Post-Flood Emergency Stream Intervention

Before repairs

After repairs

Training Manual

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Delaware County Soil and Water Conservation District
Delaware County Planning Department

In cooperation with:
The New York City Department of Environmental Protection,
Bureau of Water Supply, Stream Management Program

With permission, this document was edited and expanded for state-wide application by:
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~ I. Foreword~

After a flood event, streams may look unraveled with gravel and debris strewn all over the place. Our first reaction is to put everything back to the way it was and maybe do some extra work. Typically this extra work consists of widening and dredging the channel to increase capacity. While the pressure to get into the area and move material to protect the public is understood, it is important to understand how the stream has changed as a result of the flood. Quick assessment can give the contractor or highway superintendent valuable information that will help determine how much work needs to be done and how the problem can be best resolved. Because the damage is widespread, the objective is to do the most good with the least effort. This is accomplished by addressing the most pressing problem areas and phasing the work so more complex work is left to the later stage of flood recovery. The process is akin to First Aid where the first responder must assess the scene, decide who the priority for treatment is and only do what is required to stabilize the situation until additional assistance arrives. This training material will provide information on how to assess the situation, decide where to work and what the right approach to be under and emergency response condition.

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~ II. Introduction to Streams ~

Understanding the stream mechanics is important when conducting stream management practices because there can be an impact upstream and downstream of your project site. In the course of transporting water from the tops of mountains to the ocean, streams also transport sediment scoured from their own beds and banks. Streams and rivers are never constant, and it is important to understand how and why streams change. An understanding of how streams work is essential when approaching stream management at any level. This section is intended to serve as an overview of stream science, as well as its relation to management practices past and present.

Watershed

Streams reflect the regional climate, biology and geology. The water flowing through the drainage system reflects the watershed characteristics that influence the hydrologic cycle (**Figure 2.1**). These characteristics include the climate of the drainage basin, geology, topography, land use/land cover, infrastructure and vegetation.

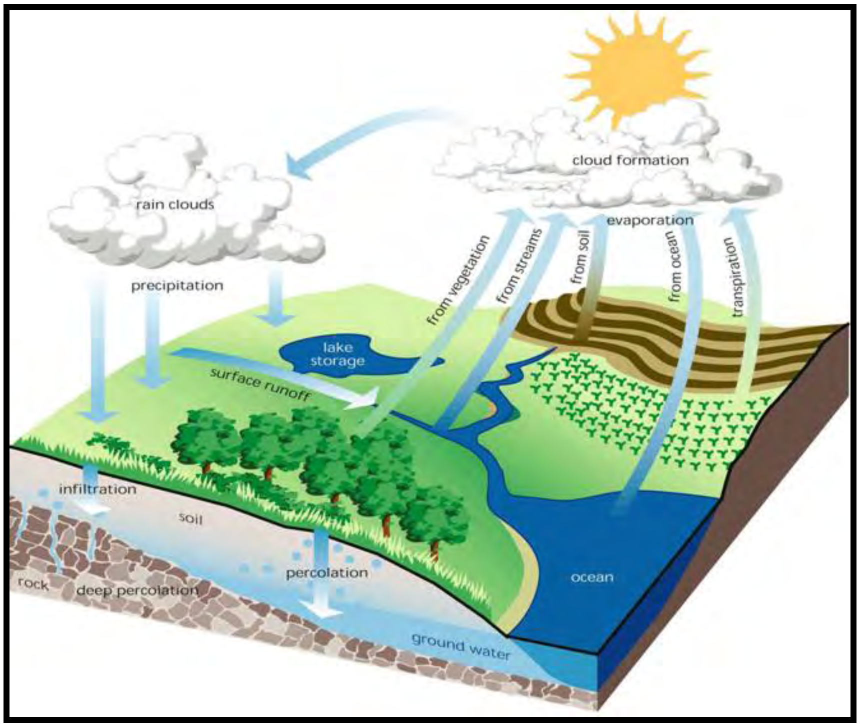

Figure 2.1 The Hydrologic Cycle (USDA-NRCS, 1998)

Drainage area or watershed size is part of the physical characteristics of the watershed. The size of the watershed is defined by the amount of land area that has the potential to drain stormwater runoff into the stream network. The shape of the watershed also plays a key role in the stream network; if two watersheds have the same size but different shapes, they will have different peak discharges and times of concentration resulting from the same storm event. Travel time for runoff to move through the stream network varies with watershed topography. A steep watershed typically exhibits a higher peak discharge than a flatter watershed. Climate, geology, topography, vegetation, etc. affect timing and amount of stream flow, referred to as the stream's hydrologic regime. **Figure 2.2** is a drainage area map for Chambers Hollow in the Town of Hamden, produced using StreamStats; a water resource program developed by the United States Geological Survey (USGS).

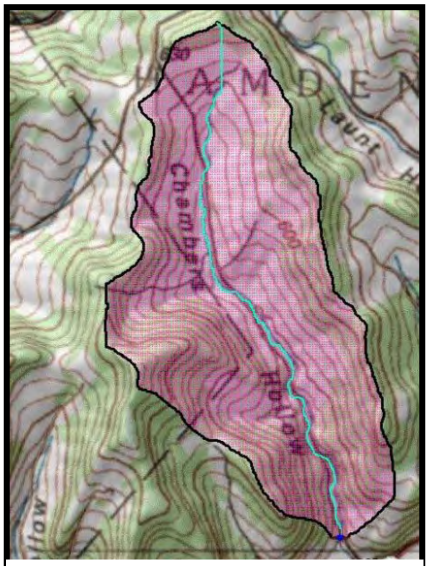

Figure 2.2 Drainage area map from USGS StreamStat

Stream Flow

Streams flow at many different levels over the course of a year, ranging from the small trickle of a dry summer to the raging torrent associated with the rapid thaw of a thick snowpack. There are essentially three basic types of stream flow: base flow, storm flow, and flood flow. Base flow sustains stream flow between storms, during subfreezing, or during drought periods and is largely the water flowing into the stream from groundwater springs and seeps. Storm flow, also known as bank full flow, appears in the channel in direct response to precipitation and/or snowmelt. Flood flow is water that gets outside of the stream banks. **Figure 2.3** illustrates the basic stream flow patterns in a typical stream cross section.

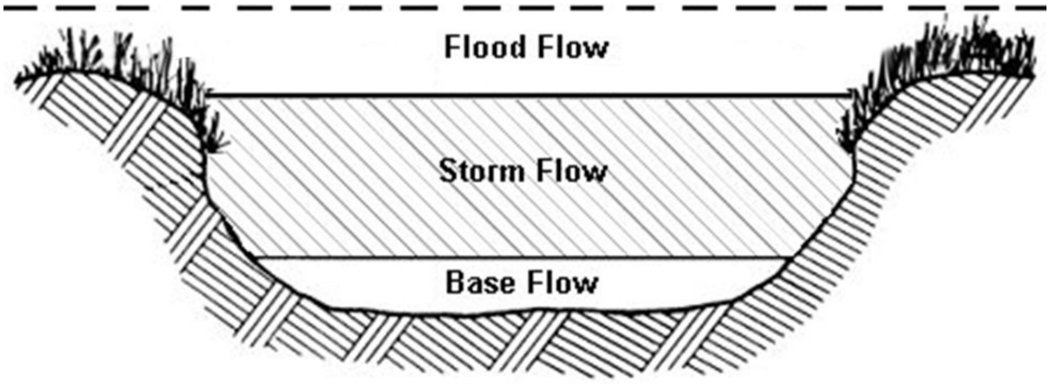

Figure 2.3 Illustration of a typical stream cross section showing stream flows.

A daily mean discharge curve for the stream gage at Margaretville, NY for the period from September 2006 to August 2007 is provided below in **Figure 2.4**. Note that the brown line indicates the average daily mean discharge (stream flow measured in cubic feet per second) for the 69 years of gage records, and the light blue line shows the daily mean discharge for the 2006-2007 period. United States Geological Survey (USGS)[1] graph also shows that most of the runoff for the watershed occurs between mid March and mid May, with a second period of runoff in the fall in November and December. This is a period when the ground is often bare and evapo-transpiration from plants is low. The precipitation that falls during this period quickly runs off and the streams are full.

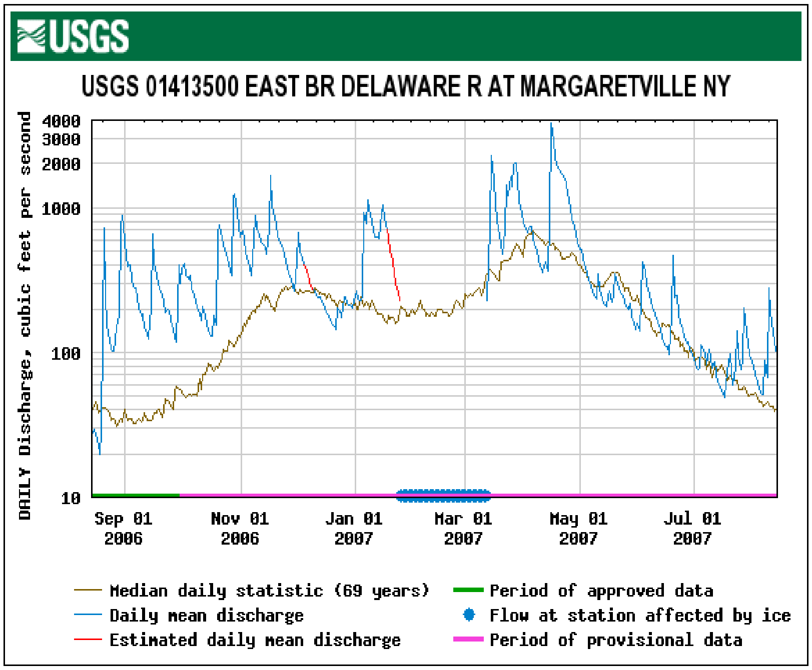

Figure 2.4 Daily Mean Discharge Curve

Stream Stability

The definition of a stable stream is: “The tendency of a stream to maintain its cross-section, plan form and profile geometry over time, effectively transporting its water and sediment supply without aggrading (building up), degrading (down cutting), or adjusting laterally (eroding its banks).” (Rosgen, 1996)

Streams that are in balance with their landscape adapt a form that can pass the water and sediment through both small and large floods, regaining their previous form after the flood passes. In many situations, however, stream reaches become unstable when some management activity has upset that balance, altering the stream’s ability to move its water and sediment effectively.

The form of a stream that is considered “stable” varies with topography. When it is in balance with mountainous terrain, a stable stream will look different than one that is in balance with rolling hills or broad floodplains. Stable streams are less likely to experience bank erosion, water quality and habitat problems. A number of factors can change the stability of streams such as changes in flow input, sediment, and land use. Channelization of the stream and placement of berms, culverts and bridges can also have a negative impact on stream stability.

