Long Road Stream Restoration Project

Assessment, Design & Implementation Report

Town of Lexington, Greene County, New York

After

Before

Report Date: February 2010

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1.0 Project Summary

Project Name: Long Road Stream Restoration Project

Project Length: 3000 Feet

Type of Project: Natural Channel Design Based Full Restoration

Project Goals:

- Water Quality Enhancement
- Infrastructure Protection
- Flood Conveyance
- Fisheries Habitat Mitigation (Passage)
- Riparian Function Enrichment
- Aesthetic Improvement

Structures:

- Cross Vanes – 12
- Stone Drop Structures – 6
- Rock Vanes – 3

Plant Materials:

- Potted Trees and Shrubs – 700
- Seed & Mulch – 373 Bails of Hay, 1500 Lbs. of Rye Seed, 100 Lbs. of Riparian Seed Mix
- Live Stakes – 8,000
- Live Fascines – 1,000 Linear Feet

Drainage Area Above Treatment: 19 Square Miles

Project Cost: Total: $1,059,104.62 (including GCSWCD Staff Time through 11/09)

2.0 Project Background

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 West Kill sub-basin as a leading producer of turbidity and TSS. In 2003, a watershed management project was initiated between the NYCDEP and the Greene County Soil and Water Conservation District (GCSWCD) in the watershed. The West Kill Stream Management 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.

Long Road Bridge during a 1996 flood event.

A primary goal of the Stream Management 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.

Prior to the Long Road project, two demonstration projects had been implemented as components of the West Kill stream management project including the Westkill Flood Hazard Mitigation Project, and the RCH Stables Stream Bank Stabilization Project.

Inventories in 2000 and 2004 identified sections of the Long Road reach experiencing large-scale erosion and bank failure suspected to be negatively impacting water quality. The position of the channel, 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, document project objectives and constraints and describe the design utilized to reduce channel and bank instability and reduce the associated water quality impacts. In addition, the Long Road project partially satisfied one requirement set forth in the Shandaken SPDES permit (SPDES Number: NY- 026 8151) and 2007 Filtration Avoidance Determination.

3.0 Project Reach Setting

The West Kill watershed is located in the central Catskill Mountain region of southeast New York State. The West Kill flows from its headwaters on West Kill and Hunter Mountains, running 9.5 miles, often adjacent to and sharing its valley with Greene County Route 6 and NYS Route 42, to its confluence with the Schoharie Creek just west of the Hamlet of Lexington. The entire 31.2 mi^2 watershed falls within the Town of Lexington, in Greene County.

Aerial view looking south at project reach (2006).

In 1885, the Catskill and Adirondack Forest Preserve was established by the NY State Assembly. An 1894 amendment to the New York State Constitution (now Article 14) directs: "the lands of the State now owned or hereafter acquired, constituting the forest preserve as now fixed by law, shall be forever kept as wild forest lands. They shall not be leased, sold or exchanged, or be taken by any corporation, public or private, nor shall the timber thereon be sold, removed or destroyed."

In 1904, the Catskill Park was designated, establishing a boundary or ‘blue line’ around the Forest Preserve and private land as well. Over the years the Forest Preserve and the Catskill Park grew, with the Catskill Park now comprising approximately 700,000 acres, about half of which is public Forest Preserve. The Catskill and Adirondack Parks are nationally unique because they are a checkerboard of public and private land; a grand experiment in how nature, even wilderness, and human society can coexist in a landscape. The entire West Kill Watershed lies within the Catskill Park with approximately 16,182 acres of land designated state owned forest.

A dominant characteristic of the West Kill Watershed’s regional setting is its location within the 2,000 square-mile New York City Water Supply Watershed. The NYC Watershed is the largest unfiltered water supply in the U.S., providing ~1.1 billion gallons of clean drinking water each day to over nine million residents in New York City and some smaller municipalities (nearly half the population of New York State). The West Kill is a tributary of the Schoharie Creek, eventually emptying into the Schoharie Reservoir, which in turn supplies water through an aqueduct into the Esopus Creek, which then flows into the Ashokan Reservoir. The Catskill system (Schoharie and Ashokan) provides approximately forty percent of NYC’s drinking water.

The NYC Department of Environmental Protection (DEP) operates this drinking water supply under a

Filtration Avoidance Determination (FAD) issued by the Environmental Protection Agency (EPA) and the New York State Department of Health. Central to the maintenance of the FAD are a series of partnership programs between NYC and the upstate communities, as well as a set of rules and regulations administered by the DEP. Due to its location within the NYC Watershed, land use in the West Kill watershed is subject to the DEP rules and regulations written to protect water quality. DEP offers a variety of watershed protection programs to encourage proper management practices within the watershed.

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 Long Road reach of the West Kill is classified by the New York State Department of Environmental Conservation as C(ts) which means that the resource may support trout spawning and is suitable for non-contact activities.

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. This waterbody is listed on the 2002 NYS DEC Priority Waterbodies List (PWL) under Hydrologic Unit Code 02020005/010 - West Kill and tributaries (1202-0062) as Habitat/hydrology known to be stressed; Minor Impacts to aesthetics (turbidity) and silt/sediment as known pollutants. Sources of pollutants are listed as; Known - streambank erosion; Suspected- habitat modification; and Possible - construction, and hydrologic modification.

The project area is located entirely within the FEMA 100-year flood plain with Newton Brook contributing to the West Kill from the south in the upper reaches of the project area.

The project reach is located in the middle reaches of the 9.5-mile long West Kill mainstem in the Town of Lexington, NY. The project reach is located within a narrow “U” shaped valley containing steep side slopes with a moderately steep valley slope of approximately 1.7%. This morphology is substantially impacted by encroachment of transportation infrastructure. County Route 6 borders the channel, and results in 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/depth ratio to classify and delineate river reaches for communication and comparison. Rosgen classifications of project reach and upstream reaches indicate upstream segments are dominated by F3 and B3c type reaches, while the project reach classifies as F3 and B3c types indicating an entrenched channel form, dominated by larger cobble substrate.

Historically, the stream channel has exhibited minimal lateral migration. Channel degradation is the dominant channel adjustment process active in the project reach. Degradation has led to increased bank heights and bank angles and has ultimately resulted in extensive bank failure.

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 2008 delineated .03 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 F**.

Archeology investigations by Tracker Archaeology Services, Inc. were performed to inventory cultural 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 the site to have an above average potential for recovery of both prehistoric remains and historic sites. Field investigation identified neither prehistoric nor historic artifacts nor features on the site. A report including mapping has been provided in **Appendix C**.

3.1 Historic Aerial Photo Assessment and Channel Monitoring

Historic aerials from 1959, 1995, 2000 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 Schoharie Basin 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 occurred in 1960, 1980, 1987, 1996, 1999, and 2005.The aerial imagery are located in **Appendix A as Maps A-1-5**.

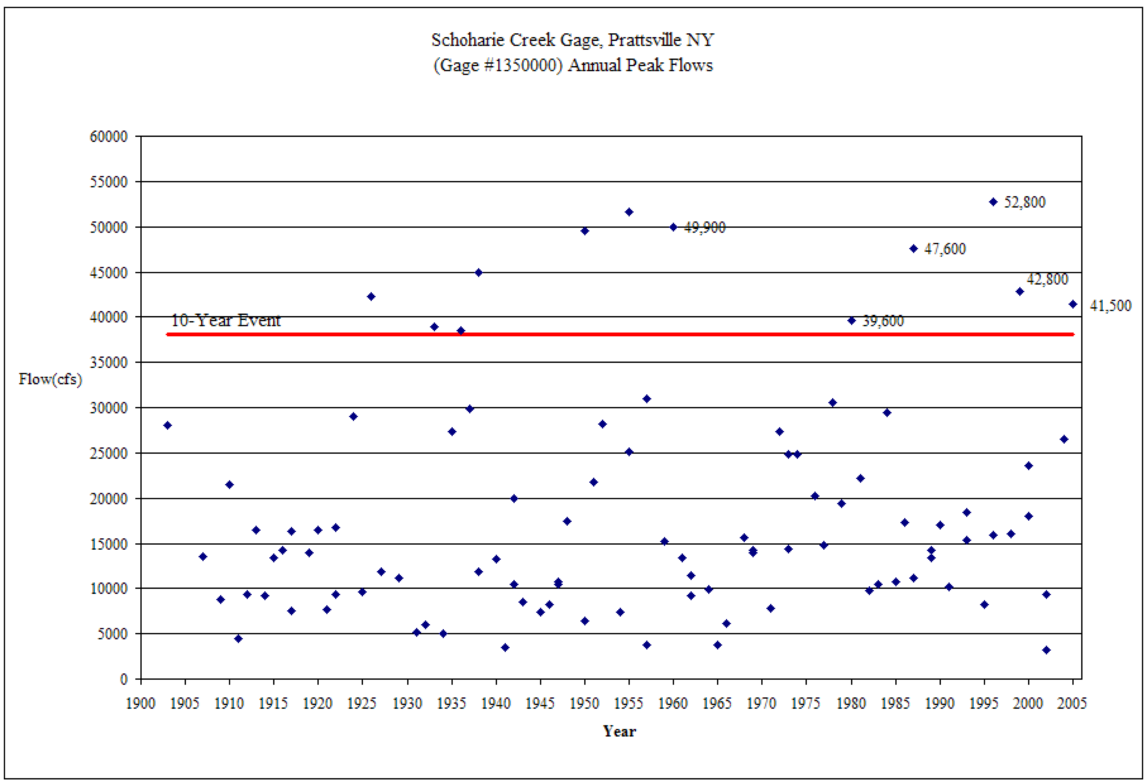


Figure 1. Historic annual peak events at nearby Schoharie Creek at Prattsville (1903-2005).

Stream corridor inventories performed in 2000 and 2004 identified this site as a top priority for restoration. Recommendations for the reach in the West Kill Stream Management Plan call for full restoration of the unit including establishing a geomorphically appropriate channel dimension and profile, enhancement of the riparian buffer, and isolation of sources of fine sediment. An excerpt from the West Kill Stream management Plan containing a description of the conditions in the unit is included in Attachment B.

