Dutchess Area Environmental Science Advisory Network (ESAN)

Recommendations for Stream & Flood Management in Dutchess County

Compiled by the

Dutchess Area Environmental Science Advisory Network

September 2008

IMPORTANT NOTICE

April 1, 2013 - The following document "Recommendations for Stream and Flood Management in Dutchess County" is an excellent resource for any municipality in the Hudson Valley. Although this document was produced in Dutchess County, the recommendations are appropriate for all counties in the Hudson River Estuary watershed. The purpose of the recommendations is to assist communities as they consider various options in addressing flooding and potential stream management. The information provided is up-to-date and presented in a clear and concise way. **All municipal personnel involved in flood and stream management are encouraged to read this document.**

Dutchess Area Environmental Science Advisory Network (ESAN)

September 5, 2008

Dear Local Officials and Interested Parties:

The Dutchess Area Environmental Science Advisory Network (ESAN) is pleased to provide you with a copy of a new ESAN report on *Recommendations for Stream & Flood Management in Dutchess County*. Primary authors of the report are David Burns and Thomas Lynch, with input from several other authors identified in the report. The ESAN is a non-advocacy network of environmental scientists who are available to provide non-biased, scientific input on important issues surrounding the use and management of natural resources and humans' interactions with the environment.

While recognizing that protection of life and property is the highest priority during extreme weather events, the attached recommendations seek such protection while also considering long-term risk abatement, ecological habitat preservation, infrastructure investments which will reduce flooding harm, and storm pre-planning measures. Two important steps are assessing where the risks for floods are the greatest in our municipalities and where there are opportunities for mitigating potential problems. We envision the document being useful to planners, engineers, and municipal leaders seeking general guidance; these general recommendations can be adopted at the local level based on site specific knowledge in particular areas about flood histories, risks, and preparedness.

For more information on this report, or the ESAN, please contact me at 845.677.5343 or findlays@ecostudies.org. The report is available online through the Cornell Cooperative Extension Dutchess County Environment Program website at http://counties.cce.cornell.edu/dutchess/002_environment/003_our_water_resources/. ESAN members are available to present these recommendations for stream & flood management to local boards and in public forums, and welcome suggestions about other critical environmental issues that need similar analysis by the Network in the future.

Sincerely,

Dr. Stuart Findlay
Cary Institute of Ecosystem Studies *and*
Chair of the Dutchess Area ESAN

Foreword

The Dutchess Area Environmental Science Advisory Network (ESAN) is a network of local environmental scientists and professionals who work to promote the improved scientific understanding of critical environmental issues by the public and local municipal officials through the collection, analysis, sharing, and diffusion of reliable and unbiased scientific information. ESAN works to provide a forum to infuse scientific knowledge into environmental decision-making; convey ecological science to the media and the general public; and provide a collaborative network for the environmental science community. To accomplish this mission, and to be able to work with all stakeholders, ESAN is an independent, apolitical and non-advocacy organization, and will draw on all available resources to present the state of our understanding of various environmental issues.[1]

This document was generated through the collaborative efforts of the Dutchess Area ESAN and is not meant as a panacea, but rather a logical approach towards the development of solutions to the complicated and recurring problem of flooding and subsequent calls for in-stream modifications. This document is organized into a series of recommendations encompassing stream management, floodplain planning and management, and needed research, as well as a section dealing with supporting technical background material.

The ESAN would particularly like to thank lead authors David Burns and Thomas Lynch for compiling the document, and Mark Vian and the New York City Department of Environmental Protection for providing assistance. Finally, the ESAN would like to thank the following individuals for their technical review and comments: Roy Budnik, Scott Chase, Allison Chatrchyan, Stuart Findlay, Nat Gillespie, Ed Hoxsie, Carolyn Klocker, Cathy McGlynn, Kirsten Menking, Rebecca Schneider, Russell Urban-Mead, and several anonymous reviewers.

Introduction

In response to the recent flooding events and damage in Dutchess County, there has been increased concern by the general public and several courses of action proposed by various local officials. The Dutchess Area Environmental Science Advisory Network (ESAN) felt it would be beneficial to develop a set of recommendations based on existing knowledge, and sound geomorphic and ecological science, to assist communities as they consider various options and potential stream management. The

[1] For information on the ESAN, contact Dr. Stuart Findlay, Cary Institute of Ecosystem Studies, at 845 677-7600 Ext. 138, or findlays@ecostudies.org.

following recommendations and background material are intended to protect human life and critical infrastructure, while preserving the ecological functions and value of streams and floodplains.

Recommendations

These recommendations are intended to be used in conjunction with one another to form a successful flood management strategy:

Stream Management

1) **The County and/or its various municipalities should identify specific infrastructure threatened by flooding or erosion through the stream feature inventory (see page 8) and interviews with local highway superintendents**. Undersized culverts and bridges should be replaced as opportunities arise (routine replacement, FEMA funding); undersized bridges should be replaced with single span bridges where practical. For road and bridge sites identified by the highway superintendents as repeatedly damaged, proper channel dimensions based on hydraulic geometry regional curves should be utilized when making both emergency and permanent repairs. Emerging geomorphic science allows for the determination of a stream channel's cross-sectional dimension for a given drainage area. A reasonable stream slope and geometric pattern can also be determined. This approach closely replicates how a stream naturally behaves and allows it to return to a healthier and more stable condition while improving water quality and aquatic habitat. Higher peak flows due to an anticipated increase in the amount of impervious surfaces and more intense precipitation events associated with global climate change should be considered when calculating the proper size of infrastructure.

