enter their dormant period.

## 6.1 Primary Bid Items

The primary bid items for this project represent the principle work items and were the basis of the bid evaluation and contract award process.

### *6.1.1 Mobilization / Demobilization*

This item covered mobilization of all equipment and labor forces to the project site for the duration of the project construction. This item was bid as a lump sum to include all equipment necessary to complete all phases of the project except for establishing access to the work area.

Contractors were informed at the pre-bid meeting that preparation of access roads to the work area would be paid on a time and materials basis according to the equipment and labor rates supplied as a component of the project bid. Contractors were aware that the cost of labor and equipment time for establishing access to the work area should not be included under any of the bid items. Material necessary to construct the stabilized construction entrance would be covered under Alternate Bid Item #7 – Item 4 Stone.

The contract bid price scheduled for this item was $37,000.00. The total amount paid for this item was $37,000.00. The bid specifications for this item are on file and available for further review at the GCSWCD office.

All aspects of this bid item were completed as expected.

### *6.1.2 De-watering*


Phase I dewatering pump intake and pipeline.

Stream channel construction was required to be completed in a dry condition in order to meet the requirements of various regulatory agencies. During all construction in the existing or proposed stream channel, the contractor was required to divert the entire stream flow around the work area. Dewatering was maintained 24 hours per day, 7 days per week during the construction period and was accomplished by a pump and pipeline scenario. Dewatering was performed in two phases and required the excavation of a sump and construction of a gravel coffer dam across the existing channel at both the top and bottom of each phase. Upon completion of the construction of the phase all areas were restored as soon as possible to preconstruction conditions. Pumping specification **CS-4 in Appendix H** and construction drawings **CR-10** and **11** in **Appendix I** display the location, extents and details of the dewatering plan.


Phase I turbidity control basin.

All construction infrastructure including roads, staging areas, borrow and storage sites, construction entrances and other infrastructure as deemed necessary by the Contracting Officer were restored as outlined in the Stormwater Pollution Prevention Plan (SPPP) that is located in **Appendix D** and on construction drawings **CR-10** and **11** in **Appendix I**. All areas were restored as soon as possible to preconstruction conditions. Sediment and erosion control measures were in place throughout the construction period and are outlined in the aforementioned appendix and follows the procedures indicated in the New York State Standards and Specifications for Erosion and Sediment Control (2005).

This bid item covered assembly, operation, maintenance, and disassembly of all dewatering equipment necessary to dewater stream flow up to 50 cubic feet per second. This item was bid as a lump sum to include all equipment necessary to complete all phases of the project.

Alternate Bid Item #6 was also included in the bidding process which provided 10 cubic feet per second of additional dewatering capacity in the event that stream flow exceeded the capacity of the primary dewatering equipment. Activation of this alternate bid item would bring the overall dewatering capacity to a maximum of 60 cubic feet per second. The alternate bid item was bid on a weekly basis at $30,000.00 per week with the understanding that the item would be paid for a minimum of one week from the date of activation. Prospective bidders were informed at the pre-bid meeting that, upon evaluation of the bids, the GCSWCD may elect to provide additional pumping capacity as an alternative to activating alternate Bid Item #6.

GCSWCD did elect to make the additional pumping capacity available to the contractor outside of the project bid items. Under an agreement with NYCDEP, GCSWCD procured a 30" axial flow pump powered by a diesel power pack. The pump was coupled with 1000 feet of 30" high density polyethylene pipeline. The total cost of the pumping equipment and pipeline included the purchase price, delivery, and final assembly of the pump, power pack and pipeline. The overall cost of the dewatering system was $111,710.51.

The auxiliary pumping equipment was mobilized to the site. The contractor was instructed that in the event that stream discharge exceeded 50 cfs, they should install the auxiliary pumping equipment according to the equipment and labor rates supplied as a component of the project bid.

Provisional real-time stream flow data from USGS Gage 01349950 - Batavia Kill at Red Falls near Prattsville, NY indicated that the stream flow at the project site exceeded 60 cfs beginning the night of August 10, 2007. In the event that GCSWCD had elected to activate Alternate Bid Item #6 to handle the additional flow beyond 50 cfs, two additional units of 10 cfs would have been necessary to accommodate the flow. This would have represented a total additional expense of $60,000. The contractor elected to handle the additional flow with his own equipment that was already installed at no additional cost rather than install the auxiliary pumping equipment.

As the cost effectiveness of the pump and pipeline purchase is evaluated in the future, the $60,000 savings that was made possible by having the auxiliary pumping equipment on site should be included in the evaluation.

