FINAL REPORT

RIVER RECONNAISSANCE REPORT FOR SUSTAINABLE RIVER MANAGEMENT

LOWER ESOPUS CREEK
ULSTER COUNTY, NEW YORK

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1.0 INTRODUCTION

The Lower Esopus Watershed Partnership (LEWP), acting through the town of Hurley, New York, has engaged Milone & MacBroom, Inc. to conduct a preliminary watershed study of the lower Esopus Creek from Ashokan Reservoir to the Hudson River. The intermunicipal partnership includes the communities of Olive, Marbletown, Hurley, Ulster, Kingston, and Saugerties. The project is funded by a grant from the NYS DEC Hudson River Estuary Program and is directed by a multitown steering committee of local officials and stakeholders. Recent flooding in 2005 helped stimulate this project.

The goal of this project is to conduct a preliminary assessment of the lower Esopus Creek, identify and discuss its overall hydrology and fluvial form, and identify major problems and management issues. The long-range objectives of the LEWP is improved watershed and river management including river corridor assessment, study flood hazard areas, education, review corridor zoning and conservation, and public outreach.

The scope of work included reviewing existing data, records of flood events, soil maps, and GIS files, plus limited site inspections of selected locations. Key references include the draft Ulster County Federal Emergency Management Agency (FEMA) Flood Insurance Study (September 2007) and the U.S. Geologic Survey Open File Report 2007-1036 on the April 2005 flood. Valuable input was received at workshop meetings and via telephone interviews and email. The scope of work for this initial river reconnaissance does not include detailed field work, water quality testing, hydraulic analysis, or recreational assessments.

1.1 Project Location

The Esopus River watershed is located in southeastern New York, extending from the crest of the Catskill Mountains to the Hudson River at Saugerties. The rugged terrain ranges in elevation from approximately 4,000 feet above sea level to near sea level at the Hudson River.

The low watershed focus area extends from the Ashokan Reservoir to the Hudson River. Selected photographs are attached in Appendix A.

1.2 Watershed Planning Concepts

Watershed planning can occur at multiple spatial and temporal scales that are selected and adjusted to manage and balance natural sustainability and human needs. The general sequence is to define and investigate existing conditions at the basin, corridor, and segment scale and then assess river adjustments, constraints, tolerance, and finally to develop management strategies with stakeholders.

The basin scale study includes area-wide parameters that ultimately influence the quantity and quality of water, sediment, and pollutants to the fluvial system. Primary topics include basin topography and geology, their influence on forest and ground cover, and the resulting basin hydrology. Sediment sources, characteristics, and yield are also addressed.

Intermediate scale corridor studies focus on river valleys of the main stem and perhaps significant tributaries. Physical and ecological control points are located. The valley bottoms, including channels, riparian wetlands, floodplains, and terraces, are influenced by river hydraulics, scour, and deposition; forming the systems' morphology. The shape and form of alluvial systems is the result of all basin and corridor forces and loads; it is a product, not a starting point. The intermediate scale understanding of fluvial systems also addresses physical and ecological processes, conditions, and distress. It should address the type and population of aquatic and benthic communities, including fin fish, shellfish, and macroinvertebrates, plus water-dependent or related mammals, reptiles, amphibians, and birds. The physical, chemical, and biological aspects of water quality drive ecological integrity and are addressed at the corridor scale, as influenced by natural and anthropogenic inputs.

Segment and reach studies focus on small scale and short-term river characteristics such as channel pattern and profile features, channel geometry, meso habitat, scour and deposition, species, riparian cover, encroachments, and bed material. Segment level river assessments may only include a few hundred meters at a time, providing a detailed assessment of very local conditions. At this scale, one can focus upon specific areas of river behavior and how it responds to distress, the river's recovery potential, and need for intervention. The segment scale also considers rare or endangered species and invasive or non-native species.

The human scale is the next tier in watershed planning studies. Humans influence vegetative cover, ground cover, hydrology, hydraulics, and water quality. Gravel mining, water withdrawals, discharges, channelization, predation, and land shaping all impact fluvial systems. Watershed management plans have to define an equilibrium point between natural systems and social, recreational, historic, and archeologic conditions.

Some watershed plans will be initiated to address specific obvious problems while others are meant to conserve natural resources before problems arise. In both cases, scoping processes help to define the proportion of effort scheduled for basin, corridor, segment, and community elements. A key facet of watershed management planning is the assessment of a river's trajectory or potential evolution, its likely condition under a "do nothing" alternative, and the potential for successful intervention.

This project was initiated in part due to concerns about recent flood events and damages along the lower segments of Esopus Creek. The American style of flood hazard studies usually focus on watershed hydrology, river hydraulics, flood delineation, and flood hazard reduction via structural and nonstructural techniques. The above format does not address other social and environmental issues. This River Reconnaissance Report follows the European format that was developed for sustainable river corridors where we also include available or readily observed information on water quality, sediment, and fluvial morphology with an introduction to key management issues such as use of levees, sand and gravel extraction, and woody debris.

Sustainable river management can also address quality of life issues such as recreation, utilities, aesthetics, and economics, which are beyond the scope of this overview.

Watershed planning usually involves a broad coalition of stakeholders who have an interest in one or more planning steps. The ideal plan is reached by consensus and includes specific identification of problems, goals and objectives, and a vision for watershed management. Short-term and long-term recommendations are usually included with an implementation schedule.

2.0 HYDROLOGY

The physical shape and form of rivers, their water quality, and extreme flows such as floods and droughts are all determined by the watershed's hydrologic characteristics.

The Catskill region has above average precipitation and thus above average stream flow. The steep terrain, narrow headwater valleys, and limited wetlands all contribute to rapid runoff.

The hydrology and rivers of New York prior to the construction of the Ashokan Reservoir are described in some detail in New York State Museum Bulletin 85 (Rafter, 1905). At that time, Esopus Creek was described as having several sites suitable for a water supply reservoir including at Big Indian, the confluence of Bushkill, the confluence of Stoney Clove, Cold Brook, and at Olive Bridge where the Ashokan Reservoir was eventually built.

Esopus Creek had several water-related businesses then, powered by the various falls. They included Diamond Paper and Saugerties Manufacturing in Saugerties, Ulster Whitehead Company at Glenerie, and Bocce Gristmill and the Hudson Pulp Company at Olive Bridge.

2.1 New York City Water Supply

The Ashokan Reservoir located on Esopus Creek at Olive Bridge is an essential part of the New York City water supply system. The Ashokan Reservoir was built between 1907 and 1915 at Olive Bridge. The earth dam is 4,650 feet long and 210 feet high, creating a 12-mile long reservoir. It feeds water into the Catskill Aqueduct that extends southeast for 75 miles to the Croton Reservoir. The total New York City water supply system delivers 1.3 billion gallons of water per day to nine million people.

Water from Schoharie Creek is diverted from the Schoharie Reservoir on the north side of the Catskill Mountains through the deep Shandaken Tunnel to upper Esopus Creek, thence flows to

Ashokan Reservoir. Upper Esopus Creek is both a recipient and donor basin with interbasin transfers. Other reservoirs of the New York City water supply system are in the Delaware River basin portion of the western Catskills and east of the Hudson.

The presence and operation of Ashokan Reservoir insures that the upper watershed is managed to protect water quality, inadvertently creating upstream opportunities for popular white water sports, fishing, and tourism.

2.2 USGS Gauging Station Data

The U.S. Geologic Survey operates 11 stream flow gauging stations in the Esopus Creek watershed, three of which are on the main stem. Two gauges are upstream of the Ashokan Reservoir and one downstream at Mount Marion. Their base data is tabulated below.