Sediment Balance

Sediment discharge has long been recognized as one of the primary variables that determine the characteristics of a stream. **Figure 2.5** below illustrates the relationship between a set of four primary physical variables (sediment size, sediment load, stream discharge and stream slope) and two opposing processes (stream bed aggradation and degradation) that determine stream

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[1] USGS stream gage information can be found on their website http://nwis.waterdata.usgs.gov/ny/nwis/rt

sediment and channel characteristics and balance. The figure suggests that a change in one of four physical variables will trigger a response in the two process variables. This in turn creates changes in stream characteristics. See **Figure 2.5a** and **Figure 2.5b**. Streams are said to be in equilibrium when the volume of water is enough to transport the available sediment without building up in the channel (also known as aggradations) or cutting down the channel bed (known as degradation). Streams will adjust their shape, size, and slope in order to transport the sediment.

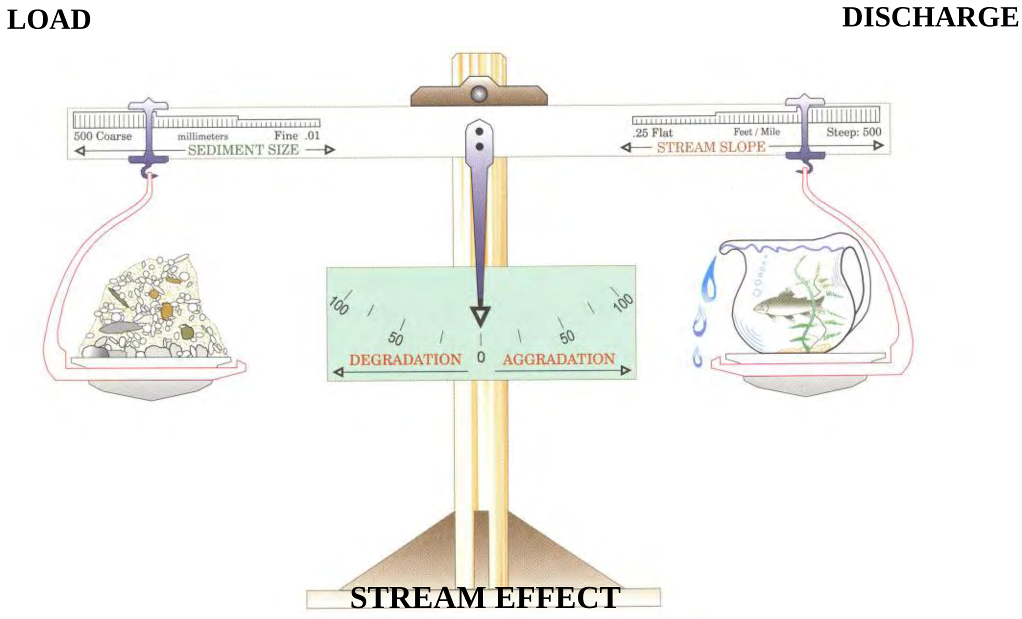


Figure 2.5 Sediment Balance (Sediment LOAD) x (Sediment SIZE) is proportional to (Stream SLOPE) x (Stream DISCHARGE) **(Rosgen, 1996)**

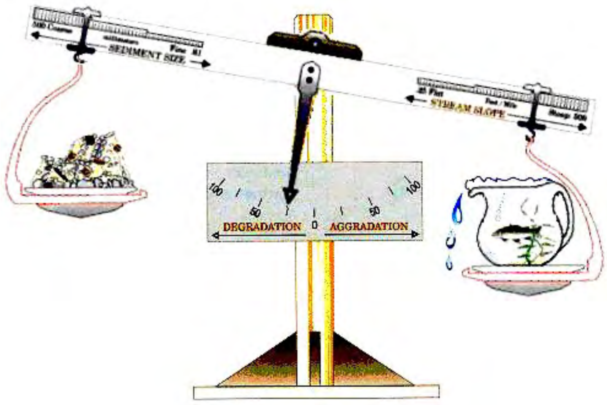


Figure 2.5a If the supply of sediment decreases or the supply of water increases, the stream will begin to erode the stream bed or degrade. (After Rosgen, 1996)

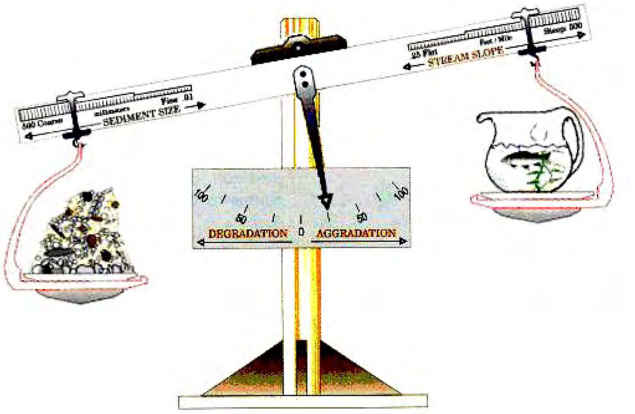


Figure 2.5b If the supply of sediment increases or the supply of water decreases, the stream will begin to fill in with gravel or aggrade. (After Rosgen, 1996)

Stream Features

The features of a stream are described in terms of their planform dimensions, their longitudinal dimensions, and their cross-sectional dimension.

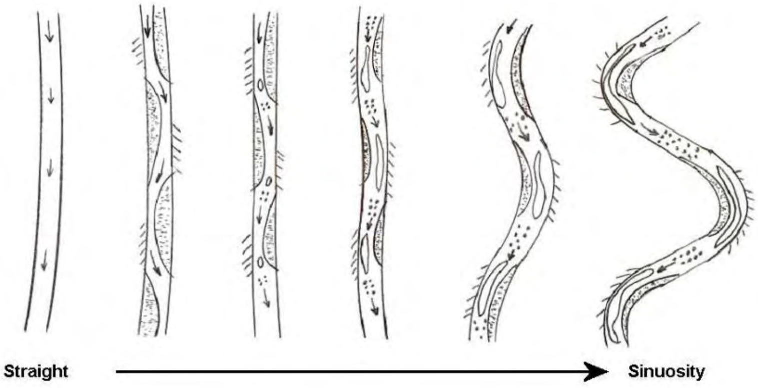


Figure 2.6 Planform of a Stream with Increasing Sinuosity (After Keller, 1972)

The overhead or "planform" view of the stream focuses on the path that the stream follows within its valley (**Figure 2.6**). Stream managers speak of a stream's sinuosity as they describe the coverage the stream meanders across the valley. Sinuosity is related to slope and energy. A stream that has sinuosity has a longer distance than a stream that is straight. The associated elevations will also differ whereas the greater the sinuosity the lower the average slope. The sinuosity of a stream is generally greater at the lower end of the valley closer to the mouth of the watershed.

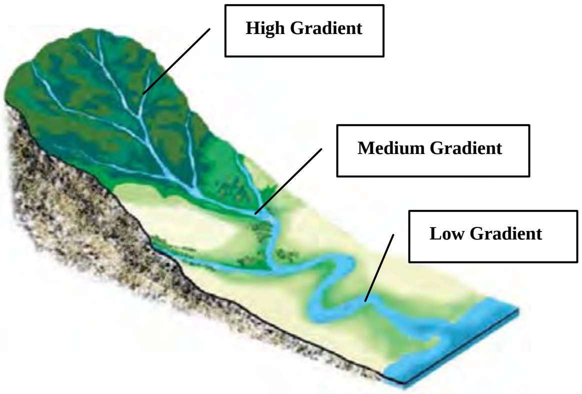


Figure 2.7 Stream's slope from high gradient to low

Longitudinal dimensions of a stream are used to describe how the stream changes from the top of the watershed to the mouth of the stream. The most important factor is the slope of the stream. Slope is a critical contributor to the energy of the stream. The energy of water flowing down a slope is needed to move sediment. A stream's slope can vary from high gradient (slope greater than 4%) to medium gradient (2%-4%) to low gradient (less than 2%)(see **Figure 2.7**). The slope of the stream typically is greatest at the top of the watershed (high gradient stream) and gradually declines as the stream flows down the valley (medium gradient stream) and makes its way to the bottom of the watershed (low gradient streams).

In terms of its cross-sectional dimension, a stream has a primary channel that conveys most of the flow throughout the year. Secondary conveyance of flow is the floodplain. Floodplains are the flat area of a stream system located above the top of the stream bank that is inundated with slower flowing water during and following flood flow events. Flood flows in some streams sections may not rise over the top of the banks and therefore may lack or are disconnected from their historic floodplain. Such stream channels are commonly called entrenched channels (**Figure 2.8**). Maximum depth is the distance from the top of the water at bank full elevation to the deepest part of the channel. If at twice maximum depth the stream cannot access it's floodplain it is considered to be entrenched.

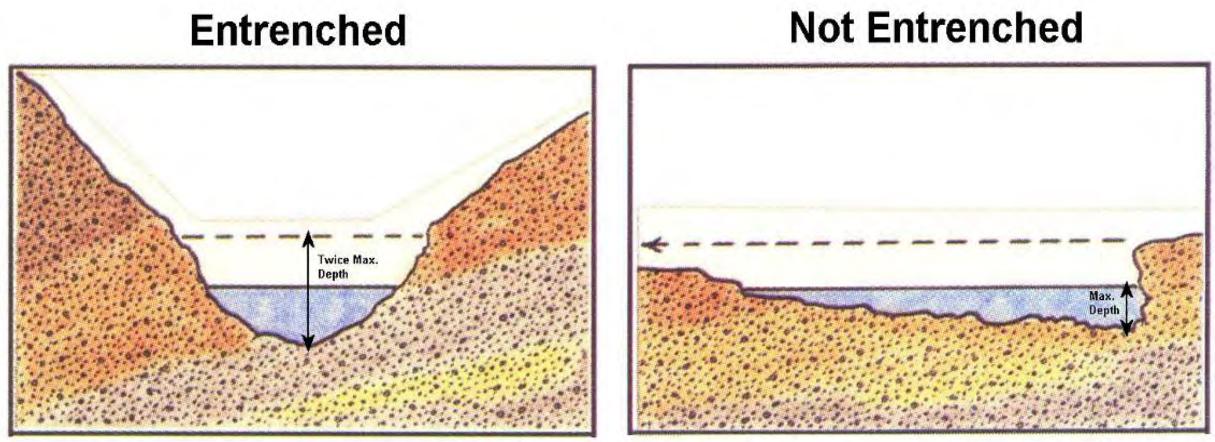


Figure 2.8 Shows entrenched channel (After Rosgen, 1996)

“The floodplain is defined as the flat area bordering a stream, constructed by the river in the present climate and inundated during periods of high flow" (Leopold, 1997). The floodplain is a critical component of stream function. The floodplain serves as an energy dissipater and depository of finer sediments during high flows. **Figure 2.9** shows a typical cross section of a stream system with bank full and floodplain. Notice that a bank full event is not considered a flood event until it over tops the banks. Bank full happens on average, every 1.2 to 2.0 years. This discharge, from relatively frequent storms, is largely responsible for the shape of the stream channel within the floodplain.