Most notable from the assessments was the wide spread application of stone revetments in the reach, and mass wasting of an extended section of the left bank in the lower portions of the restoration reach.

3.2 Channel Planform

Channel planform in the reach is controlled to a large extent by the road embankment of County Route 6 on the right bank and the valley wall on the left bank.

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.


Planform constrained by infrastructure and landfrom.

The existing sinuosity of the project reach was 1.09, considered low within Rosgen classification system for natural "F" or "B" stream reaches. The average wavelength was 1,600 feet and measures of radius of curvatures were 337, 954, and 587 feet respectively in a downstream direction. The average meander beltwidth through the reach was 312 feet with a meander width ratio of 4.33.

In general the existing beltwidth was truncated through the lower reach due to impingement of the south valley wall and the road embankment to the north. The condition had caused the reach to be historically prone to bank erosion and failure as the channel had attempted to expand its beltwidth. The imposed restriction of the corridor had caused the channel to incise into the landscape. This had resulted in increased bank heights leading to widespread failure of both the road embankment and the valley wall.

3.3 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 assists in quantifying erosion and sedimentation processes and the ecological potential of the reach. The existing channel slope through the project reach was 1.6%. The presence of headcutting and confining geologic layers such as bedrock were also inventoried for use during the design process. **Sheet LR-06 in Appendix I** depicts the existing streambed profile surveyed in fall of 2008.

Head cutting had been noted in the reach. 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 18+00 illustrated in **Sheet LR-06 in Appendix I**. The headcut inventoried at station 18+00 had migrated to a cross channel sheet piling check structure installed as a component of the road stabilization, and had created a short waterfall. This formation may have represented an impediment to fish migration through the reach.

3.4 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 project to assess the impact of the channel modifications on flood surface elevations. Modeled water surface elevations were calibrated to field identified bankfull indicators. **Table 1** summarizes the existing condition geometry during bankfull flow conditions. The data are identified by stream stationing feet referencing the upstream project extent as Station 0+00.

Bankfull flow areas for the reach averaged 201 square feet, and were highly variable, ranging from 95 to 348 feet^2. Bankfull width averaged 67 feet and hydraulic depth was 3.1 feet. Channel width to depth ratios averaged 25 indicating relatively normal width conditions under this flow condition. It is suspected that these values were heavily influenced by confinement of the channel width, and may result in sediment transport over competence considering the steep slope of the project reach.

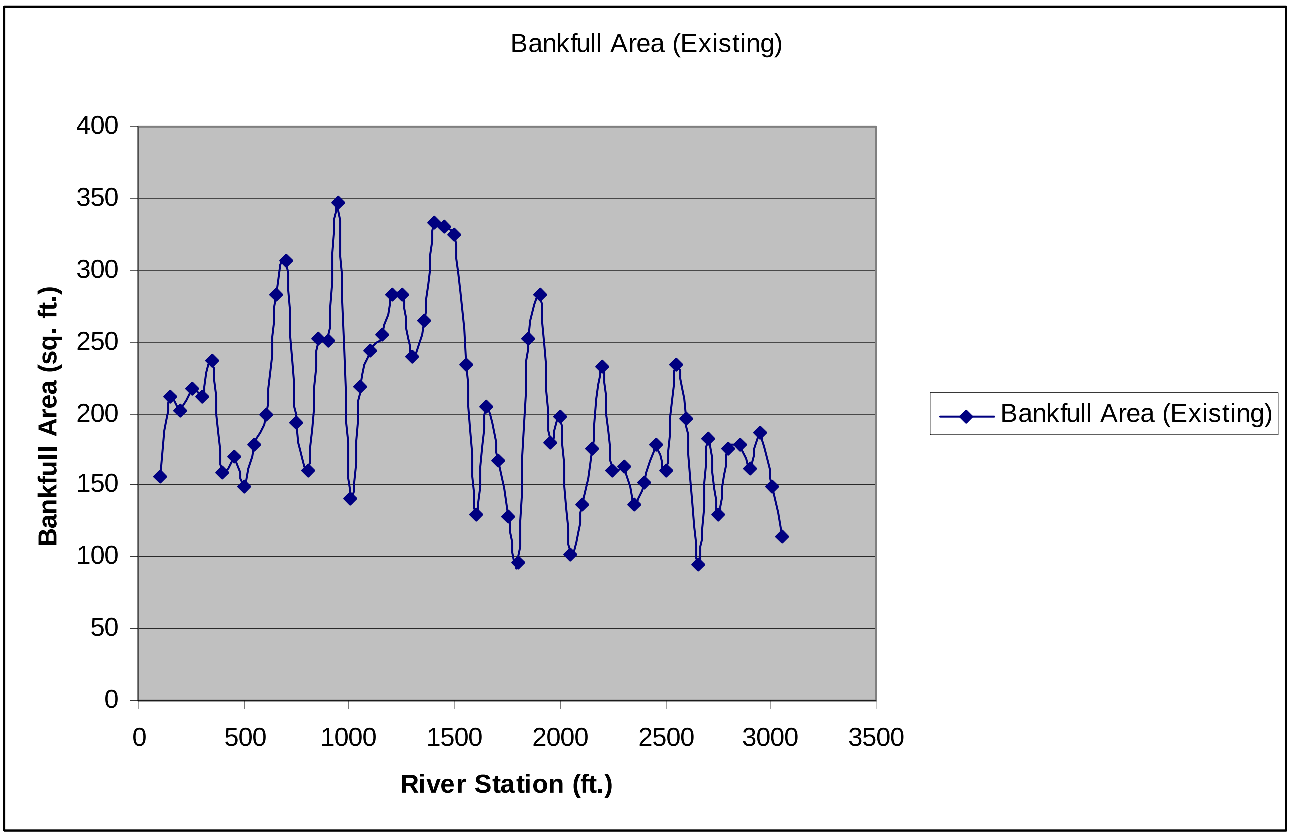


Figure 2. Bankfull existing cross sectional area through the project reach.

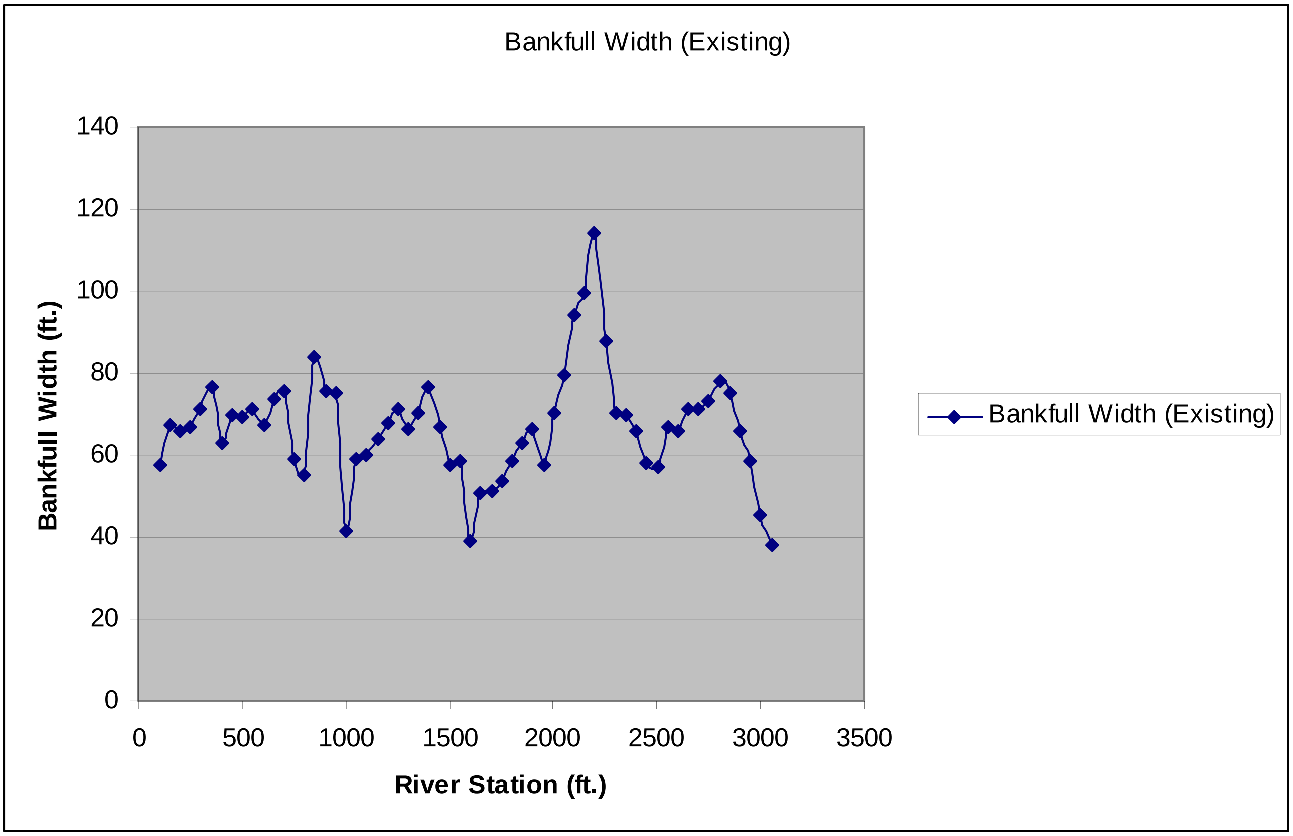


Figure 3. Bankfull channel existing width through the project reach.