The initial Primary Bid price for dewatering was $80,000.00. The total amount paid for this item was $80,000.00. Completion of the project required 23 days of dewatering.

The number of days for which pumping capacity was required in excess of the primary bid capacity indicates that the capacity included in the base bid was appropriate. A rate of 1 cubic foot per second per square mile of drainage area was used as a gross initial estimate of required pump capacity. Those estimates were refined on the basis of available USGS gage data to achieve an acceptable probability of protection from the specified pump capacity. In this case, the rate of protection from the Primary Bid pump capacity was estimated from historical gage data at 75% and in fact exceeded 90%.

Clean water bypass on this project was achieved through the use of a hydraulically driven axial pump. The advantage of this type of pump is the relatively good fuel efficiency for the discharge capacity of the pump. The most significant limitation of this pump type is the limited pressure-head that it is capable of producing. The limited pressure head makes this type of pump unsuitable for very long pumping distances in a closed pipe system or pumping circumstances where pumping more than very limited vertical distance is required. In this case, although long lengths of closed pipe were used, only nominal vertical distances were required to achieve sufficient site dewatering. This type of pump system was very well suited to these site conditions.

The bid specifications for this item are on file and available for further review at the GCSWCD office.

### *6.1.3 Stream Channel Excavation*

This bid item covered all aspects of channel and floodplain grading to the design grades and elevations as well as the control of turbid water within the work area. This item was bid as a lump sum to include all equipment, labor, fuel and other expenses necessary to complete the channel and floodplain excavation.

**Phase I dewatering outlet.**

Stream channel excavation results in disturbance of significant land area. This portion of the project implementation was scheduled in phases to minimize the land area vulnerable to erosion at all times. The phased approach to the excavation work was an effective means of reducing soil loss and erosion on the construction site.

Sediment control during construction was accomplished through collection of all turbid water within the work area, and pumping the sediment-laden water to designated filter areas. Turbidity control equipment with adequate capacity to capture and treat all turbid water within the dewatered work area was included within this item. All disturbed areas were temporarily stabilized with seed and mulch as soon as possible to minimize soil erosion. On average, disturbed areas were open for less than 14 days total. The sediment control measures ensured that no turbid water discharged from the work area.

The channel grading design was developed using a photogrammetric based topographic survey. Grading estimates developed from the survey indicated that the cuts and fills over the entire project would result in nearly a fill balance.  As grading progressed, it became apparent that there was a fill deficit project wide.

Material needed to complete the cuts and fills through the later phases of the excavation was obtained from an on-site borrow area. Access to the borrow area was developed on a time and materials basis according to the labor and equipment rates furnished by the contractor as a component of the bidding process. Fill materials were excavated from the source areas, hauled to their final location and installed to grade on the basis of the price provided under Primary Bid Item #9 – On-site Borrow Material.

The deficit in fill material on the project appears to be the result of the limited accuracy of the photogrammetric based topographic survey techniques. Onsite topographic shots were checked against the data that resulted from the photogrammetric survey, and elevation discrepancies were evaluated and accounted for in the grading design to the best extent possible. Another likely source of the material deficit was changes in the actual contour of the channel corridor resulting from high flow events that occurred after the completion of the topographic survey.

The Primary Bid price and actual cost for stream channel excavation was $282,000.00.

### *6.1.4 Rock Structures*

This bid item covered all aspects of in-stream and floodplain stream stabilization rock structures. This item was bid on a unit price basis using rock tonnage as the measure for payment. The unit bid price included all equipment, labor, fuel and other expenses necessary to obtain and install the rock material as specified in the project documents.

**Excavation and construction of a cross vane sill near the center of project reach.**

The initial Primary Bid price for rock structures was developed based on an estimated rock tonnage of 5000 tons and resulted in a bid price of $210,000.00. The total tonnage actually used to complete the project implementation was 3845.99 tons resulting in an actual final expenditure of $161,531.58.

**Completed arm of the downstream cross vane.**

The rock tonnage applied to this project is somewhat larger than projects of similar character due to the installation of long subsurface floodplain grade control sills. These grade control sills were installed at the request of the NYCDEP Stream Management Program, with the concurrence of GCSWCD, in response to channel avulsions and floodplain scour observed at the Big Hollow Stream Restoration Project following an out-of-bank flow event in 2004. These portions of the rock structures accounted for approximately 17% of the overall project rock budget. Necessity for these types of floodplain grade control structures should be evaluated on a case by case basis.

### 6.1.5 Top Soil

This bid item covered the acquisition and installation to grade of top soil materials obtained from off site. This item was bid on a unit basis by cubic yard of top soil installed. This item covered all aspects of the top soil installation including purchase, delivery, and installation of the top soil as directed by the contracting officer.