2) **Municipalities should facilitate the development of a GIS-based flood damage reporting system and database to track types of flooding, their location, and the costs associated with flood damage.** An inventory of areas likely to flood at various flows should be developed. The flood tracking database should be maintained in a uniform format by the County.

3) **Stormwater run-off and the need for infrastructure should be minimized where possible.** Where appropriate, retrofits and new construction should seek to maximize onsite infiltration and slow run-off. Wherever possible, runoff generated from impervious surfaces of rooftops, parking

lots, and walkways should be retained on-site and not routed to the roadside ditches via pipes, ditches, etc.; roadside ditches should not be scraped and left with exposed substrates. Ideally, ditches should be reconfigured to allow for regular mowing instead of scraping as the primary form of management and where scraping is necessary, a small patch of vegetated ditch should be left intact at the downstream end of the ditch to capture any eroding sediments and the ditch should be hydroseeded immediately after scraping. Finally, ditches should be disconnected from the stream channel system. Instead, infiltration basins, detention ponds or constructed wetlands should be used as ditch collection points in order to allow the water to re-infiltrate and recharge the groundwater. There are many additional proven techniques for treating, infiltrating, and storing stormwater. The Hudson River Estuary Program is a good starting point for information: http://www.dec.ny.gov/lands/5098.html.

4) **Deepening and straightening of stream channels should be avoided as these practices typically result in increased erosion and stream instability.** The slope of the stream bed is one of the factors affecting current velocity. By shortening the distance between two points while maintaining the same vertical drop, the slope and, in turn, the current velocity is increased, resulting in higher energy and more erosion downstream. Deepening the channel will cause undercutting of the steeper banks, ultimately resulting in bank failure and greater deposition of sediments at downstream locations.

5) **Removal of woody debris from the stream channel should generally be avoided.** In many Dutchess County streams, the woody debris provides prime habitat for stream fishes and aquatic invertebrates that are an important part of the food chain. Woody debris also plays a critical role in stream stability by providing roughness and capturing bedload (see page 13). Removal of woody material should only occur after consideration of the viewpoints of multiple stakeholders. Wood removal at sites posing an ***imminent threat*** to critical infrastructure, such as bridge footings and culverts, could be considered on a case-by-case basis. Such actions in regulated streams require consultation with the New York State Department of Environmental Conservation, Region 3 Permitting Office at Tel: 845-256-3054. For more information on the importance of maintaining wood in streams visit: http://anrcatalog.ucdavis.edu/Items/8157.aspx and download the report "*Maintaining Wood in Streams: A Vital Action for Fish Conservation*."

6) **Because gravel is highly mobile and provides valuable ecological habitat, its removal should generally be discouraged.** All rivers and streams, including those in Dutchess County, carry massive amounts of water and sediment during flood flows. Gravel bars form when the flood waters begin to drop, but they generally move the next time the water rises, and typically are not the root cause of increased flooding. Furthermore, the existence of a gravel bar is likely due to the stream's hydraulic characteristics, so the deposit is likely to reform if it has been excavated as a short term fix. Thus, removing a gravel bar may temporarily treat a symptom, but it doesn't solve the problem, and may cause additional bank erosion as the stream finds an alternate supply of sediment to replace what was removed. Gravel removal in regulated streams also requires permits from the New York State Department of Environmental Conservation Region 3 Permitting Office at Tel: (845)-256-3054.

Floodplain Planning and Management

1) **Municipalities should conduct a review of current floodplain ordinances and adopt revisions as appropriate**. Revisions should reflect current building trends, new technologies, compliance with regulations, and integration with broader community plans as appropriate. Municipalities should make every effort to not allow any new structures in the 100-year floodplain and should work to remove existing structures over time as opportunities arise.

2) **Communities are encouraged to participate in the development of a county-wide All Hazards Mitigation Plan.** The Disaster Mitigation Act (DMA) of 2000 resulted in significant changes in the mitigation programs offered by FEMA. Under the 2000 DMA, local communities seeking funding under the Hazard Mitigation Grant Program and Flood Mitigation Assistance Program will be required to have an All Hazards Mitigation Plan approved by FEMA to be eligible for these funds. These plans are designed to reduce repeated flood damages within a community and can improve a community's Community Rating within the National Flood Insurance Program. Several communities are currently developing plans. FEMA has Mitigation Planning Guidance Documents available at http://www.fema.gov/plan/mitplanning/index.shtm.