Station #	Station Name	Watershed Area, (MI^2)	Period of Record
01362200	Allaben	64	1963-Present
01362500	Coldbrook	192*	1931-Present
01364500	Mount Marion	419**	1970-Present

* This is about 75 percent of the inflow basin to the Ashokan Reservoir.

** Of this watershed area, 265 square miles is regulated by the Ashokan Reservoir.

The flow rates at the Mount Marion gauging station are influenced by storage at the Ashokan Reservoir, by water supply diversions to the New York City metropolitan area, by small reservoirs on Sawkill Creek and Plattekill, and by inflow diversions from the Schoharie Reservoir.

2.3 Selected Gauged Peak Flows

The USGS gauging stations are a critical source of information on both long-term mean daily and monthly flow rates plus individual flood events. In order to view the impact of the reservoir on peak flow rates, one can compare the measured upstream and downstream flows.

Selected Peak Flood Flows,
CFS at USGS Gauges

	Upstream of Reservoir		Estimated	Downstream at
Date	Allaben	Coldbrook	Reservoir Inflow	Mount Marion
March 1951	20,000	59,600		
November 1977	4,860	30,000		13,000
March 1980	15,900	65,300		19,500
January 1996	15,000	53,600		11,600
December 2000	5,820	29,200		12,400
April 2005	21,700	55,200	73,700	30,500

A comparison of the 2005 flood flows with the FEMA predicted peak flow rates (Section 4.1) indicates that it has an average return frequency of about 50 years.

The Ashokan Reservoir was not designed or equipped to act as a flood control project. However, its large surface area does help store flood waters. The above data confirms that the Ashokan Reservoir has a substantial impact upon downstream peak flood flow rates, reducing them by about 60 percent. The peak flood flows at the Mount Marion gauge, which is far downstream of the reservoir, are substantially less than the peak flood flows entering the reservoir as measured at the Coldbrook gauge. The Mount Marion gauge has peak flow data for 43 nonconsecutive years, and three of the five highest floods occurred in the past three years (2005, 2006, 2007).

The 1905 Hydrology Bulletin describes a 1878 flood along the lower Esopus Creek at Saugerties as having a peak discharge of 50,000 to 60,000 cubic feet per second, so the recent large floods of similar magnitude are not unusual.

The presence of reservoirs and their water supply diversions at Ashokan, Sawkill, and Plattekill means that the effective drainage area at the Mount Marion gauging station varies depending upon whether or not the upstream reservoirs are full and spilling and the percent of the flow that is diverted. During low runoff periods, it can be assumed there is little or no spillage, and during major floods, one can assume some spillage occurs.

Effective Watershed Areas
Mount Marion Gauge

Total watershed (Pre-reservoirs)	419 SM
Effective watershed (Without Ashokan Reservoir)	163 SM
Effective watershed (During low flow)	112 SM
Effective watershed (During floods)	Over 112, less than 419 SM

The computed mean annual flood at the Mount Marion gauge is 10,800 cfs, based on 42 nonconsecutive years of record. The mean annual flood is usually a little less than the long-term channel forming discharge. Using the NYS Region 4 hydraulic geometry study, the bankfull discharge would be 12,033 cfs for an assumed effective watershed area of 163 square miles, which excludes only the Ashokan Reservoir (Miller and Davis, 2004).

2.4 Mean Monthly Runoff

The mean monthly stream gauge data at Mount Marion provides information useful for ecological and recreational uses of the river, plus suggestions on local ground water levels and waste assimilation.

Mean Monthly Discharges
Esopus Creek at Mount Marion
From USGS Data

Month	Discharge, cfs
January	548
February	469
March	752
April	1,240
May	692
June	475
July	187
August	102
September	198
October	324
November	499
December	609

A brief review of the full data set reveals that some months have had very low mean discharges for a river of this size. The Mount Marion gauge was reactivated in 1970 and missed the 1960s drought. However, long low flow periods were recorded in 1980, 1993, and 2001. It is not unusual for summer mean monthly flows to be below 30 cfs, which is very low for a 419 square mile basin. This low flow is attributed, at least in part, to water supply diversions and irrigation use. The lower river segments below the dam would benefit from increased flows to maintain habitat and water quality if and when the water supply system can afford to do so.

The historic flows in Esopus Creek at Kingston were described in the 1905 Hydrology Bulletin as being 0.05 to 0.13 cfs per square mile, or about 40 cfs. The frequency or length of time over which these flows were observed is not known.

3.0 GEOMORPHIC ASSESSMENT

The purpose of this geomorphic assessment is to identify the major geologic processes that shape the river channel and its immediate corridor, to assess the channel form (slope, pattern, and cross section), and to identify its processes in terms of conveying both water and sediment. The methods used in this initial reconnaissance include reviewing previous reports, use of topographic maps and aerial photographs, Flood Insurance Reports, and limited site visits.

Briefly, Esopus Creek begins as a steep mountain river with confined valleys to an entrenched river along wide alluvial valleys with glacial outwash sediments. Esopus Creek has several significant waterfalls that are common in the Catskill region due to the bedrock stratigraphy with interlayered shale and sandstone. The falls include as follows:

Watershed Segment	Falls	Approximate Drop, Feet	Type
A	Bishop Falls, Olive Bridge	22	Rocky ledge
B	Glenerie	56	Cascade, multiple falls
C	Saugerties	42	Rock falls plus dam

The narrow gorge below Olive Bridge is related to the upstream migration of the falls, which is technically a knickpoint. Similarly, the falls at Glenerie is actually a series of at least five separate steps.

3.1 Watershed Context

Rivers are a product of their watersheds, and Esopus Creek is no exception. It is an unusual watershed, because of the man-made Ashokan Reservoir and water diversions, plus its mountainous topography and geology. New York State Department of Environmental Conservation identifies Esopus Creek by a Waters Index Number H-d171, with Class B water. The Federal Hydrologic Unit Code (HUC) is 02020007.

The watershed lies in southeastern New York State where it drains the central and eastern parts of the Catksill Mountains before discharging into the Hudson River estuary at Saugerties. The total relief is about 4,000 feet to the crest of Slide Mountain. To the south is the Rondout Creek watershed, which runs roughly parallel to the lower Esopus Creek to the Hudson River. To the north and west sides of the lower Esopus Creek watershed is Schoharie Creek and small tributaries to the Hudson River. The entire watershed was covered and scraped by multiple glaciers, rounding the mountain crests and creating till soils on slopes and outwash in some valleys.

The watershed is located in the M212 ecoregion as described by Bailey (USFS, 1995), which is the designation for the Adirondack-Northern New England type of mixed forest with coniferous and deciduous vegetation. It has a continental climate with mild summers and cold winters and is known for heavy snow cover. The valleys generally supported hardwood trees in presettlement years and now have mixed second growth and agricultural fields. Pure stands of spruce and fir begin above elevation 3,500 feet.

The Esopus Creek watershed is divided by the New York City Ashokan Reservoir into an upper and lower basin. The steep upper basin has 21 peaks over 3,000 feet, receiving 50 to 60 inches of precipitation per year, which is much wetter than surrounding lower regions. Most of the 256 square mile area is forest land, some of which was logged in the 1800s. Leather tanning, which required the bark of hemlock trees, was also a common forest practice. The upper watershed can be described as a source zone. This means its primary hydrologic function is the production of runoff and sediment. However, the reservoir modifies the runoff rates and is anticipated to trap most coarse sediment from the source zone.

In order to assess and describe lower Esopus Creek downstream of the reservoir, it is divided into a series of valley segments and river reaches. Each reach has fairly consistent geophysical or anthropogenic conditions; reach boundaries are typically located at confluences, bridges, or changes in channel type (see Table 1).