**Final grading with topsoil material.**

No top soil was installed on the project from off site sources under Primary Bid Item #5. Material from the project borrow area was determined to be a suitable substitute for the off-site top soil item, and was available at a cost less than that of the top soil bid item. The relative costs and savings of this decision are discussed further in section 6.1.9.

### *6.1.6 Live Fascines*

This bid item covered the live fascine portion of the bioengineering implementation. This item was bid on a unit basis by linear foot of fascine installed. This item covered all aspects of the fascine installation including harvest of the live vegetative material, assembly of the fascines, and installation of the fascines as directed by the contracting officer. Further details of the planting plan are available on page **CR-04 Proposed Vegetation Plan** of the construction drawings

The fascine quantities were measured in place to determine the amount to be paid for the bid item. The bid was prepared based on an estimated quantity of 4,000 ft. of live fascines for a total contract price of $22,000.00. The estimated quantity was based on an initial assumption that 2.5 linear feet of live fascine, on average, would be necessary for each linear foot of stream channel restored to achieve reasonable rates of revegetation. The quantity of fascines actually installed on the project was 2054 ft. for a total expenditure of $11,297.00. Installation of the full quantity of contract units was not deemed necessary by the contracting officer due to the high density of containerized plant material installed on the site by GCSWCD.

### *6.1.7 Live Posts*

This bid item covered the live post portion of the bioengineering implementation. This item was bid on a unit basis by the number of live posts installed. This item covered all aspects of the live post installation including harvest of the live vegetative material, fabrication of the posts, and installation of the posts as directed by the contracting officer. Further details of the planting plan are available on page **CR-04 Proposed Vegetation Plan** of the construction drawings

The live post quantities were counted in place to determine the amount to be paid for the bid item. The bid was prepared based on an estimated quantity of 8,000 live posts for a total contract price of $36,000.00. The estimated quantity was based on an initial assumption that 5 live posts, on average, would be necessary for each linear foot of stream channel restored to achieve reasonable rates of revegetation. The actual quantity of live posts installed on the project was 6449 posts for a total expenditure of $29,020.50. Installation of the full quantity of contract units was not deemed necessary by the contracting officer due to the high density of containerized plant material installed on the site by GCSWCD.

### *6.1.8 Cobble Fill - Imported*

This bid item covered the acquisition and installation to grade of cobble fill materials obtained from off site. This item was bid on a unit price basis using rock tonnage as the measure for payment. This item covered all aspects of the cobble fill installation including purchase, delivery, and installation of the cobble fill as directed by the contracting officer.

**Large boulder materials being salvaged before filling of the upstream high bank.**

No cobble fill was installed on the project from off site sources under Primary Bid Item #8. Materials scavenged from the existing stream channel and obtained from the project borrow area were determined to be a suitable substitute for the off-site cobble fill item, and was available at a cost less than that of the cobble fill bid item.

### *6.1.9 On-Site Borrow Material*

This bid item covered material needed to complete the cuts and fills through the later phases of the excavation which was obtained from an on-site borrow area. Fill materials were excavated from the source areas, hauled to their final location and installed to grade on the basis of the price provided under Primary Bid Item #9 – On-site Borrow Material.

Contractors were informed at the pre-bid meeting that preparation of access roads to the borrow area would be paid on a time and materials basis according to the equipment and labor rates supplied as a component of the project bid. Contractors were aware that the cost of labor and equipment time for establishing access to the borrow area should not be included under any of the bid items.

The necessary quantity of borrow material that was estimated for bidding purposes was 2500 $yds^3$, and resulted in a total bid price of $15,000.00. 6500 $yds^3$ of borrow material were actually necessary to achieve the design grades of the project. The bid price supplied by the contractor was effective for up to 5000 $yds^3$. The contractor agreed to hold the bid price provided for borrow materials in excess of 5000 $yds^3$. 6500 $yds^3$ of borrow material resulted in a total contract expenditure of $39,000.00.

**Off road truck delivering materials from the on-site borrow area.**

Although this expenditure exceeded the budget for this bid item, the quality of the material obtained from the borrow area was such that the material was a suitable substitute for the items available under both Primary Bid Item #5 – Topsoil and Primary Bid Item #8 – Cobble Fill Imported. Elimination of those two bid items resulted in a savings of $35,925.00, more than offsetting the increase in the on-site borrow material budget. The decision to substitute the on-site borrow material for the topsoil and cobble items not only resulted in an overall savings to the project budget, but also yielded a larger volume of material than the three primary bid items (#5, #8 and #9) would have yielded as estimated. The overall savings to the project budget was $14,925.00.