3) **Identify and protect flood storage areas – this includes protecting wetlands, forested riparian buffers, uplands and floodplains**. Floodplains that are connected to the stream should be protected as flood storage areas. This will help to alleviate downstream flooding by providing a

location for the floodwaters to spread out thereby reducing their velocity and destructive energy while also lowering the flood crests. Additionally, identify floodplains suitable for restoration to encourage storage of floodwaters and sediment, including berm removal, excavation of fill previously placed in the floodplain, and creation of floodplain benches. Natural impoundments including beaver ponds should also be identified and effects on storage capacity determined.

4) **Dutchess County open space funds should be utilized for a flood buyout program for repeatedly flooded properties**. To maximize the effectiveness of the funds, they could be leveraged as the local cost-share with FEMA buyout funding following a declared disaster. Once the property is purchased, any buildings should be removed and the property should be reforested and utilized for flood storage if possible.

5) **Re-establish floodplain wetlands and forests where possible.** Wetlands act as water storage locations during heavy precipitation events and release the water slowly over time. Homeowners throughout the watersheds should be encouraged to reduce lawn size by the replanting of trees since lawns provide less erosion protection and generate more runoff than forests. The Dutchess County Soil and Water District [http://dutchessswcd.org/ or 845-677-8011, ext. 3] can help homeowners obtain appropriate seedlings. The Hudson River Estuary Program's *"Trees for Tribs"* Program also provides planting materials and technical assistance to interested organizations and homeowners. Contact information is available at http://www.dec.ny.gov/lands/43668.html.

6) **Encourage landowners through multiple approaches (including tax abatements) to maintain a healthy forested riparian stream buffer.** Healthy, robust riparian zones slow erosion of stream banks, help keep streams cooler by shading, serve as an important source of organic matter for stream ecosystems, and provide habitat for wildlife. See the Cornell University, *"Stand by Your Stream"* Fact Sheet Series for more information, at http://strmhlth.cfe.cornell.edu/index.html.

Education and Outreach

1) **Dutchess County (perhaps in cooperation with Dutchess County Soil and Water Conservation District and/or Cornell Cooperative Extension Dutchess County) should**

collect information regarding flood prevention/protection. Access to current information should be established for the public at multiple repositories in Dutchess County. This would include reference materials, floodplain maps and guidance documents that should be continually updated.

2) **Municipalities should facilitate periodic notification to landowners who have special flood hazard areas (SFHA) located on their property.**

3) **Municipalities and watershed organizations should work with local and state agencies to provide periodic training sessions on flood related issues.** The audience should include municipal leaders, code enforcement staff, planning boards, landowners, realtors, highway crews, lending institutions and others.

4) **Dutchess County and municipalities should identify trained professionals to provide on-site guidance for stream modifications.** In particular, this guidance should be available immediately following floods. The existing approach to flood management of patching flood damage without stream process knowledge wastes limited funding, may leave localities more vulnerable to future floods, often makes a bad situation worse, and may create liability for already devastated communities. Minimal stream disturbance to repair immediate infrastructure problems should be the short-term goal following flooding. A long-term flood response program is needed, one that is based upon current river science and is designed to achieve channel stability while meeting human and infrastructure needs. The stream professionals will provide for rapid and coordinated expert review and guidance on a regional basis during planning, funding, permitting and construction phases of flood remediation.

5) **Dutchess County should develop a training program to include workshops, demonstrations, simulations, site visits and possibly a certification process for contractors and highway departments interested in performing natural channel design work**. The multiple agencies involved (Transportation, Health, etc.) should coordinate more closely in setting goals and laying out desirable approaches to stream management. In addition, a Stream Table can provide a great hands-on tool to illustrate how streams function and the underlying stream

morphology (*The Cornell Cooperative Extension Dutchess County Environment Program owns a stream table that is used for education and outreach*).

Research

1) **A stream feature inventory should be conducted**. The inventory provides a basic familiarity with the stream corridor and surrounding watershed and can reveal trends important to understanding the stream system. The stream feature inventory should provide the following information: a) conditions that affect hydraulic function, particularly sediment transport function such as bedrock sills and banks, cultural and natural grade controls, berms, and rip-rap or other revetment, and inadequate riparian vegetation; b) potential sources of water quality impairment in the corridor, especially eroding banks, road runoff outfalls, dump sites, and exposed septic leach fields or other hazards; c) locations of bank erosion sites that need to be documented and surveyed regularly for study of bank erosion rates; d) infrastructure, including road crossings, bridge abutments, culverts and outfalls, and utility lines or poles; e) other features such as tributary confluences, water intakes, springs, wells, diversions, and invasive species. This effort can be accomplished by trained staff utilizing a Global Positioning System (GPS) and a stream feature inventory data dictionary at a rate of approximately one mile/day.

2) **Historical records for precipitation amount, intensity and resulting stream flow response should be analyzed**. With impending climate change there is a need to document current trends (if any) in precipitation amount, intensity, timing of snowmelt and other forces potentially affecting flood frequency and magnitude. Dutchess County and the nearby Hudson Valley have several long-term weather monitoring sites suitable for analysis.