Table 1
Valley and Reach Data

Valley Segment	River Reach	From	To	Valley Length	Slope Ft/Mile
V1	V1.1	Ashokan Dam	Hurley Mountain Road	6 miles	33
V2	V2.1	Hurley Mountain Road	Hurley Town Line	4.5	9
	V2.2	Hurley Town Line	Route 209 Bridge	3.5	2.3
	V2.3	Route 209	I-587/28	2.7	4.4
	V2.4	I-587/28	Leggs Mill Road	5.2	0
V3	V3.1	Leggs Mill Road	Bedrock Exposures	0.1	63
	V3.2	Leggs Mill Road Area	Glenerie Falls	2.3	0
	V3.3	Top – Glenerie	Base – Glenerie Rapids	0.4	170
	V3.4	Base – Glenerie	Saugerties Dam	4.3	8.8
	V3.5	Saugerties Dam	Hudson River	1.0	?

All references to the left or right bank assume the viewer is facing downstream.

3.2 Lower Watershed

The lower watershed extends from the Ashokan Reservoir to the Hudson River with a length of approximately 30 miles and an incremental watershed area of 163 square miles, plus the 256 square miles of watershed in the upper watershed. It can be thought of as having three separate valley segments based upon their distinctive geology, topography, and hydrologic processes.

3.2.1 Valley Segment V1

The first valley segment extends from the Ashokan Reservoir dam southeast to the bridge at Hurley Mountain Road. This zone has two processes: it transfers water from the reservoir through the zone, plus it is the source of additional runoff and sediment. It has a narrow, steep-sided, confined valley until it begins to open up two miles above the Hurley Mountain Road bridge. Public access to the river is very limited with few roads or trails.

The valley bottom declines from elevation 400 feet near the base of the dam to elevation 200 feet near Hurley Mountain Road, over a distance of six miles with a mean valley slope of 0.6 percent.

During our field inspection, very low flows prevailed due to reservoir operations with limited discharges. The reservoir was less than full with no spillway discharge. The rocky channel at the large Hurley Mountain Road Bridge is 150 feet wide but was very shallow at this point. There is no floodplain as the valley narrows at the bridge. The transition from the free flowing rocky channel (Rosgen type B2) to the broad floodplain occurs about 100 yards upstream of Marbletown Recreation Park on Tongore Road. The park has a dug pond used for swimming, which presumably has to be periodically dredged. The bankfull width is 140 feet with a bankfull depth of four feet.

The FEMA Flood Insurance Study does not extend to the first valley segment, so no flood profiles are available.

3.2.2 Valley Segment V2

Segment two is a broad, flat, low gradient valley extending northeast from Hurley Mountain Road beyond the confluence with Sawkill Creek to Leggs Mill Road. This valley reach has several functions including a water source zone with several tributaries and a longitudinal transfer zone conveying that runoff downstream. A unique feature is that it generally has a broad terrace and floodplain that potentially provides sediment deposition and floodwater storage. However, the river is generally incised in a deep channel with limited floodplain connection except in large floods. The riverbanks are generally fairly steep and support shrub and hardwood vegetation.

Limestone bedrock was observed along the right bank of the channel where it is located along the valley wall in Marbletown. This soft, erodible bedrock is also found in the low, flat valley along Route 209 towards Ellenville, and rock cuts are visible along a portion of I-87. The broad

Esopus Creek valley, with a flat cross section, abrupt valley walls, and lack of side spurs, indicates a glacial through valley. The river flows northeast, contrary to regional topography, suggesting that the river has been captured by a limestone valley with erodible bedrock.

The most common channel type (Rosgen Classification) in valley segment 2 is F4 and F5, representing entrenched with high width to depth ratios with a moderate sinuosity and sand or gravel beds.

Reach V2.1

Reach V2.1 extends through Marbletown from the Hurley Mountain Road bridge area to the Hurley town line. This 4.5-mile long river reach has a fairly uniform 4,000 foot wide valley bottom that has extensive agricultural (corn) use. The river channel is generally located to the right side of the valley, but its slightly sinuous alignment has a historic meander belt width of up to 2,000 feet. The channel bed has an erratic but mild bed gradient with an average slope of 0.00175, or nine feet per mile.

The reach was field inspected at Marbletown Recreational Park, Fording Place, and at a roadside pull off 0.9 miles upstream of the Hurley town line. The channel has had extensive sand and gravel extraction creating a series of large stagnant ponds. All but the first pond at Recreational Park had extensive floating mats of green algae (usually from excess nutrients) and appears to be trapping sediment. Some pool widths exceed 500 feet, many times larger than the channel.

A relatively undisturbed channel section was found just downstream of Fording Place in Marbletown, between two dug ponds. This cross section has a high terrace (with a cornfield), active forested low floodplain, and a cobble to gravel bed alluvial channel. The active bankfull width is 60 feet, the average bankfull depth is three feet, and actual flow depth during the September inspection was one foot. The free flowing channel has a riffle and straight alignment.

A channel cross section was observed at a roadside pull off near FEMA station 112+00. A large dug pond, shown on the County Soil Survey of 1979, is located just downstream, with a second one on the inside of a meander bend. There is a risk of avulsion here. Along the river, limestone bedrock is exposed on the right bank, and the left stable bank has a low active forested floodplain. The bankfull width was 60 feet with a bankfull depth of four feet. It has a low gradient, slow current, influenced by downstream backwater. The downstream pond had an entry delta and algae mat on the water. Flowing river water was clear with no visible sediment or algae. The reach extends beyond the pond to Creek Side Road, a residential neighborhood on the right terrace. The channel is incised with high stable banks and a very low gradient.

Reach V2.2 is characterized more by its bed slope than by its planform or geography. It extends from the Marbletown and Hurley town line to the Route 209 bridge at the town line between Hurley and Kingston. The outstanding characteristic is that the river has little slope along the channel bed with a gradient of only eight feet in 3.5 miles, or 2.3 feet per mile. As a result, observed flow velocities are very slow. Large gravel pit ponds were dug on both sides (but out of sight from Wyncoop Road). The valley width is about 0.6 miles with very flat bottom land used largely for corn.

The channel width at Wyncoop Road is 120 feet with an unknown depth due to backwater. Water quality is poor with high turbidity, high suspended sediment, and massive floating algae. The channel is deeply incised by 20 feet without active connecting floodplains. The terraces are developed with residences and a cornfield on the left and the Hurley village center on the right. The channel entering the downstream pond has a gravel bottom riffle that provides a good equilibrium cross section with an active vegetated (but probably excavated) floodplain. The bankfull width was 40 feet with an average bankfull depth of four feet on a gravel bed.

Most of the reach has a deep incised channel extending to the I-87 bridge. The alignment is sinuous. The banks are generally stable, but minor erosion was observed on the outside of a bend, 500 feet upstream of Wyncoop Road. A few trees are down in the channel but do not cause any known problem. Two large oxbow lakes are abandoned on the terrace, attesting to previous river dynamics. One of them, near Routes 209 and 28, may have been modified or influenced by the highways.

The Wyncoop Road bridge near the center of Hurley is steel truss, approximately 150 feet long with concrete abutments. The large waterway opening is about 20 feet high. The USGS report (OFR 2007-1036) has a photograph of floodwater levels at this bridge in 2005, with the bridge opening flowing full and the road overtopping in the fields west of the bridge. The old gravel pond downstream of Wyncoop Road has extensive woody debris and sediment.

The Brinks Lane residential neighborhood is along a cul-de-sec built on the floodplain south of Wyncoop Road. This is a high flood risk area.

Portions of the river between Wyncoop Road and Route 209 have been dredged for gravel. The large in-channel gravel ponds are shown on U.S. Geologic Survey topography maps and aerial photographs but are not in the original FEMA Flood Insurance Study.

