SECTION 905(b) RECONNAISSANCE STUDY
ESOPUS CREEK & PLATTEKILL CREEK WATERSHED
GREENE & ULSTER COUNTIES, NEW YORK

1.0 STUDY AUTHORITY.

1.1 This Section 905(b) (WRDA 1986) Expedited Reconnaissance Study Analysis was prepared as an initial response to the resolution adopted by the House Committee on Transportation and Infrastructure of the United States, Docket 2772, dated May 21, 2007, which reads as follows:

"Resolved by the Committee on Transportation and Infrastructure of the United States House of Representatives, That the Secretary of the Army review the report of the Chief of Engineers on the New York and New Jersey Channels, published as House Document 133, 74th Congress, 1st Session; the New York and New Jersey Harbor Entrance Channels and Anchorage Areas, published as Senate Document 45, 84th Congress, 1st Session; and the New York Harbor, NY Anchorage Channel, published as House Document 18, 71st Congress, 2nd Session, and other pertinent reports, to determine whether modifications to the recommendations contained therein are advisable in the interest of navigation, streambank stabilization, flood damage reduction, floodplain management, water quality, sediment control, environmental preservation and restoration, and other related purposes in Esopus and Plattekill Watersheds, New York."

1.2 Funds in the amount of $100,000 were appropriated in Fiscal Year 2007 to conduct the reconnaissance phase of the study. P.L. 110-28 states "For an additional amount for "Investigations" for flood damage reduction studies to address flooding associated with disasters covered by Presidential Disaster Declaration FEMA-1692-DR, $8,165,000, to remain available until expended."

2.0 STUDY PURPOSE.

2.1 The purpose of the reconnaissance phase study is to determine if there is a Federal (USACE) interest in participating in a cost shared feasibility phase study and to find a non-Federal partner to sponsor that study. The Esopus Creek and Plattekill Creek Watershed has experienced ecosystem degradation and flood damages due to erosion, sedimentation and bank instability in stream channels. The feasibility study will then determine if there is a Federal interest in providing ecosystem restoration and flood damage reduction improvements to the watershed. The purpose of this Section 905(b) (WRDA) Analysis is to document the basis for this finding and establish the scope of the feasibility phase. As the document that establishes the scope of the feasibility study, the Section 905(b) (WRDA)

Analysis is used as the chapter of the Project Study Plan that presents the reconnaissance overview and formulation rationale.

3.0 LOCATION OF PROJECT/CONGRESSIONAL DISTRICT.

3.1 The Study Area is located within the boundaries of the watershed for the Esopus Creek *(headwaters in Oliverea shown below)* and its major tributaries, Beaverkill Creek, Sawkill Creek and Plattekill Creek, until the confluence with the Hudson River near Saugerties, NY. The study area includes the Ashokan Reservoir, owned and operated by New York City for water supply, and is generally recognized as the division between the Upper Esopus and Lower Esopus watersheds. In the upper watershed, Esopus Creek generally follows along Route 28 until the Ashokan Reservoir passing through the villages of Shandaken and Phoenicia. The Upper Esopus Creek watershed includes the major tributaries Beaverkill Creek and Stony Clove Creek. The Shandaken Tunnel also feeds the Upper Esopus near Shandaken connecting the Schoharie Reservoir to the Ashokan Reservoir. The Lower Esopus Creek watershed includes the major tributaries Stony Creek, Sawkill Creek and Plattekill Creek. The Lower Esopus Creek passes through the Town of Hurley, the City of Kingston, the Town of Ulster and under the New York State Thruway before meeting the Hudson River in Saugerties. *(See maps in Appendix A and Appendix E Hydrologic & Hydraulic Appendix)*

Esopus Creek Headwaters

3.2 The study area lies within the jurisdiction of the following Congressional Districts:

3.2.1 Congressional District 22 including Ulster and Sullivan Counties. Congressman Maurice Hinchey (D).

3.2.2 Congressional District 20 including parts of Greene and Delaware Counties. Congresswoman Kirsten Gillibrand (D).

3.3 The study area lies within the jurisdiction of the following Senators:

3.3.1 Senator Charles Schumer (D-NY)

3.3.2 Senator Hillary Rodham Clinton (D-NY)

4.0 PRIOR REPORTS AND EXISTING PROJECTS.

Prior USACE Studies Relevant to Esopus and Plattekill Creeks Watershed	
October 1962	Survey Report for Flood Control. Esopus Creek and Tributaries. New York.
August 1967 (Rev. Nov. 69, Mar. 71)	Detailed Project Report. Esopus Creek, New York. Kingston Flood Control Project. Kingston, New York
February 1978	Operations and Maintenance Manual. Local Flood Protection Works. Esopus Creek. Kingston, New York.
June 1990	Local Flood Protection. Reconnaissance Report. Shandaken Town Office and Garage. Esopus Creek, Shandaken, New York
April 2003	Initial Appraisal Report. Plattekill Creek Watershed. Ulster County, New York. For Flood Damage Reduction.
July 1998	General Management Plan. New York City Watersheds.

4.1 The following USACE reports (also summarized in the above table) are being reviewed as a part of this study:

4.1.1 Survey Report for Flood Control (1962): This study was authorized for the review of previous reports following the floods of March 1951, August 1955 and October 1955. This study did not recommend any projects.

4.1.2 Detailed Project Report (1971): Following the flood of record for the Lower Esopus Creek in March 1951, this study evaluated a flood control project to reduce damages on a sixty acre area in Kingston, NY near Interstate 587, Washington Avenue and State Route 28. The study recommended construction of a flood wall on one bank of the Esopus Creek which is currently in place now.

4.1.3 Local Flood Protection Works, Operations & Maintenance Manual: Manual for Flood Control Works on the Esopus Creek in Kingston, NY. Construction of 1570 feet of levees and 938 feet of concrete flood walls and retaining walls completed in February 1978.

4.1.4 Local Flood Protection (1990): This Reconnaissance Report for the Upper Esopus Creek in Shandaken evaluated recurring flood damages to municipal property from floods including April 1987. Federal interest was not warranted because solutions were not economically justified.

4.1.5 Plattekill Creek Initial Appraisal Report (2003): Study authorized by Section 205 CAP evaluated flood damages on the Plattekill

Creek in the Town of Saugerties. Federal interest was not warranted.

4.1.6 New York City Watersheds GMP (1998): This GMP is the framework for the NY City Watershed Environmental Assistance Program which provides assistance in implementing projects that contribute to protection and enhancement of the NY City water supply quality and quantity. This program provides $56 M in assistance.

4.2 Other reports being reviewed as a part of this study:

4.2.1 Upper Esopus Creek Management Plan (Draft), 2007

4.2.2 Stony Clove Creek Stream Management Plan, Feb 2004

4.2.3 Esopus Creek Restoration Demonstration Project, Interim Report, Dec 2003

4.2.4 Broadstreet Hollow Management Plan, Feb 2003

5.0 PLAN FORMULATION.

5.1 During a study, six planning steps that are set forth in the Water Resource Council's Principles and Guidelines are repeated to focus the planning effort and eventually to select and recommend a plan for authorization. The six planning steps are: 1) specify problems and opportunities, 2) inventory and forecast conditions, 3) formulate alternative plans, 4) evaluate effects of alternative plans, 5) compare alternative plans, and 6) select recommended plan. The iterations of the planning steps typically differ in the emphasis that is placed on each of the steps. In the early iterations, those conducted during the reconnaissance phase, the step of specifying problems and opportunities is emphasized. That is not to say, however, that the other steps are ignored since the initial screening of preliminary plans that results from the other steps is very important to the scoping of the follow-on feasibility phase studies. The sub-paragraphs that follow present the results of the initial iterations of the planning steps that were conducted during the reconnaissance phase. This information will be refined in future iterations of the planning steps that will be accomplished during the feasibility phase.

5.2 National Objectives:

5.2.1 The national or Federal objective of water and related land resources planning is to contribute to national economic development consistent with protecting the nation's environment, pursuant to national environmental statures, applicable executive orders, and other Federal planning requirements. Contributions to National Economic Development (NED) are increases in the net value of the national output of goods and services, expressed in

monetary units. Contributions to NED are the direct net benefits that accrue in the planning area and the rest of the nation.

5.2.2 USACE has added a second national objective for Ecosystem Restoration (NER) in response to legislation and administration policy. This objective is to contribute to the nation's ecosystems through ecosystem restoration, with contributions measured by changes in the amounts and values of habitat.

5.3 Public Concerns: A number of public concerns have been identified during coordination with the public for the reconnaissance study. Initial concerns were expressed in the study authorization. Additional input was received through coordination with the State of New York, local stakeholders and some initial coordination with other resource agencies. In response to the study authority, a press conference and kick-off meeting was held on October 15, 2007. A public meeting of interested stakeholders was held on November 14, 2007. An additional public meeting of potential funding partners was held on April 28, 2008 following release of the draft report. The public concerns that are related to the establishment of planning objectives and planning constraints are:

5.3.1 Flooding of the Esopus Creek and its tributaries and the associated damages to private and public property and infrastructure.

5.3.2 Erosion and destabilization of streambanks of the creeks, which in the most severe cases causes the subsidence of property into the creek

5.3.3 Debris clogging streams, trapping sediment, creating islands and threatening aquatic habitat *(see photograph of the Sawkill Creek, shown at right)*

Sawkill Creek

5.3.4 Sedimentation of channel beds and in some places also scouring of the channels both of which impact the quality of habitat for fish

5.3.5 Impact of the above problems on regional transportation and commerce.

5.4 Problems and Opportunities: The evaluation of public concerns often reflects a range of needs, which are perceived by the public. This section describes these needs in the context of water resource problems and

- **Problem: Flooding of the Esopus Creek and its tributaries**.

  Recent severe floods in the Esopus Creek watershed have caused damages to homes, businesses, infrastructure and natural features including streambanks, channels and associated habitat. Severe storms have caused food conditions in the Esopus Creek Watershed most recently in September 2004, April 2005 and April 2007. The majority of damages to the watershed occurred within Ulster County. Ulster County Emergency Management cites ten flood related FEMA federal disaster declarations from 1996 through 2007 totaling just under $25 million in damages to Ulster County property. During floods, many residents cannot reach local and regional destinations when major roads including Route 28 Route 209, Interstate 587 and NYS Thruway are inundated with water. Some residents living in the floodplain of the Esopus Creek and some tributaries need to be evacuated and relocated during these severe floods; some homes become inaccessible, even to emergency vehicles.

  Opportunity: Reduce flood damages along the Esopus Creek, Beaver Kill, Sawkill Creek, Plattekill Creek and their tributaries.

- **Problem: Erosion and destabilization of streambanks throughout the Esopus Creek Watershed.**

  Streambank erosion, land subsidence and loss of sediment is degrading the watershed and causing damages to property and habitat. The net loss of sediment from the land into the stream channels is problematic to the system. Low flow conditions do not provide enough energy to flush this sediment; instead the channels accumulate this sediment reducing capacity and degrading habitat dependent on certain temperatures and depths within the channel.

  Opportunity: Stabilize banks to prevent erosion throughout the Esopus Creek Basin.

- **Problem: Debris clogging streams, trapping sediment and creating islands.**

  Debris accumulation in the Esopus Creek watershed is clogging streams restriction flow of water downstream. Problem debris includes trees, other vegetation, rocks and trash. In some cases debris further traps sediment eventually creating "islands" which in many cases are able to further sustain vegetation which adds to the debris

problem. During flood conditions, these blockages can exacerbate flood damages to property.

Opportunity: Clearing and snagging to open channels and prevent debris build up.

- **Problem: Sedimentation of channel beds and scouring of the channels impacting the riparian and aquatic habitat.**

  Sediment balance and management issues within stream channels in the Esopus Creek watershed are negatively impacting habitat quality. Depth and temperature within the channels are being changed and are no longer meeting the requirements needed for local species to live and reproduce. Accumulation of sediment in the Ashokan Reservoir will also impact drinking water quality and quantity.

  Opportunity: Balance the sediment flow regime throughout the Esopus Basin to provide stabilized, healthy creeks.

