URBAN STREAM RESTORATION AND APPLIED PRACTICES IN NORTHEAST ILLINOIS

Jonathan Koepke, CPESC, LEED-AP[1]

INTRODUCTION:

In-stream and watershed dynamics in urban and urbanizing areas have significant impacts on local property and infrastructure, as well as the quality of the stream itself including: water quality, habitat, physical characteristics, and biodiversity. As land development occurs, natural vegetation and exposed soils are converted to buildings, pavement and other impervious surfaces. This leads to increased runoff during storm events as well as decreasing the time that it takes that stormwater to reach streams, wetlands, and other stormwater storage and conveyance systems. These hydrologic changes in a watershed often occur at a rapid pace which results in rapid destabilization and degradation of streams and rivers. Rivers and streams are naturally dynamic systems. They naturally erode and reshape themselves based on changes to the watershed or the stream itself. Erosion and deposition are natural processes that have always been important components of stream systems and in and of themselves are not undesirable. When natural stream dynamics are rapidly accelerated, however, an entire series of negative impacts to the stream and the biological systems that are depended on the stream occur. Rapid destabilization of streams often leads to significant bank and bed erosion that negatively impact stream health and frequently leads to negative impact to property, buildings and structures, as well as public infrastructure. Past approaches to stream bank and bed stabilization often involved channelization, armoring, and other gray infrastructure techniques to protect public and private property in the effected reaches of streams and rivers without taking into account the overall stream system dynamics.

Early stabilization efforts frequently led to other unintended consequences by accelerating the rate of bank and bed erosion in untreated reaches, inadvertent flooding, and other infrastructure impacts. The complex nature of stream dynamics and fluvial geomorphology when applied to urban stream systems and significantly modified watersheds require the need for detailed analysis of the morphology of the stream. Consideration of the complex factors and processes that make up fluvial morphology are critical when selecting practices or methods of stream restoration. Many agencies and cooperative partners work to accumulate and analyze case studies and detailed research in order to develop a method of evaluating and prescribing different stream restoration techniques based on the morphologic conditions in the stream reach (Lyn D.A., and Newton J.F., 2015). An accumulation of case studies,

1. Vice President, General Manager, Encap Incorporated, 2585 Wagner Court, Dekalb, IL 60115, www.encapinc.net.

research, and scholarly work on stream restoration techniques and practices helps shape and inform designers across multiple agencies in order to effectively select and design restoration practices. Ultimately, in urban streams, the designer is working to establish a condition of dynamic equilibrium in the treated stream reach. Dynamic equilibrium is defined as a stream reach that is in balance with sediment transport, aggradation, degradation, and bank and bed erosion. When those characteristics are in balance based on the inputs of sediment within the watershed, the bed load and sediments the stream transports, and discharge rate and volume, then the stream is considered to be in a relatively stable state (FISRWG, 1998). The selection then of stream restoration and stabilization practices in urban areas is dependent on not only the reach being treated, but also on the overall watershed dynamics. In addition to the physics of the actual practices implemented, including resistance to shear stresses and velocity of the water flow within the stream channel being treated, the practices must also take into account the larger picture of stream dynamics including sediment delivery and transport, within the watershed and not just within the treated reach. Successful urban stream restoration and stabilization techniques mimic the structures found in more undisturbed systems through the utilization of similar materials in an engineered configuration. In many streams the use of a combination of hard and soft armorment and stabilization solutions including stone, woody debris materials, modern geosynthetic reinforcement devices and native vegetation to stabilize and naturalize stream channels, thereby provided enhanced habitat, better water quality, and protecting property and infrastructure.

KEYWORDS:

Stream Restoration, Watershed Development, Bioengineering, Streambank Stabilization, Riparian Restoration

URBANIZATION AND WATERSHED DEVELOPMENT IMPACTS ON STREAMS IN NORTHEAST ILLINOIS

Northeast Illinois and in particular, the counties in and around the Chicago metropolitan area, experienced rapid growth and development in the post-war period of the 1950s and 60s. Expansive residential, commercial, and roadway construction through the 1970s resulted in massive amounts of land converted from pervious land cover such a rangeland or commercial agriculture, to impervious surfaces. Urbanization was rapid and expansive and resulted in a net gain of over 40% impervious surface cover of the region. Much of this development and urbanization was taking place long before the development of modern stormwater management regulations. Initial research on urban streams was focused on flood conveyance and water management. Early studies by the Illinois Water Survey (www.isws.illinois.edu) across the region found that urbanized watersheds resulted in post storm peak discharges in streams were 3.2 times and 1.9 times as high as undeveloped watersheds in the same region for 2-year storm and 100-year storm durations (Allen H.E. and Bejeck H.M., 1979). While the results of such studies were primarily focused on flooding, floodplain management, and mitigating the impacts of flooding in urbanizing communities, the resulting data gave a quantifiable figure on the amounts of water that was being pumped into the streams and rivers in the urbanizing areas.

Highly impervious watersheds result not only in increased peak flow discharges but also decreases in the lag time between storm events and the peak flow discharge (FISRWG, 1998). Hydrograph plotting of stream discharge comparisons between urban and rural watersheds exhibit the changes in stream discharge that is exhibited in urbanizing and developing watersheds (Figure 1). In many areas, the former stream channel literally tears itself apart during storm events as it attempts to accommodate the increased discharge volume and velocity. The impact to most streams in urban areas is rapid downcutting and incision as the channel attempts to cut a larger cross section to accommodate the increased discharge volume (Hammer, 1972). Series of rapid incisions and abandonment of floodplain terraces reduces the hydrological connection to the former riparian corridor and further serves to negatively impact water quality and overall stream health (Figure 2).