The Route 209 bridge over the Esopus Creek is a large structure with twin spans on a concrete pier. The channel is wide and shallow with high vegetated stable banks with stone riprap near the water line. The river's surface in this agricultural area had extensive floating algae mats during our inspection.

An interesting feature observed on aerial photographs and confirmed on the ground is a long point bar extension that wraps around a bend upstream of Route 209. This vegetated bar has become a peninsula, probably enabled by decreased peak flows and channel deposition.

Reach V2.3 – Washington Avenue Area – The I-87 bridge over Esopus Creek is a well-maintained triple span structure with two large concrete piers at the channel edges and stub abutments on sloped banks. The total span is 315 feet with about 22 feet of vertical clearance.

The waterway width is 180 feet with a bed composed of gray fine to coarse sand and traces of gravel. Large alternate bars are present upstream and downstream. The lower banks are large riprap; the upper banks are wooded. The channel has extensive algae, but the water is clear. The low flow waterway is 60 feet wide by one foot deep.

The Washington Avenue bridge is very similar to I-87 with three steel beam spans and two high concrete piers. Washington Avenue has a roadway vertical sag near the Mobil gas station at Route 31.

The river channel between I-87 and Washington Avenue has a gentle left curve, uniform width of 180 feet, and a sandy bed with algae masses. It has no visible slope and little current. The channel is incised with high vegetated banks. Riprap and boulders partially line the banks. Holiday Inn and Picnic Pizza are on the right bank.

Downstream of Washington Avenue, a modern apartment complex is on the right bank behind a low earth dike. An eight to 10 foot high concrete floodwall then continues along the right bank behind a retail shopping center to the I-587 embankment. This levee system was reportedly constructed by the U.S. Army Corps of Engineers and is certified for the 100-year frequency flood. The I-587 bridge over Esopus Creek has three spans, similar to the I-87. The shopping center is a single floor, concrete block structure with Advanced Auto Park, Radio Shack, and others. This development is at high risk. There are only two types of levees: those that have overtopped and those that will overtop in the future.

Reach V2.4 extends from the Route 28 bridge to Leggs Mill Road and is bounded by urban development at the upstream end, a bedrock control at the downstream end, and by I-87 along the left side of the valley. The right side of the valley bottom is partially developed and prone to further development in high risk areas. The channel is oversized, low gradient, alluvial, and under the hydraulic influence of bedrock controls near Leggs Mills Road. As a result, the water flow is at a very low velocity and is not free flowing. The table below summarizes riverbed elevations from the profiles in the 2007 Preliminary FEMA Flood Insurance Study.

FEMA Station (Feet)	Riverbed Elevation (Feet, NGVD)	Location
46,500	126	Leggs Mill Road
51,500	126	Sawmill Confluence
53,500	124	Route 209 Bridge
67,500	126	Kingston/Saugerties
74,000	126	Route I-587 Bridge
76,500	127	Washington Avenue

The above table indicates that there is no net riverbed slope from station 46,500 to 74,000, a distance of over five miles. Consequently, the river reach through the town of Ulster is particularly prone to high water.

Downstream of I-587, Esopus Creek has a sinuous channel with a 1,500 foot wide meander belt. The left bank is generally undeveloped, but the right bank has a floodprone residential neighborhood along the riverbanks at Orlando Street and Buckley Street. The residences, a few of which are elevated, are located on the inside of a meander bend between the river and an old oxbow pond (former meander channel). The USGS (2007) reports flood damages occurred here in 2005. Floodplain meander scrolls and oxbow ponds indicate this has been an active floodplain and is high risk for development.

The left bank opposite Buckley Street formerly had a large mobile home community of about 50 units behind a low earth levee along Farm to Market Road. This trailer park is still shown on Google aerial photographs, but a site inspection revealed all units have been removed. The low ragged earth levee was poorly designed, poorly constructed, and not maintained. This area has a high flood risk.

The levees appear to be abandoned and their continued existence should be discussed, and their impact upon the opposite floodprone area should be assessed.

The channel at Buckley Street is 145 feet wide with a bankfull flow depth of four feet and a total bank height of up to 15 feet. The substrate is silty sand. The banks are generally forested, but minor bank erosion is present. There was little visible current and a high algae level.

The mouth of the Sawkill Creek was inspected at its confluence with Esopus Creek, a short distance downstream of the Ulster Town Hall. A sedimentary delta extends half way across the Esopus Creek channel indicating high sediment loads in Sawkill Creek and low transport capacity in Esopus Creek. The remaining portion of the Esopus Creek channel is a good reference point with a measured bankfull width that narrows to only 70 feet with a bankfull flow depth of about four feet. The old gravel ponds between Route 209 and Sawkill Creek are separated by narrow berms and are at risk of diverting the river.

The nearby Parish Lane neighborhood consists of single-family residences lined up along a floodprone riverbank north of the Ulster Water District facility.

3.2.3 Valley Segment V3

The final valley segment extends from Leggs Mill Road to the Hudson River. This long, narrow valley is characterized by lateral confinement between bedrock ridges and the general lack of a floodplain. This segment functions only as a transport reach; it has little direct water or sediment inflow except at Plattekill Creek, which enters near Glenerie Falls.

Reach V3.1 begins at an extensive bedrock exposure across the riverbed about 600 feet upstream of Leggs Mill Road, also called Route 31, and ends at a bedrock rapids and exposure about 500 feet downstream. This bedrock is a hydraulic control for valley segment V2 controlling upstream riverbed and water elevations. Shallow bedrock extends past the Route 31 bridge and is visible again downstream where it forms a short rapids. The incised channel now lacks a floodplain as it bends to the left with a broad 250 foot width. The FEMA Flood Insurance Study riverbed profile depicts a 12-foot drop in only 1,000 linear feet of channel.

Reach V3.2 extends from the Route 31 bedrock exposure to Glenerie Falls near the railroad bridge, near FEMA station 33500 and the town line between Ulster and Saugerties. This low gradient incised channel is typically 150 to 200 feet wide with very low velocities and stable wooded banks. The right bank is lined with single-family residences and some seasonal-type cottages. A significant tributary, the Plattekill, enters the left bank just prior to Glenerie Falls.

Reach V3.3 consists of Glenerie Falls, which is actually a series of at least five bedrock steps with individual falls or cascades, dropping about 68 feet over a length of about 2,000 feet. The bedrock consists of both flat and displaced layers of thin gray shale, some of which breaks easily by hand. Both banks are steep and wooded. Access is available by a short trail from Route 9W to the east and from a steep trail from a residential neighborhood to the south. The falls are not fish passable, have a large island near the base, and create a hydraulic control that dominates upstream water levels.

Reach V3.4 extends from Glenerie Falls to the head pool at the Saugerties Dam. The channel is in a deep bedrock gorge with periodic bedrock exposures and no floodplain, except a short section along the left bank at the pool. It is unclear whether this ravine-like valley was created solely by fluvial erosion and upstream retreat of Glenerie Falls or in combination with a bedrock fault zone. The channel bankfull width was measured at the Glasco Turnpike Bridge and found to be 100 feet wide with a bankfull depth of only five feet. The width to depth ratio of 22 is typical of large, mature, gully-type channels with a flat bed. Scattered boulders are present on the riverbed. The left bank and valley wall have extensive shale exposures, with an easterly strike and steep (45± degree) dip.

The Glasco Turnpike Bridge is a large, high, twin span steel beam bridge with a large concrete pier in mid-channel, all in good surficial condition. A USGS stream gauge is located here. Lower Esopus Creek Road extends along the left bank on a low floodplain near the pool. The channel remains in the deep, narrow valley. The right bank is steep forested bedrock. The left floodplain has single-family wood frame residences. The channel/pond width is 300 feet. Some newer houses are raised several feet with tall foundations. This is a dead end road – a trap during floods.