5.5 Planning Objectives: The national objectives of National Economic Development and National Ecosystem Restoration are general statements and not specific enough for direct use in plan formulation. The water and related land resource problems and opportunities identified in this study are stated as specific planning objectives to provide focus for the formulation of alternatives. These planning objectives reflect the problems and opportunities and represent desired positive changes in the without project conditions. The planning objectives are specified as follows:

- To implement one or more watershed based solutions formulated based on sites for improvements within the watershed for a comprehensive approach to flood damage reduction, stream restoration and navigation improvements;
- To reduce flood damage to homes, public and private property, infrastructure and businesses;
- To reduce the threat of loss of life from dangerous flood conditions;
- To mitigate financial losses incurred due to flooding and erosion;
- To maintain or improve the heath of the watershed (environmental restoration).
- To improve land use within the floodplain appropriate for maintaining or improving aquatic and riparian habitat throughout the basin.

5.6 Planning Constraints: Unlike planning objectives that represent desired positive changes, planning constraints represent objects or activities within the study area that could impede the progress of the watershed study. The planning constraints identified in this study are as follows:

- Many of the problem areas in the basin are on private property.
- The Ashokan Reservoir is a major feature in the basin and its sole purpose is water supply.
- Native American artifacts and other cultural resources are known to be located in the area. Further investigation will be required during the feasibility phase.

5.7 Measures to Address Identified Planning Objectives. A management measure is a feature or activity at a site, which address one or more of the planning objectives. A wide variety of measures were considered, some of which were found to be infeasible due to technical, economic, or environmental constraints. Each measure was assessed and a determination made regarding whether it should be retained in the formulation of alternative plans. The descriptions and results of the evaluations of the measures considered in this study are presented below:

5.7.1 No Action. USACE is required to consider the option of "No Action" as one of the alternatives in order to comply with the requirements of the National Environmental Policy Act (NEPA). No Action assumes that no project would be implemented by the Federal Government or by local interests to achieve the planning objectives. No Action, which is synonymous with the Without Project Condition, forms the basis from which all other alternative plans are measured.

If "No Action" is taken, streambank erosion will continue along the Esopus Creek and its tributaries. This sediment and associated debris will continue to fill channels throughout the watershed, reducing the capacity for high water and high velocity events, increasing flood related damages to property and infrastructure. Areas of sediment accretion will continue to become islands where opportunistic vegetation will take root and further exacerbate the accumulation of sediment and debris within the channel.

5.7.2 Non-Structural. USACE evaluated a suite of non-structural measures as alternatives to structural measures, both for flood damage reduction, and for environmental restoration. In the preliminary analysis, no viable non-structural measures could be identified that would meet the planning objectives. Non-structural measures which are currently in-place, such as floodplain zoning restrictions, are highly valuable, and are recommended for continued implementation.

<u>Removal of Constrictions:</u>

Removal of physical constrictions to flow throughout the watershed will prevent high waters from becoming "backed up" in certain reaches. These constrictions include rock ledges. For

natural constrictions such as rock ledges, existing habitat features will be examined with consideration to the removal.

Debris Removal – Clearing and Snagging:

Debris, including large dead trees, smaller live vegetation and boulders, are currently constricting flow and trapping sediments. In some cases, trapped sediment is now growing vegetation and is creating permanent islands. Removing large debris from creek channels will improve the flow of water through the creek. A regular debris removal program, including the removal of the source of debris, will allow the stream to flow more normally and begin to flush sediment recreating a more natural channel. Existing habitat features will be examined with consideration to any removal of natural debris.

Strategic selection of sites for clearing and snagging of impending and existing debris throughout the watershed will have a cumulative impact on flow, velocity and sediment transport in the system. Source removal for impending debris should be considered for removal.

Reconnection of Stream and Floodplain:

Where streambanks are being restored, opportunities may exist to build a floodplain bank in conjunction with the improved streambank. Creation of new floodplains and reconnection to those areas will improve flood water retention, while simultaneously creating or restoring floodplain habitat. Reconnection of these two systems will reduce habitat fragmentation. Vegetation of these floodplain benches with native plants will add to the habitat value of that system.

5.7.3 Structural. USACE will evaluate a number of structural measures to achieve planning objectives, both in the reconnaissance phase and feasibility study. These measures will include structural measures to reduce flood damages and provide ecosystem/river restoration.

Levee or Floodwall Construction:

Construction of a structural feature such as a levee or floodwall on the reaches of the Esopus Creek, Sawkill Creek and/or Plattekill Creek that see the worst flood damages will serve to prevent waters from reaching people, businesses and roads. Levees and floodwalls will be difficult to justify in most areas in the basin because of low population density (i.e., lack of benefits).

Creation of Wetlands:

Where appropriate, there may be opportunities for the creation of wetland areas that could serve a dual role of aquatic habitat and natural flood storage areas.

In-Stream River Restoration Methods:

River restoration techniques including redirective and resistive methods and natural channel design will improve the overall health of the river system. Redirective methods (as shown in below photo) such as Bendway Weirs and rock revetments will focus the stream flow and flush out depositional areas within the channel over time allowing for greater channel capacity when needed.

Bendway Weirs Demonstration Project - Mississippi

Resistive methods such as longitudinal peak stone toe protection (LPSTP) will achieve streambank stabilization and direct the highest velocity flows away from vulnerable banks. Native vegetation can be incorporated in these streambank projects. Using these two kinds of restoration collaboratively and strategically throughout the watershed will improve the overall health of the ecosystem by allowing for a channel of appropriate depth, velocities and temperature.

Focusing the flow of water, aided by channel improvements within the creek bed, can be designed to flush other depositional areas of the creek that have been filled with sediment. This also generally provides for better habitat and fish passage with more consistent depth and temperature. Implementing these methods would create a healthy channel with appropriate depth and temperature conditions for habitat. The upper and lower Esopus Creek, Sawkill Creek and Beaverkill Creek all have reaches that could be improved using stream restoration methods. *(See Appendix E - River Restoration Methods)*

Streambank Restoration and Stabilization:

Streambank restoration and stabilization methods will prevent further erosion of banks protecting private and public property and infrastructure located adjacent to the creek. In-stream methods to stabilize the creek and its banks, such as longitudinal peak stone toe protection, have been shown to be effective to restore a more

natural stream bank, recreate riparian habitat and reconnect the stream to a floodplain. Environmentally sensitive streambank stabilization methods are preferred in accordance with the USACE ecosystem restoration mission. The upper and lower Esopus Creek, Sawkill Creek and Beaverkill Creek all have reaches that could be improved using these restoration methods.

Dredging:

Dredging may be needed in some reaches of the Esopus Creek where the most accretion of sediment has taken place, particularly in the lower watershed near the City of Kingston and Village of Saugerties. Near the confluence with the Hudson River, an active harbor exists in the Village of Saugerties. It is used primarily by recreational boaters with some use by commercial vessels, Coast Guard and by the historic environmental education ship, the Clearwater.

5.7.4 Watershed Approach – Systems Analysis.

In a watershed feasibility study, multiple projects may be recommended to contribute to the overall improvement of the watershed system, including environmental river restoration and flood damage reduction. Each of these projects can be evaluated as a part of an overall comprehensive approach to the restoration of the watershed. An individual project may not be able to significantly improve the watershed health or reduce flood damages by itself; however, a watershed feasibility study may recommend a series of projects that together will improve watershed health and reduce flood damages by way of a systems approach.

Watershed Management Plan

A Watershed Management Plan (an appendix to the Watershed Feasibility Study) will provide a planning tool for the region evaluating all inputs to the watershed including minor tributaries and culverts. This document will include recommendations for best management practices (BMP's) in the watershed that can be implemented by local and Federal agencies.

5.8 Preliminary Plans. Preliminary plans are comprised of one or more management measures that survived the initial screening. The descriptions and results of the evaluations of the preliminary plans that were considered in this study are presented below:

5.8.1 Preliminary Plans Eliminated from Further Consideration

Plans for dredging in this watershed have been eliminated because it is anticipated that the costs for dredging the creek beds would exceed the benefits. However, dredging in Saugerties Harbor is

already authorized and an existing Operations and Maintenance project.

5.8.2 Preliminary Plans for further Consideration (previously described)

5.8.2.1 No Action

5.8.2.2 Removal of Constrictions

5.8.2.3 Debris Removal – Clearing and Snagging

5.8.2.4 Reconnection of Stream and Floodplain

5.8.2.5 Levee or Floodwall Construction

5.8.2.6 Creation of Wetlands

5.8.2.7 In-Stream River Restoration Methods

5.8.3 Alternative Implementation Authorities

New York District may work with New York City Department of Environmental Protection (NYC DEP) to implement some of the recommendations specifically for the upper Esopus Creek watershed using the New York City watersheds project authority.

5.9 Conclusions from the Preliminary Screening. The preliminary screening indicates that the alternatives listed as preliminary plans for further consideration have the greatest potential for implementation following a watershed feasibility report for the study area. The overall watershed improvements following river restoration will include improved ecosystem function, improved habitat, stable streambanks, stable channels, more consistent flow, temperature and depth. The potential ecosystem benefits (in habitat units) from a system of projects as recommended by the watershed feasibility study would likely justify the costs of those projects. A decrease in damages due to flooding would be an ancillary benefit of the recommended river restoration projects. No significant environmental impacts are anticipated that would require mitigation. Costs of the alternatives would be determined in the watershed feasibility report. Based on this information, the recommended alternatives to address the planning objectives appear viable.

6.0 FEDERAL INTEREST.

6.1 Since ecosystem restoration and flood damage reduction are outputs with a high budget priority and that ecosystem restoration is the primary output of the alternatives to be evaluated in the feasibility phase, there is a strong Federal interest in conducting the watershed feasibility study. There is also a Federal interest in other related outputs of the alternatives including flood damage reduction that could be developed within existing policy. Based on the preliminary screening of alternatives, there appears to be

potential project alternatives that would be consistent with Army policies, costs, benefits, and environmental laws.

6.2 In addition, Federal Interest is supported by the Federal Disaster Declaration issued following the flooding that occurred during the time of April 14-18, 2007. The lower Hudson Valley, including the Esopus Creek watershed, was struck by a nor'easter, which caused significant flooding, damage, and loss of life. On April 24, 2007, a Presidential Disaster Declaration (FEMA-1692-DR, New York) was issued for most of the Lower Hudson Valley as well as other affected counties in the state. The declaration covers 14 counties, including Albany, Columbia, Dutchess, Essex, Greene, Montgomery, Orange, Putnam, Richmond, Rockland, Schoharie, Suffolk, Ulster, and Westchester.

7.0 PRELIMINARY FINANCIAL ANALYSIS.

7.1 The non-Federal sponsor for the feasibility study is ___ .

7.2 As the local sponsor, _____ will be required to provide 50 percent of the cost of the feasibility phase. The local sponsor is also aware of the cost sharing requirements for potential project implementation. A letter of intent from the local sponsor stating a willingness to purse the feasibility study and to share in its cost, and an understanding of the cost sharing that is required for project construction is included as Attachment D.

8.0 SUMMARY OF FEASIBILITY STUDY ASSUMPTIONS.

8.1 Feasibility Phase Assumptions: The following critical assumptions will provide a basis for the feasibility study:

8.1.1 Without Project Condition Assumptions

If no projects are constructed for river restoration in this watershed, it can be reasonably assumed that streambanks will continue to be unstable and subject to erosion, stream channels will continue to collect sediments due to low flow, channel depth and temperature will continue to be inconsistent not providing habitat for aquatic species, and channels will continue to have a reduced capacity for high flow conditions and will continue to cause flood damages in local communities.

8.2 Policy Exceptions and Streamlining Initiatives: The study will be conducted in accordance with the Principles and Guidelines and USACE regulations. Exceptions to established guidance have been identified that will streamline the feasibility study process that will not adversely impact the quality of the feasibility study. Approval of the Section 905(b) Analysis results in the approval of the following policy exceptions and streamlining initiatives:

8.2.1 This study would be conducted as a watershed management feasibility study including preparation of a watershed management plan as an appendix to the report following regulations including EC 1105-2-409, EC 1105-2-410, ER 1165-2-1 and Policy Guidance Letter #61.

8.2.2 The Esopus and Plattekill Creeks Watershed may be studied as one watershed feasibility report or separated into two watershed feasibility reports, one each for the upper and lower watershed, depending on the preference of the nonfederal sponsor(s).