## 6.2 Alternate Bid Items

The alternate bid items for this project represent work items that were activated at the discretion of the contracting officer and were not a component of the bid evaluation and contract award process.

### *6.2.1 Root Wads*

No root wads were installed as a component of this project.

### *6.2.2 Live Material Transplants – shrubs/trees*

All live material transplants were installed by GCSWCD Staff and volunteers. No live material transplants were installed by the project contractor.

### *6.2.3 Sediment Control Fence*

No sediment control fence was installed as a component of this project.

### *6.2.4 Clay Removal and Disposal with Replacement*

This bid item included over-excavation of clay deposits found within the final grades and elevations of the project design. Clay materials were removed from the stream channel. The materials were then disposed of in a location specified by the contracting officer. The over-excavated area was then backfilled with cobble and gravel material suitable for use in the stream bed. This item was bid on a unit basis with cubic yards of disposed clay used as the measure for payment. The clay volume was determined based on the number of truck loads hauled to the disposal site. The loads were counted by the contracting officer and confirmed daily by the contractor.

The bid price for Clay Removal and Disposal with Replacement was $40.00 per $yd^3$. A total of 600 $yds^3$ of clay were removed and replaced with cobble material, resulting in an overall expenditure of $24,000.00.

In the future, clay disposal expenditures could be reduced by completing the procedure on a time and materials basis according to the equipment and labor rates supplied as a component of the project bid. Potential bidders should be informed in the bid documents and at the pre-bid meeting of the potential for substitution.

#### *6.2.5 Clay Removal and Disposal without Replacement*

This bid item included excavation of clay deposits found within the final grades and elevations of the project design, or in the excavated trenches created during installation of the rock structures. Clay materials were removed from the stream channel. The materials were then disposed of in a location specified by the contracting officer. This item was bid on a unit basis with cubic yards of disposed clay used as the measure for payment. The clay volume was determined based on the number of truck loads hauled to the disposal site. The loads were counted by the contracting officer and confirmed daily by the contractor.

The bid price for Clay Removal and Disposal with out Replacement was $20.00 per $yds^3$. A total of 2099 $yds^3$ of clay were removed, resulting in an overall expenditure of $41,980.00.

In the future, clay disposal expenditures could be reduced by completing the procedure on a time and materials basis according to the equipment and labor rates supplied as a component of the project bid. Potential bidders should be informed in the bid documents and at the pre-bid meeting of the potential for substitution.

#### *6.2.6 10 Cubic Feet per Second Additional De-watering – all costs included*

This bid item was included in the bidding process in order to provide 10 cfs of additional dewatering capacity in the event that stream flow exceeded the capacity of the primary dewatering equipment. The alternate bid item was bid on a weekly basis at $30,000.00 per week with the understanding that the item would be paid for a minimum of one week from the date of activation.

Prospective bidders were informed at the pre-bid meeting that, upon evaluation of the bids, the GCSWCD may elect to provide additional pumping capacity as an alternative to activating alternate Bid Item #6.

GCSWCD did elect to make the additional pumping capacity available to the contractor outside of the project bid items. Under an agreement with NYCDEP, GCSWCD procured a 30” axial flow pump powered by a diesel power pack. The pump was coupled with 1000 feet of 30” high density polyethylene pipeline. The total cost of the pumping equipment and pipeline included the purchase price, delivery, and final assembly of the pump, power pack and pipeline. The overall cost of the dewatering system was $111,710.51.

The auxiliary pumping equipment was mobilized to the site. The contractor was instructed that in the event that stream discharge exceeded 50 cfs, they should install the auxiliary pumping equipment according to the equipment and labor rates supplied as a component of the project bid.

Provisional real-time stream flow data from USGS Gage 01349950 - Batavia Kill at Red Falls near Prattsville, NY indicated that the stream flow at the project site exceeded 60 cfs beginning the night of August 10, 2007. In the event that GCSWCD had elected to activate Alternate Bid Item #6 to handle the additional flow beyond 50 cfs, two additional units of 10 cfs would have been necessary to accommodate the flow. This would have represented a total additional expense of $60,000. The contractor elected to handle the additional flow with his own equipment that was already installed at no additional cost rather than install the auxiliary pumping equipment.

As the cost effectiveness of the pump and pipeline purchase is evaluated in the future, the $60,000 savings that was made possible by having the auxiliary pumping equipment on site should be included in the evaluation.

No expenditures associated with additional dewatering capacity were made under this alternate bid item.