3) **Aerial photography should be geo-referenced and used to digitize stream channel alignments and overlayed to detect historical stream channel alignments.** These historical alignments can determine the frequency and magnitude of channel migrations, typically over the last 50-60 years. The DCSWCD has historical photos and additional photos can be purchased from: http://www.apfo.usda.gov/.

Background for Further Reading on Stream Functions and Hydrology

Hydrology is the study of the properties, distribution, and effects of water on the earth's surface, in the soil and underlying rocks (groundwater), and in the atmosphere. The hydrologic cycle includes all of the ways in which water cycles from the landscape (both underground and in streams and water bodies) to the atmosphere (as water vapor and clouds) and back to the landscape (as snow, rain and other forms of precipitation) (Figure 1). Understanding the hydrology within Dutchess County will; a) assist managers in land use decisions that work within the constraints of the hydrologic cycle and, b) help to avoid exacerbating flooding or further water quality impairment.

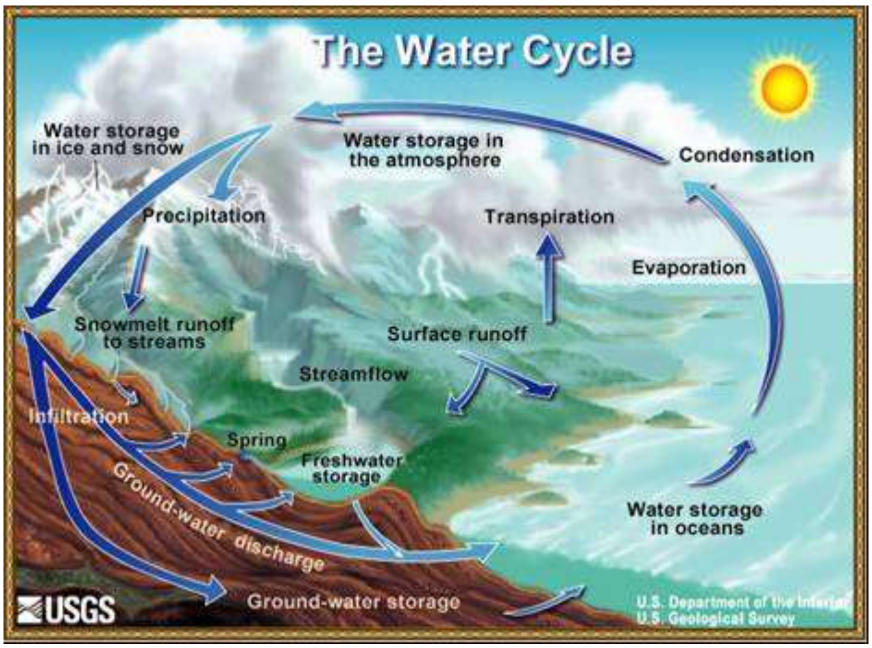

Figure 1. The Hydrologic (water) Cycle. Source: http://ga.water.usgs.gov/edu/watercyclesummary.html.

Water flowing through the streams and rivers in the County reflects the integrated effects of all watershed characteristics that influence the hydrologic cycle. Characteristics include climate of the drainage basin (type and distribution patterns of precipitation and temperature regime), geology and land use/cover (permeable or impermeable surfaces and materials affecting timing and amount of infiltration and runoff, and human-built drainage systems), and vegetation (uptake of water by plants, protection against erosion, and influence on infiltration rates). These factors affect timing and amount of stream flow, referred to as the stream's hydrologic regime. For example, a stream with an urbanized watershed where water runs off hardened surfaces directly into the stream will have higher peak discharges following storms than a watershed of similar size which is predominantly forested and allows a higher percentage of rain water to infiltrate into the ground, releasing the water slowly over time. Understanding the hydrology of a drainage basin is important to the stream manager because stream flow patterns affect aquatic habitat, flood behavior, recreational use, and water supply and quality.

There are two general categories of stream flow between which streams fluctuate over time: storm flow (also called flood flow) and base flow. Storm flow fills the stream channel in direct response to precipitation (rain or snow) or snowmelt, whereas base flow originates primarily from groundwater and sustains stream flow between storms and during subfreezing or drought periods. A large portion of storm flow is made up of overland flow, runoff that occurs over and just below the soil surface during a rain or snowmelt event. This surface runoff appears in the stream relatively quickly and recedes soon after the event. In general, higher stream flows are more common during spring due to rain, snowmelt and combination events, and during hurricane season in the fall. During summer months, actively growing vegetation on the landscape draws vast amounts of water from the soil through evapotranspiration. This demand for groundwater by vegetation can significantly delay and reduce the amount of runoff reaching streams during a rain storm.

Base flow consists of water that seeps or rises from the ground and sustains stream flow during dry periods and between storm flows. The source of base flow is groundwater that flows through unsaturated and saturated soils and cracks or layers in bedrock adjacent to the stream. In this way, streams can sustain flow for weeks or months between precipitation events and through the winter when the ground surface and all precipitation is otherwise frozen. Stable-temperature groundwater inputs keep stream water warmer than the air in winter and cooler than the air in summer – this enables fish and other aquatic life to survive in streams year-round. For these reasons it is important to protect these groundwater inputs.