9.0 FEASIBILITY PHASE MILESTONES.

Milestone	Description	Duration (mo)	Cumulative (mo)
Milestone 1	Initiate Study	0	0
Milestone 2	Public Workshop/Scoping	2	2
Milestone 3	Formulation Conference	11	13
Milestone 4	Alternative Review Conference	9	22
Milestone 4A	Alternative Formulation Briefing	5	27
Milestone 5	Draft Feasibility Report	3	30
Milestone 6	Public Review	1	31
Milestone 7	Final Public Meeting	1	32
Milestone 8	Final Report to Division	3	35
Milestone 9	Division Commander's Certi.	1	36
-	Chief's Report	4	40
-	Project Authorization	4	44

W1 Receive Funds/Begin Feasibility Study

W2 Public Workshop: Establish protocol for public involvement and agency coordination; present draft Public Involvement Plan; other public workshops to be scheduled if needed.

W3 Formulation Conference: Establish current (baseline) and likely future without project conditions for H&H and ENV; identify, describe and discuss preliminary watershed restoration sites; establish decision framework for prioritizing sites.

W4/W4A Alternative Review Conference/Briefing (Recommendations): Watershed spin-off studies (site specific projects) will be identified for Federal and local implementation. Draft Watershed Management Plan (WMP) completed.

W5 Draft Feasibility Report, Draft Environmental Document & Final WMP.

Vehicle for spin-offs selected (CAP, GI, etc...) A Watershed Study Review Conference with NAD may be scheduled (optional).

W6 Field Level Coordination (Public Review).

W7 Final Public Meeting.

W8 Submit Final Feasibility Report, WMP and Environmental Document. District Engineer's Certification.

W9 Division Commander's Certification.

10.0 FEASIBILITY PHASE COST ESTIMATE.

10.1 Based on previous watershed studies of similar size and complexity, the preliminary cost estimate for each feasibility study recommended for the Esopus Watershed is estimated to be $2,500,000 of which $1,250,000 is Federal funds and $1,250,000 is non-Federal funds or in-kind services. Based on the preference of the local sponsor(s), a specific problem or a portion of the basin may be studied, provided it is determined to have features that are separable and independent.

11.0 VIEWS OF OTHER AGENCIES.

11.1 Because of the funding and time constraints of the reconnaissance phase, only limited and informal coordination has been conducted with other agencies. Views that have been expressed are as follows:

11.1.1 New York State Department of Environmental Conservation has participated in all stakeholder meetings and discussions and is supportive of the recommendations of the Reconnaissance Report.

11.1.2 New York City Department of Environmental Protection has participated in all stakeholder meetings and discussions and is supportive of the recommendations of the Reconnaissance Report.

11.1.3 Ulster County has participated in all stakeholder meetings and discussions and is supportive of the recommendations of the Reconnaissance Report.

12.0 POTENTIAL ISSUES EFFECTING INITIATION OF THE FEASIBILITY PHASE.

12.1 Continuation of this study into the cost-shared feasibility phase is contingent upon an executed FCSA. Failure to achieve an executed FCSA within 18 months of the approval date of the Section 905(b) Analysis may result in termination of the study. There are no apparent issues at this time that impact on the implementation of the feasibility phase.

12.2 The target date for signing the Feasibility Cost Sharing Agreement (FCSA) is during fiscal year 2009. Based on the schedule of milestones in Paragraph 9, completion of the feasibility report would be in fiscal year 2012 with a potential Congressional Authorization in a WRDA 2012.

13.0 PROJECT AREA MAP.

13.1 A map of the Study Area is provided as Appendix A.

RECOMMENDATIONS.

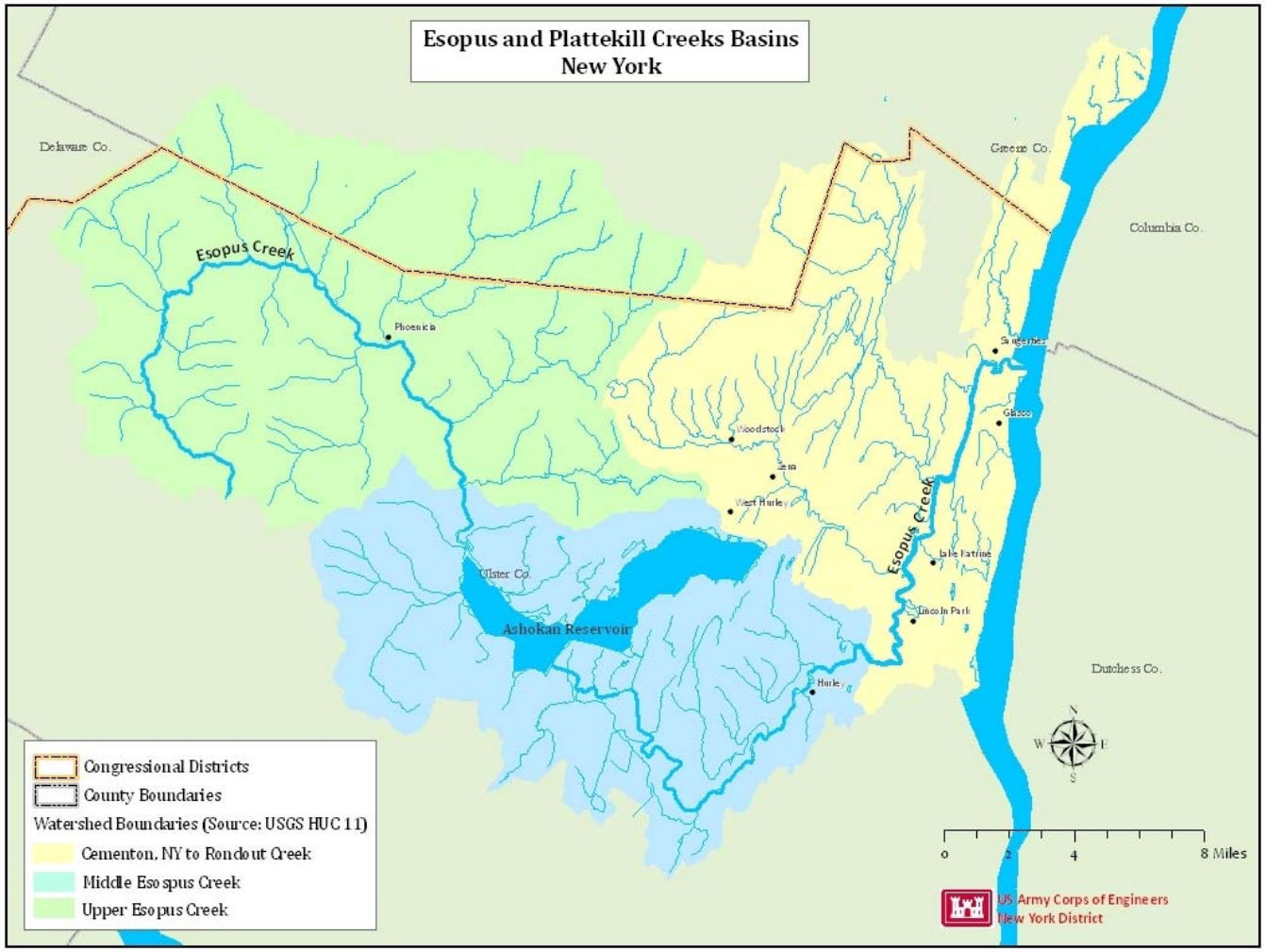
13.2 I recommend that the Esopus Creek and Plattekill Creek Watershed study proceed into the feasibility phase. The feasibility phase will continue the investigation of erosion and sediment reduction, streambank stabilization, ecosystem restoration, flood damage reduction, and related issues in the Esopus Creek and Plattekill Creek Watershed study area. _____ has expressed interest in cost sharing the feasibility study and initiating the Feasibility Cost Sharing Agreement upon completion of the Project Management Plan.

_____ _____

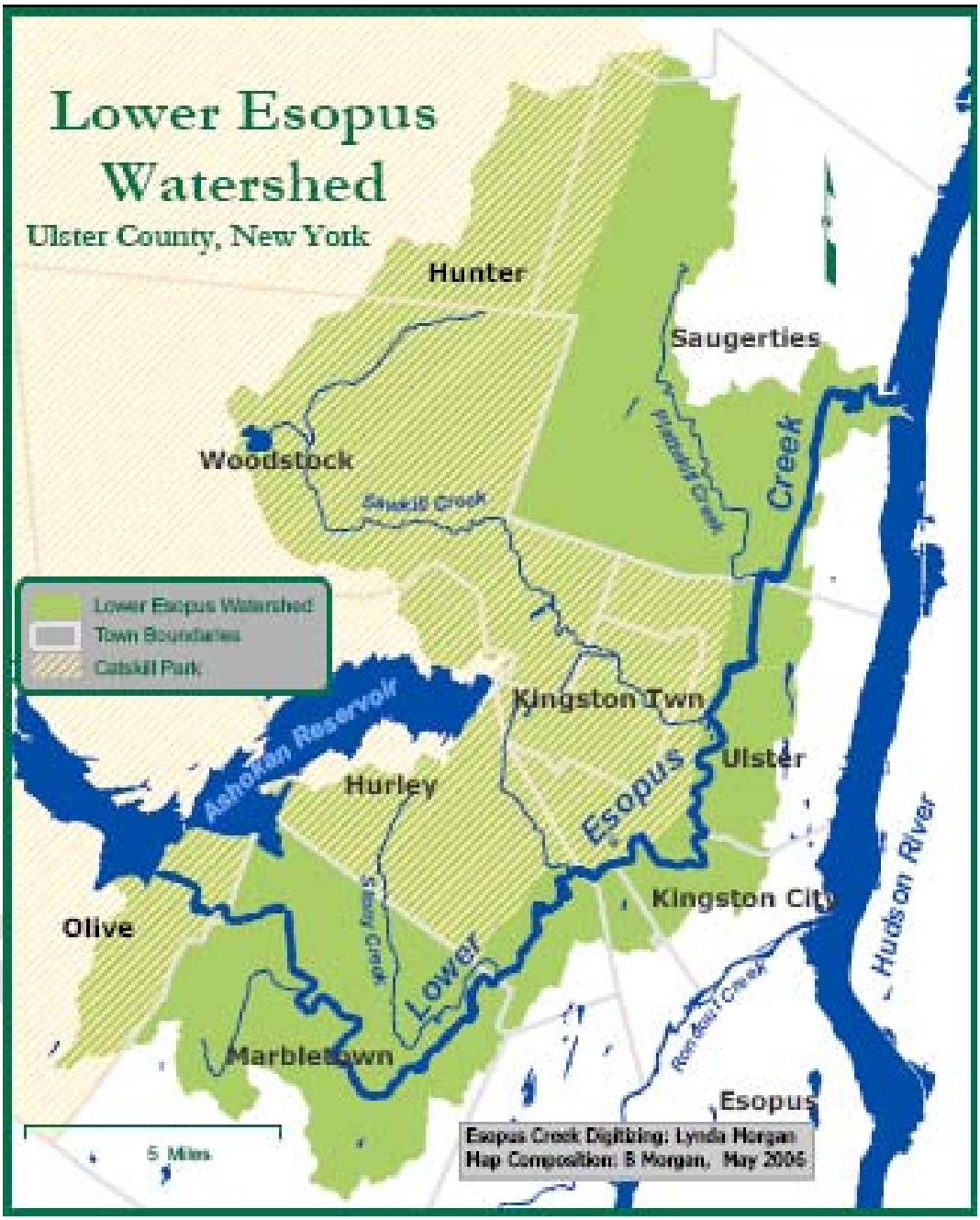
Date

Aniello L. Tortora
Colonel, U.S. Army
District Engineer

APPENDIX A: PROJECT AREA MAPS



(Maps cont.)