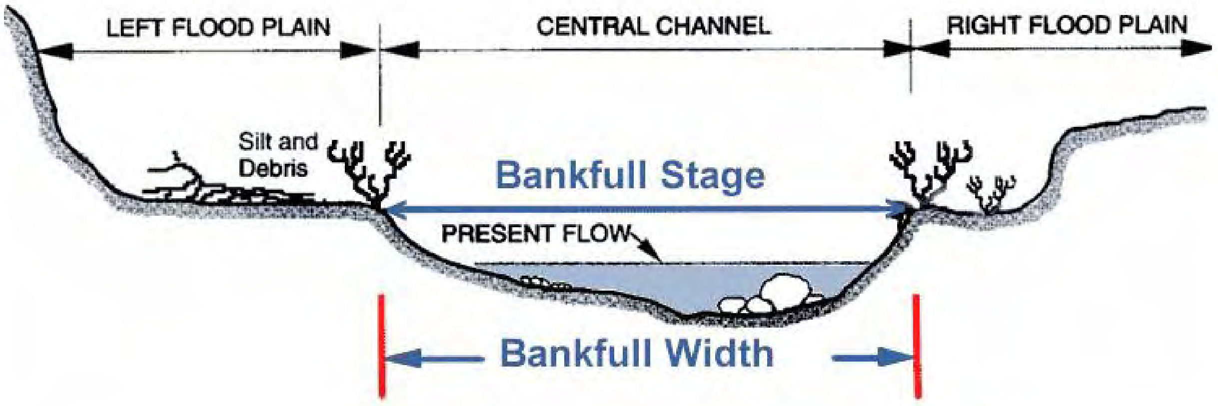


Figure 2.9 Shows a typical cross section of a stream system (After Newbury & Gaboury, 1993))

Stream Type

There are two basic stream types that can be identified in the field. One is the riffle-pool sequence illustrated in **Figure 2.10**. Typically a stable stream reach will maintain a balance in the ratio of the length of riffles to the length of pools. This balance helps regulate the velocity of water when it speeds up in riffles and slows down in the pools. Pools are important features in the stream since their low slope acts to slow the velocity (hence reduce the energy of the stream). Pools are found on the stream bends and the water enters the bend into a vortex pattern dissipating the energy in the deep water. Gravel can be found on the inside of the bend (point bar), which is a characteristic of a stable stream.

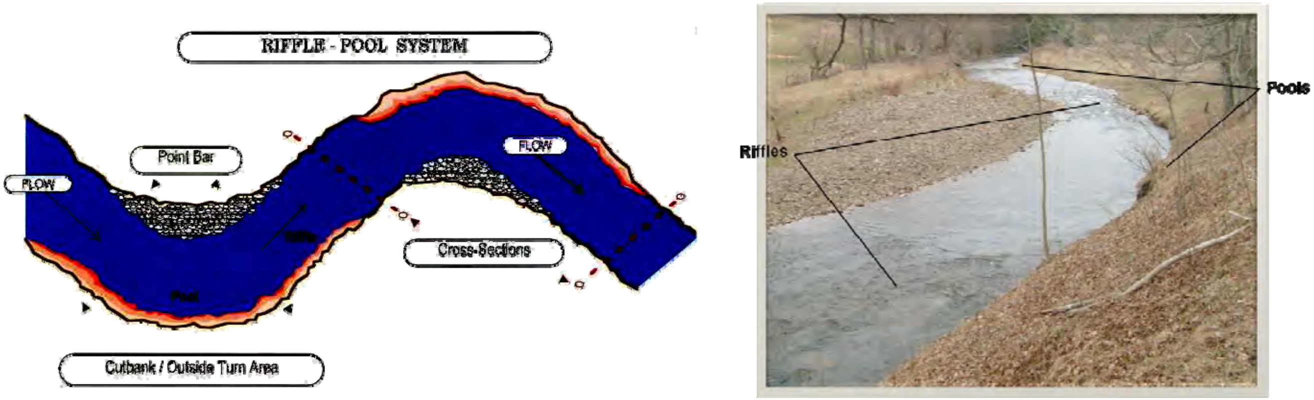


Figure 2.10 Typical Riffle-Pool Sequence (Rosgen, 1996)

The second stream type is called a step-pool sequence which is illustrated in **Figure 2.11**. The energy is dissipated through the stepped pools much like a series of speed bumps would slow down a car. This stream type is typically found in the headwaters or in steep narrow valleys.

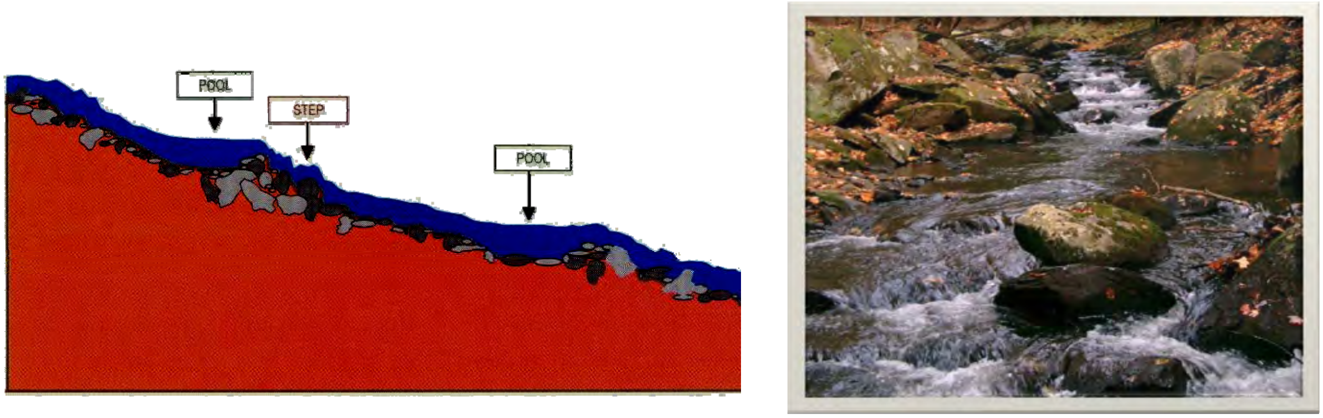


Figure 2.11 Typical Step-Pool Sequence (Rosgen, 1996)

Channel Disturbance – Evolutionary Sequence

Channels that have been disturbed by dredging, incision, or channelization follow a systematic path to recovery. This process has been documented in six classes described by Simon and Hupp (1992) in **Figure 2.12**. This process can happen naturally.

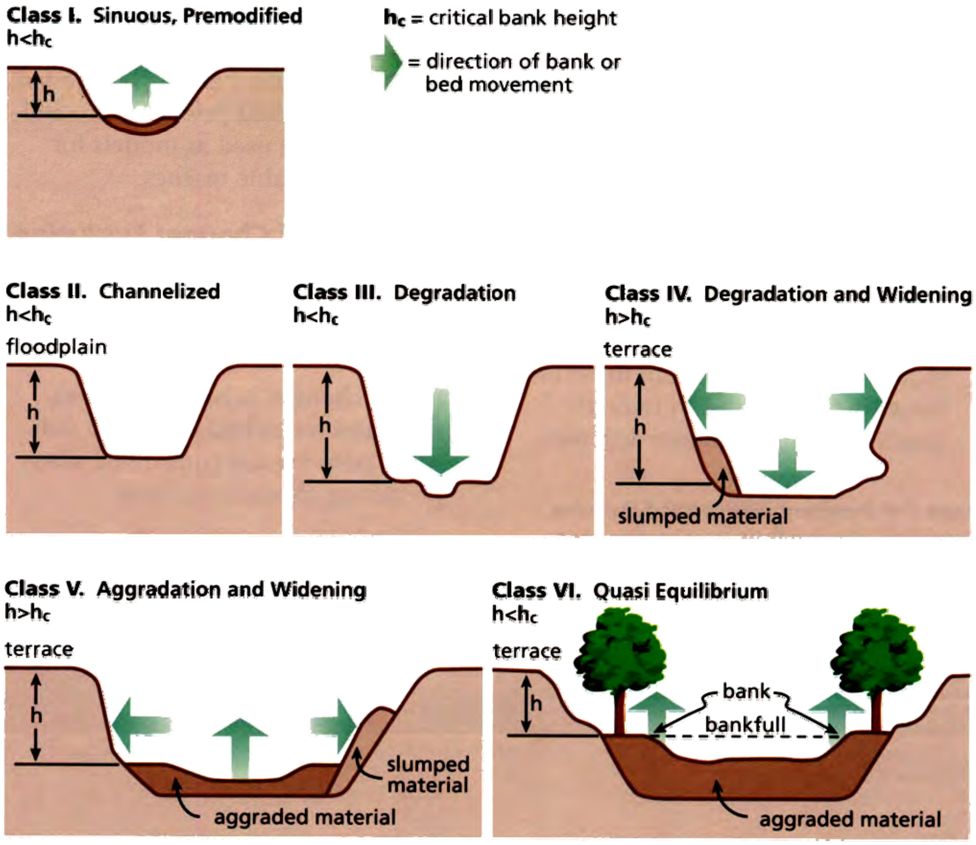


Figure 2.12 Stream Evolutionary Sequence (Simon and Hupp, 1992)

- Class I, is the channel in its natural pre-disturbed state.
- Class II, is the channel immediately after being disturbed (in this case, channelized, presumably straightened and steepened in addition to over-widened).
- Class III, is the channel eroding down (degrading) due to the flood waters being confined because channel is lower and out of contact with the former floodplain.
- Class IV, the channel continues to degrade, the banks become unstable, and the channel erodes laterally.
- Class V, the channel begins to deposit eroded material in the over-wide channel, and the newly developing floodplain continues to widen.
- Class VI, and a new channel is established and becomes relatively stable. A new floodplain is established within the original channel, and the former floodplain becomes a terrace (abandoned or inactive floodplain).

Immediate Effects of Dredging

Dredging is often proposed as a means of increasing channel capacity after a flood. On the previous page we have shown the evolutionary sequence that the stream must go through when channelization occurs. The immediate consequences of dredging are illustrated below:

Figure 2.13 (after R. Hey, 2003) shows a stream in profile view that has just been dredged. This corresponds to Simon and Hupp's Class II in Figure 2.12.

Figure 2.13

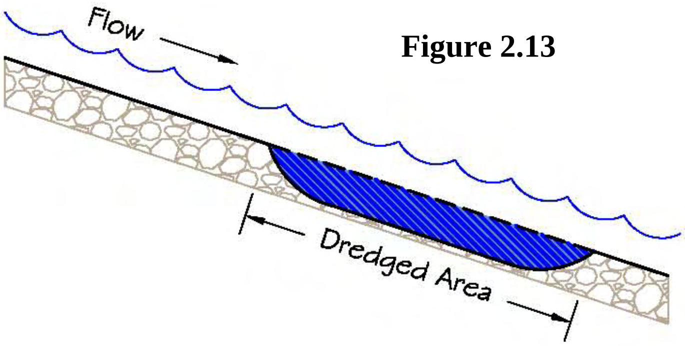
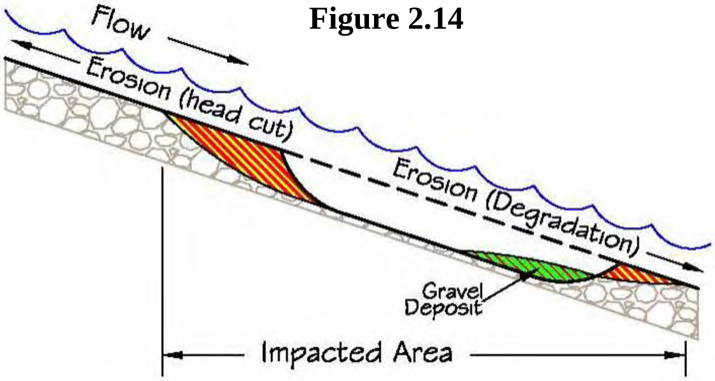


Figure 2.14



Within days, certainly no longer than weeks, the disturbances illustrated in **Figure 2.14** (after R. Hey, 2003) will be seen on the dredged stream.