FIGURE 1. A comparison of hydrographs before and after urbanization. The discharge curve is higher and steeper for urban streams than for natural streams. In Stream Corridor Restoration: Principles, Processes, and Practices (10/98). Interagency Stream Restoration Working Group (15 federal agencies) (FISRWG).

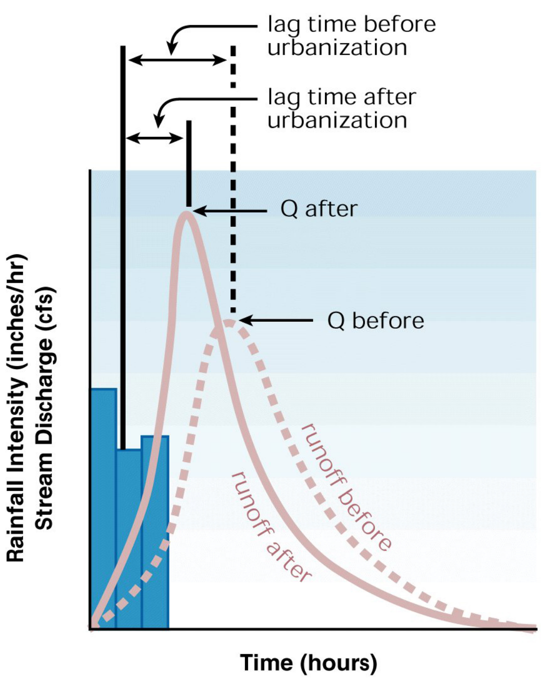
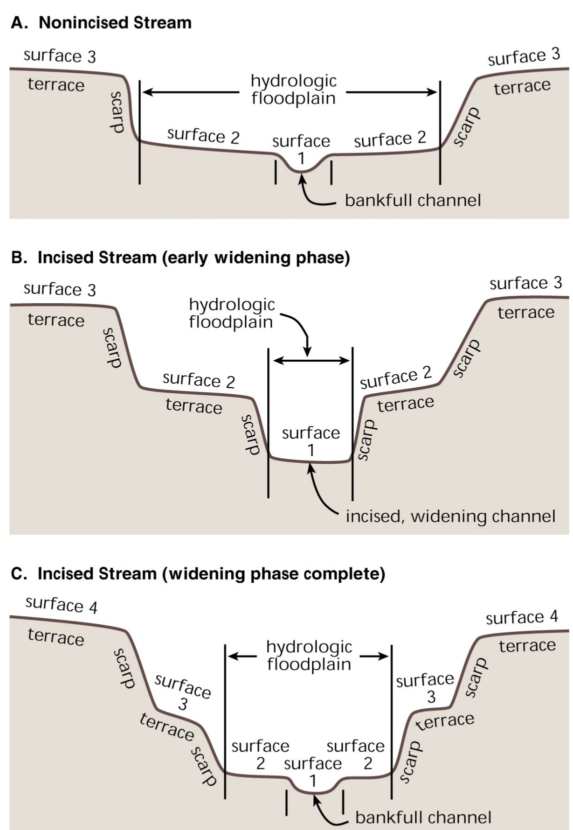


FIGURE 2. Terraces in (A) nonincised and (B and C) incised streams. Terraces are abandoned floodplains, formed through the interplay of incising and floodplain widening. In Stream Corridor Restoration: Principles, Processes, and Practices (10/98). Interacency Stream Restoration Working Group (15 federal agencies) (FISRWG).



Incised stream cross sections are the most common characteristic of northeastern Illinois streams, but this is not always caused by the process of increased peak discharge in the watershed. In many cases during the process of land development and urbanization, stream channels were realigned, moved, or piped in order to more adequately meet the straight line boundaries that were dictated by property lines and easements. This realignment and straightening of the stream ultimately reduced stream length throughout the same slope. Using the principles of dynamic equilibrium in streams, when length is reduced in a stream reach, the stream attempts to adjust itself by downcutting and eroding its banks due to the increased slope and velocities throughout the reach. Often, small streams were widened or placed into a concrete lined channel in an effort to reduce the downcutting and meandering of the stream (Figure 3). While these efforts were perhaps successful on the stretch of stream that was concrete lined, they did little to help stabilize the stream system as a whole, or provide greater capacity within the floodplain. Instead, these chutes would rapidly transport flows to downstream properties further exacerbating flooding, and bank and bed erosion to downstream neighbors.

FIGURE 3. Concrete Line Stream Channel

As greater awareness was articulated of the impact that rapid urban development in the Chicago Region was having on streams; Counties and Municipalities moved to put in place legislation to regulate and manage stormwater on new development projects. Known as comprehensive stormwater ordinances, these regulations serve first to reduce and attempt to mitigate flooding in urban streams and rivers. By requiring stormwater management ponds and managing discharge rates of stormwater runoff from new development, the ordinances attempted to undo some of the damage rapid urbanization had done to the riparian corridors throughout the Chicago region. The Chicago Metropolitan Area for Planning carries archives of their long term plans that show increasing awareness, planning and ordinances focusing on watershed and stormwater management (www.cmap.org). As research and additional technical studies took place, the ordinances were updated and improved to continue to help mitigate flooding and protect riparian corridors. In many cases however, the damage to the stream systems and the watersheds was already done. The resultant downcut and incised stream had already been significantly degraded, often destroying habitat, natural hydrologic functions, and endangering property and infrastructure. The question then became, how to address restoration efforts of these streams under their modified condition.