Lower Esopus Watershed
Ulster County, New York
Hunter
Saugerties
Woodstock
Sawkill Creek
Plattekill Creek
Esopus Creek
Lower Esopus Watershed
Town Boundaries
Catskill Park
Ashokan Reservoir
Kingston Town
Ulster
Hurley
Esopus
Kingston City
Hudson River
Olive
Stony Creek
Lower
Marbletown
Red Mill Creek
Esopus
5 Miles
Esopus Creek Digitizing: Lynda Morgan
Map Composition: S Morgan, May 2006

APPENDIX B: STUDY RESOLUTION:

U.S. House of Representatives
Committee on Transportation and Infrastructure
Washington, DC 20515

James L. Oberstar
Chairman

David Heymsfeld, Chief of Staff
Ward W. McCarragher, Chief Counsel

John L. Mica
Ranking Republican Member

James W. Coon II, Republican Chief of Staff

COMMITTEE ON TRANSPORTATION AND INFRASTRUCTURE
U.S. HOUSE OF REPRESENTATIVES
WASHINGTON, D.C.

RESOLUTION

Docket 2772

Esopus and Plattekill Watersheds, Greene and Ulster Counties, New York

Resolved by the Committee on Transportation and Infrastructure of the United States House of Representatives, That the Secretary of the Army review the report of the Chief of Engineers on the New York and New Jersey Channels, published as House Document 133, 74th Congress, 1st Session; the New York and New Jersey Harbor Entrance Channels and Anchorage Areas, published as Senate Document 45, 84th Congress, 1st Session; and the New York Harbor, NY Anchorage Channel, published as House Document 18, 71st Congress, 2nd Session, and other pertinent reports, to determine whether modifications to the recommendations contained therein are advisable in the interest of navigation, streambank stabilization, flood damage reduction, floodplain management, water quality, sediment control, environmental preservation and restoration, and other related purposes in Esopus and Plattekil Watersheds, New York.

Adopted:

ATTEST: James L. Oberstar
JAMES L. OBERSTAR
CHAIRMAN

APPENDIX C: PUBLIC NOTICE:

DEPARTMENT OF THE ARMY
NEW YORK DISTRICT, CORPS OF ENGINEERS
JACOB K. JAVITS FEDERAL BUILDING
NEW YORK, N.Y. 10278-0090

REPLY TO
ATTENTION OF:

CENAN-PL-F

August 2007

ESOPUS AND PLATTEKILL WATERSHEDS,
ULSTER AND GREENE COUNTIES, NY
RECONNAISSANCE STUDY

This notice announces the initiation of a Federally-funded reconnaissance level study to determine if Federal interest in watershed-based flood damage reduction, ecosystem restoration, and other allied water resources problems and opportunities are advisable for the Esopus and Plattekill Watersheds, New York. The New York District Corps of Engineers is conducting the study under authority of a resolution adopted on May 2, 2007 by the Committee on Transportation and Infrastructure of the United States House of Representatives.

A previous study, "Esopus Creek and Tributaries, New York" was completed in October 1962 under authority of study resolutions adopted February 15, 1951, November 14, 1955, and June 13, 1956. This report examined the localities along the Esopus Creek where improvements for flood damage reduction appeared economically favorable. Detailed investigations were made at Kingston, Shandaken, and between Mt. Tremper and Mt. Pleasant and ultimately, small projects for either flood damage reduction or snagging and clearing were constructed by the Corps in these locations. The 1962 survey report indicated that flood damage reduction opportunities along other areas of Esopus Creek would not be economically justified. The report did indicate that sediment management, erosion control and bank stabilization would prevent additional erosion and meandering of the stream channel, but any of these efforts would be economically infeasible and would have negligible effects on major flood events.

In light of the recurrence of fluvial flood damage over the past several years, including flooding, erosion, and road washouts from the storms of October 2005 and the severe storms of April 2007, which resulted in damages throughout the Esopus and Plattekill Watersheds, the Corps of Engineers will examine the entire watershed. This reconnaissance study will examine the current field conditions and study criteria to determine whether any watershed-based opportunities for flood damage reduction, ecosystem restoration or other allied purposes exist for continued Federal participation during detailed evaluation and construction. As part of this study, the water resources problem(s) in the area will be identified as will potential solutions to the problem(s). Determination of Federal interest in the project will be based on the preliminary screening of alternatives as well as the extent of support by local officials and interested parties. If continued study and project development by the Federal government is justified, this study will be followed by a more detailed cost-shared feasibility-level study.

We request any pertinent information about the project area from Federal, State and local agencies, as well as the private sector. In particular, we request information on the type and amount of damages that have occurred from storms in recent years. The information provided will be used to the greatest extent possible to define the nature and severity of the flood problems and to determine potential Federal interest in providing flood damage reduction measures. We also welcome any assistance and suggestions pertaining to the conduct of this study. All comments should be directed to Mr. Eugene Brickman, P.G., Deputy Chief, Planning Division, Eugene.Brickman@usace.army.mil, 917 790 8701; Ms. Jodi McDonald, Rivers and Lakes Section Chief, Jodi.M.McDonald@usace.army.mil, 917 790 8720; or Mr. Jason Shea, Economics and Policy Section Chief, Jason.A.Shea@usace.army.mil, 917 790 8727.

Aniello L. Tortora
Colonel, U.S. Army
District Commander

APPENDIX D: PHOTOGRAPHS

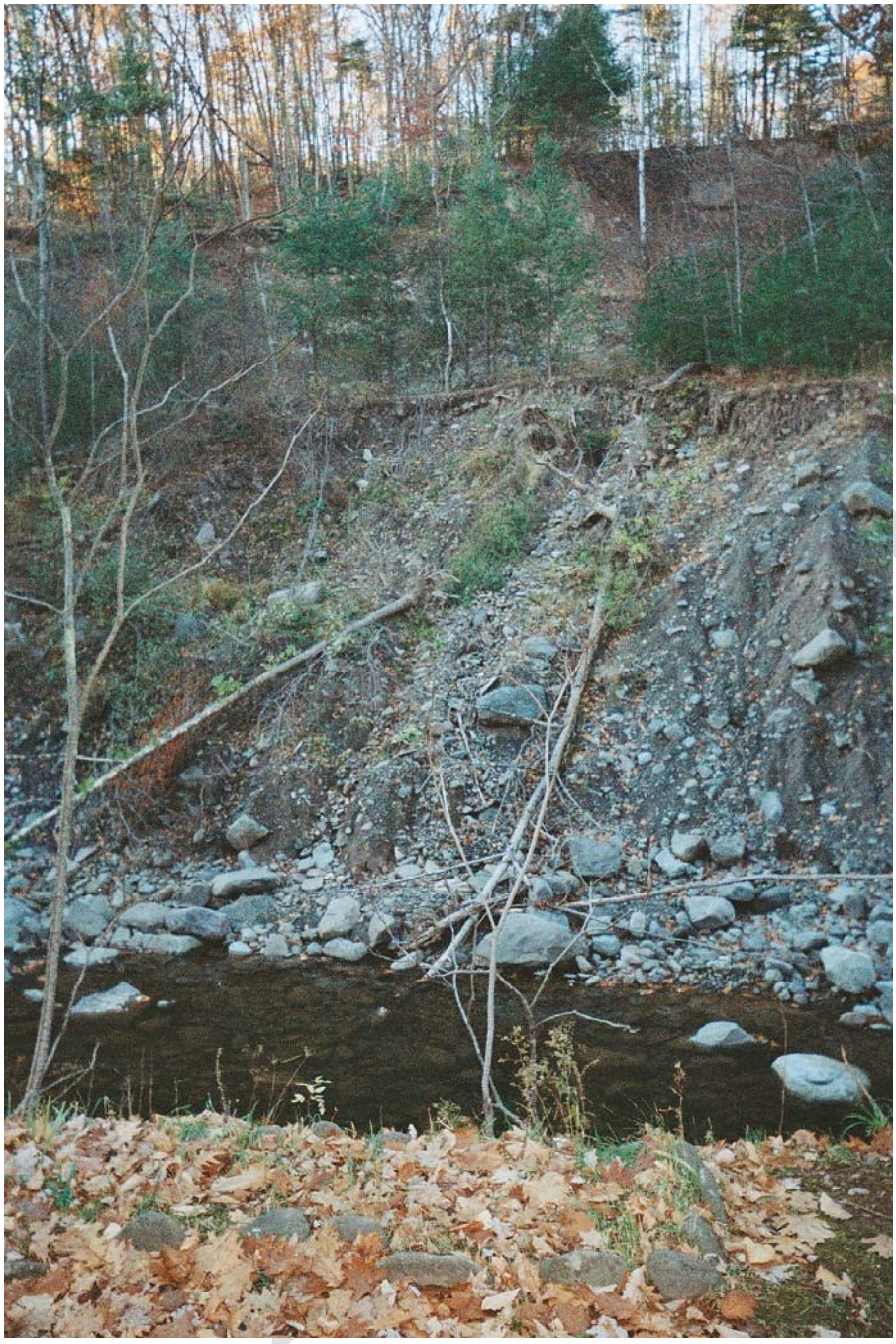
Sedimentation of Upper Esopus Creek, Oliverea

Debris and Island Formation, Sawkill Creek, Town of Woodstock

(Photographs cont.)

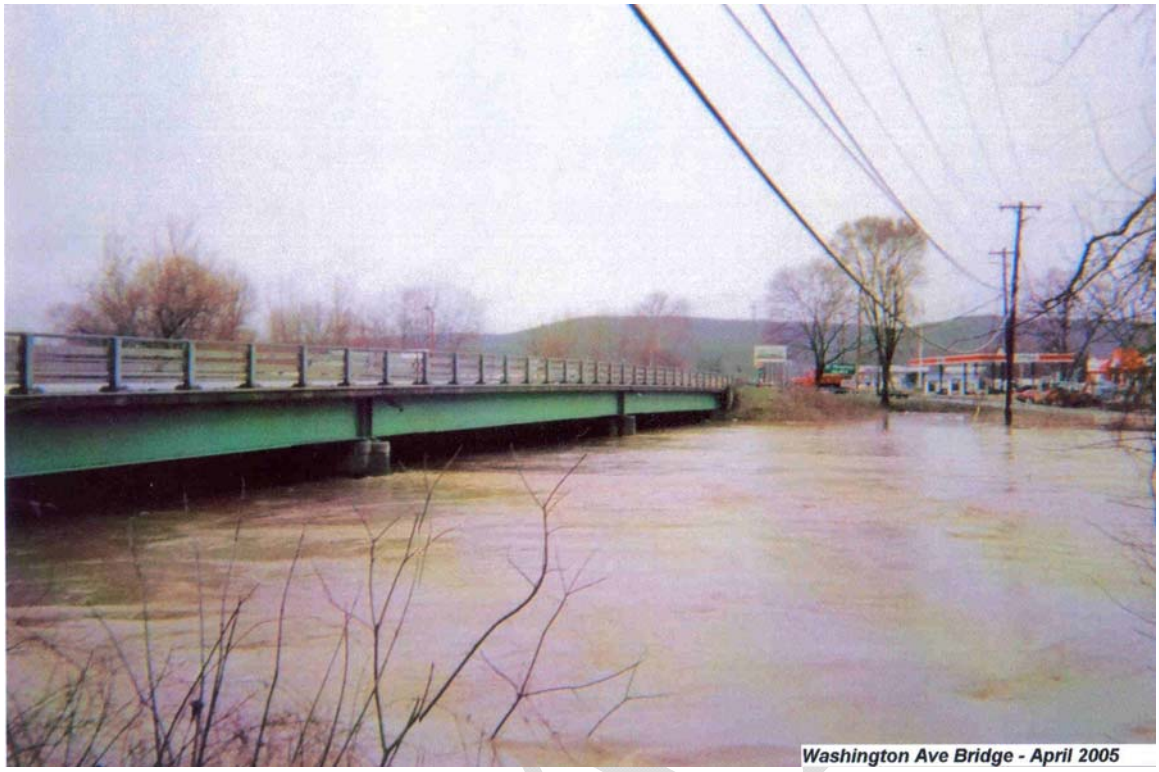
Bank Scouring and Debris Accumulation, Beaverkill Creek, Town of Woodstock

Bank Erosion and Land Subsidence, Plattekill Creek, Town of Saugerties



Bank Erosion, Beaverkill Creek, Town of Woodstock

(Photographs cont.)



Esopus Creek near the intersection of Route 28, 209, 87 and NYS Thruway, Kingston

Flood waters on Routes 28 and 209 near the Esopus Creek, Kingston

(Photographs cont.)