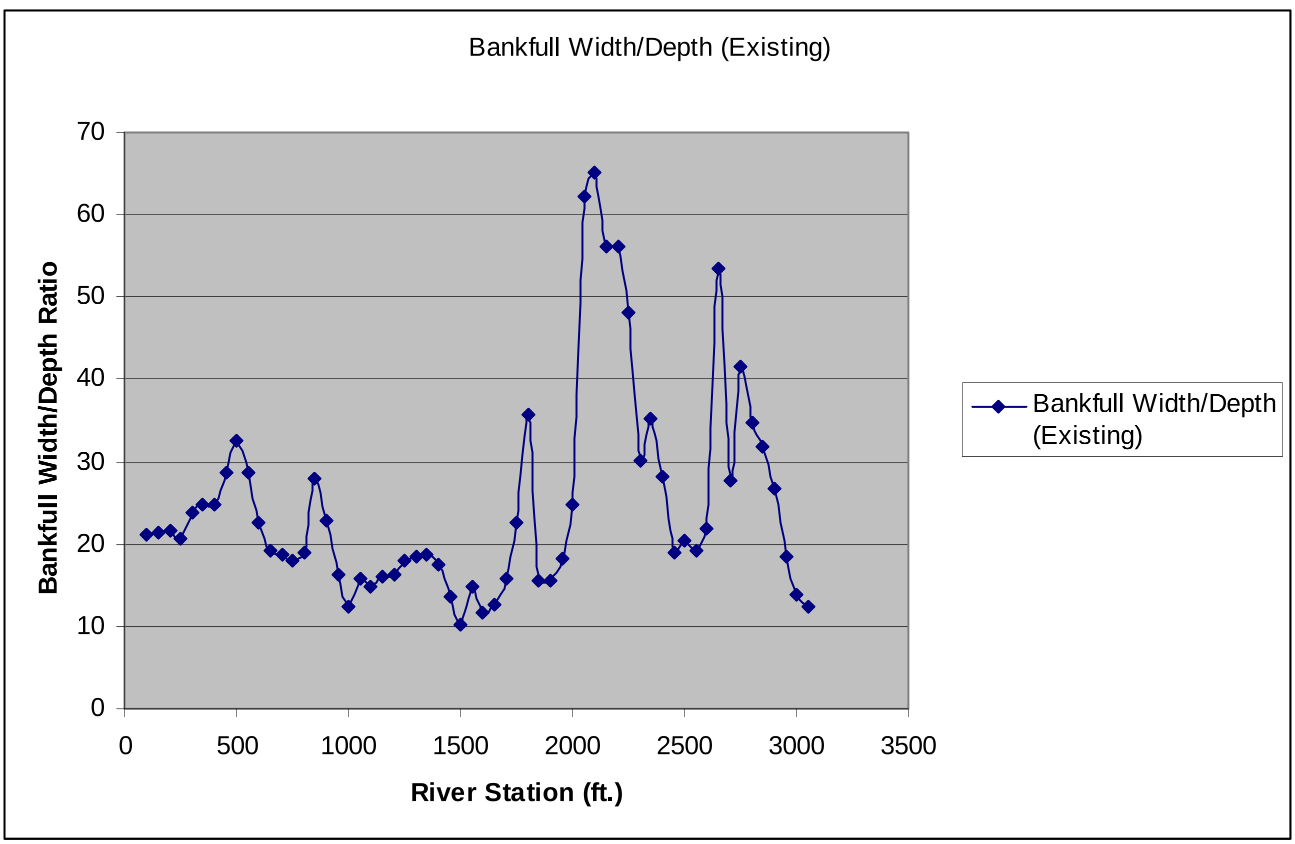


Figure 4. Bankfull channel existing width to depth ratio through the project reach.

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

River Station	Minimum Channel Elevation	Water Surface Elevation	Slope	Flow Velocity	Cross Sectional Area	Top Width	Mean Depth	Width / Depth Ratio
	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	(ft)	
102.66	983.32	987.66	0.014579	11.85	156.26	57.53	2.72	21.18
152.66	983.88	988.04	0.005093	7.32	212.42	67.26	3.16	21.30
202.66	983.37	987.53	0.008869	8.38	201.68	65.93	3.06	21.55
252.66	982.68	987.21	0.007128	7.83	217.31	66.91	3.25	20.60
302.66	982.11	986.6	0.009326	9.01	211.85	70.98	2.98	23.78
352.66	981.35	986.03	0.010371	10.37	236.37	76.38	3.09	24.68
402.66	980.81	984.84	0.015413	10.72	158.69	62.75	2.53	24.81
452.66	980.34	983.88	0.021049	11.86	169.95	69.67	2.44	28.56
502.66	979.78	982.81	0.023039	10.8	148.58	69.5	2.14	32.51
552.66	979.31	982.59	0.01099	7.97	177.95	71.31	2.50	28.58
602.66	977.94	982.15	0.008036	8.04	199.74	67.23	2.97	22.63
652.66	976.47	982.02	0.004707	7.77	283.48	73.87	3.84	19.25
702.66	974.6	981.93	0.002599	6.57	307.06	75.8	4.05	18.71
752.66	974.73	980.26	0.015111	13.65	194.08	58.95	3.29	17.91
802.66	974.49	979.1	0.019341	13.44	160.01	55.25	2.90	19.08
852.66	974.11	979.3	0.004	6.34	252.72	84.05	3.01	27.95
902.66	973.73	979.02	0.004014	6.8	250.52	75.6	3.31	22.81
952.66	973.51	979.14	0.001707	4.71	347.66	75.19	4.62	16.26
1002.66	971.48	977.06	0.012739	12.04	140.72	41.69	3.38	12.35
1052.66	970.23	976.7	0.006198	9.05	218.12	58.81	3.71	15.86
1102.66	970.93	976.66	0.004582	7.41	243.32	59.88	4.06	14.74
1152.66	971.06	976.5	0.004246	6.97	254.88	64	3.98	16.07
1202.66	970.98	976.31	0.004639	7.24	283.21	67.96	4.17	16.31
1252.66	970.79	976.04	0.005964	7.78	283.41	71.23	3.98	17.90
1302.66	971.3	975.89	0.003545	5.56	239.7	66.54	3.60	18.47
1352.66	970.57	975.7	0.00315	5.84	265.34	70.44	3.77	18.70
1402.66	970.14	975.74	0.00154	4.39	333.33	76.49	4.36	17.55
1452.66	968.5	975.55	0.001852	5.39	329.78	66.73	4.94	13.50
1502.66	966.83	975.48	0.001211	5.08	324.13	57.69	5.62	10.27
1552.66	968.07	974.9	0.004091	7.69	233.94	58.69	3.99	14.72
1602.66	968.12	973.26	0.013868	11.66	130.03	38.91	3.34	11.64
1652.66	966.08	972.54	0.005243	7.38	204.58	50.88	4.02	12.65
1702.66	965.9	971.04	0.018583	12.68	167.4	51.25	3.27	15.69
1752.66	965.16	968.75	0.041272	14.81	127.56	53.66	2.38	22.57
1802.66	963.39	966.01	0.063696	13.53	95.93	58.62	1.64	35.82
1852.66	961.28	967.41	0.002986	6	252.62	62.84	4.02	15.63
1902.66	961.34	967.41	0.002141	4.84	282.98	66.55	4.25	15.65
1952.66	961.86	966.36	0.009738	9	179.91	57.33	3.14	18.27
2002.66	961.02	965.39	0.017928	11.95	198.1	70.01	2.83	24.74
2052.66	960.09	962.13	0.086207	13.87	101.3	79.38	1.28	62.20
2102.66	958.16	960.06	0.042591	10.52	136.51	94.28	1.45	65.11
2152.66	956.31	959.29	0.018075	7.63	175.49	99.28	1.77	56.17
2202.66	953.22	958.38	0.010668	9.33	232.88	114.36	2.04	56.16
2252.66	951.13	956.1	0.023235	13.97	159.77	87.73	1.82	48.17
2302.66	948.66	954.51	0.020303	15.92	163.71	70.18	2.33	30.09
2352.66	948.77	953.13	0.027634	15.56	136.76	69.54	1.97	35.36
2402.66	947.28	952	0.028634	15.62	152.53	65.65	2.32	28.26
2452.66	945.43	951.65	0.006333	8.22	178.5	58.16	3.07	18.95
2502.66	945.43	950.39	0.013028	11.46	160.48	57.07	2.81	20.30
2552.66	944.54	950.26	0.004379	6.71	234.72	67.06	3.50	19.16
2602.66	945.45	949.14	0.001639	3.42	196.24	65.64	2.99	21.96
2652.66	944.15	946.32	0.112487	16.84	95.37	71.46	1.33	53.54
2702.66	942.48	946.86	0.012968	10.23	182.87	71.07	2.57	27.62
2752.66	940.9	944.46	0.040185	13.89	129.21	73.38	1.76	41.67
2802.66	940.84	944.35	0.016368	9.26	175.42	78.08	2.25	34.75
2852.66	940.18	943.31	0.014087	8.51	178.37	75.24	2.37	31.74
2902.66	938.61	942.32	0.012421	9.61	162.08	65.7	2.47	26.63
2952.66	937.34	942.12	0.005063	7.19	186.95	58.65	3.19	18.40
3002.66	936.03	940.58	0.01112	11.4	148.55	45.54	3.26	13.96
3052.66	936.02	939.69	0.015712	11.63	114.41	37.83	3.02	12.51

3.5 Bank Stability


Erosion and failure of high bank.

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

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, 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.

Shallow, planar and cantilever failures were all identified within the project reach. These failures were addressed by the installation of stable bank geometry achieved through bank slope and/or height reductions.