ESTABLISHING DYNAMIC EQUILIBREUM IN URBAN STREAMS

When approaching degraded urban streams, comprehensive restoration efforts focus on more than simply the stabilization of the stream banks or protection of endangered structures caused by stream meandering or downcutting. While the economic drivers of the funding of stream restoration or streambank stabilization efforts are often the protection of property and structures such as sewer and water lines, bridges, buildings, and roadways, stabilization and restoration activities that don't take into account the question of overall stream health and long term sustainability frequently fall short of their long term goals. Initial stabilization efforts in the region frequently relied on traditional engineering practices such as hard armoring including limestone rock rip rap revetment, concrete stabilization and other "gray infrastructure" approaches. While these efforts frequently stemmed erosion at specific points on stream banks and beds, it often simply redirected erosive forces further downstream.

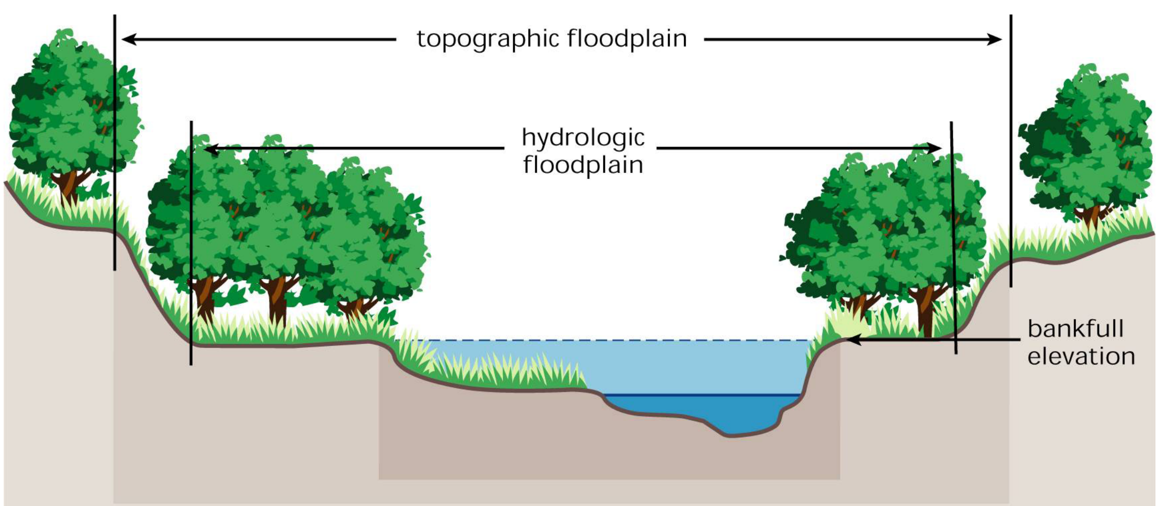
Comprehensive approaches to designing stream restoration focuses on restoring stream corridors to achieve a state of dynamic equilibrium. This method focuses restoration and stabilization efforts on analyzing the stream characteristics and conditions and then adapting a series of practices to create a channel form, profile, and structure that can adequately put the stream in "balance." Balance is defined here as a state of both relative stability, whereas the amount of sediment accumulation is roughly equal to the amount of bank and bed erosion, and also a state of resiliency whereas the stream can adjust to minor changes to the watershed or limited extreme weather events without significant degradation. This approach is as much philosophical in some cases as methodological, although it does follow certain principles and methods to achieve a final design. It serves as a framework for analysis and decision making in design and practice selection attempting to create an integrated design which efforts take into account all the natural systems integrated within the stream corridor, including riparian vegetation, habitat structures, and the morphologic features of the stream. The goal of designing for dynamic equilibrium is designing all practices for achieving as close to a "natural" "healthy" stream system under a modified watershed condition. (Lucas & Ferguson, 1995)

DESIGNING FOR COMPREHENSIVE STREAM RESTORATION

With the stated goal of establishing dynamic equilibrium within a stream restoration project, it is important to understand that when beginning the design process that streams are complex systems. Urbanization and urbanized watersheds lead to a complex mix of negative impacts to streams including not just hydrological and planform impacts, but also chemical and habitat impacts (Coles, et.al. 2012). To approach stream restoration in a sustainable manner a designer must address these complex systems in an ecosystem approach. By incorporating these concepts into the plan, the restoration project focuses on achieving multiple benefits from practices and selecting practices that achieve multiple benefits versus those that only achieve more singular goals. Regardless, of the methods selected in the design the approach in the design and planning phase ultimately directs the levels of success when evaluating practices (Lyn D.A., and Newton J.F., 2015).

One of the most critical steps in restoration planning and design relies on performing detailed and comprehensive inventories of streams. Successful and sustainable restoration design and planning is far more comprehensive than reading stream gages, running hydrology and hydraulics modeling, and analyzing practices' tolerance for sheer stresses and velocity resistance. While these elements are important and critical in final designs, these are the last steps in a comprehensive stream restoration plan. Detailed inventory of the stream reach, as well as the stream conditions upstream and downstream of the proposed reach is critical. The inventory and analysis should take into account not only the fluvial morphology of the stream (such as cross section surveys, profiles, etc.) but also include inventory of the biotic habitat of the restoration corridor. This includes not only the stream itself but also the associated floodplain and riparian zones. Biotic factors include riffles, pools, riparian vegetation, woody debris structures, and bed materials (Lucas and Ferguson, 1995). These inventories provide an opportunity to assess the overall stream health and identify areas where appropriate practices can achieve multiple benefits. Analysis of bed materials such as the presence of sand or mud bars, cobble sizes, etc. can help understand if the reach in question is in the process of aggredation (bed sediment deposition) or degradation (sed as well as estimate bed load and what bed materials are mobile under channel forming flows (FISRWG, 1998). These surveys can also help identify in the field the level of channel forming flows, limits of hydrologic floodplain, as well as the historic floodplain elevations (See Figure 4).