Esopus Creek near Esopus Avenue, Town of Ulster

Sewer Washout near Esopus Creek, Town of Ulster

APPENDIX E. HYDROLOGIC AND HYDRAULIC APPENDIX

CENAN-EN April 2008

MEMORANDUM FOR THE RECORD

Subject: Esopus Creek, Kingston New York

Hydrologic and Hydraulic Characteristics of the River Basin

Location- The Esopus Creek watershed is in the North Atlantic Storm belt. The project area extends along the right bank of Esopus creek in the City of Kingston, New York. The protection along the right bank of Esopus Creek would consist principally of levees and walls from route 587 upstream to Route 28, (Washington Avenue).

Watershed- The Esopus Creek, with a drainage area of 425 square miles, originates in the heart of the Catskill Mountains above Phoenicia, New York. It flows in a southeasterly direction for about 30 miles, and then continuous northeast about 18 miles through the City of Kingston and discharges into the Hudson River at Saugerties, New York as shown in the watershed map . This watershed is an important source of water supply for the City of New York. Its water is impounded in the Ashokan Reservoir which is located 32 miles above the mouth of Esopus Creek and 17 miles above the City of Kingston. The average slope of Esopus Creek varies from 49 feet per mile from Mt. Pleasant to Coldbrook, to 4.0 feet per mile from Kingston, to Saugerties. Principal tributaries to Esopus Creek are Plattskill, Sawkill, Little Beaver Kill, Beaver Kill, Stoney Clove, Woodland Creek, Bushnellsville Creek and Birch Creek.

Climate.- The climate of the Esopus Creek watershed is characterized by long summers and short winters. The average annual temperatures are 48.4 degrees Fahrenheit at rifton and 45.9 degrees at Roxbury, with extreme temperatures, varying from 30 to 40 degrees at Roxbury, with extreme temperatures varying from 30 to 40 degrees below zero to 100 to 105 degrees above zero. The average growing season is 145 days. The relative humidity averages about 75 percent. Prevailing winds are from the northwest with an average velocity of 8 miles per hour.

Annual and Monthly Precipitation. The average annual precipitation for the watershed is approximately 49.1 inches as derived from the published rainfall data. The annual extreme values at individual stations were 79.43 inches at West Shokan (1945), and 21.79 inches at Kingston (1964). The monthly extremes as observed at individual stations were 25.27 inches in October 1955 at west Shokan, and zero inches at West Shokan in October 1924. The distribution of precipitation throughout the year is somewhat uniform with slightly higher amounts during the summer months.

Snowfall- the average annual snowfall over the watershed is approximately 50 inches. The depths of snow given are fresh fallen snow with an approximately water content of one inch of water to 10 of snow.

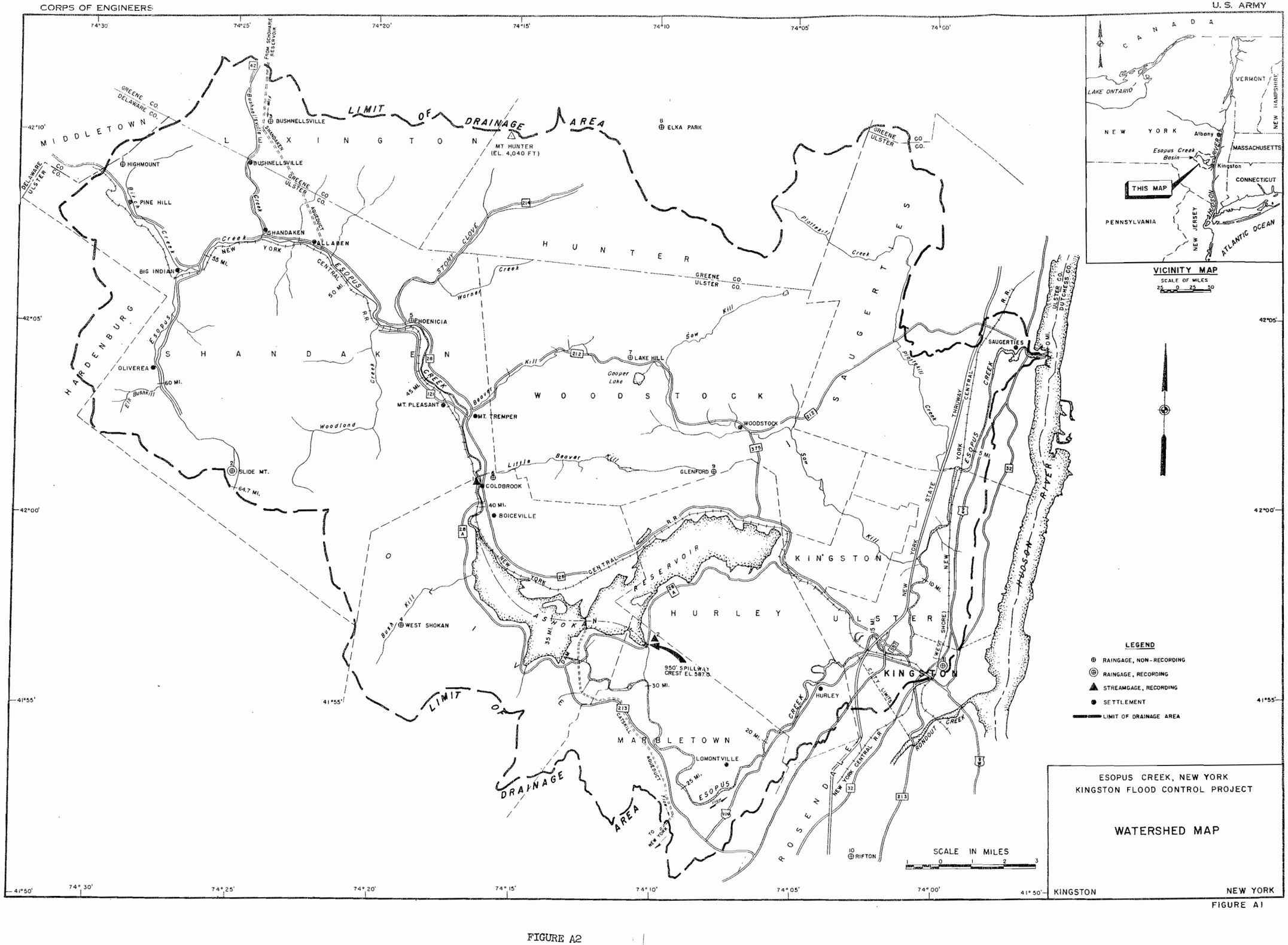
Past Storms – A review of major storms which have occurred in the northeastern states reveals that the Esopus Creek watershed is located in the North Atlantic storm belt. Some of the notable storms which have caused flood conditions in the basin occurred during the following periods: 22-24 August 19333, 9-24 march 1936, 24-25 November 1950, 29-31 March 1951 and 14-18 October 1955. The most recent of these storms – April 2005 and April 2007 have cause scouring and erosion at streambank, inundation of flood plain and erosion at bridges and Embankments.

Flooding Potential

The first step of assessing the flooding potential of Esopus creek is to identify or develop H&H data. This is usually done using a recent study. In many cases, the hydrologic and hydraulic data generated by FEMA to develop the FIRM is sufficient for this level of analysis. A comparison of the USGS Log Pearson Type III frequency analysis or peak flows on the Esopus Creek and the frequency-discharge curve obtained from FEMA must be made to determine whether the H&H analysis is accurate. Therefore, updated hydrologic and hydraulic data might be needed before an assessment of flooding could be made for this preliminary analysis.

CORPS OF ENGINEERS

U.S. ARMY



VICINITY MAP

SCALE OF MILES

25 0 25 50

LEGEND

- RAINGAGE, NON-RECORDING
- RAINGAGE, RECORDING
- STREAMGAGE, RECORDING
- SETTLEMENT
- LIMIT OF DRAINAGE AREA

ESOPUS CREEK, NEW YORK
KINGSTON FLOOD CONTROL PROJECT

WATERSHED MAP

KINGSTON NEW YORK

FIGURE A1

FIGURE A2

APPENDIX F. ENVIRONMENTAL MEMORANDUM

CENAN-PL-E 15 January, 2008

MEMORANDUM FOR THE RECORD

SUBJECT: Site Visit to Esopus and Roundout Watersheds

Date:	2 day site visit, 18 December -19 December 2007
Location:	Kingston, Ulster County, NY
Purpose:	Conduct site visits for 2 New York District (NYD) recon projects
Corps Staff:	Tricia Aspinwall, CENAN-PL-F
	Dave Derrick, CE-ERDC-CHL-MS
	Juan Carlos Escajadillo, CENAN-EN
	Kate Mulvey, CENAN-PL-E
	Jason Shea, CENAN-PL-F
Attendees:	NYSDOT Region 8 & Region 1 representatives
	NYCDEP representatives
	NYSDEC representative

3. Reference subject as above.

4. The undersigned attended a site visit with the above listed attendees. The ensuing paragraphs are a summary of what was observed with recommendations of future activities from the CENAN-PL-E perspective.

5. The purpose of a 905(b) Recon Study is to identify federal interest as well as local problems and opportunities for action. The purpose of the December site visit to Ulster County was to allow members of the project team to visit several representative sites within the Esopus and Roundout Watersheds and understand the range of stream bank erosion and flooding issues found within each watershed.

6. This Memorandum for the Record (MFR) will preliminarily identify stream bank erosion problems, estimate the potential impacts of these defined problems and suggest ways to quantify biological impacts where possible.

Types of Problems and Related Issues in each Watershed:

7. Esopus and Plattekill Creek Watersheds
   a. *Upper Esopus and Beaverkill Creek*
      PL-E staff observed falling banks, scoured banks, scattered tree debris and sediment forming islands within the channels of this section of the watershed. There are some places in this area where the river lacks enough resistance to dissipate energy and slow down the stream flow.

In one such case in Beaverkill, the river is trying to 'make itself longer' as an alternative way slow down the flow according to Dr. Dave Derrick of ERDC. However at this location, the river is restricted by its proximity to the Route 212 and is therefore scouring the bank adjacent to the road surface. One method of dissipating this energy would be to introduce a deep pool where the fast water is located and allow for a riffle, run, pool, glide configuration. In this Beaverkill scenario where the stream can not be longer, it would 'have hills to climb' if a deep pool is created as advised by Dr. Derrick.

Based on conversations with New York City Department of Environmental Protection (NYCDEP), the representative sites the project team visited in the Upper Esopus and Beaverkill Creek are not among the worst sediment depositing sources in the area. USACE should continue to coordination with NYCDEP and access their list of stream bank erosion sites that contribute the most sediment to the river system. These are the sites that would be most important to consider for stabilization projects.

Sediment deposited into the Upper Esopus and Beaverkill Creek is eventually deposited into the Ashokan Reservoir, which in addition to being a source water supply, is very important Trout habitat and thus a major interest to the Trout fishing community. For instance, Trout Unlimited has been active in the Catskills for over 40 years; their mission is to Conserve, Protect and Restore Coldwater Fisheries and their watersheds (Trout Unlimited).

Ulster County participates in a New York State Department of Environmental Conservation (NYSDEC) Trout stocking program on the Esopus. In the spring, yearling and older Brown Trout (Salmo trutta), either 8-9 inches or 12-15 inches, are stocked with the help of County Federated Sportsmen (NYSDEC). Optimal brown trout riverine habitat includes clear, cool to cold water; low silt rocky substrate in riffle-run areas; a 50% to 70% pool to 30% to 50% riffle-run habitat combination with areas of slow, deep water; well vegetated, stable stream banks; abundant instream cover; and relatively stable annual water flow and temperature. Brown Trout tend to occupy the lower reaches of low to moderate gradient areas [1%] in suitable high gradient rivers (Raleigh et. al. 1986).

Increased sedimentation from unstable banks on the Upper Esopus and Beaverkill Creek could negatively affect these habitat conditions and could also cover the nests that females build in spawning gravel.

b. *Lower Esopus Creek, Sawkill Creek and Plattekill Creek*
PL-E staff observed falling banks, scoured banks, scattered tree debris and sediment forming islands within the channels of this section of the

watershed. This area of the watershed is more developed residentially and commercially and therefore has a greater proportion of impervious cover including home/business structures and paved driveways/parking lots.

