Critical Analysis of the Stream Restoration Design for Brickelmaier and Goodman Parks in Hollin Hills

By

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I am writing to comment on Fairfax County's plan to undertake stream restoration in Goodman and Brickelmaier Parks in the Hollin Hills neighborhood. While I am a former resident of Hollin Hills, having grown up in the 1960s-70s on Brentwood Place and White Oaks Drive, my comments are based on my expertise as a fluvial geomorphologist (river geologist) and stream restoration specialist, the focus of my more than 25-year career to date. Before commenting directly on the County's restoration plans and offering an alternative approach, let me provide more background on my credentials and a short fluvial geomorphology and stream restoration primer, so my comments on the County's plans are more understandable and fully appreciated.

Professional Background

I earned an MS and PhD from the University of Arizona in Geosciences with a focus in fluvial geomorphology (river geology) and hydrology after completing a BS in Geology with Honors from Virginia Tech, one of the strongest undergraduate geology programs in the country. I first became involved in and published about stream restoration (Field, 1997) during my time as a geology professor at Western Washington University where I received both the university-wide and Geological Society of America's national teaching award. My involvement with stream restoration became even stronger after moving to New England in 1999 to be closer to family. Continuing as a professor at a small college in Vermont, I served as an advisor for the State of Vermont's development of a protocol for assessing the cause of and best treatments for bank erosion and channel migration on rivers in a state hard hit by floods in the 1990s (Web citation 1).

Over the course of my career I have worked on rivers in 15 states and 14 other countries around the world. Interested in becoming more directly involved in stream restoration projects, I moved out of academia in 2002 to found Field Geology Services, LLC, a small consulting firm based in Maine focused exclusively on fluvial geomorphology and stream restoration. Since its inception in 2002, my company has assessed the causes of channel instability on hundreds of miles of river, ranging from some of the largest in the world (Ganges-Brahmaputra river system in Bangladesh) to the very smallest of streams such as found in Goodman and Brickelmaier Parks. Only by understanding how bank erosion, channel migration, and other channel instabilities relate to human activities on rivers (e.g., urbanization) can sustainable solutions be developed to address these problems. Based on the results of these assessments, I have also designed and completed dozens of successful stream restoration projects on more than 30 miles of stream with trees/wood featuring as a significant component of these projects.

Many of the stream restoration projects I have completed have been in urban settings where the streams are often designated as impaired for aquatic life. I, with the involvement of others, received an Environment Merit Award from the United States Environmental Protection Agency for restoration efforts near the Maine Mall intended to remove the stream from the impaired list (Figure 1). Throughout these years as both a professor and practitioner, I have literally reviewed hundreds of stream restoration project designs, monitored the results of completed projects, overseen construction of my own project designs, taught short courses to government agency staff, and through this process have developed a sense for which types of restoration projects (or other human interventions) work and don't work in various riverine settings around the world.

Figure 1. Log jams (left) constructed on an incised portion of Long Creek in South Portland, ME to restore floodplain flow (right).

Fluvial Geomorphology and Stream Restoration Primer

[Throughout my comments below, I use the terms "river" and "stream" rather interchangeably as the distinction between the two is informal and based only on an ill-defined size difference, so no significance should be attributed to my varying usage of both.]

While efforts to improve fish habitat on degraded streams goes back to at least the 1880s (Thompson, 2005), stream restoration has burgeoned into a multi-billion dollar industry annually since the 1990s (Bernhardt et al., 2005) aimed at not only improving habitat but also addressing flooding, erosion, and non-point source pollution. Stream restoration has become a catch-all phrase to embody just about any river engineering project, since the term "restoration" is often viewed favorably by regulators tasked with approving project proposals for work on rivers. As such, reviewing these projects must be done carefully to ensure the stated objectives of the project will be achieved through the proposed remedies. Many well-intentioned projects often fail to achieve their stated objectives with individual structures and projects as a whole unraveling due to an inadequate understanding of natural river processes and the impact of human activities in the stream channel or larger watershed (Miller and Kochel, 2010).

In my view, projects completed on rivers and streams can rightfully be called "stream restoration" only if they achieve all of the following three things: 1) they move the stream towards an equilibrium condition; 2) they are sustainable over time (and as such do not require maintenance after completion); and 3) they do not destabilize (i.e., worsen conditions) upstream or downstream sections of the stream. Many flood control, bank stabilization, and habitat enhancement projects are worthy of completion, but do not necessarily qualify as restoration projects based on these requirements. Recognizing the difference and making such distinctions can lead to better preparation for necessary onsite maintenance and mitigation of offsite impacts for those projects that do not truly represent restoration projects. Successful restoration projects arise only from a thorough understanding of river processes and the concept of equilibrium.