3.6 Channel and Bar Material Characteristics

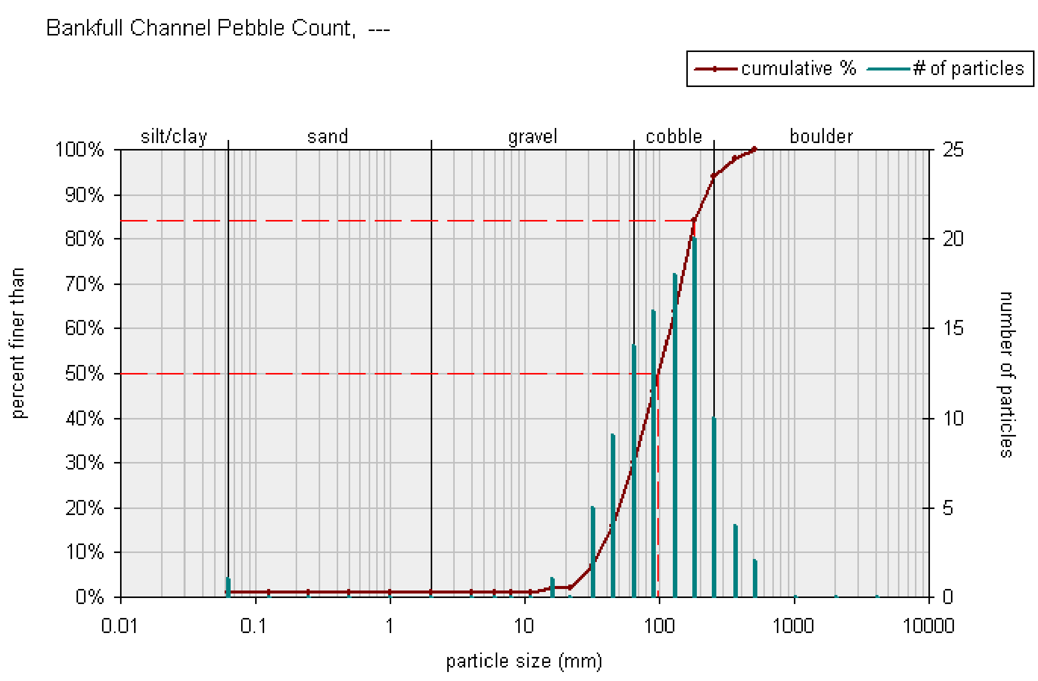

View looking downstream at bank failure and cobble bar.

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 was in the medium cobble size range (D50=97mm) with large portion of the sample in the large cobble class. 6% of materials were boulders and 84% of the sample was estimated to be smaller than 180 mm. The gradation of materials was moderately well sorted containing a large portion of grain sizes in the cobble class (dispersion 2.0). The distribution was considered normal and negatively skewed with a geometric mean of 90 mm and a D50 of 97 mm. Sample materials were generally well rounded and not well imbricated.



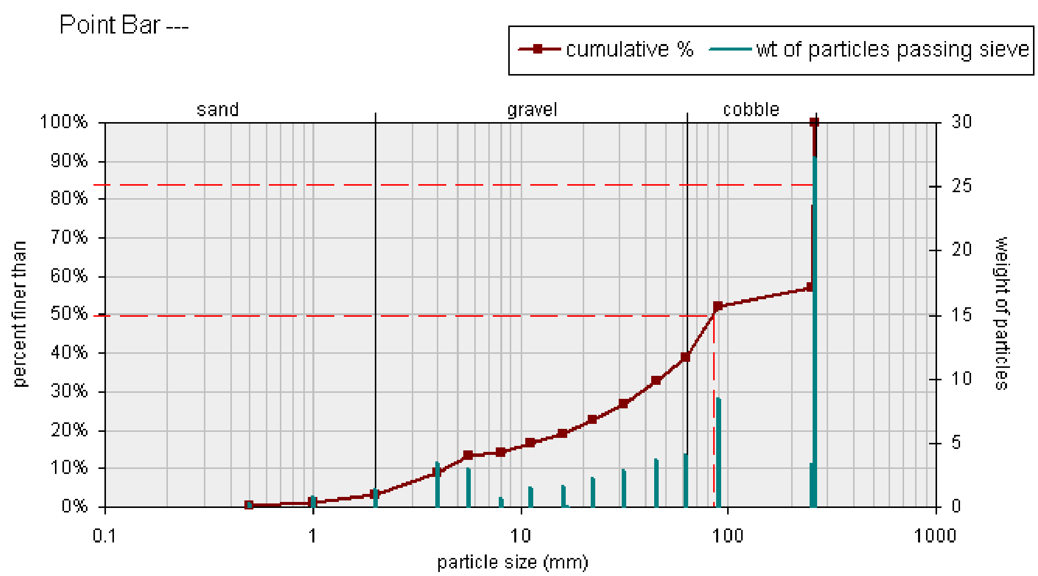
Size (mm)	
D16	45
D35	71
D50	97
D65	130
D84	180
D95	280

Size Distribution	
mean	90.0
dispersion	2.0
skewness	-0.04

Type	
silt/clay	1%
sand	0%
gravel	29%
cobble	64%
boulder	6%

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 particles were found on the bar near the sample site characterized as very large cobbles generally measuring approximately 250 mm.



	Size (mm)		
D16	10	D65	250
D35	51	D84	260
D50	85	D95	260

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

3.7 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.

3.7.1 Flood Frequency Analysis

Analysis of flood frequencies was performed on two 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 significant contribution of the West Kill to its drainage (13%). Flood frequency analysis was performed using PeakFQ Version 5.2, a program available from USGS. PeakFQ provides estimates of instantaneous annual-maximum peak flows for a range of recurrence intervals, including 1.25, 1.5, 2, 2.33, 5, 10, 25, 50, 100, 200, and 500 years (Annual-exceedance probabilities of 0.6667, 0.50, 0.4292 0.20, 0.10, 0.04, 0.02, 0.01, 0.005, and 0.002, respectively). The Pearson Type III frequency distribution is fit to the logarithms of instantaneous annual peak flows following Bulletin 17B guidelines of the Interagency Advisory Committee on Water Data. The parameters of the Pearson Type III frequency curve are estimated by the logarithmic sample moments (mean, standard deviation, and coefficient of skewness) with adjustments for low outliers, high outliers, historic peaks, and generalized skew. **Table 2** displays the discharge estimates and the corresponding return interval for the analyzed gages.

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

USGS Gage #	USGS Gage Name	DA (mi^2)	Return Interval (Years)										
			1.25	1.5	2	2.3	5	10	25	50	100	200	500
			Discharge for Indicated Return Intervals (CFS)										
01349711	West Kill Below Hunter Brook	4.97	323.4	412.7	543.7	613.4	991.9	1405	2091	2745	3540	4507	6106
01349810	West Kill near West Kill, NY	27	1751	2187	2784	3085	4576	6014	8132	9939	11950	14190	17560
01350000	Schoharie Creek at Prattsville, NY	237	8482	11100	14720	16560	25680	34420	47100	57730	69360	82080	100700

An analysis that normalized discharge estimates by drainage area for each gage was used to estimate project reach discharges. Drainage area normalized discharge estimates and discharge estimates for the project reach for specific frequencies up to the 500-year event can be seen in **Table 3**.

Table 3. Drainage Area Normalized discharges and Estimated Discharges for the Long Road Reach.

USGS Gage #	USGS Gage Name	DA (mi^2)	Return Interval (Years)										
			1.25	1.5	2	2.3	5	10	25	50	100	200	500
			Discharges Normalized by Drainage Area for Listed Return Intervals (CFS/Mi^2)										
01349711	West Kill Below Hunter Brook	4.97	65.1	83.0	109.4	123.4	199.6	282.7	420.7	552.3	712.3	906.8	1228.6
01349810	West Kill near West Kill, NY	27	64.9	81.0	103.1	114.3	169.5	222.7	301.2	368.1	442.6	525.6	650.4
01350000	Schoharie Creek at Prattsville, NY	237	35.8	46.8	62.1	69.9	108.4	145.2	198.7	243.6	292.7	346.3	424.9
Average Normalized Discharge		N/A	55.2	70.3	91.5	102.5	159.1	216.9	306.9	388.0	482.5	592.9	767.9
			Estimated Project Site Discharge for Indicated Return Intervals (CFS/Mi^2)										
Long Road Project Site (CFS)		19	1049.5	1335.5	1739.2	1947.8	3023.6	4120.9	5830.7	7372.1	9167.7	11265.3	14591.0

3.7.2 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 of 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** estimated the 1.5-year storm at approximately 70 cfs/mi^2 or 1336 cfs. The evaluation of NYCDEP regional curves of unmodified watersheds suggested that bankfull discharge should approximate 1230 cfs. Calibration of the existing HEC-RAS model produced water surface elevations verifying bankfull discharge at 1230 cfs. Although reliable indicators of the bankfull stage were limited in the project reach due to the high frequency of disturbance, the HEC-RAS model results generally confirm an incipient flooding condition at 1230 CFS. 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 1007 cfs. The discharge of 1230 cfs falls within the range of the discharges resulting from the four methods above, and was the bankfull discharge value selected for preliminary design.

3.7.3 Hydraulic Analysis

Hydraulic Analysis of the project reach for the 100 year flood was performed using a HEC-RAS model that was prepared using topographic survey data of the existing site conditions collected for the purposes of project design. Channel and floodplain resistance coefficients were developed using field collected sediment data and aerial imagery, and verified through comparison to the effective flood insurance HEC-RAS study. **Table 4** provides a summary of the model output.