FIGURE 4. Riparian Zone



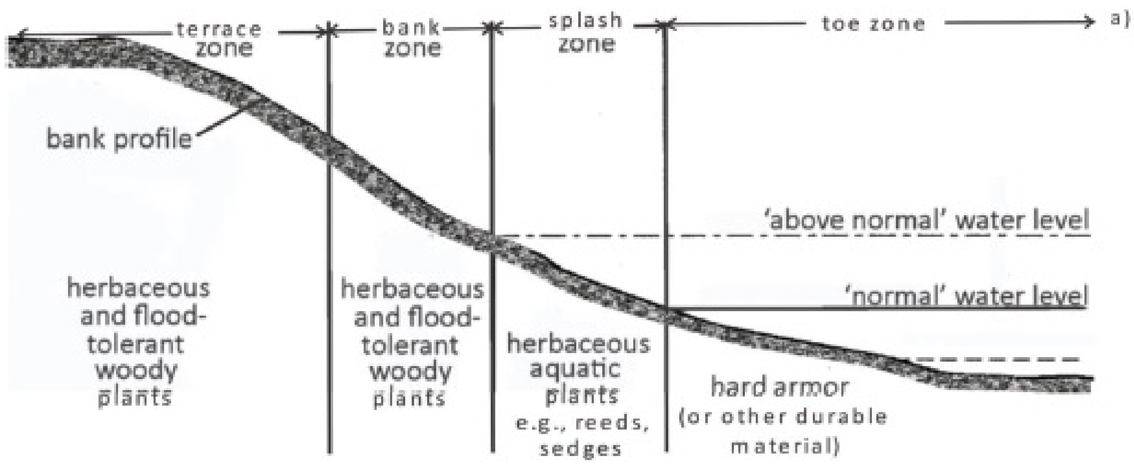
When evaluating the overall goals of urban streambank restoration several general themes emerge in Northeast Illinois when approaching projects. Typically in order to achieve a state of dynamic equilibrium, floodplain connectivity and alignment become critical issues. In order to create a stable morphology the stream banks need to be cut back and the profile either raised or stabilized in an effort to spread out channel forming flows and to more frequently connect the stream with the larger associated floodplain. A frequent floodplain hydrologic connection also serves to hydrate the floodplain and restore historic floodplain wetlands which serve important habitat, water quality and flood storage roles. The creation of pothole wetlands associated with the floodplain frequently improve these functions and can be incorporated into the final project. With all cases, there is often a limit to the project both in scope and scale that is influenced not by the stream and riparian conditions, but instead is constricted by budgets and property lines. While not ideal from a strictly ecosystem perspective, we also must consider the human element of project. Is the project within a public park? Will it be accessible? Are trails and other active use considerations important in incorporating into the design? Are property lines or limits restricting what is possible regarding creating re-meanders or otherwise significantly modifying the stream alignment? These considerations must be incorporated into the overall design in order to make the project practical and constructible.

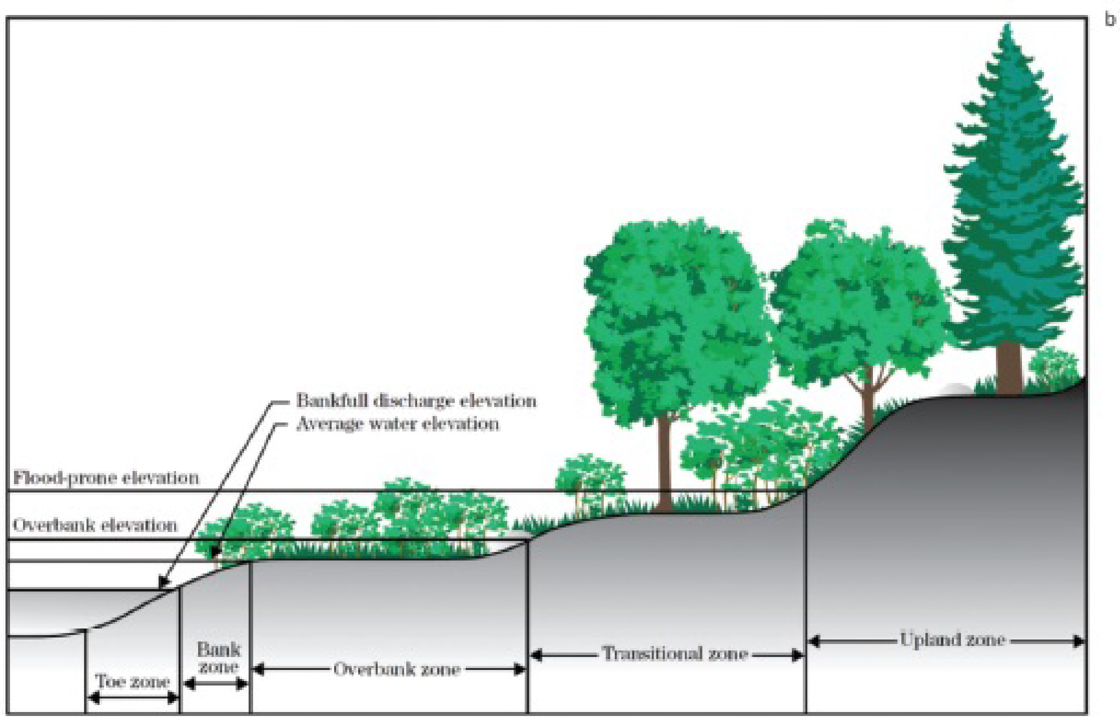
When calculating storm events and discharges while designing streambank stabilization and restoration practices the key storm event in understanding channel morphology and dynamics is the stream under channel forming flow. Channel forming flow is considered the most frequent flood event that causes the channel to either erode or form itself and is generally accepted as the flow under a year and a half flood recurrence interval or Q1.5 where Q is the variable meaning discharge of the stream. This widely used principle dictates a great deal about the stream channel and morphology. Often described as bank-full flow, it also serves as a measure of identifying a stable channel cross sectional area and ideal width to depth ratio based on analogous stable streams within a region (Lucas & Ferguson, 1995). These parameters also identify those areas of the streambank that are most susceptible to frequent erosive velocities as well as the hydrologic conditions of those portions of the bank that are either above or below the Q1.5 elevation (Figure 5). Case studies and literature review identifies the portion of the stream submerged under the bank-full flow as the most critical treatment area for selection of long term treatment options (Lyn D.A., and Newton J.F., 2015). Under this consideration, it is critical that the method of stabilization within this zone be appropriate for the condition of the stream reach. Failures to select methods appropriately often can lead to unintended consequences and bank failure.