#### *6.2.7 Item 4 Access Roads*

This bid item covered the acquisition and installation of Item 4 stone materials obtained from off site and used to construct stabilized site access points. This item was bid on a unit price basis using rock tonnage as the measure for payment. This item covered all aspects of the Item 4 installation including purchase, delivery, and installation of the Item 4 as directed by the contracting officer.

100 tons of Item 4 was estimated to be necessary to prepare the stabilized construction entrances for an estimated expenditure of $4,000.00. 277.45 tons of Item 4 was actually used for a total actual expenditure of $11,098.00. This expenditure exceeded the estimate by $7,098.00. The funds necessary to cover the excess expenditure on this bid item were transferred from funds budgeted for other project items.

### 6.3 Time & Materials Work

#### *6.3.1 Clearing & Grubbing*

Clearing and grubbing necessary to complete the project implementation was conducted on a time and materials basis according to the equipment and labor rates provided by the contractor as a component of the bidding process.

Clearing and grubbing consisted of the clearing, grubbing, and disposal of trees, snags, logs, brush, stumps, shrubs, and rubbish from the designated areas. These areas were flagged in order to minimize any impacts to adjacent vegetation. Grubbed areas were completely revegetated as part of the project as indicated on construction drawing **CR-04**. Clearing and grubbing also included removal of concrete, wood or steel structures within designated areas. Significant materials, primarily consisting of wood, metal roofing and farm equipment, near and around the Conine farm were removed from the site and disposed of as a component of the project.

**Clearing and grubbing of Phase II.**

The project site had several stands of knotweed (*Polygonum Cuspidatum*). This species is an invasive plant, not native to the region. It is extremely prolific, and can grow from small cuttings of either the rhizome or vegetative growth. This species is detrimental to stream bank stability, and must be handled and disposed of carefully. Areas of Knotweed were grubbed to a depth sufficient to remove all rhizomes as determined by GCSWCD. Design specification **CS-04** in **Appendix H** details all clearing and grubbing activities and construction drawing **CR-10** displays the extents of operations. The grubbed material was disposed of in a disposal pit. The location of the disposal pits was determined by GCSWCD. The material was covered as follows:

- Where six feet of cover depth was attainable, the material was placed in the disposal pit, and covered with a minimum of six feet of clean fill, free of knotweed material.

- Where six feet of cover depth was not attainable, the material was placed in the disposal pit, and covered with black plastic and a minimum of three feet of clean fill, free of knotweed material.

The total project expenditure associated with clearing and grubbing was $21,690.50. The Engineer's Estimate for this task was $31,600.00.

### *6.3.2 Access Preparation and Site Cleanup*

Project site access and cleanup was conducted on a time and materials basis according to the equipment and labor rates provided by the contractor as a component of the bidding process. This included preparation of access roads to the work area and material borrow area, cleanup of relic machinery and debris, and final grading of the borrow area.

The total project expenditure associated with access preparation and site cleanup was $29,148.00. The Engineer's Estimate for this task was $28,000.00.

### *6.3.3 Wetland Grading*

Mitigation of 0.5 acres of wetland was required as a component of the United States Army Corps of Engineers permit. Excavation necessary to create the wetland mitigation work was conducted as a component of the stream channel excavation bid as the turbidity settling basin required for the stream channel excavation process was used as the final wetland mitigation area.

No project expenditures were associated with wetland grading.

**Stabilized borrow area access road and channel.**

### *6.3.4 Constructed Riffle*

A constructed riffle was proposed as a component of the channel design. Construction of the riffle required that select coarse material be collected from the existing stream channel and installed to grade in the location of the proposed riffle. The riffle materials were collected and hauled to the riffle location on a time and materials basis according to the equipment and labor rates provided by the contractor as a component of the bidding process. The materials were then installed to the design grades and elevations as a component of Primary Bid Item #3 – Stream Channel Excavation.


**Section of the constructed riffle displaying salvaged and seeded coarser substrate.**

The total project expenditure associated with creation of the constructed riffle was $7,260.00.

## 7.0 Project Non-contract Activities

A variety of project implementation tasks, outside the scope of the contract with Evergreen Mountain Contracting Inc., were completed by GCSWCD's vegetation management staff, plant materials center and with the help of volunteer labor forces. These tasks included project site survey control and installation of containerized plant material and acquisition of auxiliary pumping equipment.

### 7.1 Project Site Survey Control

Precision grading of the stream channel and floodplain is an integral part of NCD project success. In order to achieve the fine grading tolerances necessary for this type of project, GCSWCD maintained survey staff on-site at all times that grading and structure placement activities were in progress. Grade stakes, spot elevation checks, survey control network, and quantity estimates were all performed and maintained by GCSWCD staff.