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

River Station (ft)	Discharge (cfs)	Minimum Channel Elevation (ft)	Water Surface Elevation (ft)	Slope (ft/ft)	Flow Velocity (ft/s)	Froude #	Power (lb/ft s)	Shear Stress (lb/sq ft)
102.66	1030.95	983.32	987.66	0.014579	11.85	0.84	37.93	3.2
152.66	1125.66	983.88	988.04	0.005093	7.32	0.57	8.75	1.2
202.66	1037.99	983.37	987.53	0.008869	8.38	0.61	17.2	2.05
252.66	1034.97	982.68	987.21	0.007128	7.83	0.55	13.73	1.75
302.66	960.41	982.11	986.6	0.009326	9.01	0.59	20.87	2.32
352.66	752.5	981.35	986.03	0.010371	10.37	0.52	30.48	2.94
402.66	1080.96	980.81	984.84	0.015413	10.72	0.86	36.58	3.41
452.66	898.66	980.34	983.88	0.021049	11.86	0.82	50.9	4.29
502.66	1091.15	979.78	982.81	0.023039	10.8	1	41.21	3.81
552.66	1168.38	979.31	982.59	0.01099	7.97	0.77	16.01	2.01
602.66	1096.5	977.94	982.15	0.008036	8.04	0.63	15.14	1.88
652.66	835.24	976.47	982.02	0.004707	7.77	0.39	12.17	1.57
702.66	991.76	974.6	981.93	0.002599	6.57	0.35	6.89	1.05
752.66	744.43	974.73	980.26	0.015111	13.65	0.62	66.57	4.88
802.66	904.79	974.49	979.1	0.019341	13.44	0.8	68.15	5.07
852.66	1131.85	974.11	979.3	0.004	6.34	0.49	7.01	1.11
902.66	1098.12	973.73	979.02	0.004014	6.8	0.48	8.36	1.23
952.66	1051.14	973.51	979.14	0.001707	4.71	0.29	2.7	0.57
1002.66	1098.32	971.48	977.06	0.012739	12.04	0.84	46.64	3.87
1052.66	979.95	970.23	976.7	0.006198	9.05	0.52	19.06	2.11
1102.66	988.3	970.93	976.66	0.004582	7.41	0.44	10.72	1.45
1152.66	999.04	971.06	976.5	0.004246	6.97	0.43	9.02	1.29
1202.66	816.38	970.98	976.31	0.004639	7.24	0.37	10.15	1.4
1252.66	698.15	970.79	976.04	0.005964	7.78	0.38	12.95	1.66
1302.66	1202.5	971.3	975.89	0.003545	5.56	0.48	4.89	0.88
1352.66	1124.22	970.57	975.7	0.00315	5.84	0.42	5.39	0.92
1402.66	1156.92	970.14	975.74	0.00154	4.39	0.31	2.21	0.5
1452.66	1023.82	968.5	975.55	0.001852	5.39	0.3	3.86	0.72
1502.66	1111.31	966.83	975.48	0.001211	5.08	0.28	2.99	0.59
1552.66	1061.77	968.07	974.9	0.004091	7.69	0.46	11.42	1.49
1602.66	1151.58	968.12	973.26	0.013868	11.66	0.91	43.93	3.77
1652.66	1129.32	966.08	972.54	0.005243	7.38	0.53	11	1.49
1702.66	810.88	965.9	971.04	0.018583	12.68	0.72	58.33	4.6
1752.66	903.03	965.16	968.75	0.041272	14.81	1.1	104.83	7.08
1802.66	1208.33	963.39	966.01	0.063696	13.53	1.77	93.29	6.89
1852.66	1142.01	961.28	967.41	0.002986	6	0.43	5.69	0.95
1902.66	1187.77	961.34	967.41	0.002141	4.84	0.37	3.05	0.63
1952.66	1083.67	961.86	966.36	0.009738	9	0.68	21.02	2.34
2002.66	737.79	961.02	965.39	0.017928	11.95	0.65	49.78	4.17
2052.66	1164.09	960.09	962.13	0.086207	13.87	1.89	107.02	7.72
2102.66	1141.38	958.16	960.06	0.042591	10.52	1.32	45	4.28
2152.66	1186.21	956.31	959.29	0.018075	7.63	0.93	16.24	2.13
2202.66	979.35	953.22	958.38	0.010668	9.33	0.65	23.54	2.52
2252.66	993.35	951.13	956.1	0.023235	13.97	1.01	78.5	5.62
2302.66	906.39	948.66	954.51	0.020303	15.92	0.87	105.21	6.61
2352.66	1015.71	948.77	953.13	0.027634	15.56	1.13	107.36	6.9
2402.66	866.69	947.28	952	0.028634	15.62	0.93	109.35	7
2452.66	1185.52	945.43	951.65	0.006333	8.22	0.69	15.07	1.83
2502.66	1052.4	945.43	950.39	0.013028	11.46	0.81	41.41	3.61
2552.66	1119.46	944.54	950.26	0.004379	6.71	0.49	8.28	1.23
2602.66	381.13	945.45	949.14	0.001639	3.42	0.64	1.2	0.35
2652.66	1069.64	944.15	946.32	0.112487	16.84	1.97	185.73	11.03
2702.66	1019.83	942.48	946.86	0.012968	10.23	0.74	31.17	3.05
2752.66	1049.94	940.9	944.46	0.040185	13.89	1.26	88.74	6.39
2802.66	1070.9	940.84	944.35	0.016368	9.26	0.82	25.74	2.78
2852.66	1104.6	940.18	943.31	0.014087	8.51	0.79	20.04	2.36
2902.66	1122.02	938.61	942.32	0.012421	9.61	0.85	21.56	2.24
2952.66	1211.81	937.34	942.12	0.005063	7.19	0.65	8.35	1.16
3002.66	1131.13	936.03	940.58	0.01112	11.4	0.81	32.16	2.82
3052.66	1212.88	936.02	939.69	0.015712	11.63	1.09	36.87	3.17

3.7.4 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 critical shear stress values corresponding with the bed material D50 and D84. The model indicated that the critical shear stress for both the D50 (97 mm) and the D84 (180 mm) particle sizes were mobile during bankfull flow condition throughout much of the project reach.

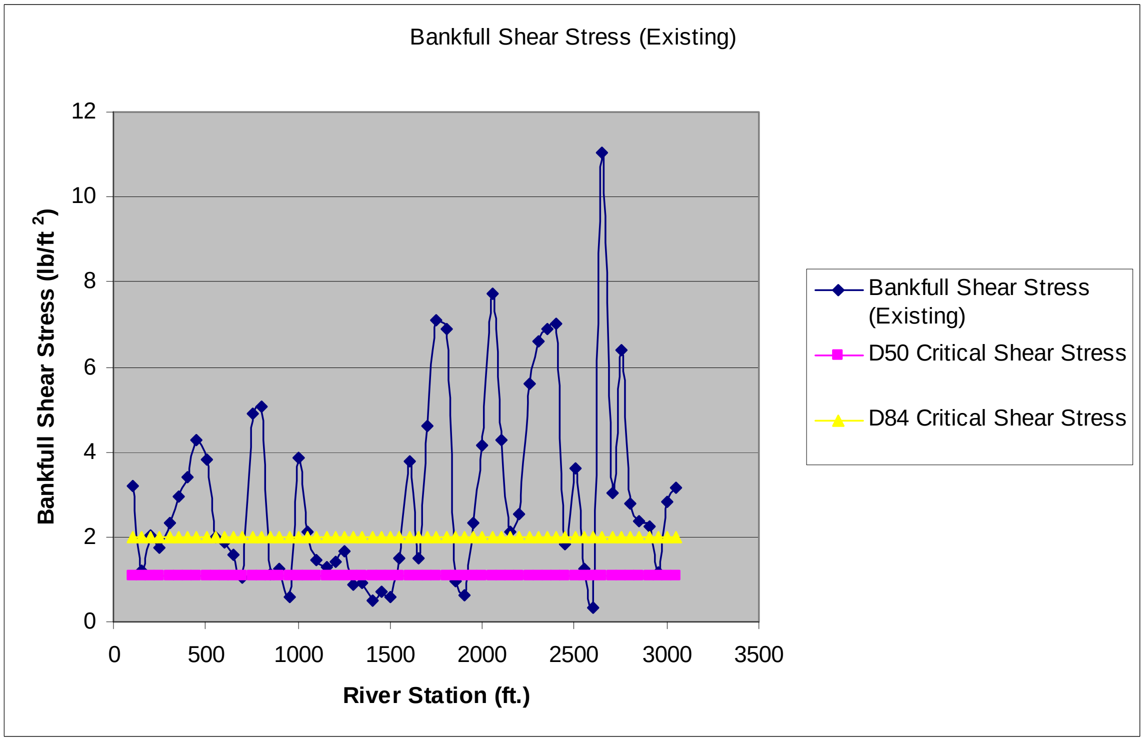


Figure 7. Channel average shear stress and channel armor threshold values.

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 that the reach located upstream of the project reach had historically supplied an inconsistent sediment regime to the project reach. The eroded sediments consisted of finer material including fine clay and silt as well as larger bedload material. The delivery of excess sediment to the project reach from bounding reaches appeared to have resulted in a general fining of the bed particle distribution, and does have the potential to have affected 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 Wildland Hydrology, Inc. (2001). Entrainment analysis estimated that a mean depth of 2.5 feet would be required to transport the larger material found on the bar formations. The average existing mean channel depth averaged 3.0 feet, indicating the reach was supply-limited, and a potential for degradation during bankfull conditions existed. That finding was supported by site monitoring data.

Bank erosion and failure in project reach.

4.0 Proposed Design


Image of bank erosion and associated cobble bar.

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.

4.1 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 was negatively affected by excessive streambank and bed erosion. The restoration of the reach presented 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 stream channel’s bed and banks, conveyance of water and sediment, and riparian vegetation condition. Further, it was 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. Fish passage in the reach was impacted by steel sheet oiling grade control structures that were exposed by repeated high flows. Moderation of the profile through those areas is expected to facilitate fish passage through the reach. County route 6 has experienced repeated damages associated with instablility of this stream reach. Infrastructure stability is expected to be significantly enhanced as an outcome of this project.

4.2 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 set of channel dimensions meeting appropriate channel morphology conditions and bank stability objectives in light of the physical site constraints. The alignment was constrained most notably by a naturally narrowing valley morphology, and encroachment of County Route 6 on the riparian corridor.

A wetland inventory identified 0.03 acres of wetland located in and around the project site (**Map W-1 in Appendix A)**. The design proposed 0.03 acres of wetland disturbance within the project grading extent **(Map WD-1 in Appendix A)**. Proposed wetland mitigation included replacement of 0.03 acres of wetland in the form of increased riverine wetlands along the margin of the restored stream channel.

Archeological field investigation identified neither prehistoric nor historic artifacts or features on the site. A report including mapping has been provided in **Appendix C**.

As proposed the project required the clearing and grubbing of approximately 6.8 acres of riparian lands including forested floodplain in the middle portion of the project reach. This cover type has been identified as potential habitat of the Indiana bat (*Myotis sodalis*) in New York State, on both the federal and state endangered species list. Investigation was performed to determine any potential affect the project may have had 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 1,500 feet), and further, that in the unlikely event the bats are present, they would most likely benefit from the stream restoration project as proposed.