STRUCTURAL BANK AND TOE PROTECTION

Traditional urban streambank stabilization methods, as described previously, frequently relied on limestone rock rip rap or other stone dumped across banks or erosion prone areas in an attempt to reduce erosion directly in the treated reach. These efforts have been modified over time and modernized in many cases with additional technologies for bank stabilization that incorporated hard armoring such as rock gabions or articulated concrete block mats. Rock rip rap gabions are essentially cages of wire filled with quarried stone that are then tied together to stabilize streambanks. Articulated concrete black mats are similar to gabions but are formed concrete blocks that are tied together using steel cables and pinned in place to stabilize soil and protect In Northeast Illinois, a number of permitting agencies and many design engineers have been moving away from stone toe revetment as the primary solution to bank erosion and towards a soft armoring or a bioengineering approach. Structural and armoring solutions tend

FIGURE 5. Definition of various zones according to (a) USACE1997, (b) NEH





to have little effect on velocity and energy dissipation withstanding configurations such as stream barbs or bendway weirs which serve to control thalweg migration and dissipate erosive energy within a meander. Stream barbs and bendway weirs are lines of stone dug into the bank and extending out toward the center line of the stream that are used to control erosive flows against the banks of a stream through a meander. The thalweg or deepest portion of the stream where the highest flow velocities occur, are then held toward the center line of the stream and are pushed away from the streambank, thereby reducing erosion. Traditional urban structural control and stabilization methods rely on stabilizing a bank in place rather than working to control overall stream morphology. Frequently these practices include gabions and other structural controls with a minimal account for vegetative and other habitat enhancement practices. Gabion structures in some cases are used out of necessity due to the channel and bank's proximity to buildings, structures, property lines, or other infrastructure (Figure 6 and 7). When used as such they are necessary methods, but also require that the designer understand the morphology and condition of the stream reach as well as conditions upstream and downstream of the treated reach.

FIGURE 6. Structures Undermined by Streambank Erosion

FIGURE 7. Bank Erosion Confined by Property Limits

When overall stream morphology and dynamics are misunderstood or practices applied inappropriately, failures of structural practices occur. An inventory and study of urban stream restoration practices performed by Wayne Kenney, Streams Engineer Specialist and Thomas Ryterske, Resource Conservationist, of the USDA-Natural Resources Conservation Service in the DuPage County Illinois area from 2003–2004, found a series of misapplied structural practices or practices that did not take in to account total stream morphology. Examples of the failed practices included undermined gabion wall bank stabilization due to downcutting of the stream because no bed stabilization practices were included in the project (Figure 8). Other practices inappropriately constricted channel flow when treating only one bank of a stream with A-Jax (a concrete cross block product used as an alternative product to Rip Rap or Gabions) which caused accelerated bank erosion on the opposite bank (Figure 9). These examples exhibited design with limited scope that exhibited incomplete analysis of the entire stream and watershed, and fell fall short of incorporating natural channel design with a goal of establishing the reach in dynamic equilibrium. Failing structural stabilization practices such as these also exhibited a common approach at the time of traditional civil engineers to design projects from property line to property line rather than exploring how the project reach would fit in the larger picture of stream dynamics and principles of fluvial geomorphology. Many of these challenges and failures helped push a more green or bioengineered approach to stream restoration and bank stabilization.