These areas are recorded as having major flood events, including: homes in the town of Ulster, residential basements and the town hall along Route 209 at the Sawkill confluence and Lake Katrine Area, and a large corn field on Route 209. In Marbletown, there are homes that are raised on poles and there is evidence of a former bridge structure with a narrower span than is required by the current bridge over Esopus.

8. Roundout Creek and Wallkill River Watershed

a. Roundout Creek Watershed

PL-E staff observed sediment forming islands, some channelization, and hardened shorelines due to bank erosion within the channels of this watershed. There was scouring observed here but less than in the Esopus and Plattekill Creek Watersheds.

Ulster County also participates in a New York State Department of Environmental Conservation (NYSDEC) Trout stocking program on the Roundout. In the spring, yearling and older Brown Trout (*Salmo trutta*) and Brook Trout (*Salvelinus fontinalis Mitchill*), both either 8-9 inches or 12-15 inches, are stocked with the help of County Federated Sportsmen (NYSDEC). The optimal Brook Trout Habitat is consistent with the optimal Brown Trout habitat described above. However, Brook Trout tend to occupy headwater stream areas. A comparison between Brown and Brook Trout shows that as streams become smaller and colder, more Brook Trout are present (Raleigh 1982).

As with the Upper Esopus and Beaverkill Creek, the increased sedimentation from unstable banks on the Roundout could negatively affect trout habitat conditions and could also cover the nests that females build in spawning gravel.

b. Wallkill River Watershed

PL-E staff was briefed by PL-F about frequent flood events in the 3000 acres of watershed that is part of Black Dirt Agricultural Region. All water from this area flows through a narrow passage and vegetation and debris frequently constrict flow. One major constriction is a landfill property that is expanding the river channel. An HTRW review/report, as described below, is recommended to determine if the landfill is allowing contaminants to leach into the River.

9. PL-E Recommended Actions

Coordination / Consultation Opportunities

a. The project team coordinated one day of the site visit with Dr. Derrick and New York DOT to view potential restoration sites in Ulster County. NYD staff requested further specific project assistance and input from Dr. Derrick on the Esopus & Plattekill Watershed Reconnaissance 905b and the Roundout Watershed Reconnaissance. Dr. Derrick is interested in possibly setting up a demonstration project to build momentum for these recon projects. Further communication with Dr. Derrick is recommended. USACE should also continue to coordination with NYCDEP and access their list of stream bank erosion sites that contribute the most sediment to the river system

b. Monitoring
PL-E recommends that USACE conduct temperature, dissolved oxygen, spawning gravel size, and siltation monitoring in Upper Esopus and Beaverkill Creek to use as imputs in the Habitat Suitability Index (HSI) for Brown Trout. This monitoring should also be conduced for both Brown Trout and Brook Trout in the Roundout. The HSI could be used as a basis for predicting probable project impacts, documenting post-project impacts, and guiding habitat protection, mitigation, enhancement and management decisions (Raleigh et. al. 1986).

c. Modified Engineering Solutions
PL-E recommends that any construction opportunity identified in the Engineering MFR for this site recon, incorporate native vegetated cover for bank stabilization as well as to support habitat, in particular for trout.

d. Environmental Resource Inventory
An inventory should be prepared describing the existing biological, ecological and natural resources within the project area. This will be accomplished via literature review, reconnaissance, wetland delineation, aquatic, benthic, and terrestrial surveys with a subsequent report for each.

e. HTRW Studies/Reports
A Phase One Environmental Site Assessment should be conducted to identify all potentially impacted sites within the project area, including any leaching effects of the landfill within the Wallkill River Watershed. This task involves the researching for existing reports on sites with environmental impacts and listing all that information into one document. This effort should be accomplished through literature/library searches, conducting field inspections to field check and confirm reports and by conducting interviews.

f. NEPA Compliance and General Permit Coordination

Catherine Mulvey
Project Biologist
PL-E

References

NYsSDEC http://www.dec.ny.gov/outdoor/23282.html

Raleigh, R.F., L.D. Zuckerman, and P.C. Nelson. 1986. Habitat suitability index models and instream flow suitability curves: Brown trout, revised. U.S. Fish Wildl. Biol. Rep. 82(10.124). 65 pp.

Raleigh, R.F 1982. Habitat suitability index models: Brook trout. U.S. Dept. Int., Fish Wildl. Serv.

Trout Unlimited http://apwctu.org/

APPENDIX G. RIVER RESTORATION TECHNIQUES

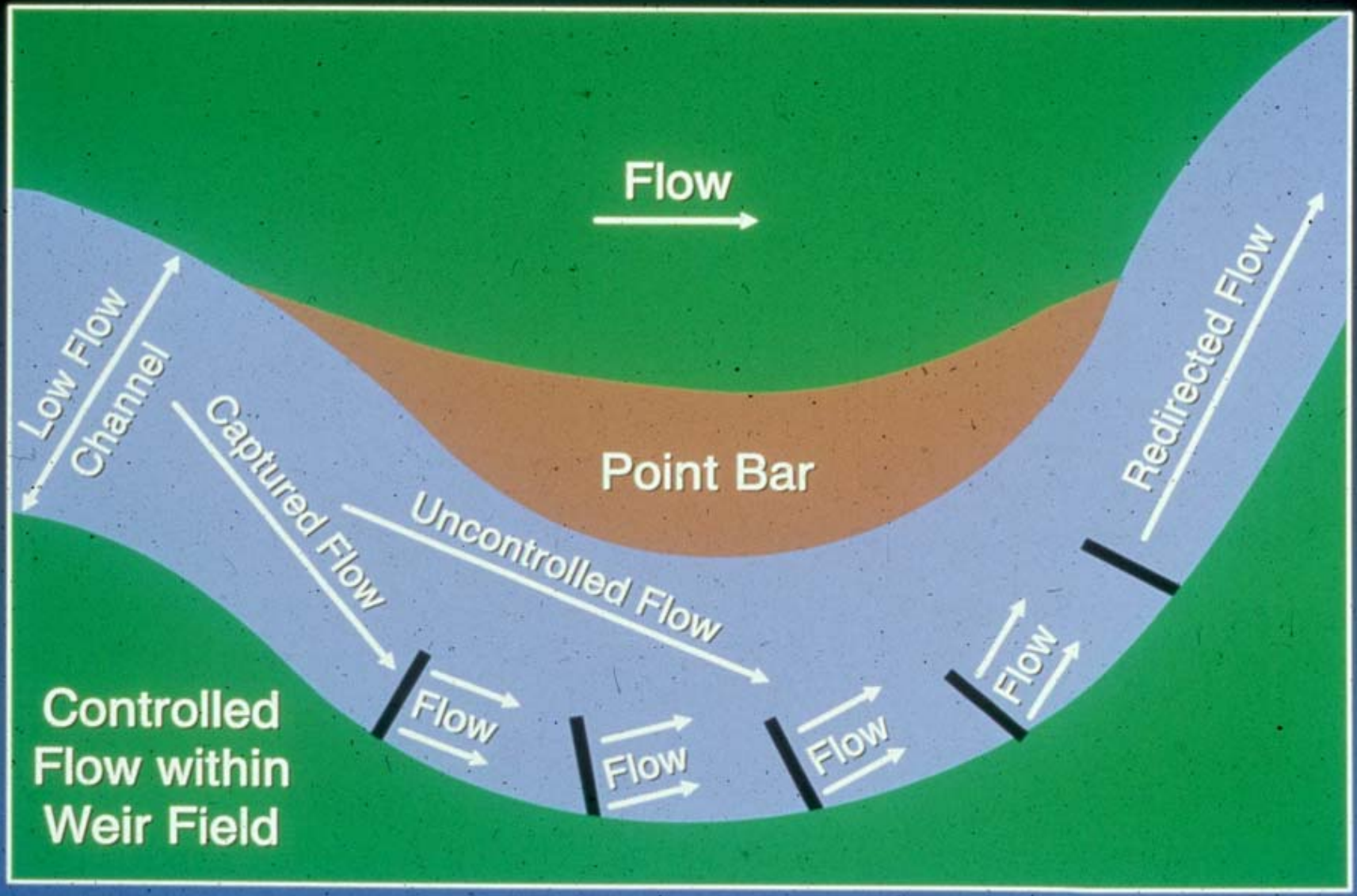
River Restoration Techniques

- Redirective Tools:
  - Bendway Weirs
- Resistive Methods:
  - Longitudinal Peak Stone Toe Protection (LPSTP)
  - Longitudinal Fill Stone Toe Protection (LFSTP)