There have been reports of flooding along Oakridge Park Road along the pool upstream of the dam, a road without alternate access during high water. This flooding is due to insufficient spillway capacity and the close proximity of dwellings to the pool rather than channel flow conditions. The nearby Saugerties Village Beach also floods. Invasive species, milfoil and water chestnut are reported in the pool.

The dam across Esopus Creek at Saugerties is approximately one mile upstream of the Hudson River. It has a concrete spillway, ogee (rounded) crest, about 25 feet high by 375 feet long, located between bedrock abutments in an incised confined valley. There are no fish passage facilities. These falls, and certainly the upstream falls, would have precluded predevelopment anadromous fish runs to interior areas. The base of the dam is located upon exposed shale bedrock with a stepped falls and another 10 feet of drop. The Route 32 bridge, an older single-span steel truss, is 400 feet upstream. The dam was reportedly owned and used by the Martin Cantine Corporation, which made paper products. The plant on the left bank was destroyed by fire in 1978, leaving a large vacant parcel of land on a bluff overlooking the river. Overgrown dam gates and controls are located at the left abutment.

Reach V3.5 consists of an estuary transition area between the dam and the Hudson River. It begins with an incised bedrock channel that opens up beyond the Hudson River banks. The mouth of the Esopus Creek has a beautiful harbor connecting to the Hudson River sheltered by a sedimentary delta. The Hudson River at this point is both tidal and saline. The river mouth-harbor is a natural deposition zone and is not sustainable without periodic dredging. There are several marinas and public access points. This delta extends half way across the Hudson River, verifying the Esopus Creek historic sediment load. The Hudson River total width is 4,000 feet. Lighthouse Drive extends out along the delta bar into the Hudson River, with an overdeveloped residential community in a high hazard floodprone area. This exposed area should be self-evacuated prior to floods.

The New York Coastal Management Program has identified the Esopus Creek Estuary as an important site for fishery resources with a wide range of freshwater and brackish water species. Listed species include marine and anadromous fish such as striped bass, white perch, shad, alewife, blueback herring, and smelt, while freshwater species include largemouth and smallmouth bass. The adjacent segment of the Hudson River has short nose sturgeon habitat.

The habitat and recreational value of this estuary is closely related to upstream water quality, sediment loads, and water flow rates.

4.0 FLOOD HAZARDS

4.1 FEMA Flood Insurance Study

A preliminary Flood Insurance Study (FIS) for Ulster County, New York has been issued by FEMA dated September 29, 2007. It includes the Lower Esopus River Valley communities of Marbletown, Esopus, Ulster, Kingston, and Saugerties. This FIS is a compilation of previous individual FIS reports of each town, with some new information and new digital maps.

In many of the county towns, hydrology data in the new report was carried over from the original reports from the 1980s. For Esopus Creek, new data was generated for a "limited detailed study" of the segment from the Marbletown and Hurley town line to Hurley Mountain Road. The original flood flow rates were predicted with a HEC-1 computer model. This data was updated assuming the reservoir was part full, compared to gauging station data, and extended up to the reservoir site.

FEMA Summary of Peak Discharges

Flooding Source and Location	Drainage Area (square miles)	Peak Discharges (cfs)			
		10-Yr.	50-Yr.	100-Yr.	500-Yr.
Esopus Creek					
Glasco Turnpike at Mount Marion	419.0	13,814	34,270	54,913	149,802
At Interstate Route 587/State Route 28	319.0	10,462	30,573	45,452	109,230
350 feet downstream of Hurley Mountain Road	279.7	10,600	30,640	44,700	107,000
From Hurley Mountain Road upstream to the confluence with Ashokan East Spillway Channel	256.0	10,600	30,250	44,250	101,000
Upstream of the confluence with Ashokan East Spillway Channel	11.6	1,570	2,730	3,310	4,930

The Flood Insurance Study is an important tool that identifies floodprone areas that should be addressed in municipal land use regulations.

The FEMA Flood Insurance Program provides data on predicted floodwater elevations, which are printed on rate maps and on river profiles (Appendix B). A requirement that FEMA recommends be incorporated into local floodplain zoning and building codes are for the lowest habitable floor of residential buildings to be above the 100-year frequency base flood elevation. Local regulations in the lower Esopus Creek valley should include compliance with FEMA land use requirements.

Flood Insurance Studies have limitations. Their floodwater computations are not updated very often and assume there are no debris blockages or ice dams along the river. They also assume the river alignment is constant, without allowance for cutting across meander bends or avulsions. Flood Insurance Studies do not consider ecological floodplain values nor the presence and recharge of ground water wells located in floodplains.

We recommend that:

1. All communities adopt floodplain zoning
2. Meet or exceed minimum FEMA criteria
3. Require the lowest floor of residential buildings to be two feet above the FEMA base flood elevations
4. Expand the width of the "no build" floodway to include potential channel migration areas
5. Establish buffer zones along rivers to conserve natural resources, renovate surface runoff water quality, and provide shade over the river (see Section 5.8)

4.2 Flood Hazards and Assessment

An important part of any flood mitigation study is to identify the source and type of flooding that occurs at each floodprone area. This assists in evaluating alternative methods of reducing flood hazards, determining if there is a potential solution, and in prioritizing the implementation of management strategies. The overall potential flood types along Esopus Creek include landslides, debris, precipitation, snow melt, and dam failures.

The fundamental issues are whether floodwaters are unnaturally high, can floodwater elevation be lowered, or are developed areas simply too low with respect to floodwater levels. It is recognized that some developed areas may be too low to protect from flooding, in which they may be protected with dikes, individually floodproofed, raised, relocated, or acquired and demolished.

Many factors contribute to floodwater elevations, including upstream, lateral, and downstream conditions. Local flood elevations should not be taken out of context of their surroundings.

Floodwater Types

Upstream Sources	Lateral Spread	Downstream Backwater
Conveyance	Inside channel	Small bridges or culverts
Low gradients	Top of bank	Dams
Avulsions	Floodplain	Obstructions
Diversions	Wetlands	Constrictions
Dam releases	Tributaries	Base level
Dam failures	Channel migration	Low gradients
	Dike failures	Ice or debris dams

4.3 Floodwater Elevations

The FEMA Flood Insurance Study (2007) includes computed water elevations along Esopus Creek for peak flows corresponding to floods with statistical occurrence frequencies of 10, 50, 100, and 500 years. This important report contains a mixture of old and new data, much of which is from the 1980s. It also has a plot of the riverbed profile from the Saugerties Dam to Hurley Mountain Road. Unfortunately, the dam itself is not shown.

The Suro and Firda (2007) measured high water marks in the field following the April 2005 flood event and compared them with the FEMA Study. They found that this flood had peak water elevations between that of a 10- and 50-year frequency flood in Marbletown and Hurley, higher than a 50-year frequency flood in Kingston at I-87 and Washington Avenue, and under a 50-year flood at Leggs Mill Road. An exceptional flood level of over the 100-year frequency was measured at Glenerie Boulevard. This latter level, higher than predicted by FEMA, may simply reflect the difficulty of hydraulic analysis at the Glenerie waterfalls. The floodwater elevation bulge at Kingston may be due to the inflow of water from nearby Sawkill Creek.

The relatively higher actual flood profiles in 2005 compared to FEMA in the Ulster area may also reflect locally high runoff from Sawkill Creek and Plattekill Creek, which have little impact in Marbletown and Hurley.

The floodwater profile elevations predicted by the FEMA Flood Insurance Study (Appendix B) and actually measured by the USGS (2007) are powerful tools to understanding fluvial processes and community risks. Several observations really stand out.