FIGURE 8. Gabions Undermined by Streambed Erosion

FIGURE 9. A-Jax Stabilization Leading to Erosion of Opposite Banks

VEGETATIVE AND BIOENGINEERING STABILIZATION SOLUTIONS

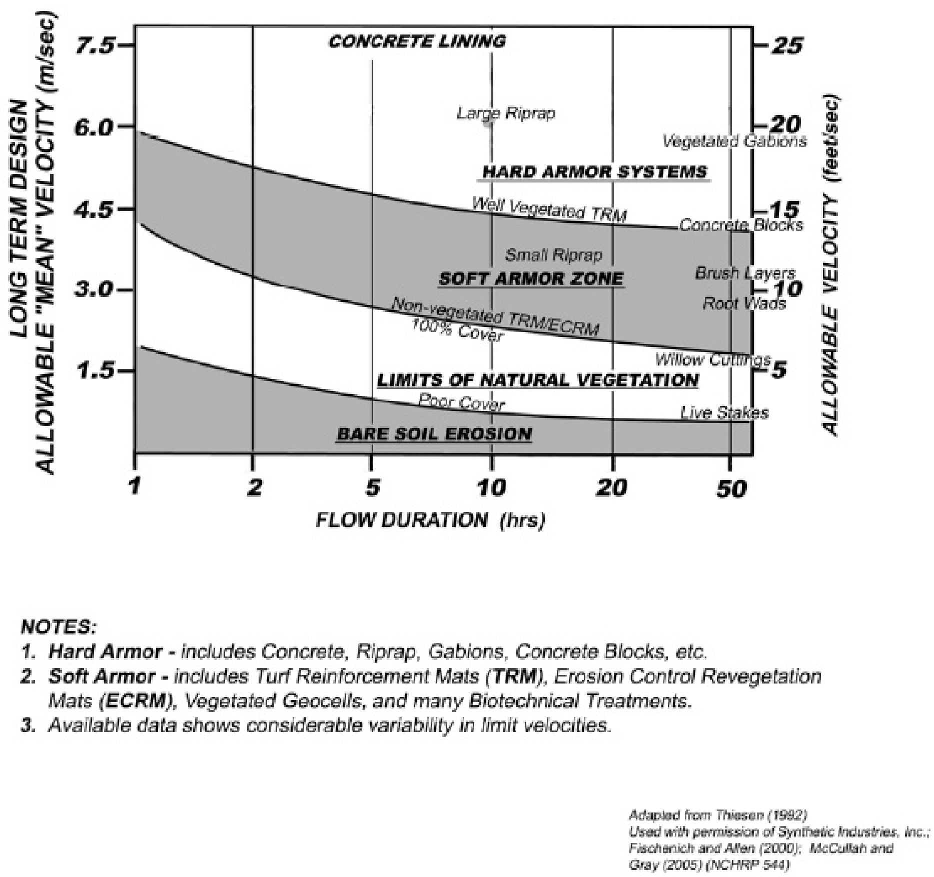
Designs that incorporate bioengineering or 'soft' armaments often show preference in several federal guidelines, representing a more 'natural' solution that addresses wildlife habitat considerations as well as stabilization issues. Especially in areas aiming to maintain certain level of aesthetics or natural integrity, bioengineering and vegetative practices offer a design option with a fair amount of control while still not appearing out of place in a natural setting. Concerns with wildlife habitat improvement or creation, especially in urbanized areas, can also be addressed with the inclusion of native plant species that provide extended ecological function in addition to stabilization. The key is still the erosive forces in the bank zone and the ability of the vegetation to withstand erosive velocities.

Vegetative stabilization methods are not without complications, as permanent vegetative stabilization can be difficult to achieve in areas subject to harsh or unpredictable environmental conditions. Long periods of shoreline inundation, high stream velocity, space restriction, as well as existing streambank stability can exclude the sole use of vegetative stabilization as a legitimate option for a project. A key factor in using vegetation as a permanent method of bank stabilization is to ensure that the species selected are appropriate for the soil types, hydrology, and sunlight regimes within the reach. Additional site considerations, including soil nutrient composition and existing water quality, may limit plant availability for a site. Considering this, it is important to plan for the site not only during the establishment period, but for the site at maturity. For example, seasonal water level fluctuations or establishment of large trees may require the established plant community to adapt to various hydrologic and sunlight regimes. If species selected are inappropriate for the site, they will not survive or thrive and will leave soils exposed and prone to erosion.

During the establishment period of vegetative streambank stabilization and in conjunction with utilizing native vegetation, modern erosion control and vegetative reinforcement technologies have expanded the capabilities of modern bioengineering practices. Rolled Erosion Control Products (RECPs) and Turf Reinforcement Matting (TRMs) are manufactured products that create rolls of materials comprised either of natural materials or polypropylene in various configurations that are laid across the soil and anchored to protect soil surfaces from erosion and help establish or reinforce vegetation. Commonly used RECPs and TRMs include the use of coir, straw, coconut, jute, and other biodegradable materials laid in a mattress and then mechanically stitched together utilizing thin monofilament or polypropylene in various densities. These materials have different structural degradation times which provide either temporary erosion control until live woody stakes, shrubs, or herbaceous vegetation can fully establish and stabilize the soil or more permanent erosion control. Originally developed for slope and channel stabilization, these products have been successfully adapted to streambank stabilization applications. Bioengineering practices that incorporate these products are important tools in urban settings where accessibility and interaction with people and use of riparian vegetation as passive recreation spaces are desired.

The development of high technology in the erosion control industry has also led to a great deal of testing and engineering of the products used for many bioengineering practices. Many manufacturers pay for rigorous testing at university laboratories and develop sophisticated engineering software that designers can use to select the appropriate products for practices and applications on a project. As these products provide additional strength and stabilization for vegetation, it is an important to consider the longevity of the product and its performance over the long term as well as what the success of the practice would be if the vegetation establishment is not successful. When evaluating the use of vegetative, stone or structural bank stabilization practices, a matrix can be developed that helps guide designers when selecting the category of practice to apply based on duration of need and flow considerations (Figure 10) (Miller, et. al., 2012)

FIGURE 10. Decision Matrix on Bank Restoration Techniques



METHODS OF MEANDER/REDIRECTIVE CONTROL PRACTICES

Highly effective structural practices utilized in integrated natural channel design include the use of stone and cobble structures that control thalweg channel migration as well as scour control. Redirective practices are structural practices include the use of stream barbs, bendway weirs, and j-hooks as well as the use of log vanes. Stream barbs, bendway weirs, and j hooks are stone structures that protrude from eroded streambanks that serve to push the thalweg of the stream toward the center of the channel as well as direct the most erosive forces of the stream away from the banks (Figure 11 and Figure 12). Upstream facing stream barbs and j hooks also serve to hold up flow and build up water on their shoulder or upstream face creating quiescent zones that deposit sediments while also slowing up flows and dissipating erosive velocity. These structures are highly effective when used in conjunction with vegetative and biotechnical practices to stabilize and meander movement. Log vanes are similar types of structures, however they utilize anchored tree trunks or logs to achieve the same goal of directing the thalweg of the stream away from actively eroding banks. Log vanes need to be constructed of solid, large diameter trees and embedded into the bed and banks to prevent them from being undermined, bypassed, or displaced in high flows. These in-stream stone and woody structures also serve to provide valuable refugia and habitat for macroinvertebrates, crustaceans, and fish species.