Bendway Weirs

Bendway Weirs

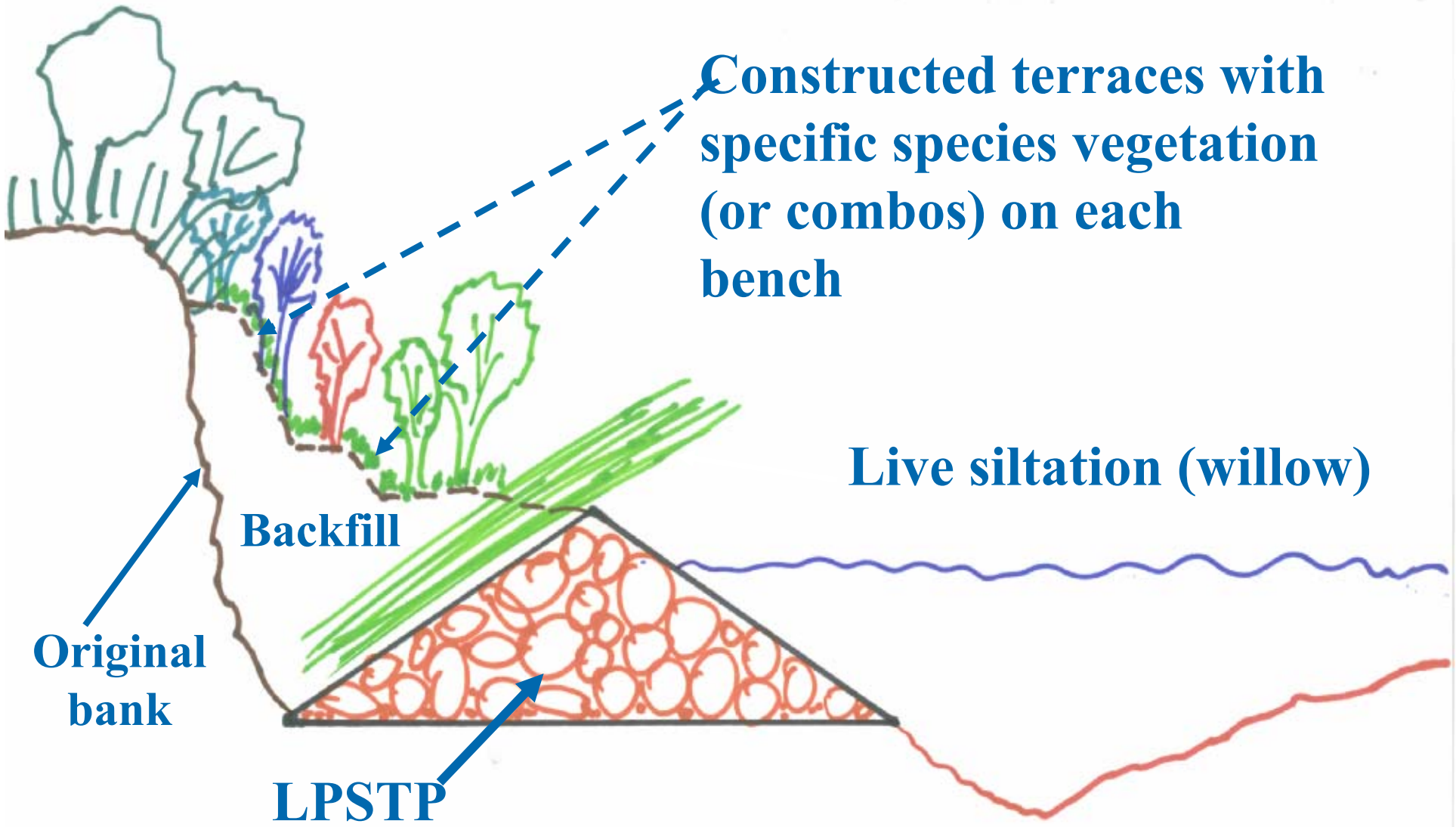
Bendway Weir Theory




Bendway Weirs
-Moving fast water away from
the bank during flood

Hydraulic Improvements Due to Bendway Weirs

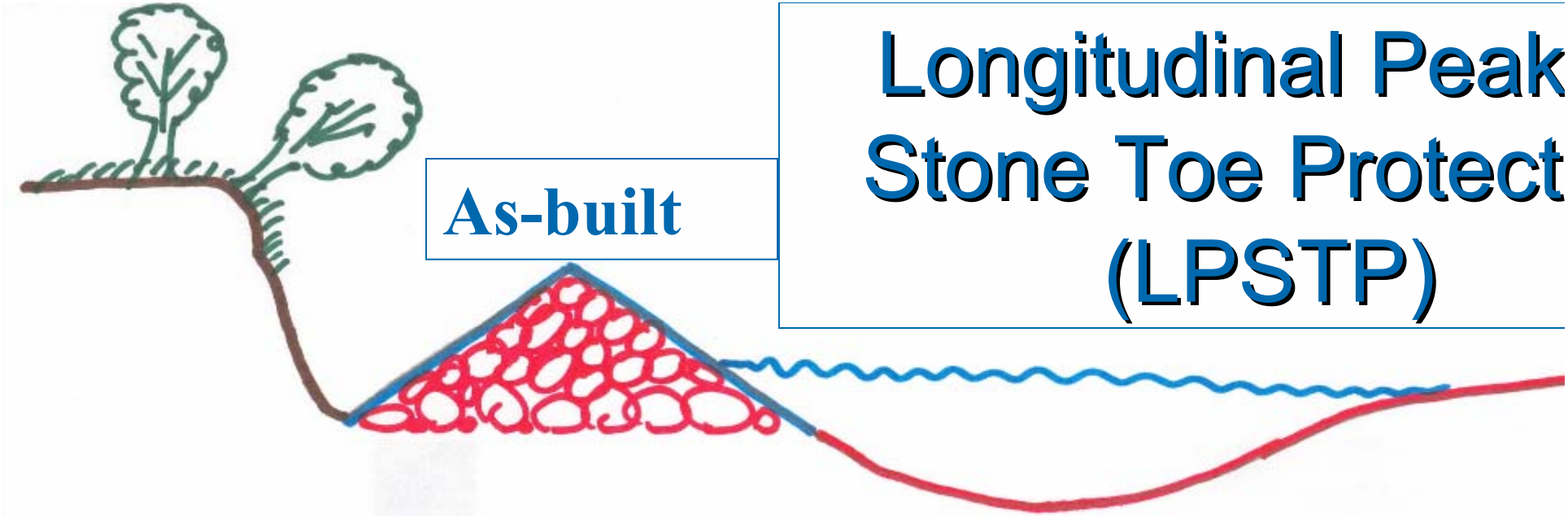
- **Deposition occurs on the outer bank of the bend**
- **Velocities are reduced near the outer bank**
- **Flow is generally parallel with the outer bank of the bend**
- **The deepest section of the river (the thalweg) is moved away from the outside of the bend toward the center of the channel**

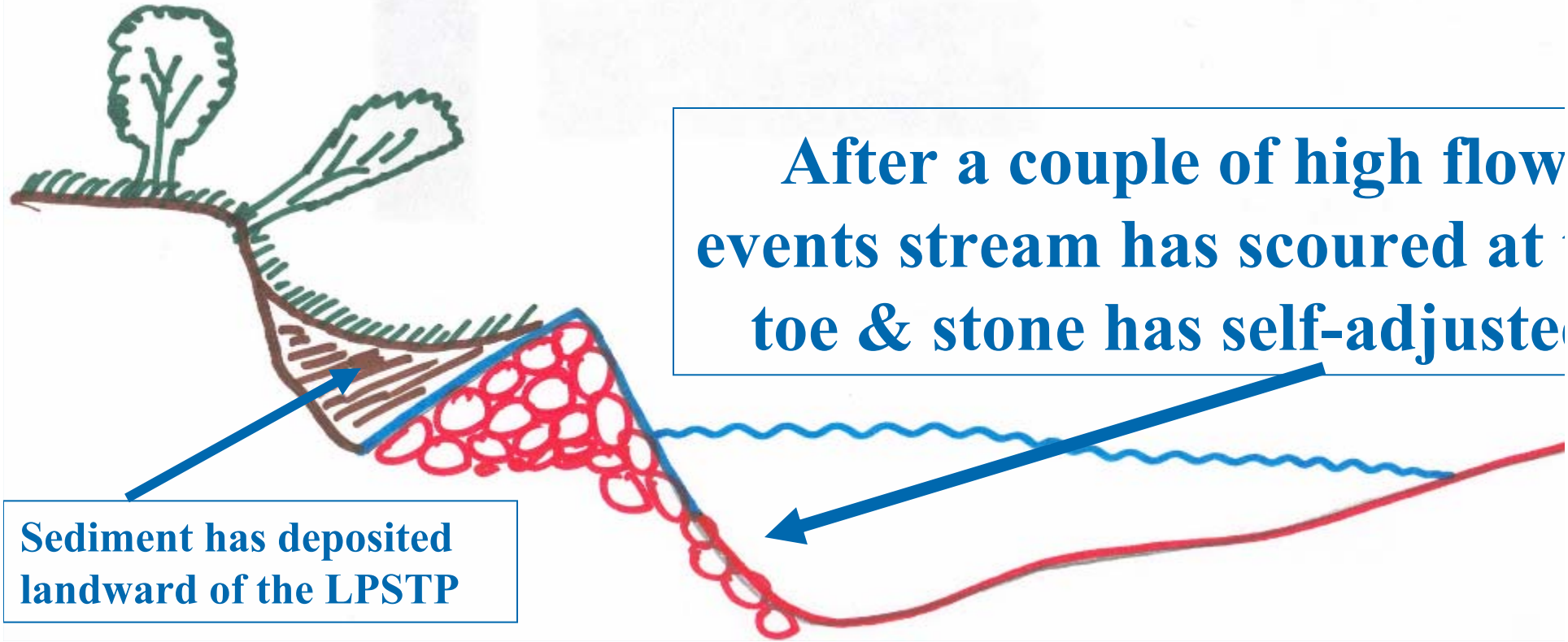


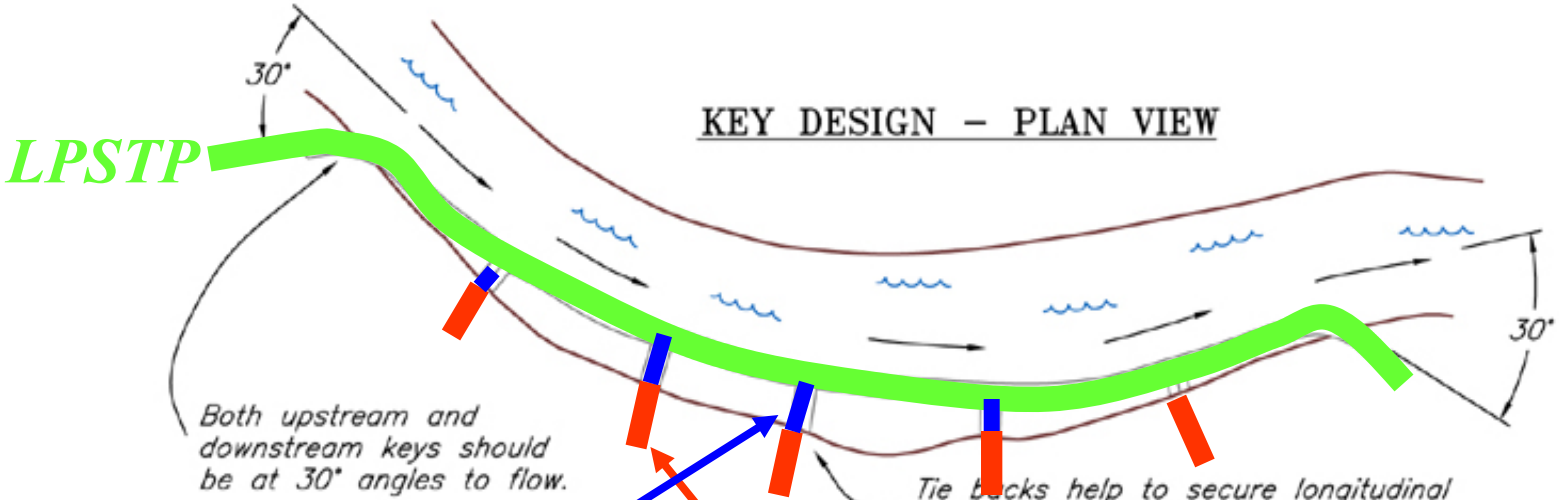
Longitudinal Peaked Stone Toe Protection (LPSTP)

Constructed of a well-graded, self-adjusting, self-filtering stone (no filter fabric underlayment)

Longitudinal Peak Stone Toe Protect (LPSTP)

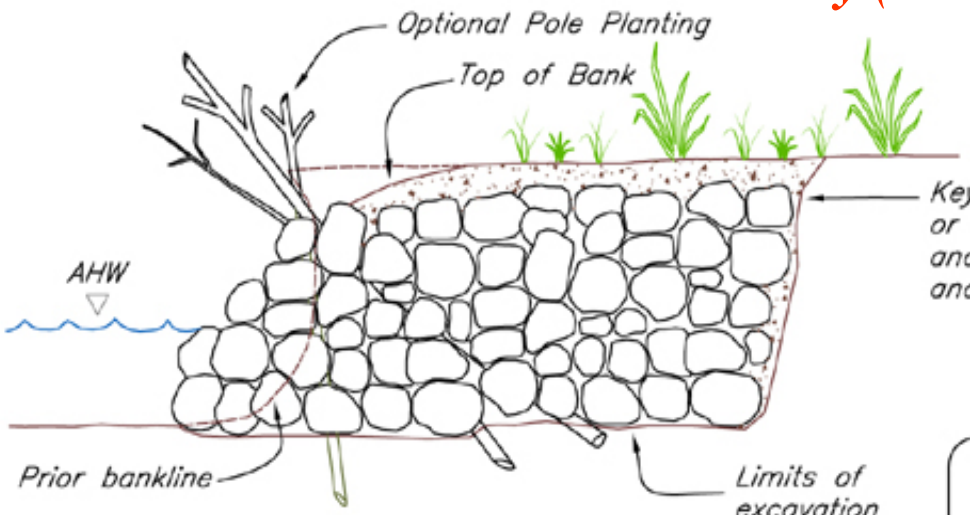






Tie-back (blue line) will connect key to LPSTP

Key (red line) will connect tie-back to bank



CROSS-SECTION OF KEY

KEY DESIGN

FILE: NRRIFF

Functions and Attributes of Longitudinal Peaked Stone Toe Protection

- **Resists** the erosive flow of the stream, only stabilizes the toe, does not protect mid and upper bank areas.
- "Smoothed" longitudinal alignment results in improved flow near toe.
- Success depends on ability of stone to launch into scour hole.
- Bank grading is not needed (existing vegetation is not disturbed).
- Weight of stone (loading of toe) might resist some shallow-fault geotechnical bank failures.
- Captures alluvium and upslope failed material on bank side of structure.
- Good where outer bank alignment makes abrupt changes, where the bank must be built back out into the stream (realignment of channel, or construction of a backfilled vegetative bench or terrace for habitat improvement and/or velocity attenuation), where a minimal continuous bank protection is needed, or where a “false bankline” is needed.
- Works well in combination with other methods (bendway weirs, or bioengineering within the stone {joint planting, Bent willow poles} or in mid to upper bank areas {live siltation, brush layering, live staking, rooted stock}).

Longitudinal Peaked Stone Toe Protection {installed 1977, picture taken Sept 2003} at Batapan Bogue, Grenada, MS.