Hydrologists use a hydrograph, which is a graph showing the volume of flow (discharge) in a stream over time, to analyze flow patterns and trends such as flood frequency or drought cycles. A stream gage, a device that primarily measures water level, is necessary to monitor stream discharge and develop a hydrograph. The United States Geological Survey (USGS) maintains two continuously recording stream gages on streams that flow through Dutchess County: Wappinger (established in 1928 with some earlier data, drainage area of 181 mi^2, USGS ID# 01372500) and Tenmile (established in 1938, drainage area of 203 mi^2, USGS ID# 01200000). Prior to 1996, a crest stage gage was maintained at Lexington starting in 1929. All gage information is available online at the USGS website:

1) for the Wappinger Creek at (http://waterdata.usgs.gov/ny/nwis/uv/?site_no=01372500&PARAmeter_cd=00065,00060) and
2) for the Tenmile River at Gaylordsville, CT at

(http://waterdata.usgs.gov/ny/nwis/uv/?site_no=01200000&PARAmeter_cd=00065,00060).

3) In addition, the Cary Institute of Ecosystem Studies has operated a gage on the East Branch of the Wappinger Creek near Millbrook, NY; and
4) Faculty of Vassar College have recently installed a gage on the Casperkill Creek in Poughkeepsie, NY.
5) There are also several historic gages with varying levels of information. They can be accessed at: http://waterdata.usgs.gov/ny/nwis/nwis.

These stream gages measure the stage, or height, of the water surface at a specific location, typically updating the measurement every 15 minutes. By knowing the stage we can calculate the magnitude of the discharge, or volume of water flowing by that point, using the relationship between stage and discharge called a rating curve. Using this rating curve, the volume of flow in the stream at the gage location can be determined at any time just by knowing the current stage. Discharge can also be calculated for any other stage of interest. Additionally, we can use the historic record of constantly changing stage values to construct a picture of stream response to rain storms, snow melt or extended periods of drought, and to analyze seasonal patterns or flood characteristics.

The Wappinger gage at Red Oaks Mill has a period of record covering almost 80 years. Data gathered over long time periods can be analyzed to see seasonal trends, changes from year to year, or changes in long-term averages for the entire length (period) of the gage record. The gages provide information that can be analyzed to determine whether or not recent flood damage might be due to increased intensity of storm events, ongoing development in watersheds and its attendant change in hydrology, or a combination of these and other factors. The hydrograph below of the April 2007 illustrates flood flows that caused damage in Dutchess County (Figure 2).

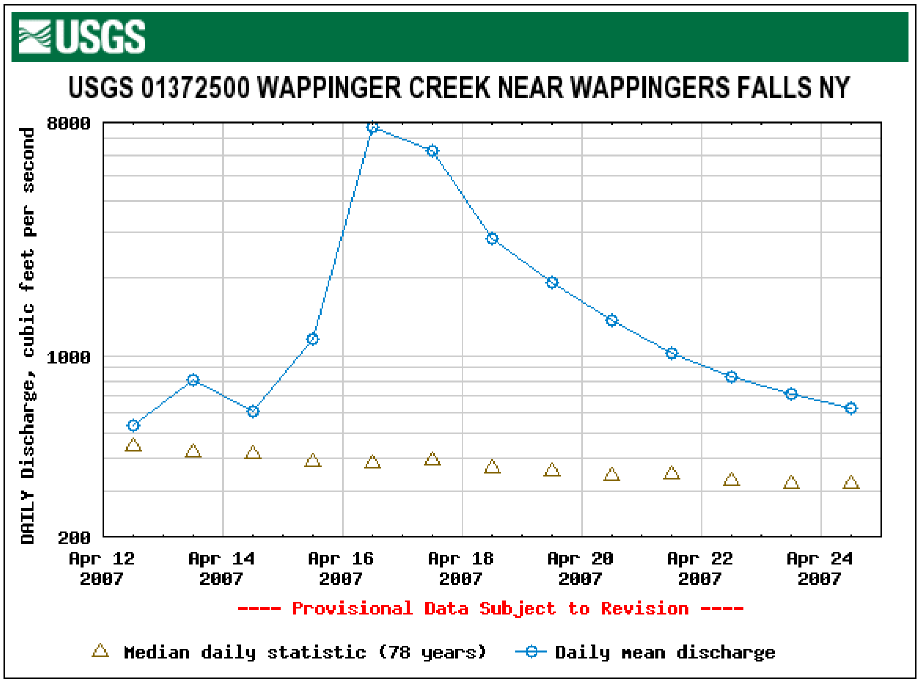

Figure 2. Daily average flow during the flood of April 2007 on Wappinger Creek.

The Wappinger Creek rose from a daily average of 613 cubic feet per second (CFS) to 7,640 CFS in approximately 48 hours. This event was not unique in that this daily average was exceeded by higher flows (and flooding) in 1938, 1949, 1955, 1973 and 1984 (Figure 3). Following 1984 there was a period of relatively lower flows (perhaps due to lower average precipitation) until 2006 and 2007. At the same time that Dutchess County was experiencing lower precipitation and stream flows, there was a dramatic increase in development with its attendant increase in impervious surface. Some of this development unfortunately took place in floodplains.