1. The Saugerties Dam raises water elevations that back up almost to the Glasco Turnpike. Flooding around the perimeter of its pool area cannot be relieved without lowering or modifying the dam's spillway.

2. Glenerie Falls creates a huge increase in water elevations; the bedrock has limited channel bed erosion and forces a step in the profile. However, there is some floodwater slope from Leggs Mill Road to the falls, suggesting that this incised channel is too small and needs a floodplain connection. Removing bedrock from the crest of both falls would help reduce upstream floodwater levels, but these procedures obviously have historic and scenic impacts.

3. Water profiles change grade at the Sawkill delta and are very flat upstream through Ulster to Kingston. This channel reach is very flat, contributing to poor flow conditions all the way past Kingston to Hurley. The delta created by Sawkill Creek is an obstruction, but the extent of its impact on floodwater elevations has not been computed. In this channel reach, there is virtually no bed gradient, and water profiles are due to "backwater."

Increasing the channel width would not be expected to influence floodwater levels but would increase the low flow, low velocity issues.

4.4 Bridge Hydraulics

River floodwater profiles in urban areas are often influenced by flow through bridge or culvert waterways. Undersized bridges can substantially increase floodwater levels and even more so where the approach roads are raised above the floodplain, creating a barrier. In some communities, a single undersized bridge can raise water elevations by several feet or trap debris that influences flow water levels.

The predicted floodwater profiles in the FEMA Flood Insurance Study have been reviewed to identify if and where large head losses occur. In addition, USGS (2007) data on measured water elevation on each side of bridges is helpful.

USGS Site #	Bridge	Town	USGS Measured Head Loss
3	County Route 5	Marbletown	0.42
6	U.S. Route 209	Marbletown	0.24
9	Wyncoop Road	Hurley	0.73
10	U.S. Route 209	Kingston	1.61
12	I-87	Kingston	1.19
13	Washington Avenue	Kingston	0.41
14	I-587, Washington Avenue	Kingston	0.8
18	Route 209	Lake Katrine	0.35
21	Leggs Mill Road	Lake Katrine	2.66
24	Glasco Turnpike	Glenerie	1.61
25	Route 32	Saugerties	0.1

The only three bridges that really stand out in terms of their impact on raising floodwater levels are at Glasco Turnpike, Leggs Mill Road, and the Route 209 bridge in Kingston. The first two bridges named above have significant waterway openings, but their channels are constrained and shallow due to bedrock, plus they have large piers in the waterway. The Glasco Turnpike bridge, in a deep ravine, has a head loss but may not affect developed areas.

The high head loss at the Route 209 bridge could impact Hurley and buildings off Wyncoop Road; further study is needed. Flat water profiles extend upstream of Route 209 for a long distance.

In general, the measured head losses at the bridges (USGS, 2007) exceed the predicted values in the FEMA Flood Insurance Study. It may be due to debris or modeling limitations. The model should be carefully reviewed.

4.5 Flood Monitoring and Warnings

Some of the residential, commercial, and retail areas near lower Esopus Creek could be both isolated by floods and subject to inundation. A formal flood monitoring system could be used, based upon upstream flow gauges and reservoir levels, to provide advance warning of pending floods. It would be particularly helpful to receive advance notification before the reservoir's spillway becomes active and releases excess floodwater.

5.0 MANAGEMENT ISSUES

This initial River Reconnaissance Report has identified several management issues that will need to be addressed in a more detailed watershed management plan. Several specific issues are identified below.

5.1 Levees

During spot inspections of Esopus Creek, one formal levee system at Washington Avenue was observed, plus one less formal levee at Farm to Market Road in the town of Ulster. We are also aware of some discussions about the use of levees in other areas that are or may be floodprone.

Use of riverine levees must be carefully assessed to evaluate and compare their positive and negative impacts. On the positive side, levees can protect high value floodprone areas from inundation and damages and have a long record of successful applications. Levees need to have good foundations, low permeable soils, adequate freeboard against overtopping, and regular maintenance. They should have a riparian buffer between them and the bank. Most urban levees will require an interior drainage system to control direct runoff to their landward side. Levees should be designed by a professional engineer and are subject to regulatory permit programs. "Homemade" levees should not be allowed; they are a hazard to all. Levees within the FEMA floodway are regulated as fill material.

Flood control levees can have serious adverse impacts. By preventing overbank flows on floodplains, they reduce floodwater conveyance and storage by reducing the cross-sectional area of flowage. They will often raise floodwater elevations on the opposite bank; and upstream, it is noted that flooding has occurred opposite both of the observed levees. In rural areas, levees isolate the floodplain from the river causing habitat fragmentation and loss, plus the removal of riparian vegetation. The existing FEMA hydraulic model of Esopus Creek can easily be used to check the impact of existing and proposed levees.

Levees require regular maintenance to provide the intended level of performance. Earth levees need to be mowed and kept free of trees, animal burrows need to be filled, and crest elevations adjusted for settlement or scour. Concrete levees need to be inspected for scour, displacement, cracks, and debris loads. Underground seepage beneath levees is a common failure mode.

Flood control levees can provide a false sense of security. All levees have to be planned and designed for a specific floodwater level. If one waits long enough, it is likely that all levees can be overtopped leading to catastrophic results. A former U.S. Army Corps of Engineers' General once remarked that there are only two kinds of levees: those that have overtopped and those that will overtop.

5.2 Sand and Gravel Extraction

Aerial photographs and site inspections reveal numerous large ponds created along Esopus Creek by the extraction of sand and gravel. The gravel ponds are generally old, most of which are shown on photographs in the 1979 County Soil Survey. They are many times wider than the natural channel and probably deeper, although some show evidence of bars and debris.

Sand and gravel aggregates are needed by modern society for manufacturing concrete, bituminous asphalt, and for winter road traction. However, mining sand and gravel from river channels can have adverse impacts, and alternate sources should always be considered from upland or disconnected terrace sources. In-channel gravel ponds that are out of scale with the river create ultra low velocity zones that promote the growth of algae and may become eutrophic due to organic decomposition and oxygen consumption. Their solar exposure enables thermal uptake and warm water which may impact aquatic habitat and reduce cold water species such as trout.

Almost all instream extraction sites end up trapping sediment, altering downstream river balances by preventing passage of coarse bed material with possible additional downstream bank or bed erosion. Deep ponds may also create upstream headcuts (bed erosion) by undermining the channel. Stable river channels have a sediment balance between erosion and deposition; gravel mining often upsets that balance. The combination of instream gravel mining plus floods can lead to new upstream riverbed erosion or avulsions where the river changes alignment. Bridges that are located upstream of gravel mining sites are specifically susceptible to channel scour and should be inspected after major floods.

Under current conditions, Esopus Creek appears to have little bedload sediment inflow and transport except at the confluence of major tributaries (Sawkill Creek, Plattekill). As a result, the channel remains oversized for its base flow and has impaired channel habitat. Removal of sediment from the river can cause secondary erosion and seldom lowers floodwater levels along low gradient channels.

One unusual features of the lower Esopus Creek gravel ponds is that they reportedly provide aquatic habitat during the prolonged low flow periods. Some portions of the channel have little to no base flow due to withdrawals, so the gravel extraction sites have the beneficial impact as serving as an aquatic refuge. However, their long-term impact is unknown. In-channel gravel pits typically collect organic sediments that decay and reduce dissolved oxygen levels.

5.3 Water Quality

This River Reconnaissance project did not include water quality sampling, testing, or review of existing water quality data. However, one could not help but to notice extensive algae masses in and on the waters of Esopus Creek during both field inspections.