FIGURE 11. Detail Drawings of Stream Barb

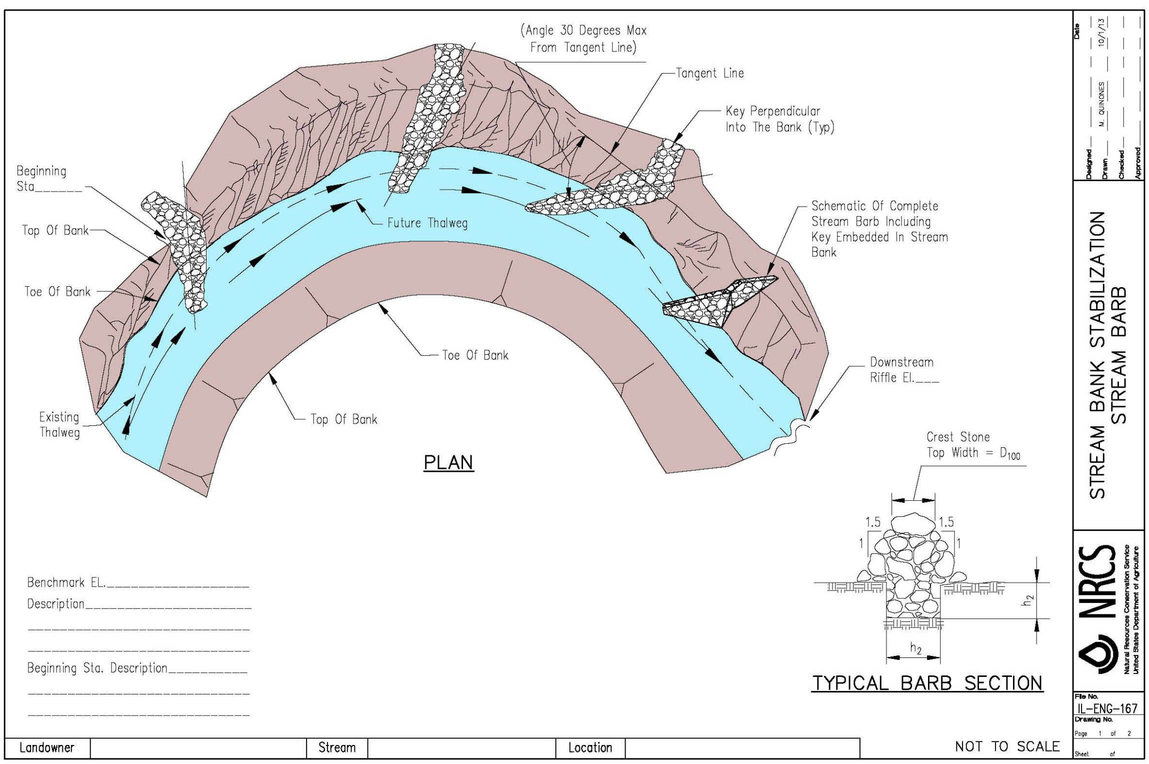
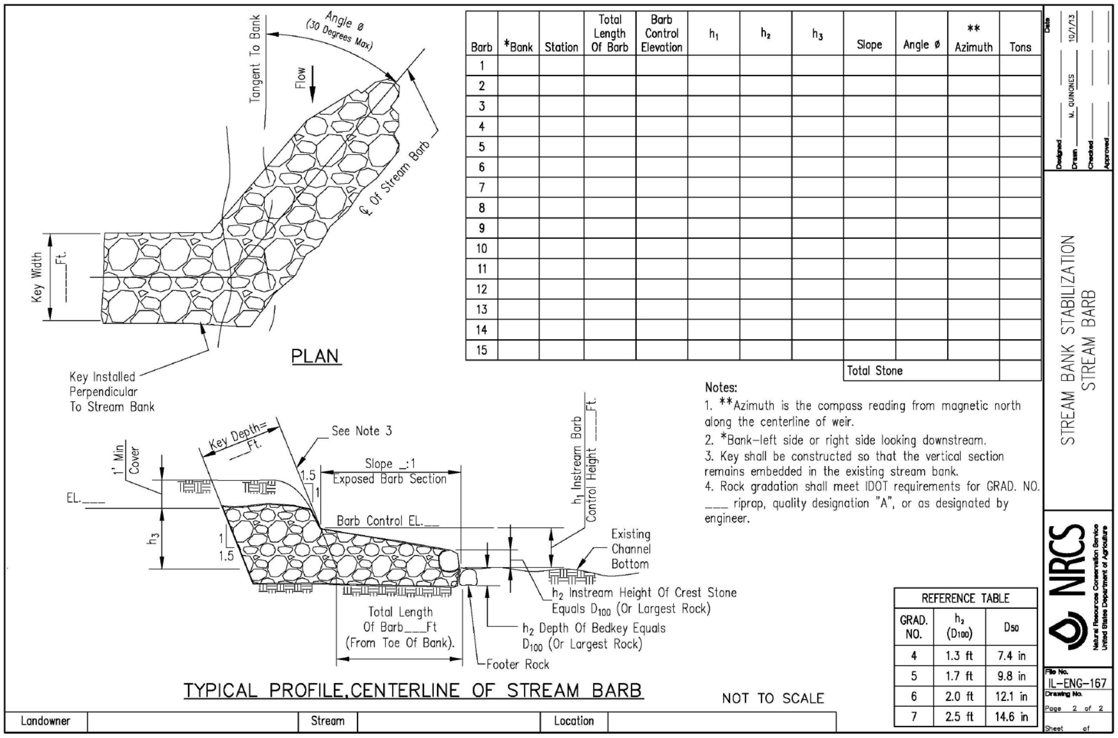