Three things are occurring in the stream when it is dredged:

- A headcut occurs as a steep abrupt change in elevation in the stream bottom which forms upstream of the dredged area. The headcut will continue to move upstream releasing a huge amount of sediment supply from the bed and banks.
- This new sediment will be deposited at the location shown in the sketch labeled gravel deposit.
- Since the headcut is in effect lowering the elevation of the channel, erosion will occur downstream of the gravel deposit and outside of the area dredged. This occurs because the stream is trying to achieve equilibrium with a new bottom elevation and slope. In short, it is trying to match downstream with what is happening upstream.

Figure 2.15 is an illustration of a headcut that shows the instability that progresses upstream and the impacts that happen downstream.

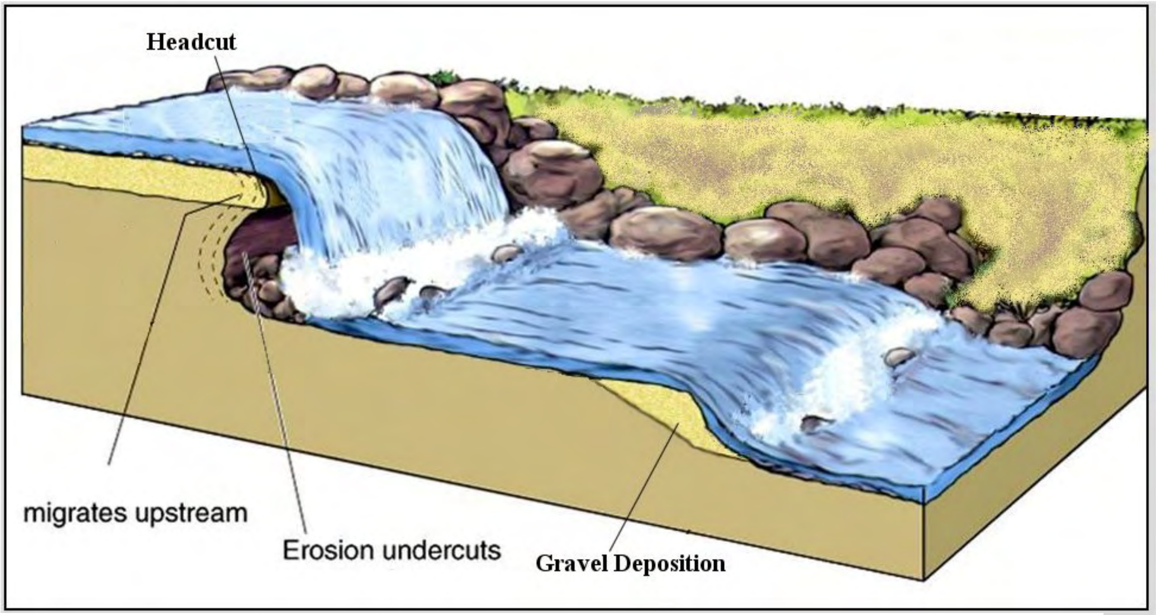


Figure 2.15 Headcut illustration showing instability of the stream channel

All of this leads to serious instabilities in the reach. Unfortunately, that is not all that can happen. The headcut, if left unchecked, will proceed upstream and destabilize more of the stream. The erosion and gravel deposition will proceed downstream and destabilize the downstream reach. If the upstream and downstream reaches are stable then this chain reaction will result in an unstable reach. If the unstable reach was further compromised with improper stream management such as dredging, the impact will further destabilized the reach resulting in steeper bank erosion. This will be greater nuisance to the municipality or landowner which may be a danger to public safety and may cost additional funding to correct the situation. The example shown in **Figure 2.16,** shows a headcut moving upstream on Third Brook in Walton, NY after post-flood work using traditional deeper -wider u-shape (parabolic) stream channel was completed to repair damages from the 2006 storm event. This headcut eroded the streambed down 6 feet which has compromised existing high eroding banks within the reach. The municipality has received funding to repair some areas of the reach and is currently in the process of developing a stream management plan to address several mass slope failures within the reach.

Figure 2.16 Headcut on Third Brook in Walton, NY

Human Activities and Impacts on Stream Health

The distinction between natural and human disturbances is important to understand. Human disturbances often significantly alter natural conditions and can have a longer lasting impact on the capability of the stream to function. These disturbances can include logging practices, livestock overgrazing, cropping practices, construction and maintenance of highway infrastructure, real estate development, gravel mining, dredging, channelization, berming, and introduction of non-native species in the riparian corridor. All of these practices have impacted stream stability on a watershed scale.

Highway/Public Utility Infrastructure Influence

Some of the most easily visible impacts to stream stability result from the construction or maintenance of highway infrastructure. Roads are commonly located close to streams, especially in mountainous regions that typically have narrow and winding valleys. Road encroachment has narrowed and deepened many streams, resulting in increased velocity. This causes the bed of the stream to degrade and, ultimately, to become incised, like a gully in its valley. This means that the stream reach has become unstable, which can lead to rapid streambank erosion as well as impairment of the water quality and stream health. Worse yet, these local changes can spread upstream and downstream, causing great lengths of stream to become unstable.

Roadside ditches collect stormwater runoff, carrying it away from the road and sometimes directly into streams. Roadside ditches have an impact on water quality and quantity. Without stormwater retention and/or filtration, runoff may impact streams by transporting contaminants, excess sediment, and excess nutrients as well as carrying excess water. The re-direction of water away from property, fields or roads without giving the water the chance to absorb into the ground, will increase runoff into the streams which raises water levels during storm events. If ditches are maintained without re-seeding, their discharge to streams can increase sediment (turbidity) in the stream system. This can aggravate gravel deposition problems.

Proper culvert installation and sizing is also important for stream stability (see **Figure 2.17**). Culvert installation that utilizes improper size, slope, and headwall can lead to streambank erosion and/or gravel deposition both upstream and downstream of the culvert.

Figure 2.17 Culvert Conveying on Holliday Brook Colchester, NY

Orientation, size and approaches for bridges have had a considerable impact on stream system stability. Bridges built wider than the stream's natural dimensions will lead to the deposition of sediment under and near the structure during periods of low or base flow. Localized scour may also be present. Sediment that is deposited under the bridge may affect the designed flow capacity of the channel beneath the bridge. In many instances, the sediment must be excavated to maintain the design capacity. Bridges built narrower than the stream's natural dimensions will exhibit a depositional wedge upstream of the structure. This may lead to water to become backed up behind the bridge, resulting in local flooding upstream. Bridge approaches are usually built across floodplains in order to have a gradual transition onto the bridge. These become a floodplain block (see Figure 2.18).

Figure 2.18 Bridge results in elimination of Floodplain

Bridges can force water and debris that would normally be on the floodplain through a narrow opening, concentrating energy that can cause problems downstream of the bridge, such as streambank and stream bed erosion or debris plugging bridge openings. Allowing the water to convey thru floodplain culverts placed in bridge approaches will allow water to access the floodplain and reduce the risk of water backing up behind the bridge debris jams under bridges (**Figure 2.19)**.

Figure 2.19 Floodplain culverts along Delaware County Route 2 Hamden, NY

Residential and Commercial Development Influence

Development of new residential and commercial districts can have a significant impact on the watershed and on the ecology of the riparian (streamside) area. Developments require access roads and utility lines that often are required to cross streams. Stormwater runoff in a natural landscape is compared to runoff in a developed landscape in **Figure 2.20**. Homeowners who enjoy their stream and desire to be close

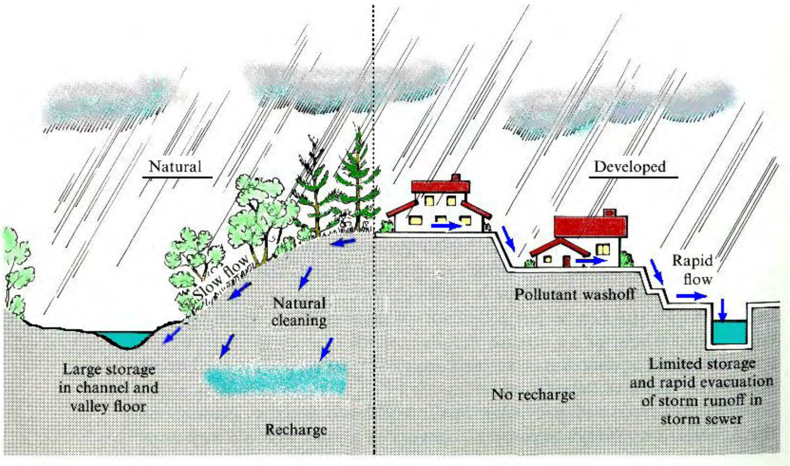


Figure 2.20 Natural vs. Developed Runoff (Dunne & Leopold, 1978)

to it may clear all the trees and shrubs along it to provide views and access. They may replace natural conditions with an un-natural mowed lawn that provides little benefit to stream health or local wildlife. Mowed lawn will increase stormwater runoff that would normally be a slow flow that would be absorbed by the trees, shrubs and ground. This leads to increase water to the stream system that may produce new streambank erosion or increase existing erosion issues. Landowners that live close to a stream and desire access to the water can minimize the destabilization of the streambank. Careful selection of a route to the stream and locating access where the water's force on the bank is lower, a landowner can minimize disturbance to riparian vegetation and the streambank. Minimizing the disturbance in the flood prone area and promoting a dense natural buffer provide property protection, aesthetic value and wildlife habitat. Landowners should be aware of planting appropriate riparian species along the stream to maximize streambank stability.

Impervious surfaces such as houses, buildings, paved parking lots or driveways will not allow for water to be absorbed into the ground. This water will become surface water runoff that is directed into ditches or swales to be removed from the property and directed towards the stream. The increase stormwater runoff to the streams will raise water levels and will reduce groundwater recharge.

Agricultural Influence

The abundance of water and cold-hardy grasses have supported agricultural industries for centuries. As fields were created to obtain the most profitable land for growing crops or grazing cattle, the streams were moved to maximize property. Streams were pushed to the sides of valleys which are no longer the lowest point of elevation. These streams are traditionally maintained and reinforced to stay in place by berms, riprap or other stabilization methods. **Figure 2.21** illustrates the stream reaction to the displacement where the channel bed is filled with gravel and erosion on the streambank occurs. When water flows over the streambanks during storm events the water will flow to the lowest elevation of the valley.