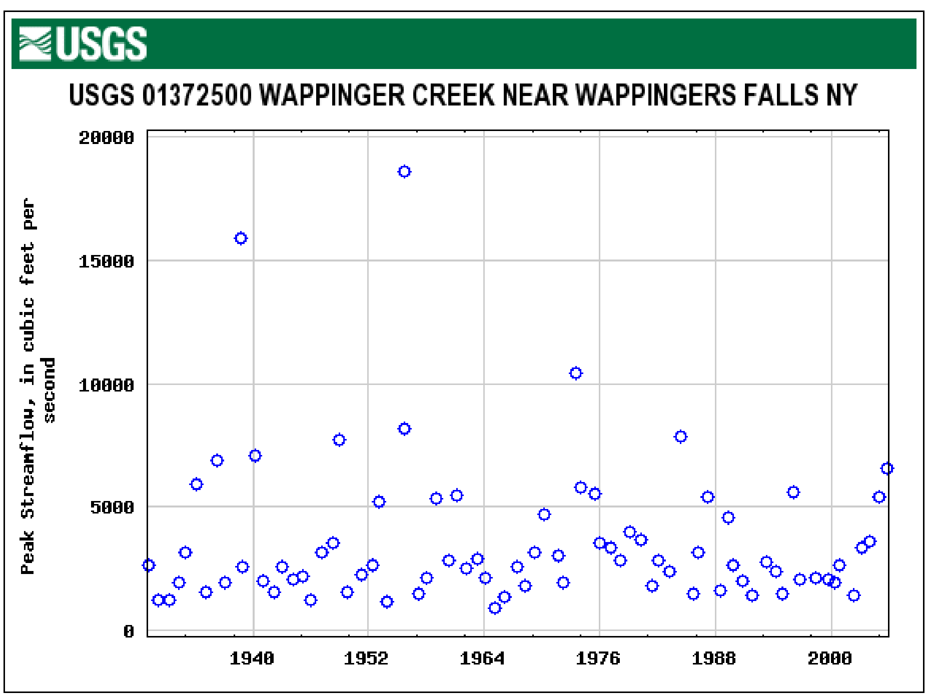

Figure 3. Peak stream flows on Wappinger Creek for the period 1929 to 2006.

Another approach to interpreting flooding magnitudes and patterns uses analysis of flood frequency distributions that indicate the probability of floods of different magnitudes. In other words, how likely is it that a flood of a given size will occur in any one year, or over a period of years? For example, each year it is possible, but not likely, that we will see a large flood (a flood so large it might recur once every 100 years on average) and almost a certainty we will see a small one (1-2 year recurrence). This value is actually calculated as a percent likelihood, but is most often converted to a number of years (e.g. the 100-year flood). This number of years is called the "recurrence interval" (RI) or "return period" of an event of certain size. For example, the flood with a 20% chance of occurring or being exceeded in any single year corresponds to what is commonly referred to as a "5-year flood" (each of these values is the inverse of the other - just divide 1 by % probability to get RI in years, or divide 1 by RI in years to get % probability). This simply means that on average, for the period of record, a flood of this magnitude will occur about once every 5 years. This probability remains the same year to year over time for a particular size flood to occur, although the actual distribution of flood events in time is not regular. Many years may go by without a certain magnitude flood or a flood of a particular magnitude may occur several times in a single year. For example, we might expect to see about 2 "5-year floods" for every 10 years of record, but any particular 10 year period may contain more or fewer floods of this size.

Introduction to Stream Processes

Living near a stream or river involves both benefits and risks; to enjoy the benefits, the risks are accepted. Both the pleasures as well as the dangers of living near streams stem in part from their ever-changing nature. Icy spring flood-flows are exciting and beautiful until they flow over their banks and run across yards into the basement windows or suddenly tear out a stream bank and begin flowing down the only access road to homes. For many reasons, the relatively flat land in the

Figure 4. The Fishkill Creek in Beacon, NY. *Photo courtesy of Dave Burns***.**

floodplain of a stream may be an inviting place to build a home or road –in fact, it may be the only place. However, long-time residents of floodplains know only too well that it is not a matter of *if* they will see floodwaters, but of *when*.

Even though streams are dynamic systems, their changes are predictable based on season or storm event. If we take the time to observe them carefully, we can begin to understand patterns of stream behavior and, more importantly, learn how to make proximity to streams and rivers more beneficial and less risky.

Streams drain water from the landscape, but they also carry bedload - gravel, cobble, and even boulders, that have been eroded from streambeds and banks upstream. During a storm event the water begins to rise in the stream channel. At some point the force of the water begins to move the material on the bottom of the channel. The gravel, cobble and boulders tumble against each other as they are pushed downstream by the force of the floodwaters and the stream banks vibrate with the force of these collisions. As the storm waters recede, the force decreases and the gravel and cobble stop moving.