FIGURE 12. Detail Drawings of Stream Barb



BANK PROTECTION AND STABILIZATION PRACTICES

Bank protection and stabilization practices serve to stabilize and protect streambanks from scour and erosion. The majority of these practices combine hard and soft armoring while utilizing natural materials to stabilize streambanks primarily on the outside banks of meanders. These practices can be as simple as grading back the slopes of the streambank and establishing vegetation, to complicated stone toe protection with brush with soil encapsulated in high technology turf reinforcement matting with geogrid soil anchoring and herbaceous plantings. Bank stabilization practice examples include the use of rootwad revetments, stone toe protection, gabion baskets, vegetated geogrid soil lifts, bank shaping, and a variety of combinations of these practices. These bank stabilization practices include hard armoring and vegetation or the combination of the two to create systems that stabilize streambanks.

GRADE CONTROL STRUCTURES

Rock riffles, step pool structures, cross veins and other in stream grade control structures are critical elements of natural channel design and provide stable points in the streambed to control downcutting and scour within the channel. Rock riffles mimic natural stream riffles where stone is placed across the channel to shallow the flow depth and create an area of rapidly moving water. When anchored into the bed and bank, they act as stable points in the bed slope profile and reduce downcutting of the stream bed. Step pools and cross veins act in a similar manner however are focused on controlling stream bed erosion on much steeper grades. They are frequently constructed of larger diameter stone and include steeper grade transitions and are utilized more frequently on steeper grades and in hilly and mountainous terrain. Grade control structures may be constructed of a variety or combination of materials based on region. In Northeast Illinois the predominant use of grade control is the use of rock riffles. With relatively flat topographic features (outside of a few coastal areas along Lake Michigan and some river bluff areas), most streams do not exhibit ravine type drop weir structures or other structures that are designed to stabilize streambeds under steeper bed slopes. Also, as a majority of the streams in Northeast Illinois are prairie streams, the use of log step or log weir structures are less common than in other regions where forested areas are more prevalent. Rock riffle structures are especially critical in urban streams to protect other bank stabilization practices from being undermined on the long term. The use of riffles also accomplishes the goal of replacing natural riffle and pool habitat which has been lost in many urban streams due to scour.

Stream Restoration Practices; an Integrated Approach Toward Natural Channel Design

Most regulatory authorities (USACE, USDA-NRCS, EPA, etc.) have comprised guidelines for streambank stabilization projects, reinforcing the importance of site-specific considerations for stabilization practices. An underlying theme of toe protection is evident throughout various government agency reports—considering the limitations of bioengineering in vulnerable toe areas, structural reinforcement is often the most successful stabilization method. Emphasis is placed on incorporating structural toe protection in combination with permanent vegetation stabilization, considering that few situations, excepting considerably low flow situations, would allow for permanent, substantial vegetative establishment alone stabilize the banks on a long term basis without scouring. As mentioned above, the toe zone is considered the most critical area of bank treatment and stabilization for successful streambank protection. Under the designed flow conditions, it is important to understand erosive velocities and sheer stresses at critical points. Based on cross sectional area, flow velocities and sheer stresses may exceed the value at which vegetation or other soft stabilization methods can withstand without reinforcement.

CONCLUSION

The most successful projects in working toward dynamic equilibrium in stream restoration projects are those that take a site specific and integrated approach to select practices for use in a project. These projects typically involve a multitude of practices applied wherever they are deemed most appropriate in the reach to achieve the projects goals of restoring and stabilizing the stream. Integrated geotechnical practices used in conjunction with vegetative and structural practices provide the most effective projects in the watershed scale. This does not however mean a desiger should put as many practices as they can fit into a project, but it does mean that having multiple practice approaches in a project also build factors of safety and some redundancy into the project approach.

Streams provide inherent complications for comprehensive stabilization and restoration, primarily because they fail to adhere to property lines, city limits as well as other commonly established 'borders', and continually fluctuate with seasonal hydrologic regimes. Due to the dynamic nature of streams and watersheds, successful stabilization projects need to incorporate efforts that are comparably dynamic. In many urban areas the stream channel itself is still in the process of adjusting to the urbanized watershed. Fluvial Geomorphology while fast in comparison to some geologic processes, in the human timescale is a relatively slow moving process. A stream channel's morphology (width to depth ratio, cross sectional area, meander radius, etc.) takes decades to adjust to an urbanizing watershed. If projects are designed to mimic these geomorphic features in a reference natural stream in a rural area, the practices selected may not be effective on the long term because the stream may be still attempting to modify itself in morphology to fit the new urbanized watershed (Brown, 2000). With all designs, effective analysis of the watershed and stream, good planning with a detailed understanding of the principles of fluvial geomorphology, and proper selection of practices which are comprehensive in their approach and methodology are critical to project success. Using a cookie cutter approach to stream restoration is a recipe for project and practice failure.

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