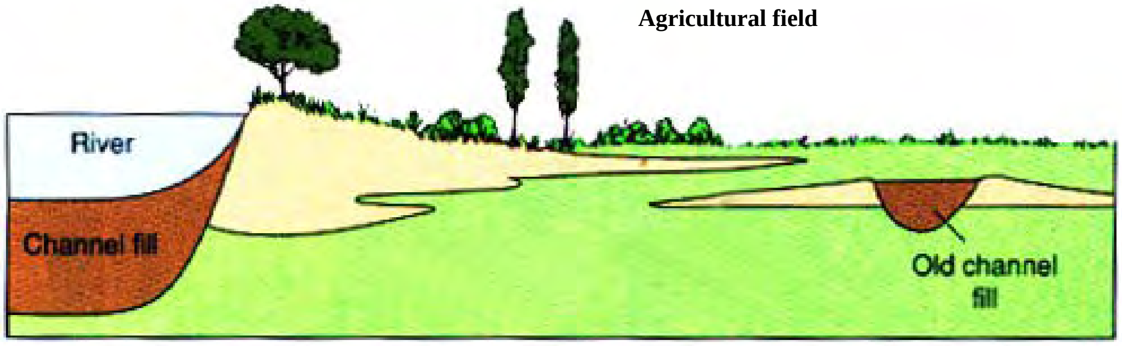


Figure 2.21 Stream that has been moved to higher elevation in a valley.

~ III. Flood Response~

After a flood event, streams may look unraveled with all the gravel and debris all over the place. A first reaction is to put everything back to the way it was and maybe do some extra work. Some of these attempts at fixing the streams have been "band-aid" solutions for spot problems and have often created additional problems. Understanding the stream conditions and using stream friendly techniques can help contractors and municipalities prioritize post-flood unstable reaches for treatment. Identifying areas that are in most need of help is essential. Often looking upstream and downstream can help a contractor determine the best fit channel shape. Allowing the stream to be re-connected to the floodplain will help maintain the new constructed channel. Remember that what you do at a given site should not significantly affect areas upstream and downstream. A variety of management strategies can be provided to address post-flood issues problems on both short and long-term bases.

Protocol

There is a need to develop a protocol for flood response to ensure the best results with minimal adverse impacts. Developing an emergency plan can help with organization of resources and determine where work is needed. Assessing and correcting stream channel conditions on a short-term basis can be completed with minimum adverse effect on the streams and can save time and money in the long run.

Immediate Priority

During and after a flood certain things need to be completed and they must be done immediately. Immediate priority items include, but are not limited to:

- Opening clogged bridges
- Opening closed roads
- Keeping important installations functioning, such as:
    - Power plants
    - Fire stations
    - Rescue centers
    - Water wells and systems
    - Sewage treatment plants and systems
    - Hospitals

Immediate priority items are those facilities and infrastructure which need to be repaired and/or kept open in order that further recovery may be allowed to continue, or to prevent immediate loss of human life.

High Priority

High priority items are those items of work that are necessary for the first part of the cleanup process. Generally, one of the first high priority items is to get the stream channels back into some sort of a functioning condition. The reason this needs to be accomplished is to:

- Open up clogged channels so they can convey their normal flow.
- Put channels back in place to prevent continued flooding.
- Open up clogged bridges to prevent additional flooding should there be another storm.
- Stabilize streambanks to prevent erosion. If left unchecked this can lead to deposition, which in turn can lead to more localized flooding.
- Attempt to stabilize landslides, at least on a temporary basis, so they do not slide into the channel and trigger an avulsion and/or localized flooding.
- Get the channel into a condition such that the natural processes of streams can begin to return the stream to its pre-flood condition.

Other work may also qualify as high priority. This training guide is intended to describe an efficient method that may be used for the emergency repair of impaired stream channels after a flood. The material which follows concentrates primarily, although perhaps not exclusively, on post-flood emergency channel repair.

Assess the Stream Reach

Knowing where to work and where not to work in a stream will help save time and money. Not all streams will need to have work done to them after a flood, even if at first glance, they appear to be in bad condition. In many cases the stream will have created a new, stable condition. Therefore, the first thing to do is assess the condition of the stream.

Appendix A is the “Problem Itemization Sheet”. It is a check list of problems commonly found after a flood. It is highly recommended to take copies of this sheet out in the field, to be used in the assessment of streams. The sheet can be used to:

- Identify the number of problem sites
- Itemize the number and type of problems on a given reach
- Identify the most severely impacted reaches
- Prioritize reaches with more severe problems
- Determine manpower and equipment needs
- Serve as documentation for state or federal reimbursement
- Help document work done under an emergency permit
- Serve as documentation for additional permits

When a damaged reach is assessed, the upstream and downstream reaches should be assessed as well. For example, the upstream reach is not damaged, it is possible to measure certain physical features and then “duplicate” that reach at the damaged reach.

Perform the Work

When the assessment is complete and priorities have been established, work can begin to restore the damaged steam reaches.

Assess and Document Further Needs

Documentation is important for any project. This information can be used for flood aid reimbursement and/or future long term mitigation planning. A stream manager/contractor should provide the following:

- Project sketch or drawing
- Before and after photos
- Written description of work
    - Date
    - Time
    - Equipment
    - Material
    - Labor force

Note any future work that needs to be done. Even though the channel may be reformed to the approximate correct size, long term mitigation may be required. Such as:

- Vegetation that may need to be planted
- Structures that may be required to permanently stabilize the stream

A post construction assessment should be made. Staff from your local SWCD and DEC offices can be asked to provide technical assistance and to help with a monitoring plan.

Improper Sizing of Channels

Over-sizing or under-sizing a stream may create future problems for the area and should be avoided. Dredging the entire stream from top to bottom creates more problems. If the stream is disconnected from its floodplain, the stream will begin to down-cut, causing the streambanks to be taller, steeper, and more unstable. This can create a whole new set of problems that will end up costing more money in the end.

An example of improper stream sizing is the classic parabolic shape, or u-shape, channels. This technique is highly discouraged due to the fact that the parabolic shape concentrates the water flow with no energy dissipation and the smooth surface increases the water velocity. The series of figures below show the sequence of stream evolution after the Third Brook stream located in Walton, NY was fixed after the 2006 flood event using the parabolic design.

Figure 3.1 shows an area of stream directly after a flood event. This area appears to be in bad condition, but it is in relatively stable form. The sediment after a flood flow settles out into an overlapping or shingle-like effect wedging sediment material together. This interlocked material is less likely to move in a smaller storm event.


7-06-06

Figure 3.1 Section of stream that has been flooded.


8-14-06

Figure 3.2 The classic parabolic stream channel shape.

Figure 3.2 is in the same location as in Figure 3.1 after some stream construction was conducted. Notice the classic parabolic shape stream channel. Re-arranging the stream bed and banks loosened the sediment material which allows this material to be more transportable. The smooth bank and rounded streambed allows for the water to speed up.

Figure 3.3 shows the stream channel two months later. Notice that the stream has begun to erode its streambanks and become wider. The loose sediment is easily transported downstream.


10-23-06

Figure 3.3 Two months of stream channel evolution.

Figure 3.4 shows the stream channel three months after construction. The stream has continued to adjust, further eroding its streambanks and creating a floodplain. The original floodplain is so high that it is now a terrace.

Figure 3.4 Three months of stream channel evolution.

Proper Sizing of Channels

To avoid situations such as described on the previous pages, it is necessary to work with the stream and to have an understanding of how streams work. The simplest solution is to do nothing and allow natural processes to do the work. But in most situations this cannot happen due to existing infrastructure such as homes, bridges, or roads that are threatened.

Various solutions are provided in the next few pages as an alternative to just going into a stream and "winging it". There is no one answer that fits all streams, and in some cases technical assistance may be needed. In these cases, contact your SWCD or regional DEC staff for any assistance.

There are two ways to properly size channels:

- The Stable Riffle Reach Concept
- Using Regional Bank Full Hydraulic Geometry Tables

The Stable Riffle Reach Concept:

This is the preferred method. In some cases only a section of stream is damaged, typically associated with riffles. The simplest solution in this case is to look upstream and/or downstream of the area to find a relatively undisturbed "stable" riffle section. Measure the width, depth, and slope of this area and duplicate these measurements at the impacted area. A suggested method of surveying the cross section is shown in **Figure 3.5**. These measurements should be checked using the Regional Bank Full Hydraulic Geometry Tables as the example table is shown in **Figure 3.9**. This "duplicating" method will allow for natural processes to adjust the stream and have minimal adverse impact to the stream health. It will also give you information about the presence and size of important features of the stream, such as the floodplain benches, pool depths, or the stream's meander geometry.

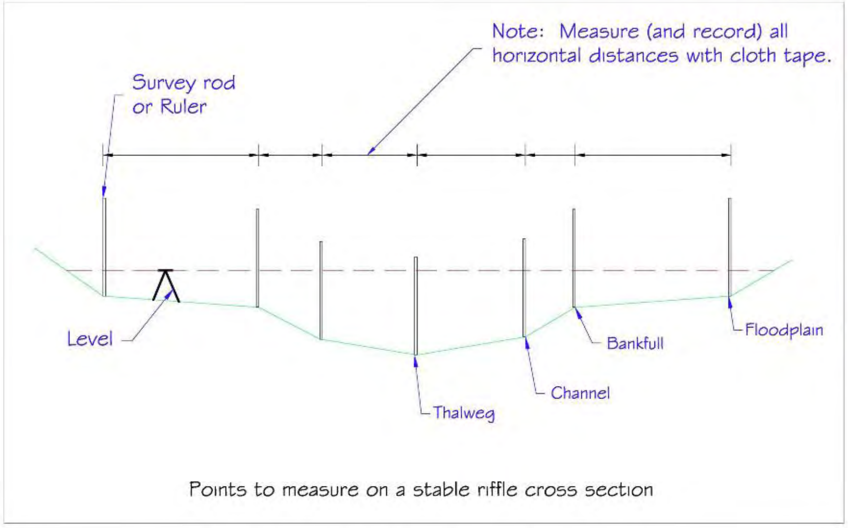


Figure 3.5 Surveying A Stable Riffle Cross Section

When you have finished your survey your sketch of the riffle cross section should approximate something like **Figure 3.6**.