The shape and size of a stream channel are determined by the amount of water and bedload it carries. Within certain limits, the form (morphology) of a stream is self-adjusting, self-stabilizing and self-sustaining. If stream managers alter the ability of a stream to self-regulate, the stream may remain unstable for a long time as its channel erodes and meanders in an attempt to reach a new state of stability.

Over the period since the last glaciers retreated some 12,000 years ago, Dutchess County streams have been shaped by regional conditions. Climate, topography, geology and vegetation of a region usually change only very slowly over time. Therefore the amount of water moving through a stream from year to year, or streamflow regime, is variable but somewhat predictable within broad limits at any given location.[2] This stream flow regime, in turn, defines when and how much bedload will be moving through the stream channel from year to year. Together, the movement of water and bedload carve the form of the stream channel into the landscape. In the absence of human influence, streamflow regime tends to be fairly consistent year after year which provides for relatively slow changes in stream channels. Over the 120 centuries since glaciers covered the region, the stream channel and the landscape conditions evolved in a dynamic balance.

However, as human activity altered the landscape (e.g. clearing forests for pastures or straightening stream channels to avoid having to build bridges), the balance between streams and their landscapes was changed. Some parts of streams seem to change form very quickly, while others parts remain much the

[2] One exception is when the vegetation changes quickly, such as can happen during forest fires, volcanic eruptions or even rapid commercial or residential development.

same year after year, even after great floods. Why is this? Streams that are in dynamic balance with their landscapes develop forms that can pass the water and bedload associated with both small and large floods, often regaining their previous forms (although specific locations may shift) after the flood passes. This is the definition of stability. In many situations, however, stream reaches become unstable when some human activity on the watershed has upset that balance and altered the stream's ability to move its water and bedload effectively. Due to the increase in impervious surfaces associated with development, increase in ditches and the drainage network, and /or increased erosion from soils in the watershed, the volume of water or sediment that the stream must carry increases. To compensate, the stream must widen or deepen its channel.

The potential force generated by water that moves its bedload is determined by its slope and its depth: the steeper and deeper the stream, the more force it exerts. For example, if changes made to a stable reach of stream reduce its slope and/or depth, the stream may not be able to effectively move the bedload supplied to it from upstream. The likely result will be that the material will be deposited in that section and the streambed will start building up or aggrading. This can often be seen upstream of bridges.

Changes in the length of a stream also affect its ability to move its bedload. When a stream is straightened it becomes shorter; this means that its slope is increased resulting in an increase in its potential force to move its bedload. Road encroachment narrows and deepens many streams which increases potential force to the point of stream bed degradation. In these cases streams become deeply incised within their valleys. Both aggradation and degradation result in a stream reach that has become unstable. Rapid bank erosion, as well as impairment of water quality and stream health, is likely to occur. Unfortunately these local changes can spread upstream and downstream causing great lengths of stream to become unstable.

The stream pattern we now see throughout Dutchess County is the result of millions of years of landscape evolution. Fractured bedrock was chiseled repeatedly by rivers and then glaciers and then rivers again. As glacial ages came and went, the valleys were eroded out of the mountains and their remnants washed out to sea. As the steeper streams coming off the mountainsides flowed into more gently sloped channels running through the main valley, the streams became wider and shallower. The valleys developed floodplains and the streams flowing through them became less steep. Stream pattern and shape progressively adjusted to assume new stable forms in balance with the new landscape. This adjustment often causes the river to meander over its floodplain. As time progresses, the meanders will increase in amplitude as erosion occurs on the outside of bends and deposition takes place on the inside. Streams, particularly in low gradient floodplains, are constantly changing the location of their channels. This is completely natural and should be anticipated. Failure to give the stream “room to roam” will produce ongoing problems that will require large and reoccurring expenditures over time.

As the earth’s climate warmed, grasses and trees returned to the floodplains and the conditions that determined the balance between stream shape and the landscape changed once again. Stream banks that had a dense network of tree and shrub roots anchoring the soil were better able to resist the erosive power of flood flows and consequently a new stable stream form emerged; a new balance was struck between resistive and erosive forces. Dense mats of woody roots are essential for maintaining stable stream banks. If streamside trees and shrubs are removed, banks will often begin to erode resulting in water quality impairment or loss of habitat.

Summary

The hydrology of Dutchess County affects how the stream corridor should be managed. Flood history and dynamics play a large role in determining the shape, or morphology, of stream channels and the hazards associated with land uses on the banks and in the floodplain. For example, the number of applications for stream disturbance permits (from NYS DEC) typically increases following floods as landowners and municipalities attempt to repair damage caused by flooding. If we want to minimize flooding impacts on property and infrastructure, it is critical that we understand that flooding of variable severity is inevitable and we should plan accordingly. Historically, this “planning” has emphasized constraining and controlling stream channels. Results of this type of planning are often costly and sometimes catastrophic, such as when berms or levees fail or bridges wash out. These “control” approaches typically result in ongoing maintenance costs that can draw valuable community resources away from other projects. With a better understanding of stream and floodplain processes, we can reduce these costs.