### 7.2 Containerized Plant Material

Riparian vegetation is a key component of stability for C stream types like the one designed for this restoration project. In order to accelerate the revitalization of the riparian vegetation community on the project site, more than 3,500 containerized trees and shrubs were planted on the disturbed portions of the floodplain and terrace slopes.

**November 3, 2007 volunteer planting day.**

The trees and shrubs were planted by GCSWCD staff with the help of volunteer labor forces. The volunteer planting day served as a valuable opportunity to convey the goals and objectives of not only the Conine Stream Restoration Project, but also of the cooperative stream management initiative being undertaken by NYCDEP and their project partners.

An educational presentation was given at the volunteer planting day by GCSWCD. The presentation outlined the accomplishments of the Stream Management Program and included a discussion of the fundamentals of stream process.

## 8.0 Project Expenditure Summary

The total project expenditures on the Conine Project amounted to $974,418.59. The contract bid items, unit prices and total expenditures are summarized in Table 9 on the next page.

**Table 9. Summary of Project Expenditures.**

## Conine Stream Restoration Project

**PRIMARY BID ITEMS**

| Bid Item | Item Description | Estimated Units | Estimated Cost | Actual Cost |
|---|---|---|---|---|
| 1 | Mobilization/Demobilization | Lump Sum | $ 37,000.00 | $ 37,000.00 |
| 2 | De-watering | Lump Sum | $ 80,000.00 | $ 80,000.00 |
| 3 | Stream Channel Excavation | Lump Sum | $ 282,000.00 | $ 282,000.00 |
| 4 | Rock Structures | Per Ton | $ 210,000.00 | $ 161,531.58 |
| 5 | Top Soil | Cu yd | $ 25,925.00 | $ 0.00 |
| 6 | Live Fascines | per foot | $ 22,000.00 | $ 11,297.00 |
| 7 | Live Posts | each | $ 36,000.00 | $ 29,020.50 |
| 8 | Cobble Fill - Imported | Per Ton | $ 10,000.00 | $ 0.00 |
| 9 | On Site Borrow Material | Cu yd | $ 15,000.00 | $ 39,000.00 |
| | | Total | $ 717,925.00 | $639,849.08 |

**ALTERNATE BID ITEMS**

| | | | | |
|---|---|---|---|---|
| Alt 1 | Root Wads | each | $ 3,200.00 | $ 0.00 |
| Alt 2 | Live Materials Transplants | each | $ 0.00 | $ 0.00 |
| Alt 3 | Sediment Control Fence | per foot | $ 12,000.00 | $ 0.00 |
| Alt 4 | Clay w/replacement | Cu yd | $ 50,000.00 | $ 24,000.00 |
| Alt 5 | Clay w/out replacement | Cu yd | $ 50,000.00 | $ 41,980.00 |
| Alt 6 | 10cfs additional De-watering | Per Week | $ 0.00 | $ 0.00 |
| Alt 7 | Item 4 Access Roads | Ton | $ 4,000.00 | $ 11,098.00 |
| | | Total | $ 119,200.00 | $ 77,078.00 |

**TIME & MATERIALS WORK**

| | | | | |
|---|---|---|---|---|
| TM-1 | Clearing & Grubbing - bid rate | | $ 31,600.00 | $ 21,690.50 |
| TM-2 | Access Prep & Site Cleanup - bid rate | | $ 28,000.00 | $ 29,148.00 |
| TM-3 | Wetland Grading | | $ 10,000.00 | $ 0.00 |
| TM-4 | Constructed Riffle | | $ 0.00 | $ 7260.00 |
| TM-5 | Auxiliary Pipeline Fabrication, Assembly, Installation and Operation | | $ 25,852.40 | $ 1,420.00 |
| | | Total | $ 95,452.40 | $ 59,518.50 |