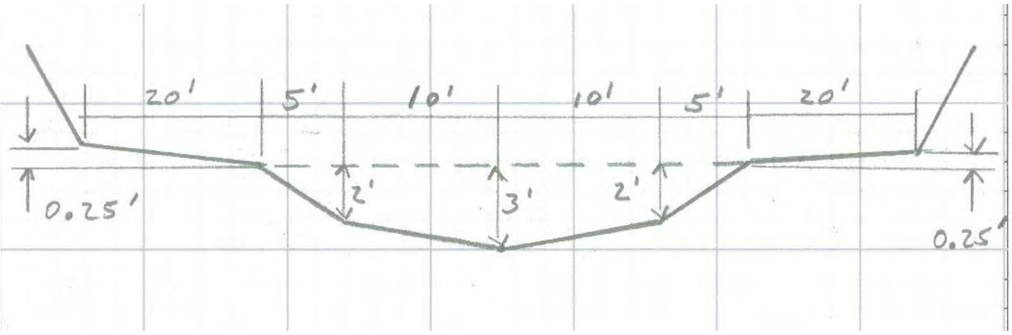
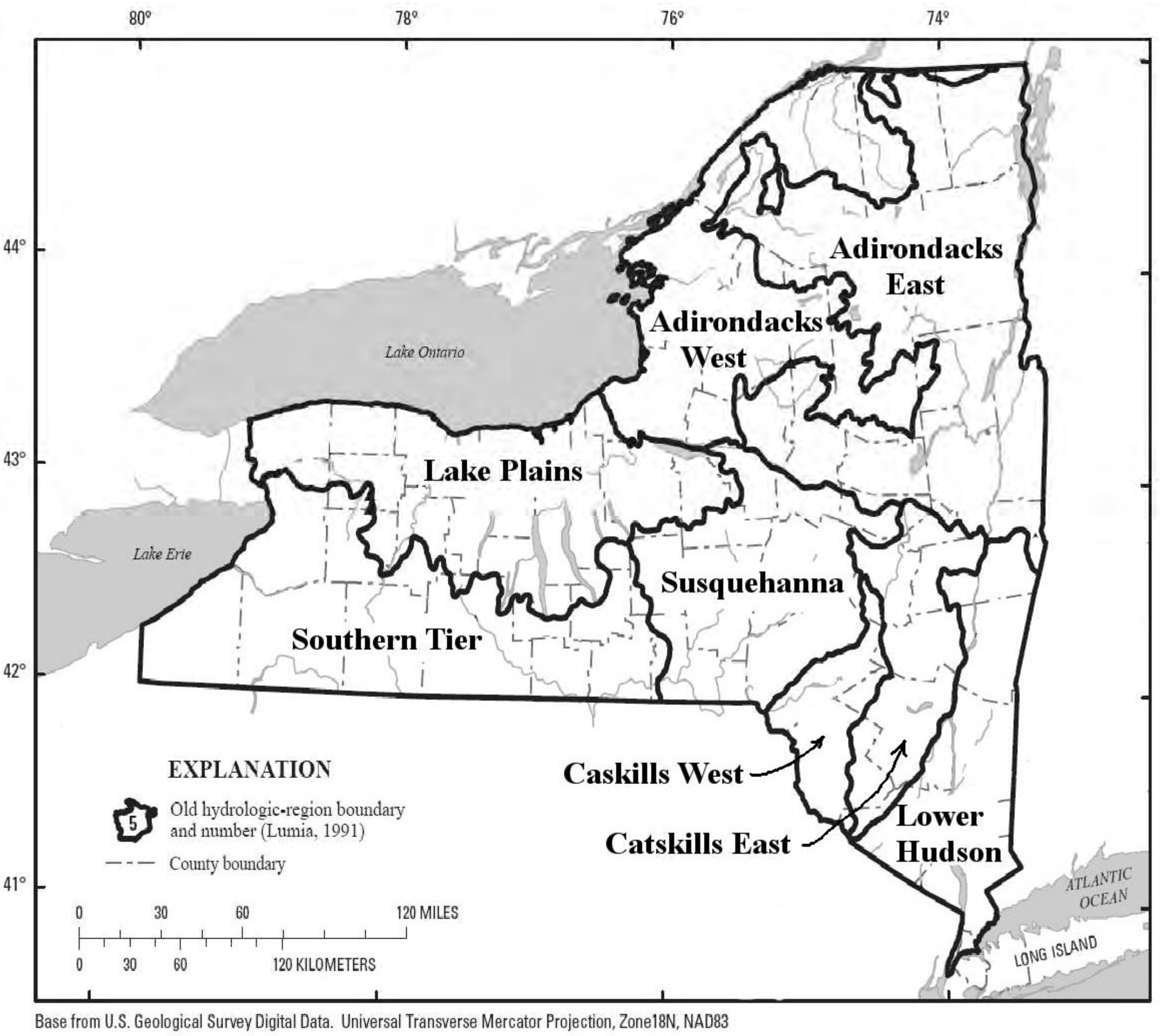


Figure 3.6 Sketch of Stable Riffle Cross Section

Using Regional Bank Full Hydraulic Geometry Tables:

In cases where the stream was completely devastated by a flood event a determination of the bank full hydraulic geometry can be used to determine stream channel dimensions. Regional bank full discharge and channel-characteristic models have been developed by the USGS using linear regression equations to relate bank full discharge and bank full channel dimensions (width, depth, and cross-sectional area) to drainage-area size. Regional Bank Full Hydraulic Geometry Tables for use throughout New York State were developed by DEC using information gathered from USGS stream gaging stations. New York's highly variable physiographic features and climate necessitated that the state be divided into hydrologic regions on the basis of the physiographic and geologic characteristics that affect streamflow. The resulting tables are therefore specific to eight distinct geographic regions in the state as shown below in **Figure 3.7**.



Base from U.S. Geological Survey Digital Data. Universal Transverse Mercator Projection, Zone18N, NAD83

Figure 3.7 Hydrologic Regions in New York State

Bank Full Hydraulic Geometry vs. Drainage Area for Selected Hydrologic Regions

Bank Full Hydraulic Geometry Tables have been produced for each of eight geographic regions of the State: 1) Western Adirondacks, 2) Eastern Adirondacks, 3) Lower Hudson, 4) Catskills East, 4a) Catskills West, 5) Susquehanna, 6) Southern Tier, and 7) Lake Plains. Regional boundaries were established based on variability in the physiographic features and climate between each region. If the drainage area is known, the tables found in Appendix C give dimensions that can be used for the emergency reconstruction of stream channels.

The drainage area (D.A.) and can be found by:

- Using the USGS *StreamStats* website found at: http://water.usgs.gov/osw/streamstats. Instructions for use are found on the left side of the web page. Click on "State

Applications” to access New York. Additional instructions for using the USGS NY State site are in **Appendix D.**

- Using maps created by DEC, available for each county, to be made available on the DEC website.

Note: The Bank Full Stream Channel Statistics can also be calculated using *StreamStats;* however, presently the USGS website does not calculate the necessary construction dimensions that can be found in the Bank Full Hydraulic Geometry Tables found in Appendix C.

Based on the Regional Bank Full Hydraulic Geometry Tables, SWCD staff can design a typical cross section that can be used for the emergency reconstruction of a severely damaged stream. These tables are to be used for emergencies only! An example Regional Bank Full Hydraulic Geometry Table is shown below in **Figure 3.8.** A typical stream channel cross-section would look much like the one shown below in **Figure 3.9**.

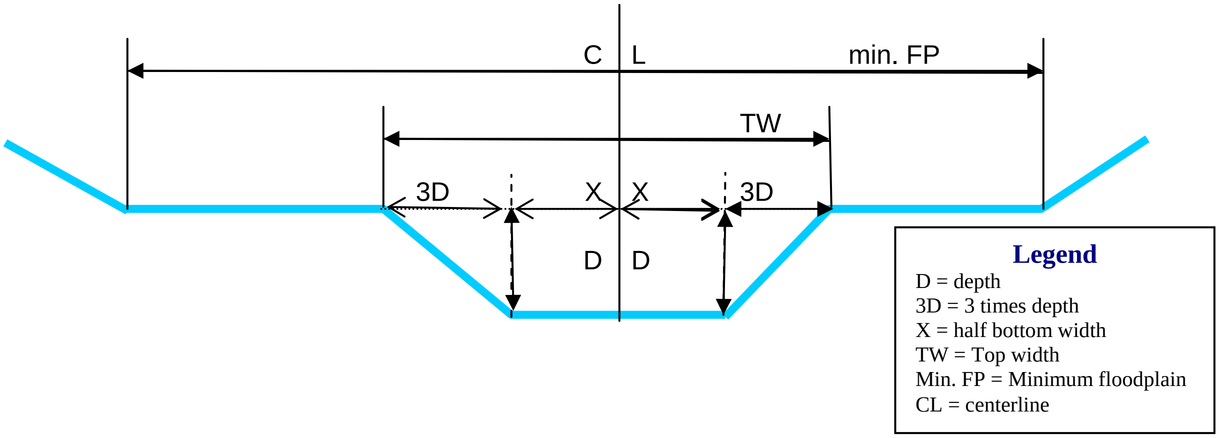
Figure 3.8 Example Regional Bank full Hydraulic Geometry Table

				Construction Dimensions					
DA (sq. mile)	Bank-Full Area (sq. ft)	Bank -Full Width (ft)	Bank-Full Depth (ft)	channel bank side slope	D (ft)	3D (ft)	X (ft)	TW (ft)	Min. FP (ft)
1	7	8.1	0.9	**2:1**	1.3	2.6	1.5	8.1	18
2.5	16	13.9	1.2	**2:1**	1.5	3.0	4.0	13.9	31
5	31	21.1	1.5	3:1	2.1	6.3	4.3	21.1	46
7.5	46	27.0	1.7	3:1	2.3	6.8	6.7	27.0	59
10	60	32.0	1.9	3:1	2.4	7.3	8.7	32.0	70
12.5	73	36.6	2.0	3:1	2.5	7.5	10.8	36.6	81
15	87	40.9	2.1	3:1	2.6	7.9	12.5	40.9	90
17.5	100	44.8	2.2	3:1	2.7	8.2	14.2	44.8	99
20	114	48.6	2.3	3:1	2.8	8.5	15.8	48.6	107
22.5	127	52.1	2.4	3:1	2.9	8.8	17.3	52.1	115
25	140	55.5	2.5	3:1	3.0	9.0	18.7	55.5	122
27.5	153	58.8	2.6	3:1	3.1	9.3	20.1	58.8	129
30	166	62.0	2.7	3:1	3.2	9.5	21.5	62.0	136
32.5	179	65.0	2.7	3:1	3.2	9.7	22.8	65.0	143
35	191	68.0	2.8	3:1	3.3	9.8	24.2	68.0	150
37.5	204	70.8	2.9	3:1	3.4	10.1	25.3	70.8	156
40	217	73.6	2.9	3:1	3.4	10.3	26.5	73.6	162
42.5	229	76.4	3.0	3:1	3.5	10.4	27.8	76.4	168
45	242	79.0	3.1	3:1	3.5	10.6	28.9	79.0	174
47.5	254	81.6	3.1	3:1	3.6	10.8	30.0	81.6	180
50	267	84.2	3.2	3:1	3.6	10.9	31.2	84.2	185

To determine the dimensions of a typical stream cross-section that can be used for the emergency reconstruction:

1) Select the table for the drainage basin that your project is in.
2) Select the drainage area (DA) in the selected table that most closely matches the DA at your project site.
3) Under "Construction Dimensions" read the channel dimensions tabulated.
4) Build the channel to these "approximately bank full" channel dimensions.

Figure 3.9 Typical Stream Cross Section for Emergency Stream Intervention



Classroom Examples on How to Use Bank Full Hydraulic Geometry Tables

Some examples are provided below using the tables. The answers are provided below each example with a detailed explanation.