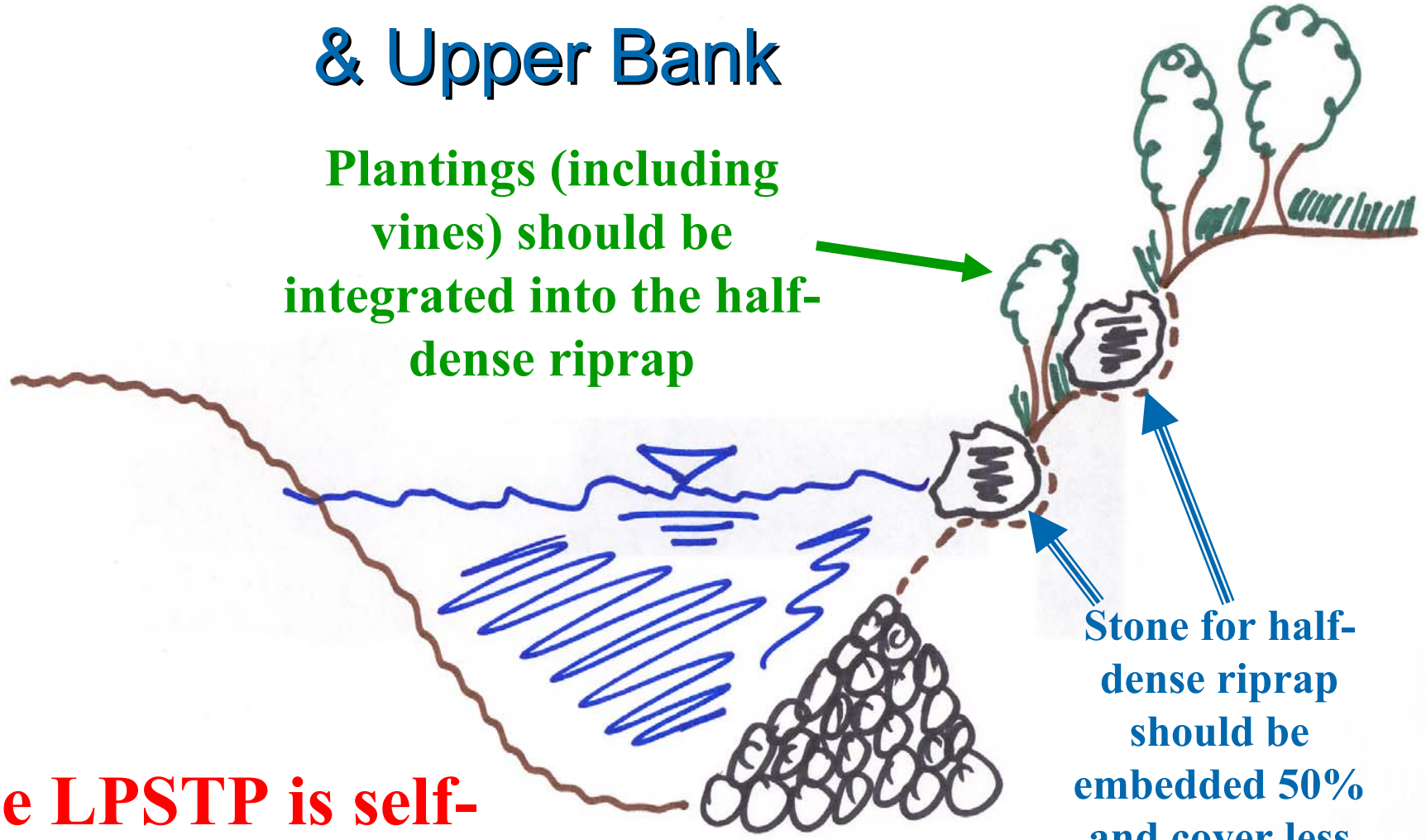
LPSTP has launched as intended (note steep angle of repose), armored the scour hole as expected, with mature vegetation assisting overall bank stability


LPSTP, tie-backs, and keys (keys are in the bank)

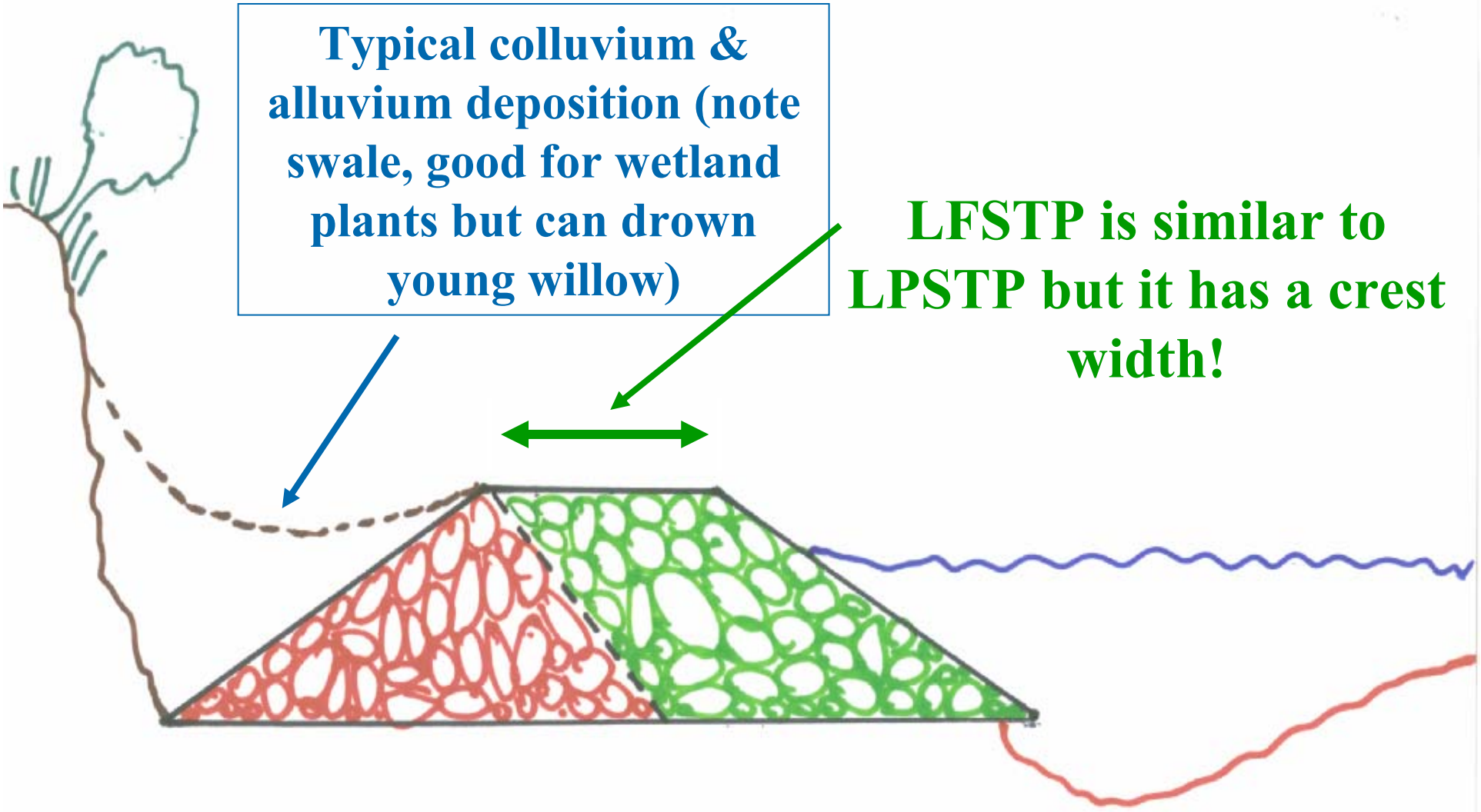

LPSTP
Oct 4, 2007 - After 6 years
robust native vegetation


LPSTP

LPSTP with Half-Dense Riprap on Mid & Upper Bank

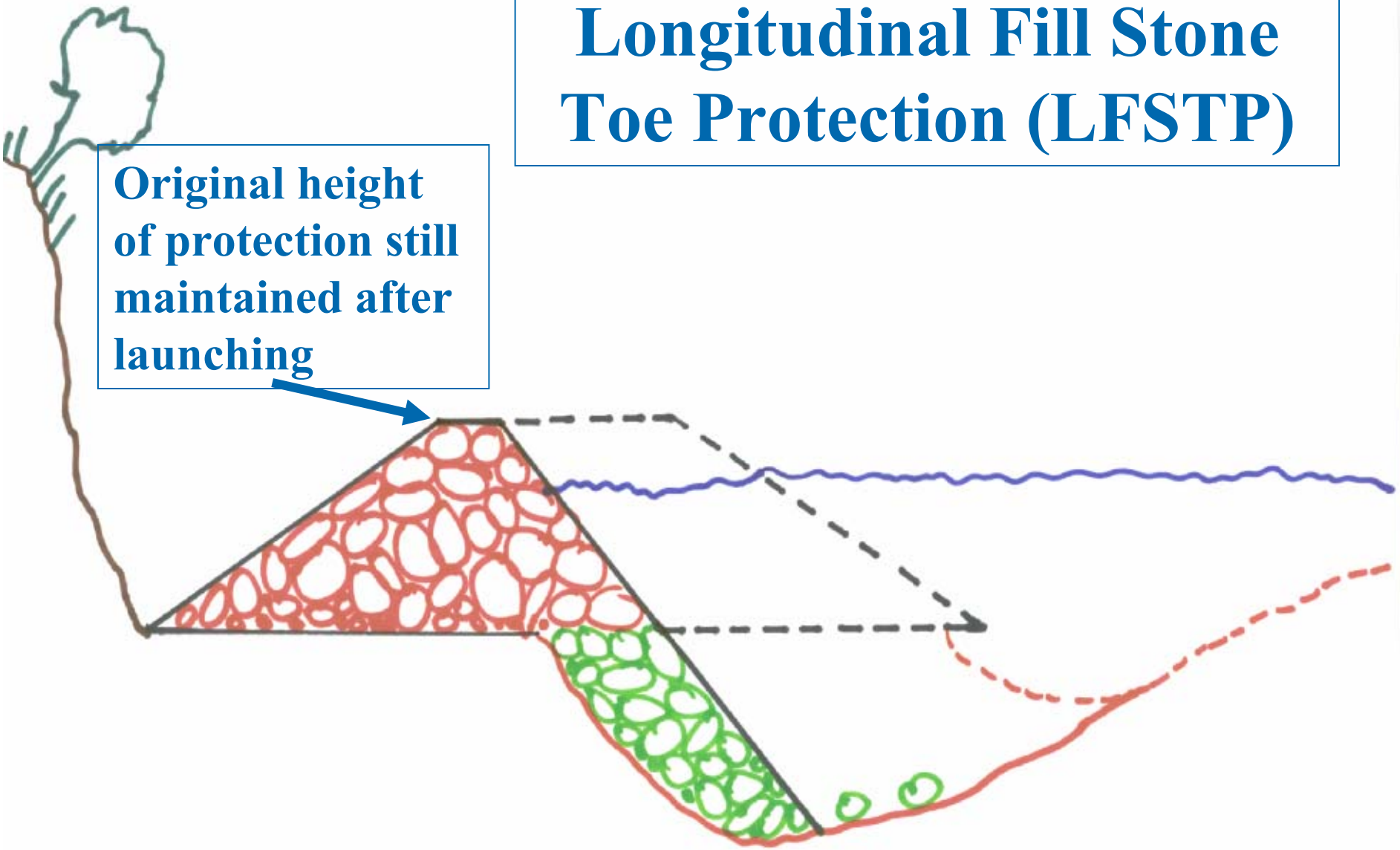


The LPSTP is self-adjusting, the Half-Dense Riprap is NOT.



Longitudinal Fill Stone Toe Protection (LFSTP)

Longitudinal Fill Stone Toe Protection (LFSTP)



Longitudinal Fill Stone Toe Protection (LFSTP) (also called a "Weighted Toe" or a "Reinforced Revetment")

- **Description -**Longitudinal Fill Stone Toe Protection (LFSTP) is similar to LPSTP, except that instead of coming to a peak, the crest has a specified width. Therefore, LFSTP has a trapezoidal cross-section as compared to the triangular cross-section of LPSTP.

- **Advantages -** Same as LPSTP. In addition, in areas of deep scour LFSTP provides sufficient rock to self-adjust (launch) into the scour hole while still maintaining its original crest height.

- **Design considerations -** The maximum scour depth should be calculated. The volume of stone required to launch into and armor the scour hole (with an appropriate margin-of-safety incorporated into the design) should be calculated. Based on these calculations, the crest width (volume of launchable stone needed from the LFSTP) can then be back-calculated.