Landowner approval of the project was prerequisite to project construction. Implementation of the project required 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 6 primary 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 required 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.

4.3 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 a reference reach database 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.

4.4 Design Components

The proposed channel design included restoration of 3,000 linear feet of the stream channel. Channel reconstruction included modification of the channel geometry and stream channel profile, floodplain and adjoining banks and terraces. The design included three primary types of rock structures including vanes, cross vanes and drop structures to promote channel stability during vegetation reestablishment. Construction specifications are located in **Appendix H** and construction drawings can be found in **Appendix I**.

4.4.1 Channel Reconstruction

During the design process, channel sizing was applied 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 indicated an average width of 95 feet and depths of 3.5 feet for the project reach. Several regional curves developed by NYCDEP SMP relating drainage area to width and depth estimated a width 70 feet and mean depth of 2.9 feet.

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

Investigator/Source	Formula	BankfullWidth	Bankfull Depth
Bray (1982)	W=2.38 *Q2^.53	124	2.7
(General)	d=.226*Q2^.33		
Emmett (1972)	W=2.39*Qbf^.5	84	3.1
(Alaska Meander Streams)	d=.26*Qbf^.35		
Drage & Carlson (1977)	W=4.66*Qbf^.47	132	1.9
(Braided Streams)	d=.13*Qbf^.38		
USGS Channel Width	W=(Q2/.4)^1/1.82)	100	2.9
(Used Williams (1986) W/d Relationship)	d=0.12*W^0.69		
Lacey (1948)	W=2.67*Qbf^0.5	94	3.2
	d=(Qbf/(13.5*((D50*25.4)^.5)))^.333		
Yukon Placer 1990 DFO W/D Charts	W=2.73*Qbf^0.5	96	2.3
(converted from metric)	d=0.22*Qbf^0.33		
Leopold et al. (1956)	W=5*Qbf^.5	175	1.0
	d=0.1*Qbf^.0.33		
Simons & Albertson (1971)	W=2.5*Qbf^.51	94	5.6
	d approx R= 0.43*Qbf^0.43)		
Nixon (1959)	W=1.67*Qbf^.5	59	5.8
	d=0.55*Qbf^0.33		
Nash (1959)	W=1.32*Qbf^.54	62	6.3
(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	51	4.4
	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	66	2.7
NYCDEP Regional Curves (Region 4)	d=1.05*DA^0.32		
	Average	95	3.5
Source: FischenIck (2000), Esopus Creek Asessment & Conceptual Design Report			

The existing channel was considered over-efficient and channel incisement had amplified bank erosion and channel instability. Improving the width-depth dimensions of the over-confined sections and creating a single channel in the braided area of the reach provided for improved sediment transport continuity 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 was 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 2.7 feet for the proposed slope of 1.5% and produce a bankfull shear stress of approximately 2.5 lbs/ft^2. These dimensions verify that the proposed mobile bed pavement particle size of approximately 287 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.

Base flow channel dynamics were enhanced through the creation of pools downstream of 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.

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 channel dimensions were drafted and incorporated into a design template, which was transposed onto the existing topographic survey of the project site. Modifications to the channel and floodplain dimensions were made to achieve the best feasible geometry 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 design resulted in a more consistent slope and corridor width 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 profile 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 was 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 step/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.

The proposed channel reconstruction and structure installation was expected to generate a material surplus of approximately 4,500 cubic yards. Disposal areas within the project area were identified to dispose of the surplus material generated during the channel excavation. All material disposal areas were to be located outside of the 100 year floodplain.

Exposures of glacial clay materials were inventoried in the bottom of the pools and in several banks through the reach. To mitigate the water quality impacts of clay material entrainment during and after 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 **LR-09** 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. Coarser materials used in the construction of riffle features are specified on detail **SR-07b** on sheet **LR-09 in Appendix I,** remaining pool areas utilized detail **SR-07a** in regards to the levels and locations of materials within a typical cross section.

Table 6. Summary of proposed conditions during bankfull flow.

Long Road Stream Restoration	
Channel Design Summary	
Stream Type	F3/B3c/B3
Drainage Area (sq. mi.)	18.7 - 19.6
Bankfull Width (ft)	
Riffle	69.4 - 80.3
Pool	90.2 - 104.5
Bankfull Slope (ft/ft)	1.0% - 2.2%
Target Particle Size (ft)	0.64 - 1.3
Bankfull d_{mean} (ft)	2.55 - 2.88
Width / Depth (ft)	24.1 - 31.5
Bankfull A_{xs} (sq.ft)	199.7 - 204.9
Bankfull V_{mean} (ft/s)	6.1
bankfull Q (cu.ft/s)	1217 - 1263
Ratio D_{riff} / d_{mean}	1.43 - 1.8
Riffle Depth (ft)	3.8 - 4.6
Ratio D_{pool} / d_{mean}	1.9 - 2.4
Pool Depth (ft)	4.9 - 6.2
Floodprone Width (ft)	103.8 - 116.0
Entrenchment Ratio	1.4 - 1.6

4.4.4 In-Stream Structures

The design incorporated four general types of in stream structures to promote reach stability including; rock vanes, cross vanes, stone drop structures and tree revetment. The structures were intended to 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 incorporated the use of available root wads in high stress areas along the streambanks where applicable. These structures were intended to be created in the form of tree revetment and assist the vanes to ensure bank protection and habitat enhancement. Several rock vanes were installed along the proposed channel restoration in order to re-direct channel currents and reduce the potential for excessive channel migration and erosion. The vanes were constructed of large diameter rock, and were oriented in an upstream fashion with an interior acute angle of 20 – 30 degrees. The length of the rock vanes averaged 60 feet and keyed into the streambanks at an elevation approximately one foot below the bankfull stage. The vanes were keyed into the streambanks a minimum of 18 feet to prevent scour and flanking of the structures in the event of a large flood.

Several rock cross vanes were installed through the project length to provide stream bank protection along with grade control for the channel bottom. The cross vane structures re-direct channel currents and provide energy dissipation, while maintaining transitions between physical bed features. The cross vanes were 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 was constructed with an interior acute angle of 20 – 30 degrees. The length of the rock cross vanes averaged 60 feet and they were keyed into the streambank at an elevation approximately one foot below the bankfull stage. The cross vanes were keyed into the streambank a minimum of 7 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 LR-04** and details on **LR-09**. **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 summary.

Station (ft)	Type	Volume (yds^3)	Tons
300	Cross Vane	236	520
384	Drop Struct.	115	254
500	Rock Vane	97	212
625	Rock Vane	81	179
775	Cross Vane	228	502
859	Drop Struct.	127	280
1050	Cross Vane	212	467
1126	Drop Struct.	105	231
1300	Cross Vane	197	433
1600	Cross Vane	167	368
1661	Drop Struct.	115	254
1825	Cross Vane	196	430
2000	Cross Vane	227	500
2175	Cross Vane	235	517
2375	Cross Vane	226	496
2435	Drop Struct.	122	268
2550	Cross Vane	243	536
2750	Cross Vane	218	480
2806	Drop Struct.	121	267
2925	Cross Vane	192	422

4.4.5 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 was employed to initiate the development of a functioning riparian community. Native willow and dogwood species were planted on the streambanks. Pre-rooted sedge bags, single or double rows of live fascines and live stakes were applied to floodplain benches, along side each vane, on outside bends and to other areas of special concern. All other areas of disturbance were treated with conservation seed mixtures and mulched to minimize soil losses. Various species of woody trees and shrubs, appropriate for the riparian zone, were planted in the disturbed upland areas.

Wetlands and improved riparian buffer were constructed to mitigate the disturbance of approximately 0.03 acres of wetland within the grading extent. Wetland was developed along the margin of the restored channel in addition to the reestablishment of 4.2 acres of riparian buffer. The attached project drawing **(LR-04)** further clarifies the proposed location of the riparian buffer revegetation activities. Riparian vegetation was established by use of a riparian seed mixture, with species selected for known riparian and wildlife values **(Table 8)**. The species selected for this area are tolerant of irregular surface inundation and are expected to survive in saturated soil conditions. The riparian seed mixture will encourage the establishment of a uniform herbaceous cover. The seed mix used was "Riparian Buffer Mix" marketed by Ernst Conservation Seeds, Inc.

Table 8. Proposed riparian seed mixture.

Common Name	Scientific Name
Big Bluestem (Turkey Foot Bluestem)	*Andropogon gerardii (A. furcatus)*
Common Milkweed	*Asclepias syriaca*
Blue False Indigo	*Baptisia australis*
Fox Sedge	*Carex vulpinoidea*
Partridge Pea	*Chamaecrista fasciculata (Cassia f.)*
(Silky Dogwood)	*Cornus amomum*
Showy Tick Trefoil	*Desmodium canadense*
Riverbank Wild Rye	*Elymus riparius*
Virginia Wild Rye	*Elymus virginicus*
Joe Pye Weed	*Eupatorium fistulosum*
Spotted Joe Pye Weed	*Eupatorium maculatum*
Boneset	*Eupatorium perfoliatum*
Grass Leaved Goldenrod	*Euthamia graminifolia (Solidago g.)*
Ox Eye Sunflower	*Heliopsis helianthoides*
Soft Rush	*Juncus effusus*
Wild Bergamot	*Monarda fistulosa*
Deer Tongue	*Panicum clandestinum (Dichanthelium c.)*
Switchgrass	*Panicum virgatum*
Tall White Beard tongue	*Penstemon digitalis*
Staghorn Sumac	*Rhus typhina (R. hirta)*
Black Eyed Susan	*Rudbeckia hirta*
Little Bluestem	*Schizachyrium scoparium (Andropogon scoparius)*
Indiangrass	*Sorghastrum nutans*
Blue Vervain	*Verbena hastata*
Giant Ironweed	*Vernonia gigantea (V. altissima)*
Arrow Wood	*Viburnum dentatum*

5.0 Project Construction Summary

5.1 Construction Schedule

Project construction was undertaken during the summer/early fall season with the completion of the stream channel excavation and structure placement attained on September 22nd. Construction occurred during normal base flow periods, and equipment was staged from dry portions of the dewatered streambed, wherever possible, to avoid damage to the existing adjacent riparian vegetation.