Example 1:

Flooding has occurred in Woodhull, NY in the south Branch of Tuscarora Creek and repairs work is needed on a small stretch of stream. There is a bridge ¼ mile downstream of the affected area with a drainage area of 19.6 square miles. Using the appropriate Regional Bank Full Hydraulic Geometry Table from Appendix C, find the following:

a) Bank full width b) Bank full depth
c) Bank full area d) Floodplain width

Answer to Example 1:

- Determine the geographic region in which the site is located. In this case, it is in the Southern Tier Region (see figure 3.7). Use the Southern Tier table.
- Locate in the table the drainage area (DA) for the site. If there isn't an exact match, use the table value that is slightly higher than the actual site value. In this case, the closest DA is 20.0 square miles.
- The answers are highlighted in the table below:
    - Bank full width = 59.3 ft. Bank full depth = 2.47 ft.
    - Bank full area = 127.88 ft^2 Floodplain width (FP) = 130.45 ft.

Southern Tier Region

Bank Full Hydraulic Geometry vs. Drainage Area for Selected Hydrologic Regions

				Construction Dimensions					
DA (sq. mile)	Bank-Full Area (sq. ft)	Bank -Full Width (ft)	Bank-Full Depth (ft)	channel side slope	D (ft)	3D (ft)	X (ft)	TW (ft)	Min. FP (ft)
1.0	17.60	16.90	1.04	3:1	1.38	4.13	4.32	16.90	37.18
2.5	32.28	24.81	1.30	3:1	1.62	4.85	7.56	24.81	54.58
5.0	51.08	33.17	1.54	3:1	1.85	5.55	11.04	33.17	72.98
7.5	66.80	39.31	1.70	3:1	2.01	6.02	13.63	39.31	86.49
10.0	80.82	44.35	1.82	3:1	2.13	6.39	15.78	44.35	97.57
12.5	93.68	48.70	1.93	3:1	2.23	6.70	17.65	48.70	107.13
15.0	105.70	52.56	2.01	3:1	2.32	6.96	19.32	52.56	115.64
17.5	117.06	56.07	2.09	3:1	2.40	7.20	20.84	56.07	123.35
20.0	127.88	59.30	2.16	3:1	2.47	7.41	22.24	59.30	130.45

Example 2:

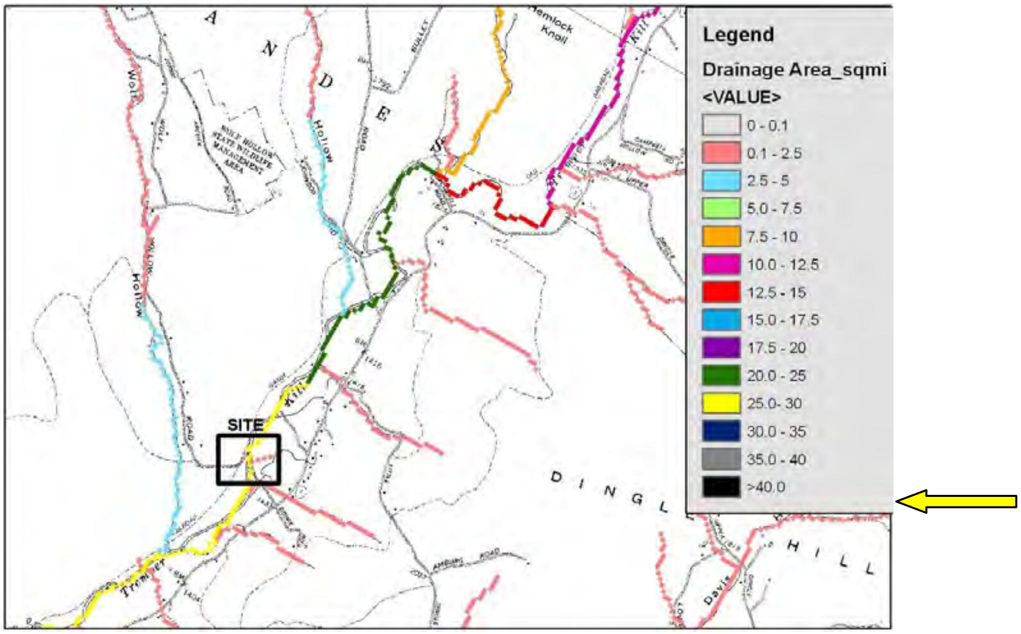
Flooding has occurred in Andes, NY on a portion of the Tremper Kill stream near Wolf Hollow Road. From the map provided below, determine the approximate Drainage Area (DA), then use the appropriate table to determine the approximate construction dimensions.

Answer to Example 2:

- On the map below, the reach in question is color-coded yellow. The key tells us that this means that the DA is between 25 and 30 square miles; therefore we will use the values for the 30 square mile drainage area.
- The project is located in the East Branch Delaware River basin, and falls within the "Catskill West" region. Use the table for this physiographic region.

- Under D.A. we find 30, then reading across under the heading Construction Dimensions we get the following answers:
    - D = 3.1 ft
    - 3D = 9.3 ft
    - X = 19.8 ft
    - TW (top width) = 58.1 ft
    - Min. FP (minimum floodplain) = 127.8 ft

It is best practice to make a sketch of the cross section using these dimensions, and then refer to the sketch during stakeout and construction.



Re-connecting Floodplains

When streams are disconnected from floodplains by berming or dredging, the natural balance is disrupted – often with undesirable impacts. Berms are described as an earthen embankment or wall, usually built to provide protection or a result of side casting during stream channel dredging. **Figure 3.10** shows the same flood event occurring in both diagrams. The diagram on the left depicts slow, shallow water on the floodplain. The diagram on the right shows the same water volume, but the floodplain access has been blocked with a berm. There is a lot of water and energy that is stored behind the berm. If the structure fails it could cause devastation in its path. It is, therefore, an important component of any long-term restoration project to give prioritization to floodplain re-connection.

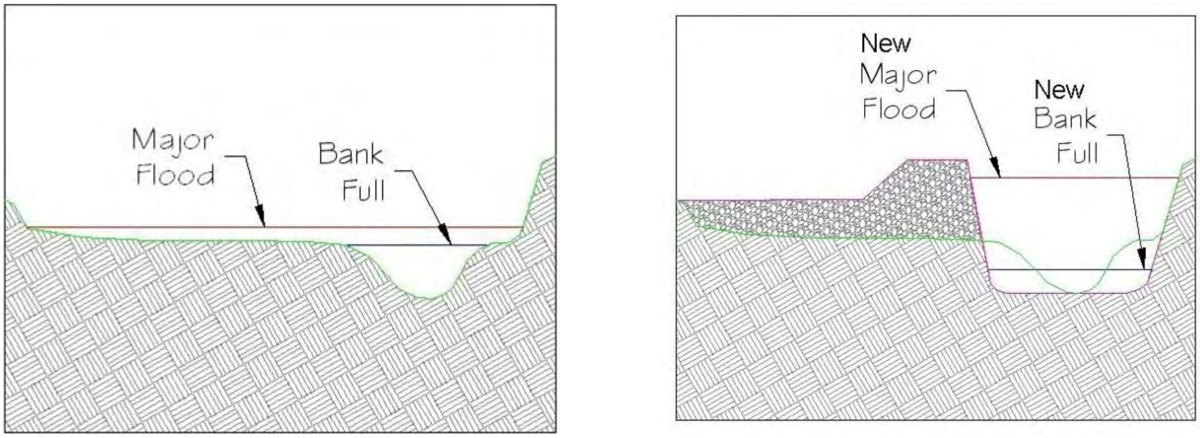


Figure 3.10 Shows the same flood situation on a fully functional floodplain vs. a filled in floodplain and berm.

Figure 3.11 is picture of a functioning floodplain during a storm event. Notice the slow moving water with low energy moving on the floodplain. **Figure 3.12** is picture of a berm protecting a corn field that was breached during a storm event. Notice the high energy that was released when the berm was compromised and destroyed the field.

Figure 3.11 Functioning Floodplain

Figure 3.12 Berm that was breached in 2005 storm event

Post-Flood Intervention using Bank Full Hydraulic Geometry Tables

SWCD utilized the Regional Tables during the 2006 flood event in the Town of Walton. The photographs below are before and after channel re-construction efforts.

Figure 3.13 is a picture taken after the flood and before any stream construction has begun. The stream was filled with debris and sediment. Construction consisted of excavating the stream channel using dimensions determined from the Regional Tables.


07/06/2006

Figure 3.13 Shows stream channel after flood event.

Figure 3.14 is a picture at the same location taken after stream channel construction. Notice a floodplain was constructed.


07/19/2006

Figure 3.14 Stream channel after Post Flood Intervention.

Figure 3.15 was taken two years later at the same location. The stream has kept the general form of the cross section with a few natural adjustments. The stream is stable with minimum efforts.


7-08-08

Figure 3.15 Two years after Post Flood Intervention.

Effect of Slope on Post-flood Emergency Reconstruction

If the stream slope is found to be 4% or greater in the mountainous regions of New York, the stream *will* almost inevitably have a step-pool sequence. If the stream slope is 2% - 4% the stream *could* be a step-pool sequence. Step-pool sequence requires special construction measures and designs, such as cross-vanes or other structures designed to mimic the operation of step-pools. In post-flood emergencies, there is not enough time for such design and implementation. In an emergency, immediate priority requires the channel be constructed as has been previously described using the Regional Tables. Stream work on a steep grade will require careful monitoring. Contact SWCD or DEC to monitor the repair work, and if necessary, devise and implement a long-term stabilization program. If it is not an immediate priority or you are not sure how to proceed, please contact SWCD or DEC.

Consideration of Upstream and Downstream Impacts

Impacts upstream and downstream of a stream restoration project always need to be considered. For example, if a streambank is to be armored with rip rap or other hard material, consideration must be given to increased velocities and erosion potential on an opposing downstream bank. Likewise, if a restoration project is designed to improve sediment transport through a reach, deposition potential downstream must be assessed. It is a goal with natural stream channel design to not only repair an impacted reach but to *not* create undue stress elsewhere in the stream system.

Using Vegetation and Natural Channel Design Structures

Woody debris can be found in abundance after a flooding event. The large amount of debris poses huge problems such as difficulty removing the debris from the stream, disposal once removed, and the cost of disposal. The simplest solution is to utilize the woody debris onsite for streambank stabilization.

Woody debris can be utilized in post-flood intervention saving time and money to implement additional projects. Placing a large tree into the streambank oriented so that the root mass is facing the water pointing upstream and the trunk is buried into the bank, is referred to as a root wad (see **Figure 3.16**). The bottom of the root ball should be below the channel grade to avoid the toe of the root wad to be washed out and be braced with boulders or crisscrossed with other logs. Several layers maybe necessary to get the depth of the structure below the stream channel bed. The exposed root mass dissipates water, protects the streambank and provides good aquatic habitat. Root wad details can be found in **Appendix-E**.

Figure 3.16 Root wads were placed in two layers with large boulders or logs to hold them in place

Figure 3.17 shows a stream that has been impacted by the 2006 flood event. The stream's original channel was to the left of the willow tree and an agricultural field is located on the right where the stream is now flowing. Note the location of the willow in both pictures. **Figure 3.18** shows the stream placed back into the original channel using the Regional Hydraulic Geometry Tables and typical cross-sections. The large woody debris found on-site was used as root wads to protect the streambank and newly formed floodplain.

Figure 3.17 Stream impacted by the 2006 Flood.