**GREENE COUNTY SWCD ITEMS**

| | | | | |
|---|---|---|---|---|
| GC-1 | Seed & Mulch | | $ 30,000.00 | $ 30,000.00(TBD) |
| GC-2 | Trees & Shrubs | | $ 40,000.00 | $ 40,000.00(TBD) |
| GC-3 | Auxiliary Pumping Equipment Purchase and Delivery | | $ 118,147.60 | $ 110,290.51 |
| | | | $ 188,147.60 | $ 180,290.51 |

| | | |
|---|---|---|
| Grand Total | $1,120,725.00 | $ 956,736.09 |

## 9.0 Post Construction Monitoring

An as-built survey is conducted immediately following construction in order to ensure that the design has been built to its specifications. The as-built survey also provides the baseline condition for comparison against regular inspections and annual monitoring surveys to evaluate stability and performance of the restoration project. Project inspections will include photographic documentation of the project reach and a visual inspection of the rock structures, channel stability, bioengineering and riparian vegetation and wetlands.  The inspections are conducted annually during the project site survey as well as during and after significant flow events.  The project monitoring surveys include measurement of key physical parameters that are used as indicators of channel and structural stability. Long term monitoring of water quality is being performed by NYCDEP, which includes measurements of total suspended solids (TSS) and turbidity.  Monitoring has proceeded for several years prior to construction above and below the restoration site and a report on this project's effectiveness at reducing turbidity is a Filtration Avoidance Deliverable due in December 2012.

**Aerial image of pre constructed condition taken July 2007.**

**Aerial image of constructed condition taken September 2007.**

### 9.1 Stream Channel Stability Monitoring

A five-year project-monitoring program will be initiated to confirm the stability of the project site.  The monitoring program will include: an as built survey with establishment of permanent monitoring cross-sections as determined by on-site personnel, yearly cross-section and longitudinal profile surveys completed during the same season, yearly pavement/sub-pavement sampling, yearly assessments of banks, photo-documentation both yearly and after large flow events, and a yearly description of conditions.

The relationship of channel morphology "at-a-station", and general morphology trends through the reach will be analyzed using the collected data. These physical measures will be further stratified by specific stream feature.  The change in physical parameters will be determined and an evaluation of the observed rates of change will be conducted. The rates of change will be correlated to available gage data to reveal associations to hydrologic inputs from storm events and their impacts on sediment transport.

These rates can be further evaluated by comparisons within the reach, against regional values, stream channel classification indexes, and reference reach data. The channel parameters can be applied to channel evolution models to review the effectiveness of treatment in halting or accelerating a channel process.

In the case of long term monitoring data, the individual treatments can be compared, quantified and delineated. As the monitoring period increases project effectiveness will be evaluated, in terms of performance of the project at multiple scales, in comparison to other natural channel design projects and treatments in the watershed.

USACOE Nationwide Permit 27 requires monitoring and reporting to document the performance of the restoration. The permit requires that three copies of reports on the status of the stream restoration and the riparian buffer and wetland establishment activities will be provided to the Corps of engineers New York District office. The reports will include the riparian buffer and wetland establishment data collected during the growing season. The reports will be submitted no later than October 31 in the first, second, third and fifth years after the authorized activities have been completed. These reports will include the following at a minimum:

**Constructed wetland mitigation area after a rainfall event.**

- As-Built drawings of the stream reach, in plan view, that locate all in-stream stabilization and habitat structures in relation to the bankfull elevation of the Batavia Kill in reporting years 1 and 5.

- Level II stream reach classification for the 1,650 linear foot reach to include channel dimensions at bankfull in riffle and pool sections, a longitudinal reach profile, a pebble count, and the identified stream types. Monitoring and classification to be performed in years 1-3 and 5.

- Photographs of the restored stream channel taken at least once each year during normal flow conditions, and also taken immediately following all bankfull flow events that occur during the five year monitoring period.

- A written description of existing conditions in the project vicinity, including the condition of the restored section of channel and the habitat and stabilization structures, conditions of the upstream and downstream reaches from the permit area, how the restored section of stream channel and associated features are accomplishing the primary goal of improving water quality, and observed usage by fish and wildlife.

### 9.2 Riparian Vegetation and Wetland Mitigation Monitoring

Establishment of wetlands equal to the amount of wetlands impacted within the project extent is necessary to remain in compliance with the USACOE Nationwide Permit 27. As proposed this project will establish 4.5 acres of riparian buffer achieved through the planting of appropriate vegetation, the implementation of a Japanese Knotweed (*Polygonum cuspidatum*) management plan, and the establishment of 0.5 acres of compensatory wetlands along and adjacent to the Batavia Kill. Implementation will be conducted in a way that will ensure the following:

- The established wetlands will meet the federal wetland criteria outlined in the report entitled "Corps of Engineers Wetlands Delineation Manual", dated January 1987, with current Corps of Engineers guidance.

- All planting and seeding in conjunction with the wetland establishment effort will have an 85% survival and/or coverage rate of hydrophytic vegetation which will be met or exceeded at the end of the second growing season following the initial planting and seeding of the site, if the 85% survival rate is not met at the end of the second growing season, all necessary measures to ensure the level of survival by the end of the next growing season will be taken, including regrading and re-planting if necessary.