5.2 Project Access

Project access was attained using existing access routes as outlined on construction drawings **LR-10 in Appendix I**. Whenever possible all construction activities and transport utilized the existing and proposed stream channels as work areas in order to minimize the damage to surrounding floodplain areas and vegetation.

5.3 Dewatering and Erosion and Sediment Control

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 diverted 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 three 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 each phase all areas were restored as soon as possible to preconstruction conditions. Pumping specification **CS-4 in Appendix H** and construction drawing **LR-10 and 11** in **Appendix I** display the location, extents and details of the dewatering plan.

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. In the event that adequate sediment control could not be accomplished using existing filter areas, the Contractor was required to develop open sediment basins constructed of hay bales lined with filter fabric. These constructed basins were placed near the locations of the existing filter areas and pre-treated the discharge before it enters the existing filter areas. All disturbed areas were temporarily stabilized as soon as possible to minimize soil erosion. The sediment control measures ensured that the minimum practicable amount of turbid water discharged from the work area.

All construction infrastructure including roads, staging areas, borrow and storage sites, construction entrances and other infrastructure as deemed necessary by the project engineer were restored as outlined in the Stormwater Pollution Prevention Plan (SPPP) that is located in **Appendix D** and on construction drawings **LR-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).

5.4 Clearing and Grubbing

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 prior to removal in order to minimize any impacts to adjacent vegetation. These areas were completely re-vegetated as part of the project as displayed on construction drawing **LR-05**. Clearing and grubbing also included removal of concrete, wood or steel structures within designated areas.

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 **LR-10** displays the extents of operations. The grubbed material was disposed of in a disposal pit. The location of the disposal pits were 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.

5.5 Construction Sequence

Construction sequencing consisted of first excavating the proposed stream channel and filling the existing channel areas. The excavation of the proposed stream channel was initially done in rough format, in close approximation of the final grade channel elevations. Upon the completion of the rough channel grading, rock structures were installed in sequence around the proposed stream meander. After all rock structures were installed around a specific meander, the channel was brought to finish grade. Work was performed largely in the dry, though some equipment operation did take place in ponded areas where excavation to groundwater elevation occurred.

The acquisition of plant material for the bioengineering component of the project was conducted in late September as the plants began to enter the dormant period of their growth cycle. The bioengineering components of the project were installed expeditiously after harvesting in order to reduce the probability of damage to the plant material.

6.0 Project Bidding

6.1 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 seven Primary Bid Items and five Alternate Bid Items. 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.

6.2 Contract Award

Two 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.	$731,740.00
T.C. Briggs Contracting & Supply, Inc.	$925,140.00
Engineer's Estimate	**$829,270.92**

The contract was awarded to Evergreen Mountain Contracting, Inc. by the GCSWCD Board of Directors at their July 16, 2009 board meeting. The bid forms received are on file and available for further review at the GCSWCD office.

7.0 Project Contract Activities

Project construction commenced on August 10, 2009 with mobilization, dewatering equipment installation and clearing and grubbing activities in Phase I of the project sequence. Project dewatering began on August 14, 2009, and continued through September 21, 2009. Project dewatering was sustained for approximately 39 days. Planting of containerized tree and shrub 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 begin to enter their dormant period.

Phase I stream channel excavation.

7.1 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.

7.1.1 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.

Contractors were informed at the pre-bid meeting that preparation of access roads to the work area would be paid as a component of the Mobilization / Demobilization Bid Item of the project bid. Contractors were aware that the cost of labor and equipment time for establishing access to the work area should be included under their bid for the item. Material necessary to construct the stabilized construction entrance would be covered under Alternate Bid Item #4 – Item 4 Stone.

The contract bid price scheduled for this item was $50,000.00. The total amount paid for this item was $50,000.00. 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.

7.1.2 Stream Channel Excavation

Phase I stream channel excavation.

This bid item covered all aspects of channel and floodplain grading to the design grades and elevations. 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.

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 provided by GCSWCD and was not included in this bid 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 the minimum practicable amount of turbid water discharged from the work area.

The Primary Bid price and actual cost for stream channel excavation was $205,000.00.

7.1.3 Rock Structures

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

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.

The initial Primary Bid price for rock

structures was developed based on an estimated rock tonnage of 7620 tons and resulted in a bid price of $320,040.00. The total tonnage actually used to complete the project implementation was 9089.3 tons resulting in an actual final expenditure of $381,750.60.

The rock tonnage actually applied to this project exceeded the proposed tonnage for Primary Bid Item #3 by a significant margin (19%). This overage is attributable to two factors. The first factor was that an extra rock vane was added to the design in lieu of the tree revetment that was deleted from the design due to site constraints. The second factor was that due to the confined conditions on the site, Heavy Stone Fill was used on the project instead of the Medium Stone Fill listed in Primary Bid Item #7 in order to resist the anticipated forces of flood flow. Heavy Stone Fill is more costly to ship and handle than the Medium Stone Fill. Therefore, the budget for Primary Bid Item #7 was transferred to this item in order to cover the overage. The total expenditure for rock amounted to 5% less than the combined budget for Primary Bid Items #3 and #7.

The final count of structures installed on the project included twelve cross vanes, 6 drop structures and three rock vanes.

The rock tonnage applied to this project is also somewhat larger than projects of similar character due to the highly confined site conditions. While the design includes a bankfull channel that was developed to endure the forces of flow at the bankfull stage, the confined conditions of the site made flows exceeding bankfull difficult to design for. The approach to stabilizing the channel for those higher flows was to counter the forces of erosion with increased structural measures including rock vanes, cross vanes and rock drop structures.

Completed cross vane in upper reach of project.

Monitoring and maintenance decisions for this project should be especially sensitive to evidence of incision into the bed and failure of any of the vertical control measures installed to ensure profile stability in the reach.

7.1.4 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.

No top soil was installed on the project from off site sources under Primary Bid Item #4. On site materials were determined to be a suitable substitute for the off-site top soil item.

7.1.5 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 **LR-05 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 2,000 ft. of live fascines for a total contract price of $13,000.00. The estimated quantity was based on an initial assumption that 1000 linear feet of live fascine would be necessary for each bank of restored stream channel to achieve reasonable rates of revegetation. The quantity of fascines actually installed on the project was 3750 ft. for a total expenditure of $24,375.00. Installation of fascines in excess of contract estimated units was deemed necessary by the contracting officer due to the high shear stress conditions anticipated in the reach and the availability of quality material for construction of the fascines.

7.1.6 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-05 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 $44,000.00. The estimated quantity was based on an initial assumption that slightly over 2.5 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 8600 posts for a total expenditure of $47,300.00. Installation of live posts in excess of contract estimated units was deemed necessary by the contracting officer due to the high shear stress conditions anticipated in the reach and the availability of quality material for construction of the posts.

7.1.7 Medium Stone Fill

This bid item covered the acquisition and installation to grade of medium stone 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 medium stone fill as directed by the contracting officer.

No medium stone fill was installed on the project from off site sources under Primary Bid

Item #7. Project expenditures that were saved on this item were used to offset additional rock structure materials utilized under bid item #3.

7.2 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.

7.2.1 Root Wads

No root wads were installed as a component of this project. Though proposed in the initial design, channel confinement conditions would have required disturbance of high, steep slopes in order to install the proposed root wads. Upon observation of subsurface conditions and consultation with the Contractor and Engineer, the tree revetment that was proposed along project stations 22+00 – 24+00 was replaced with a rock vane.

7.2.2 Sediment Control fence

This bid item included the costs of materials, delivery, installation as directed by the contracting officer and removal of sediment control fence. This item was bid on a unit price basis using linear feet of installed fence as the measure for payment. The sediment control fence was intended to prevent release of turbid runoff from the work area and staging areas to ensure compliance with regulator permit requirements.

Bids for this item were prepared based on an estimated quantity of 3000 linear feet of sediment control fence resulting in an anticipated project expenditure of $45,000.00. The actual quantity of sediment control fence installed on the project was 800 linear feet resulting in an actual project expenditure of $12,000.00.

7.2.3 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 would have been removed from the stream channel and disposed of in a location specified by the contracting officer. The over-excavated areas would then have been 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.

No clay was excavated and replaced using this bid item.

7.2.4 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.

400 tons of Item 4 was estimated to be necessary to prepare the stabilized construction entrances for an estimated expenditure of $12,800.00. 89.27 tons of Item 4 was actually used for a total actual expenditure of $2,856.64.

7.2.5 Backup De-watering

This bid item was included in the bidding process in order to provide 30 cfs of additional dewatering capacity in the event that stream flow exceeded the capacity of the primary dewatering equipment or in the event that the primary dewatering equipment was out of service. The alternate bid item was bid on a 2 week basis at $65,000.00.

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

7.3 Time & Materials Work

7.3.1 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 **LR-05**.

Clearing and grubbing of Phase II.

The project site had limited 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 **LR-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.

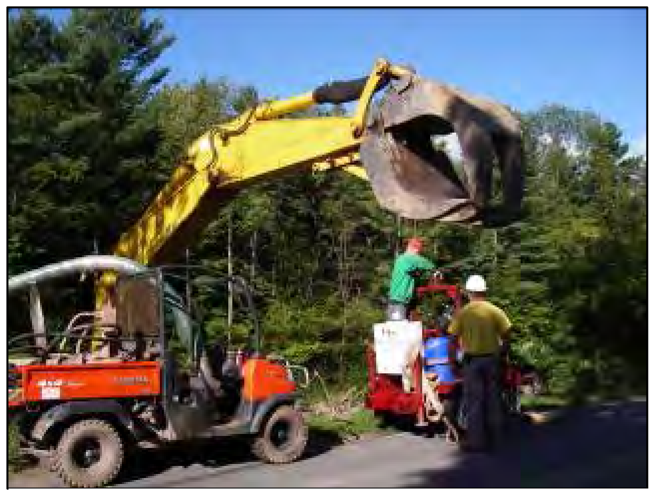
- Where six feet of cover depth was not attainable, the material was placed in the disposal pit, and covered with black plastic and a minimum of three feet of clean fill, free of knotweed material.