At Hurley Mountain Road's bridge over Esopus Creek and the nearby Marbletown Recreation Park, the water was absolutely clear and free of both color and turbidity during both 2008 inspections; and even at the Fording Place in Marbletown, the visual water quality was good. However, a little downstream in Hurley at Wyncoop Road, floating algae was observed; and the channel was covered with floating algae at the Route 209 bridge. The watershed's modified hydrology, agricultural runoff, and gravel pits are all likely to affect water quality.

Excessive algae growth affects not only visibility and color but also causes taste and odor. Decaying algae masses create oxygen demand and reduced dissolved oxygen levels. The above combinations alter habitat and discourage recreation. A likely cause of the algae blooms is excessive nutrients from agricultural activities and urbanization. This should be investigated further.

We did review a Biological Stream Survey of Esopus Creek dated 2007, prepared by Watershed Assessment Associates for SUNY at New Paltz. This assessment was prepared by college students under the direction of a professional aquatic biologist. Physical, chemical, and biological parameters were measured at seven stations, six of which were along Esopus Creek with one on Sawkill Creek. The results indicate that the river's biological assessment profile (BAP) declines as one moves downstream, with only slight impairment at Route 5 and "notable decline in water quality" occurs by Fording Road. Water quality was moderately impaired at Wyncoop Road in Hurley with low dissolved oxygen. By CR41, Leggs Mill Road, the river was moderately impacted and eutrophic. The study concludes that agricultural runoff and discharge from the Ulster County Wastewater Treatment Plant are likely contributing to water quality declines.

NYDEC (2008) indicates in the Waterbody Inventory and Priority Waterbodies List that lower Esopus Creek has minor impacts due to nutrient encroachment from urban runoff and agricultural nonpoint sources, plus hydrologic modifications. However, increasing the river's base flow alone may not be sufficient to improve water quality unless it is in conjunction with nutrient controls.

The regional office of NYDEC indicates that lower Esopus Creek is a warm water fisheries habitat, exempt from low flow release criteria. This latter point is not unusual for older and critical water supply systems. The river reportedly supports bass, sunfish, yellow perch, carp, and other warm water species.

Extending and expanding vegetated riparian buffer zones is one technique to shade water, moderate temperatures, and filter surface runoff.

5.4 Flood Hazards

The FEMA Flood Insurance Study and USGS (2007) report have both identified numerous neighborhoods where flood hazards exist. The respective communities should adjust their land use regulations zoning maps to incorporate the FEMA mapped floodplain and floodway areas and to confirm that building codes meet or exceed FEMA requirements. It is noted that while elements of the Flood Insurance Study have been updated and a draft report issued some elements of the study such as channel cross sections are old data and should be spot checked.

Mitigating flood hazards can be thought of as a three-part process including risk control, on-site damage control, and flood control. Risk control consists of active and passive measures to minimize the risk of damage, largely through land use planning, advance warning, and evacuation planning.

On-site damage control focuses on protecting individual buildings by their elevation, floodproofing, and site grading to reduce or avoid damages. Flood control efforts focus on active construction programs to reduce floodwater levels or create barriers. Several homes were observed that have been recently raised, and the large mobile home community in Ulster has been removed.

Review of the floodwater profiles, predicted and measured, has not revealed significant, unnaturally high water levels. In contrast, the flood hazard areas are almost all in areas where people built too close to the river. There is little opportunity to reduce floodwater levels without massive intervention. The future watershed management plan should review all three approaches to reducing flood hazards with a review of each floodprone neighborhood and review of town regulations.

We recommend that the partnership communities review municipal floodplain land use and building regulations and compare them with model regulations from FEMA and the Association of State Floodplain Managers. Where appropriate, municipal land use practices should be brought into compliance with recommended criteria. The intent of floodplain regulations is to minimize the incremental growth in future hazards, including damage to public and private property and human life.

5.5 Sediment Budget

Rivers carry sediment as well as water in the downstream direction, and the balance between the amount of sediment entering the channel versus its transport capacity is a key factor in channel stability. This is known as the sediment budget. Rivers may move sediment that is suspended in the water or move bed load along the channel bed by pushing, rolling, or flipping stones.

Rivers that receive excessive sediment from upland and upstream sources will tend to have sand bars and an aggrading or rising bed that decreases channel depth and the size of bridge openings. Rivers that convey or transport more sediment than they receive will tend to erode their channel beds and have above average number of bank failures.

The lower Esopus Creek sediment budget is unclear; there are no known sediment measurements, so one has to reply on indirect observations, hypothesis, and experience. The main stem river has the Ashokan Reservoir, a huge water body that will trap most of its coarse sediment inflow. The Ashokan Reservoir can be assumed to periodically release less than natural water flow rates that have no bed material and reduced suspended material.

The second major source of sediment loads in rivers is from land surface erosion of unvegetated soils, largely at construction sites and fallow agricultural fields. Surface erosion by overland flow generally creates fine grain materials that contribute more to suspended load than bedload. Extensive agricultural fields were observed along the lower river, with little or no erosion control other than contour plowing. These fields are likely a significant source of sediment.

Lateral tributaries such as Sawkill and Plattekill Creeks are fairly steep and do transport gravel and cobble bedload sediments. This material enters and settles in Esopus Creek in the form of localized bars.

In-channel processes also impact the river's sediment budget. Bank and bed erosion is often a major sediment source, but lower Esopus Creek generally has stable vegetated banks. The entrenched channel has low gradient, so little further bed erosion or incision is possible. The other significant in-channel feature is multiple abandoned gravel mined ponds, creating low velocity zones where sediment can settle. The broad, shallow, low gradient river normally has low velocities and low sediment transport capacities except during floods. However, floods are infrequent; the river is underfit due to hydrologic modifications.

In conclusion, lower Esopus Creek has limited coarse grain bedload input and moderate to high suspended sediment loads. The river has limited sediment transport and capacity due to low bed slopes, so the long-term trend is predicted to be towards the slow accumulation of fine grain and sand material in the channel, particularly in the abandoned gravel mine pits.

5.6 Fluvial Morphology Summary

The lower portion of Esopus Creek has three distinct valley segments: the first and third are bedrock controlled, while the middle segment has an alluvial channel from Hurley Mountain Road in Marbletown to Glenerie Falls in Hurley.

The alluvial channel in valley segment 2 is generally incised 10 to 20 feet below its floodplain, and annual floods are contained within the bank elevations. The channel gradient is controlled by bedrock exposures, primarily at Glenerie Falls and near Leggs Mill Road. The channel bed has a very low gradient and low bedload sediment loads representing an equilibrium condition.

The channel's dimensions at the channel forming bankfull discharge are bi-modal, reflecting the bi-modal hydrologic regime (with and without Ashokan Reservoir spillage). The legacy channel has bankfull widths of 120 to 180 feet, which is consistent with the Regional Hydraulic Geometry curves for New York State Region 4 (Miller and Davis, 2004) as well as the Simon (1960) regime equation. However, in the true active alluvial reaches with post dam deposition, measured bankfull widths of 60 to 70 feet are inconsistent with the reduced (post dam) effective watershed areas of 63 to 163 square miles and represent temporary deposits at bars.

Because of its reduced peak flows, the normal channel response is to have sediment deposition and contract its width and depth. However, there is little bedload inflow, so this is a very slow process. In summary, the channel is underfit to its floodplain, overfit to its mean annual flood, and prone to sediment deposition.

The channel's planform is slightly to moderately sinuous, which is consistent with its low gradient and silty fine sand banks. The floodplain and terrace have numerous oxbow lakes and meander scrolls representing previous channel migrations. However, under current modified hydrology and low bedload, lateral channel movement and sudden avulsions will be less likely. The sinuosity from Hurley Mountain Road to Route 209 in Hurley is 1.27, while it is 1.35 from Route 209 to the confluence of Sawkill Creek.