References/Resources for Further Information

The Center for Watershed Protection, Aquafor Beech Limited, & Step by Step. 1999. *Impact Assessment of Instream Management Practices on Channel Morphology*. Waterbury, VT: Vermont Geological Survey Agency of Natural Resources Department of Environmental Conservation. Available online at: http://www.anr.state.vt.us/DEC/GEO/watheda.htm.

Chemung County Soil & Water Conservation District. 2006. *Stream Processes: A Guide to Living in Harmony with Streams*. Available online at: http://www.chemungcountyswcd.com/PDF/Soil%20&%20Water%20Guide.pdf

Cornell Cooperative Extension of Ulster County. 2007. Phase 3 Stream Management Practice Assessment Case Study: Gravel Mining to Alleviate Flooding in Phoenicia In the *Upper Esopus Creek Management Plan Volume III: Watershed and Stream Characterization, DRAFT 01/25/07,* pg 156-165. Kingston, NY: Cornell Cooperative Extension of Ulster County. Available online at: http://www.esopuscreek.org/documents.html.

Cornell Cooperative Extension of Ulster County. 2007. *Upper Esopus Creek Management Plan*. Kingston, NY: Cornell Cooperative Extension of Ulster County. Available online at: http://www.esopuscreek.org/documents.html.

Federal Emergency Management Agency (FEMA). Hazard Mitigation Planning. http://www.fema.gov/plan/mitplanning/index.shtm.

Green County Soil and Water Conservation District. 2003. *Batavia-Kill Stream Management Plan*. Cairo, NY: Green County Soil and Water Conservation District. Available online at: http://www.gcswcd.com/stream/bataviakill/smp/.

Greene County Soil and Water Conservation District. 2007. *Schoharie Creek Management Plan*. Cairo, NY: Green County Soil and Water Conservation District. Available online at: http://www.gcswcd.com/stream/schoharie-eastkill/SchoharieCreekSMP/.

Journal of the American Water Resources Association. February 2007 - Vol. 43 Issue 1 Page 1-280. *Special Issue on Ecology and Hydrology of Headwater Streams* (Vol. 43 Issue 1 Page 1-280). Available online at: http://www.blackwell-synergy.com/toc/jawr/43/1.

Meyers, Judy L, et al. 2007. *Where Rivers are Born: The Scientific Imperative for Defending Small Streams and Wetlands*. American Rivers and the Sierra Club. Washington, DC. Available online at: http://www.americanrivers.org/.

NYS Department of Environmental Conservation (DEC), Hudson River Estuary Program. Watersheds and Stream Programs for the Hudson River Estuary. http://www.dec.ny.gov/lands/5098.html.

NYS Department of Environmental Conservation (DEC), Region 3 Permitting Office. Permits and Licenses. http://www.dec.ny.gov/63.html.

New York State Wetlands Forum. http://www.wetlandsforum.org/.

Opperman, Jeff. 2006. *Maintaining Wood in Streams: A Vital Action for Fish Conservation*. University of California, Department of Agriculture and Natural Resources. Available online at: http://anrcatalog.ucdavis.edu/Items/8157.aspx.

Schneider, Rebecca. 1998. *Stand By Your Stream Guidance Fact Sheets*. Cornell University Cooperative Extension. Available online at: http://www.dnr.cornell.edu/ext/wetlands/streams/sbys.htm.

Strayer, Dave. 2007. "Flooding is caused by more than just rainfall." Poughkeepsie Journal, April 22. Available online at: http://www.fishkillcreekwatershed.org/media/PoJo_04_22_07.htm.

Upper Susquehanna Coalition. Natural Stream Design: http://www.u-s-c.org/html/NSD.htm.

US Department of Agriculture (USDA). Aerial Photography Field Office. Order Aerial Imagery online at: http://www.apfo.usda.gov/.

USDA, National Resources Conservation Service. 1998. National Engineering Handbook: Stream Corridor Restoration; Principles, Practices and Processes. Washington, DC: USDA. Available online at: http://www.nrcs.usda.gov/technical/stream_restoration/.

US Geological Survey. National Water Information System. Stream Gage Data available online at: http://ny.water.usgs.gov/.

Vermont Department of Environmental Conservation. River Management Program, River Corridor Protection and Management Fact Sheet. Available online at: http://www.anr.state.vt.us/dec/waterq/rivers/docs/rv_rcprotectmanagefactsheet.pdf

Vermont Department of Environmental Conservation, Water Quality Division. 1999. River Gravel Excavation: When, Where, and Why it Should or Should Not Be Done. http://www.vtwaterquality.org/rivers/htm/rv_management.htm#analyzing.

Vermont Department of Environmental Conservation. River Management Program, Clean and Clear. http://www.anr.state.vt.us/cleanandclear/rivstrm.htm.

Water Words that Work (Effective Communication). http://waterwordsthatwork.com/

West Virginia Conservation Agency. 2005. West Virginia Statewide Flood Protection Plan (Executive Summary and Appendix H: Dredging and Stream Channel Restoration). http://www.wvca.us/flood/ (accessed April 26, 2007).