A very limited amount of knotweed was encountered on this project site. All knotweed collected during the clearing and grubbing operations was buried in a disposal pit on the right floodplain along project stations 6+50 – 8+00.

The total project expenditure associated with clearing and grubbing was $105,713.00.

7.3.2 Dewatering Installation

Dewatering for the project was provided by GCSWCD. Installation of the provided equipment was completed 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 assembly of the dewatering pipeline, installation of the pumping equipment, relocation of the equipment as necessary to complete the project, and removal of the equipment and pipeline upon completion of the project.


Installation of turbidity control equipment.

The total project expenditure associated with handling of the dewatering equipment was $44,766.74.

7.4 Change Orders

Change orders were executed for this project in order to document necessary project expenditures that were unanticipated at the time of bidding. A total of seven change orders were executed throughout the duration of project construction. The details of those change orders are provided in the subsections below.

7.4.1 Pipe Rental

Due to challenging site conditions the contracting officer determined that heavier duty dewatering pipeline than GCSWCD had available would be necessary to complete the project under the limited time available for construction. The Contractor agreed to provide 1000 feet of 30" HDPE butt fusion pipe for the duration of the project at a lump sum rental rate of $20,000. All costs of assembling and installing the pipeline were paid on a Time &

Materials basis according to the Labor, Equipment and Markup rates provided on the Contractor's supplemental bid form.

The total project expenditure associated with this change order was $20,000.00.

7.4.2 Remobilization

This was a “No-Cost” change order executed in advance of the start of construction. Adverse weather conditions and delayed permit approvals leading up to project construction resulted in a relatively late project start. The Contractor agreed, in order to compel the project Owner to begin construction despite the late project start, to hold the original lump sum bid for Bid Item #1 Mobilization & demobilization of $50,000 even in the event that the project needed to be stopped during the winter months and resumed in subsequent seasons. Timely completion of the project nullified the need for remobilization under this “No Cost” change order.

7.4.3 Time & Materials Work (Payment Request #1)

Clearing and grubbing work and pump and pipeline assembly and placement were conducted on a time and materials basis. This change order documented the change in the contract price resulting from the time and materials work completed between August 10, 2009 and August 25, 2009.

The expenditures associated with this change order are discussed in sections 6.3.1 and 6.3.2 above.

7.4.4 Time & Materials Work (Payment Request #2)

Clearing and grubbing work and pump and pipeline assembly and placement were conducted on a time and materials basis. This change order documented the change in the contract price resulting from the time and materials work completed between August 26, 2009 and September 22, 2009.

The expenditures associated with this change order are discussed in sections 6.3.1 and 6.3.2 above.

7.4.5 Primary Bid Item Balancing

Primary bid items on the contract were estimated and 100% over or under the estimated bid items was noted as allowable on the bid from. This change order balanced the unused and overused estimated items and resulted in a total of zero remaining for completion for the close of the contract.

The total contract change amount for this change order was -$23,315.10. The details of the primary bid items utilized during project construction are discussed in section 6.1 above.

7.4.6 Alternate Bid Item Balancing

Alternate bid items on the contract were initially added to the contract as one unit for each alternate bid item. This change order balanced the under-used and over-used estimated items and resulted in a total of zero remaining for completion for the close of the contract. The total contract change amount for this change order is -$51,027.36. The details of the alternate bid items utilized during project construction are discussed in section 6.2 above.

7.4.7 Fuel Reimbursement

Fuel for dewatering operations was not included in the original contract amount. Dewatering equipment was fueled by Evergreen Mountain Contracting, to be replaced by Greene County Soil & Water. The total fuel used by GCSWCD for dewatering was 2,434 gallons. 700 gallons of fuel were replaced directly from GCSWCD's storage tank at the Mitchell Hollow Shop. The remaining 1734 gallons was paid back at a rate of $2.48 per gallon, the rate that Evergreen Mountain Contracting has demonstrated that they are paying for off-road diesel fuel.

The total contract change amount for this change order is $4,300.

8.0 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 with the help of volunteer labor forces. These tasks included project site survey control, installation of containerized plant material and seeding and mulching for sediment and erosion control.

8.1 Project Site Survey Control

Precision grading of the stream channel and floodplain is an integral part of Natural Channel Design 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.

8.2 Containerized Plant Material

Riparian vegetation is a key component of a functioning riparian corridor. In order to accelerate the revitalization of the riparian vegetation community on the project site, more than 700 containerized trees and shrubs were planted on the disturbed portions of the floodplain and terrace slopes.

October 23, 2009 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 Long Road Stream Restoration Project, but also of the cooperative stream management initiative being undertaken by NYCDEP and their project partners.

8.3 Seeding and Mulching

A dense, vigorous ground cover serves as the initial step in establishing control of sediment and erosion on a freshly graded construction site.

Seeding and Mulching.

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 the minimum practicable amount of turbid water discharged from the work area.

Permanent riparian vegetation was established by use of a riparian seed mixture, with species selected for known riparian and wildlife values **(Table 6, Section 3.4.5)**. The species selected for this area are tolerant of irregular surface inundation and are expected to survive in saturated soil conditions. The riparian seed mixture will encourage the establishment of a uniform herbaceous cover. The seed mix used was “Riparian Buffer Mix” marketed by Ernst Conservation Seeds, Inc.

A total of 373 bails of hay, 1500 lbs. of rye seed mix and 100 lbs. of riparian buffer seed mix were applied to the project site in order to meet the permit requirements and riparian ecology goals of the project.

9.0 Project Expenditure Summary

The total project expenditures on the Long Road Stream Restoration Project amounted to $908,854.57. The contract bid items, unit prices and total expenditures are summarized in Table 9.

Table 9. Summary of Project Expenditures.

Long Road Stream Restoration Project

PRIMARY BID ITEMS

Bid Item	Item Description	Estimated Units	Estimated Cost	Actual Cost
1	Mobilization/Demobilization	Lump Sum	$ 50,000.00	$ 50,000.00
2	Stream Channel Excavation	Lump Sum	$ 205,000.00	$ 205,000.00
3	Rock Structures	Per Ton	$ 320,040.00	$ 381,750.60
4	Top Soil	Cu yd	$ 18,700.00	$ 0.00
5	Live Fascines	per foot	$ 13,000.00	$ 24,375.00
6	Live Posts	each	$ 44,000.00	$ 47,300.00
7	Medium Stone Fill	Per Ton	$ 81,000.00	$ 0.00
		Total	$ 731,740.00	$ 708,425.60

ALTERNATE BID ITEMS

Alt 1	Root Wads	each	$ 3,200.00	$ 0.00
Alt 2	Sediment Control Fence	per foot	$ 45,000.00	$ 12,000.00
Alt 3	Clay w/replacement	Cu yd	$ 100,000.00	$ 0.00
Alt 4	Item 4 Access Roads	Per Ton	$ 12,800.00	$ 2,856.64
Alt 5	Back-up De-watering (50cfs)	Lump Sum	$ 65,000.00	$ 0.00
		Total	$ 226,000.00	$ 14,856.64

TIME & MATERIALS WORK

TM-1	Clearing & Grubbing		$ 65,000.00	$ 105,713.00
TM-2	De-watering Operations		$ 20,000.00	$ 44,766.74
		Total	$ 85,000.00	$ 150,479.74

GREENE COUNTY SWCD ITEMS

GC-1	Seed & Mulch		$ 65,862.72	$ 11,332.48
GC-2	Trees & Shrubs		$ 40,000.00	$ 8,819.63
GC-3	Turbidity Control Pumping Equipment Purchase and Delivery		$ 22,954.47	$ 24,877.59
			$ 128,817.19	$ 35,092.59

		Grand Total	$1,171,557.19	$ 918,791.68

10.0 Post Construction Monitoring

An as-built survey was conducted immediately following construction in order to document the accuracy of the project implementation. The as-built survey provides baseline conditions for comparison against regular inspections and annual monitoring surveys to evaluate stability and performance of the restoration project. Project inspections include photographic documentation of the project reach and a visual inspection of the rock structures, channel stability, bioengineering and riparian vegetation. 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 in the watershed is being performed by NYCDEP, which includes measurements of total suspended solids (TSS) and turbidity.

10.1 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, fourth and fifth years after the authorized activities have been completed. These reports will include the following at a minimum:

- 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 West Kill in reporting years 1 and 5.

- Level II stream reach classification for the 3,000 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 1-5.

- 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 of fish and wildlife.

10.2 Riparian Vegetation Monitoring

As proposed this project will establish 4.2 acres of riparian buffer achieved through the planting of appropriate vegetation and the implementation of a Japanese Knotweed (*Polygonum cuspidatum*) management plan. Implementation will be conducted in a way that will ensure the following:

- 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 4.2 acre riparian area will not consist of more than a total of 5% areal coverage of common reed (Phragmites australis), purple loosestrife (Lythrum salicaria), reed canary grass (Phalaris arundinacea), Japanese Knotweed (Polygonum cuspidatum), Tartarian honeysuckle (Lonicera tartarica), and/or Eurasian milfoil (Myriophyllum spicata).

Three copies of reports on the status of the stream and riparian buffer restoration activities will be provided to the Corps of engineers New York District office, with the riparian buffer establishment data collected during the growing season, no later than October 31 in the first, second, third, fourth 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 establishment sites. The location of the plot 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 establishment sites. Photographs of the riparian buffer 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.

11.0 Operation and Maintenance

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 the stream restoration project.

11.1 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 and NYSDEC and NYCDEP.

11.2 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.

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Appendix A - Maps

Appendix B – Excerpts: West Kill SMP

Appendix C – Archaeology Report

Appendix D– Stormwater Pollution Prevention Plan

Appendix E – Wetland Delineation Report

Appendix F – Project Permits

Appendix G – Geotechnical Recommendations

Appendix H - Design Specifications

Appendix I – Construction Drawings and Details