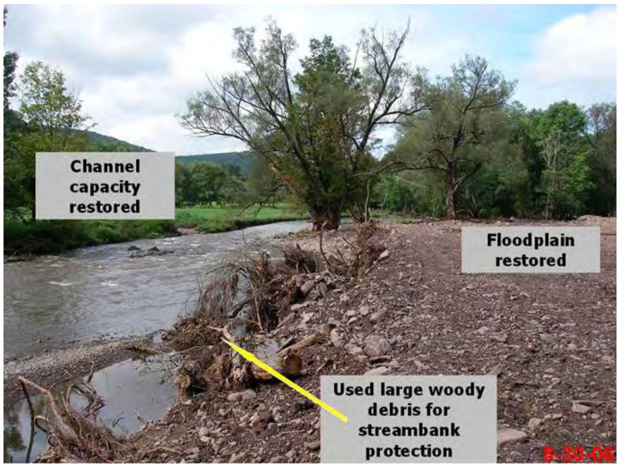


Figure 3.18 Stream construction using Regional Bank full Hydraulic Geometry values, typical cross-section and root wad.

Natural channel structures can be used to reduce stress on the streambank by re-directing stream flow toward the center of the stream. These typically include single arm vanes or cross-vanes that are made out of large rocks but logs maybe used in some small streams. Rock vane structures are built with layers of large rocks, one layer that is well-footed below the stream bed, and well-tied into the stream bank. The vane arm slopes from the top of the stream bank to the stream bed. A rock cross-vane is simply two single arm vanes with a throat in the center (**Figure 3.19**). Vegetative plantings are done around both at the ends of the vane arms (where they are tied into the stream bank). There is, however, a standard design for using them in restoration projects requiring technical data and they are expensive to be placed, so this option may not be feasible without funding.

Figure 3.19 Rock Cross-Vane

Limiting Gravel Removal

As storm flows subside, bed material overlaps and becomes wedged together like shingles; this process is called imbrication. Bed material mobilizes during high water events, and when the water velocity slows down, the material drops out. This interlocking material becomes less mobile. Rearranging the stream bed and banks loosens the interlocking material, and allows the material to become more transportable in the next highwater event. **Figure 3.20** is an example of imbrication after the June 2006 food. Gravel removal at a project site should be given careful consideration. Some gravel bars, such as transverse bars (those bars across a stream that direct flow toward a stream bank), center bars (those in the center of a stream with flow on both sides), or deposition near drainage structures should be considered for removal. Point bars (those on the inside of a bend) actually serve a hydraulic function (**Figure 3.21**). Point bars are formed by lack of stream energy on the inside of a bend and are partially eroded away during flood events, then are re-deposited as flood flows subside. Removing point bars will reduce stream energy at low flows, thereby creating potential for increased deposition in the form of transverse and/or center bars.

Figure 3.20 shows imbrication after the 2006 flood.

Figure 3.22 shows downcutting after dredging.

A straightened stream will also adjust itself. Notice in **Figure 3.22**, how the stream was manipulated into the classic parabolic shape. This adjustment was made after the June 2006 flood event, and this photo was taken in October 2006. The stream has adjusted itself by downcutting approximately 6 feet and eroding the streambanks. The stream will continue to adjust by transporting loosened sediment downstream until it reaches equilibrium and re-builds a floodplain at a new elevation.

Figure 3.21 Looking upstream at a point bar in the Tremper Kill Sub-basin

Environmental Permitting

Compliance with State and Federal Environmental Permitting Laws will need to be established before work can commence. This compliance will need to be documented prior to receiving any Federal Emergency Management Agency (FEMA) or State Office of Emergency Management (SOEM) disaster relief funds. Work without the necessary permits can lead to significant fines and the need to redo the project and possible no reimbursement from funding agencies.

The DEC regulates activities in and around the water resources of New York State pursuant to the Environmental Conservation Law (ECL) Article 15, Title 5, Protection of Waters Program and the federal Clean Water Act, Section 401 Water Quality Certification (WQC) Program. An Article 15 Permit is required for temporary or permanent disturbances to the bed or banks of a stream with a classification and standard of C(T) or higher and for excavation and fill in Navigable Waters. An Article 24 Freshwater wetland permit may also be needed if State protected Wetlands are present.

Examples of activities requiring this permit are:

- Placement of structures in or across a stream (i.e., bridges, culverts or pipelines);
- Fill placement for bank stabilization or to isolate a work area (i.e., riprap or other forms of revetment);
- Excavations for gravel removal or as part of a construction activity;
- Lowering streambanks to establish a stream crossing;
- Use of heavy equipment in a stream to remove debris or to assist in-stream construction.

A state Water Quality Certification is required for any project that required Federal permitting or funding (*e.g.* FEMA funds).

DEC Permit Procedures

In addition to normal permitting procedures, the DEC has two expedited permitting processes available to respond to emergency and disaster situations.

Emergency Authorizations (EA)

- Issued for emergency actions to protect life, health, property and natural resources
- Written pre-notification & plan required (For municipalities, notification within 24 hours if pre-notification is not possible)
- DEC must certify or deny the EA within 2 business days
- Expire in 30 days; ca be renewed for an additional 30 days

General Permits for Disaster Recovery

- Expedited review process
- Valid for all restoration work not just Emergencies
- Available for a set period after a Natural Disaster (i.e. 6 months)
- Expiration date is variable
- These permits can be issued during a site visit or in response to an application received at the DEC office

- For more information see **Appendix F** – Stream Disturbance Permit Regulations in Natural Disasters

Emergency Authorizations (EA) and Permit Conditions

All Emergency Authorizations and Permits will contain enforceable conditions designed to ensure that the project will not impact adjacent landowners, protect natural resources and maintain state water quality standards. These conditions will include:

- Isolating and dewatering the work area
- June 15 – September 30 work windows for trout waters where practicable
- Proper bedding of culverts
- No discharge of turbid waters
- Proper stabilization and re-vegetation of work site

For permit applications and any questions regarding the permit process, contact the Regional Permit Administrator at your local regional DEC office as listed on the DEC website at: http://www.dec.ny.gov/about/39381.html.

Protection of Waters permit information is also available on the DEC website: http://www.dec.ny.gov/permits/6042.html.

Local Municipal Floodplain Development Permits

Nearly every municipality in New York State participates in the National Flood Insurance Program. A condition of program participation is that any development within a mapped Special Flood Hazard Area (area that has a one percent or greater chance of being flooded every year, often called the 100-year floodplain) must receive a floodplain development permit from the municipality. The definition of "development" is:

"any man-made change to improved or unimproved real estate, including but not limited to buildings or other structures, mining, dredging, filling, grading, paving, excavation or drilling operations or storage of equipment or materials." (FEMA regulations, 44 CFR 59.1)

Prior to any excavation, dredging, or grading, the local floodplain administrator, usually a building code or zoning official, must approve the plan. Approval is based on a determination that the development will not result in physical damage to other property, such as stream bank erosion and increased flood velocities.

Some locations have detailed flood maps that include regulatory floodways. The floodway is a narrower portion of the floodplain that must be kept free of encroachment in order to pass the base flood flow without causing any increase in flood elevations. They are shown on Flood Insurance Rate Maps as cross hatched areas within the floodplain, or for maps published prior to 1988, they are shown on separate Flood Boundary and Floodway Maps. No encroachment into any regulatory floodway is allowed by local laws passed to comply with FEMA regulations unless an engineering analysis is performed that concludes that the encroachment will not increase the base flood elevation (elevation of the one percent annual chance flood) by any measurable amount.

The Department of Environmental Conservation serves as the state National Flood Insurance Program coordinating agency and in the role, provides technical assistance to local communities and others on how to comply with floodplain development requirements. The Floodplain Management Section of DEC can be reached the DEC's regional offices, or at 518-402-8185, or by e-mail at fldplain@gw.dec.state.ny.us.

U. S. Army Corps of Engineers (USACE) Permit Requirements

Section 10 of the Rivers and Harbors Act requires a permit from the USACE for any work (including structures) in or affecting navigable waters of the United States.

Section 404 of the Clean Waters Act requires a permit for any activities that involve or result in the discharge of fill material into waters of the United States. Waters of the United States include: 1) navigable waters and adjacent wetlands, 2) tributaries to navigable waters and wetlands, regardless of their DEC classification.

Typical flood response actions that require a permit are:

- Channel shaping
- Sediment removal
- Bank stabilization
- Culvert and bridge repair or replacement
- Road repair or replacement that takes place in water
- Cofferdams or temporary fills required to complete the work

Minor projects with minimal individual and cumulative impacts may be authorized under general permits including Nationwide Permits. Many Nationwide Permits require pre-construction notification to the USACE prior to the commencement of work, especially if the activities:

- Are located in or near wetlands
- Are located in or near riffle pool complexes
- May affect historic property
- May affect endangered species

All terms and conditions of the Nationwide Permit must be complied with even if pre-construction notification or prior written approval of the USACE is not required. Special conditions, such as monitoring requirements, may be added to a permit by the USACE to assure that impacts are minimal.

The U.S. Army Corps of Engineers also has emergency procedures (33 CFR Part 325.2), which may be used to authorize work when their existing permit processing procedures are not timely enough for responding to emergency work.

DEC ***no longer forwards permit applications to the Army Corps***. The applicant must send a copy of the application to the Army Corps. If the emergency is a federal declared disaster, the

USACE will accept complete jurisdictional inquiry forms which are available from State Office of Emergency Management (SOEM).

Nationwide permits may be used to authorize the types of activities typically done in response to flooding events:

- Nationwide Permits 3 – Maintenance
- Nationwide Permit 13 – Bank Stabilization
- Nationwide Permit 27 – Aquatic Habitat Restoration, Establishment, and Enhancement Activities
- Nationwide Permit 33 – Temporary Construction, Access and Dewatering
- Nationwide Permit 37 – Emergency Watershed Protection and Rehabilitation
- Nationwide Permit 45 – Repair of Uplands Damaged by Discrete Events

Nationwide Permits, like all permits from the USACE, require compliance with:

- Wild and Scenic River Act (Delaware River)
- Section 7 of the Endangered Species Act
- Section 106 of the National Historic Preservation Act

If a project would affect any of these conditions then notification will be triggered.

For more information contact the regional USACE office at:

For DEC Regions 1, 2 and 3
US Army Corps of Engineers NY District
ATTN: Regulatory Branch
26 Federal Plaza, Room 1937
New York, NY 10278-0090
email: CENAN.PublicNotice@usace.army.mil

For DEC Regions 1, 2,
Westchester County and
Rockland County - (917) 790-8511

For the other counties
of DEC Region 3 -(917) 790-8411

For DEC Regions 4, 5
Department of the Army
ATTN: CENAN-OP-R
NY District, Corps of Engineers
1 Buffington Street
Building 10, 3rd Floor
Watervliet, NY 12189-4000
(518) 266-6350 - Permits team
(518) 266-6360 - Compliance Team
email: cenan.rfo@usace.army.mil

For DEC Regions 6, 7, 8, 9
US Army Corps of Engineers
Buffalo District
ATTN: Regulatory Branch
1776 Niagara Street
Buffalo, NY 14207-3199
(716) 879-4330
email: LRB.Regulatory@usace.army.mil

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