- All planting and seeding in conjunction with the remainder of the riparian buffer establishment effort will have an 85% survival and/or coverage rate of hydrophytic vegetation which will be met or exceeded at the end of the second growing season following the initial planting and seeding of the site. If the 85% survival rate is not met at the end of the second growing season, all necessary measures to ensure the level of survival by the end of the next growing season will be taken, including regrading and re-planting if necessary.

- All vegetation within the 4.5 acre riparian area, including the 0.5 acre wetland establishment areas, will not consist of more than a total of 5% areal coverage of common reed (*Phragmites australis*), purple lustrife (*Lythrum salicaria*), reed canary grass (*Phalaris arundinacea*), Japanese Knotweed (*Polygonum cuspidatum*), Tartarian honeysuckle (*Lonicera tartarica*), and/or Eurasian milfoil (*Myriophyllum spicata*).

All grading and planting in conjunction with the riparian buffer and wetland establishment effort will be completed by November 30, 2008.

Three copies of reports on the status of the stream restoration and the riparian buffer and wetland establishment activities will be provided to the Corps of engineers New York District office, with the riparian buffer and wetland establishment data collected during the growing season, no later than October 31 in the first, second, third and fifth years after the authorized activities have been completed. These reports will include the following at a minimum:

- All plant species, along with their estimated relative frequency and percentage cover, identified by using plots measuring 10 feet by 10 feet with at least one representative plot located in each of the habitat types within the riparian buffer and wetland establishment sites. The location of the plots will be identified on the plan view engineering drawing.

- Vegetation cover maps, at a scale of one inch equals 100 feet, or larger scale, for each growing season in the above listed reporting years.

- Photographs showing all representative areas of the riparian buffer and wetland establishment sites. Photographs of the riparian buffer and wetland establishment sites shall be taken at least once each year during the period between June 1st and August 15th. Photographs of the restored stream channel will be taken at least once each year during normal flow conditions, and will also be taken immediately following all bankfull flow events that occur during the five year monitoring period.

- A remedial plan, if necessary, outlining all practicable steps taken or proposed to be taken to ensure the success criteria outlined above are met by the specified due date of the next monitoring report.

## 10.0 Operation and Maintenance

GCSWCD staff applying rye seed mix for initial vegetation establishment.

During the initial years after project completion, as the restoration site experiences a range of flows and the channel sediment becomes naturalized, projects usually require modifications and design enhancements. Project sponsors must be prepared to undertake adjustments in channel form and/or rock structures as indicated by the project monitoring. It is believed that as project vegetation becomes established the overall operation and maintenance of the project will decrease. The creation of a project Operation and Maintenance Plan, in addition to the Landowner Agreements, is recommended and should utilize data collected from the project monitoring. The Landowner Agreements are temporary easements between the landowner and GCSWCD, and are for a term of 10 years. The agreement stipulates that the GCSWCD is responsible for maintenance and repairs of the project for a period of three years and monitoring of the project for a period of 10 years if funding is available. The agreement also stipulates that the Landowner must not (within the next 10 years): disturb vegetation within the project area, disturb rock structures, disturb the soil, construct any permanent structures within the project area, or commence any work within the project area without notifying the GCSWCD. These measures may help ensure the stability of both the stream restoration project and the constructed wetlands.

### 10.1 In Stream Maintenance

The channel and in-stream rock structures may require some modification and enhancement. The monitoring and inspections performed by project partners will assist in prescribing the modification of rocks to ensure structural integrity, as well as any debris and sediment maintenance measures. The annual project status reports will document these needs and modifications and will require notification and approval by ACOE, NYSDEC and NYCDEP.

**Upstream cross vane during high flow event.**

### 10.2 Riparian Vegetation

Vegetative establishment in the project area is a critical component to the project's long-term stability. General site constraints and gravelly soil conditions limit the success and establishment of the designated vegetative elements of the project. Careful planning, monitoring, and maintenance are required for all of the installed vegetation. Increased browsing pressure from mammals, potential for disease, and extreme weather conditions can reduce the success of the plant materials. Inspection and monitoring of the plant materials throughout the initial stage of development will assist in ensuring plant viability. Supplemental installation of plant material, as needed, in the form of bioengineering and riparian planting will ensure effective riparian establishment. Plantings will require maintenance to ensure proper moisture at critical times.

# 11.0 Conclusion

Careful monitoring and evaluation of project performance is the most critical component of evaluating project success. Observations made relevant to the performance of various aspects of project should be incorporated into future restoration designs. As restoration projects mature, they may serve as valuable additions to our limited stream reference condition data set.

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