Dredging the low gradient channel reaches in Hurley and Marbletown probably has little to no impact on floodwater levels. This can easily be checked with use of the FEMA hydraulic model. Similarly, removal of the observed trees and debris in the river would have little impact.

5.7 Woody Debris Management

Portions of lower Esopus Creek have accumulated coarse woody debris in the form of blown down trees, logs, and brush that partially obstruct the channel. Prior to European settlement, this was believed to be a common condition that provided shelter and habitat for aquatic species and on steep streams helped to regular flow velocities. Many modern channels in humid developed areas have been cleared; first for 19th century timber drives of harvested trees and cord wood, later for flood control and navigational, and more recently for recreational boating.

Some river restoration programs are adding (anchored) woody debris back into channels. It helps to provide habitat, reduces flood flow velocities, and provides bank erosion protection. However, this is only practical if it does not induce flooding or interrupt other functions and processes.

The Esopus Creek is a wide, low gradient plain bed channel where woody debris provides one of the few habitat variations, but if it completely blocks a channel, then debris and log jams should be modified to open up free-flowing slots. Excess material can be relocated and spread out to still provide habitat.

5.8 Stream Channel Buffers

Some portions of the Esopus Creek and its tributaries have extensive forest land along the riverbanks, while other reaches have either agricultural land or developments very close to the river. Extensive research reported in the literature indicates that conserving vegetated buffer zones along streams and rivers is one of the best ways to protect water quality, reduce flood damages, and provide habitat.

Buffer zones help to absorb and filter surface runoff, provide infiltration, trap sediment, reduce flow velocities, and temporarily store local runoff. In addition, buffer zones have vegetation that helps to reinforce riverbanks and minimize channel erosion.

The conservation of buffer zones supplements floodplain management. They provide space for river alignment adjustments, convey overbank flood runoff, and provide a transition between aquatic and terrestrial habitats. Buffer zones are an undeveloped portion of the larger floodplain immediately adjacent to the stream or river. Their vegetation helps to shade the water and reduce thermal warming.

The effectiveness of buffer zones is influenced by their slope, soils, and vegetation. Recommended buffer zone widths are usually between 25 to 200 feet in size, with a common width of 100 feet.

5.9 Instream Flows

The Esopus Creek watershed has at least three reservoirs at which surface water is stored and diverted for public water supply purposes. The major Ashokan Reservoir diverts most runoff from a reported watershed area of 256 square miles, resulting in lower downstream discharge rates during both wet and dry weather.

The residual net watershed area downstream of all reservoirs is still 112 square miles at the Mount Marion gauge site. This contributing area is adequate to maintain a year round flow but at less than natural rates.

Historically, flow releases from reservoirs were based on meeting specific narrow objectives such as supporting a specific species or being adequate for recreation resulting in steady release rates. The resulting discharges were called minimum flows. Today, there is expanded knowledge about ecosystems and a trend towards having reservoir releases that parallel natural flow regimes with a time-dependent range of flows with multiple objectives.

The current trend in predicting and setting instream flows is both complex and time consuming, requiring detailed hydrology, ecological, and geomorphic studies of the river, plus a thorough understanding of available water resources. The studies need clear, concise goals and objectives, stakeholder involvement, and an institutional process to conduct studies and resolve differences, all leading (ideally) to a consensus.

It is becoming common practice for instream flows to be related to temporal lifecycles of aquatic species coupled with meeting water supply needs. During dry years, instream flow releases may need to be adjusted downward. Overall, the goal for intra-annual flows is to have them mimic natural variability of the river's annual hydrograph with designated periods for reservoir filling.

It is premature to recommend specific instream flows for the Esopus Creek at this time, but we can say that increased flow releases would be beneficial.

5.10 Field Data Needs

This River Reconnaissance Report is based on readily available information and limited site inspections. There are several areas where additional field data would be of immediate assistance in completing the picture of how the river works and to better define flood hazards.

One of the next major steps in assessing flood hazards and potential remedial actions to reduce damages will be to receive, update, and utilize the FEMA hydraulic model. It can be used to test the impact of modifications to various hydraulic control points such as bridges, bedrock outcrops, dikes, and channel cross sections that are critical for water passage.

Key areas for survey data include:

a. Bridge opening sizes and elevations
b. Bedrock elevation and cross sections near Leggs Mill Road and the crest of Glenerie Falls
c. Dike locations and elevations
d. Elevation of selected low buildings
e. Cross sections at the mouth of Sawkill Creek

6.0 SUMMARY

1. Upper Esopus Creek has very complex hydrology due to significant water diversions to New York City and the receipt of runoff from the Schoharie Reservoir in the northern Catskills. The bi-modal hydrology of peak flows will vary depending upon whether or not the various reservoirs are spilling water.

2. The U.S. Geological Survey stream gauging stations have recorded previous flood events and prove that Ashokan Reservoir reduces peak flow rates in the pus River Valley. Without the reservoir, peak flows would be much higher and the floodplain inundated more frequently, resulting in higher damages.

3. Lower Esopus Creek's morphology is dominated by its bedrock setting and history. Valley Segment 1 is stratified shale of the Catksill Mountains; Segment 2 is a long, wide, flat valley floodplain in a limestone region; and Segment 3 is a narrow valley between folded shale deposits.

4. The dam in Saugerties controls water elevations in Segment 3 due to its backwater. It also is a total fish block. Reports of flooding around the perimeter of its pool indicate that either the spillway has insufficient capacity or residences are simply too close to the water.

5. The FEMA Flood Insurance Study indicates that there is very little head loss at most of the various bridges over the river, so they have negligible impact on floodwater elevations. The dimensions of key cross sections should be resurveyed as there have been extensive channel modifications due to instream gravel mining and potential deposition of both sediment and woody debris. The new survey data should be compared with the FEMA study.

6. The river is generally underfit and incised. This limits active floodplain inundation to rare great floods and creates a false sense of security. Small annual floods are generally contained within the banks. Bedrock prevents further natural incision.

7. The dominant characteristic of lower Esopus Creek is its unusually low gradient, leading to low flow velocities, interspaced with abrupt grade changes and vertical transitions at Saugerties falls and dam, Glenerie Falls, and bedrock at Leggs Mill Road. The bedrock exposures prevent further (short-term) channel incision and control floodwater levels.

8. The review of existing published data and site inspections did not reveal significant channel contractions, obstructions, or structures that artificially raise floodwater levels. Many minor collections of woody debris or sediment bars were observed, but they are generally too small and localized to affect floodwater levels. They do interfere with small boat recreation.

9. We recommend that the Lower Esopus Creek Partnership review floodplain zoning land use regulations and building codes to ensure compliance with current model codes and criteria. Low gradient channels that overtop their banks on alluvial plains (upstream of Leggs Mill Road) are prone to meandering, with lateral migration or avulsions. We recommend use of broad buffer zones. The FEMA Flood Insurance Study has been reissued with new maps, but they appear to be based on old channel surveys and outdated hydraulic analysis which should be used with caution. The recommendations in Section 4.1 should be considered for adoption.

10. Portions of lower Esopus Creek have excellent vegetative buffers along the stream banks, while other sections have little or none. We recommend that vegetative buffers along stream banks be created and/or expanded to shade water, reinforce banks, and filter runoff. Riparian buffers help trap agricultural sediments and nutrients.

11. The incised, wide, low gradient channel has low flow velocities and thus is particularly sensitive to low flow rates. The channel size is proportional to a 419 square mile watershed at Mount Marion but normally receives runoff from only 163 square miles. We recommend that a more comprehensive study of instream flows be conducted, including the potential for modified flow management in conjunction with improved nutrient management.

12. The water quality and ecological impact of the in-channel gravel pits should be monitored. Their inflow and outflow waters should be sampled for temperature, dissolved oxygen, and total suspended solids.

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