The concept of "equilibrium" is a guiding principle in fluvial geomorphology and stream restoration. A stream (or river) is considered to be in equilibrium when its dimensions (such as its width, depth, slope, and sinuosity) remain stable (i.e, largely unchanged) through time. (Sinuosity is a measure of how much the stream meanders.) Stream stability when discussing equilibrium is often confused with a static, or unmoving, condition but nothing could be further from the truth. Rivers can change their position as they migrate across a floodplain while maintaining a stable equilibrium condition by balancing the amount of erosion (on the outside bend of meander for example) with an equal amount of deposition (on the inside bend) such that the shape, width, and other dimensions of the river remain essentially constant over time (Figure 2). Embodied in the concept of equilibrium is that the amount of sediment entering a reach of river at the upstream end equals the amount of sediment exiting at the downstream end such that the "continuity of sediment transport" is maintained. Sediment should not be thought of as moving down a river on a conveyor belt as some sediment entering the reach is stored as a result of deposition (on sand bars for example) while different sediment particles, in roughly equal amounts, are removed through erosion.

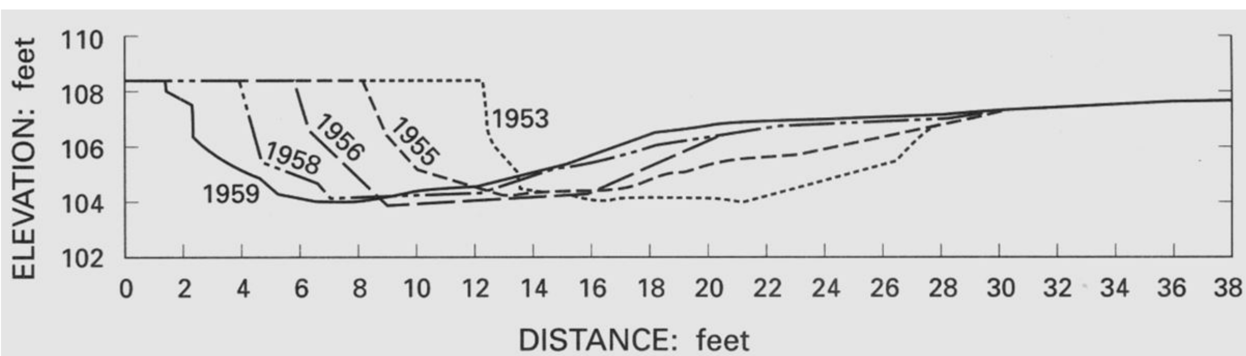

Figure 2. Repeated cross sections at the same location on Watts Branch, MD over a period of several years show how the channel maintained the same shape and dimension despite migrating over time. (From Leopold et al., 1964)

Within the context of equilibrium, a static condition, where the stream remains "frozen" in the same position over time due to the armoring of the bed and banks of the channel, should not be confused with stream stability. Although the channel dimensions in a static reach of river may remain unchanged over time, equilibrium cannot be maintained along the full length of a river if portions of the channel are made static (through armoring), because the stream channel's continued migration upstream or downstream would eventually become disjointed from the static reach. This leads to a change in the stream's shape (e.g., sharper bends) where the different sections of channel meet, violating the very principle of equilibrium.

Equilibrium should be considered a "river utopia" with rivers adjusting their dimensions towards an equilibrium condition but never quite attaining that state due to changes in external forcing conditions that determine the river's equilibrium dimensions. Some of these changing conditions include trees falling into the channel, sediment introduced from tributaries, long-term variations in discharge accompanying variations in climate, and humans modifications to the channel itself or surrounding watershed. Areas that are far removed from an equilibrium condition are prone to dramatic adjustments (e.g., rapid and significant erosion) that become less pronounced as the equilibrium condition is approached. Therefore, understanding what the equilibrium stream dimensions might be under the existing conditions (be they completely natural or altered by humans) is paramount to identifying where the river may be unstable (i.e., not in equilibrium) and how the river might adjust to ultimately achieve an equilibrium condition.
Ultimately, the dimensions of a river channel change so as to maintain the continuity of sediment transport. For example, if a channel is too wide and flow too slow to transport the sediment delivered from upstream, deposition will occur and the resulting narrowing of the channel will increase the flow's velocity and ultimately enable the more efficient transport of sediment delivered from upstream. Once the stream is able to transport the sediment volume coming from upstream, then the continuity of sediment transport is maintained and an equilibrium condition is reached. However, if the source of upstream sediment then declines in volume, the stream would erode the banks (to regain the lost sediment) and widen to a point where not as much sediment can move through the reach and, thus, again come into balance with the new levels of sediment delivered from upstream. Within this context, erosion and deposition should not be viewed as necessarily undesirable processes as they are in fact essential for achieving equilibrium. Of course, erosion and deposition are sometimes hazardous, degrade aquatic habitat, and can impact downstream reaches, so restoration is often warranted to reduce the negative impacts of these processes. Studying the patterns and rates of erosion and deposition, rather than simply assuming they need to be stopped, can provide vital clues as to the most effective restoration treatments that will best mitigate hazards, enhance habitat, and decrease downstream sediment loading while moving the stream towards a stable equilibrium condition.

A simple way I have developed to identify where a stream is out of equilibrium and prone to instability is by remembering that "rivers don't like fast changes". Rivers don't like sharp right angle bends where all the turning occurs at one point but rather trend towards the development of smooth meanders where a little bit of turning occurs everywhere along the river's length – a condition that minimizes the amount of energy expenditure at any given point (Figure 3). The same holds for a river's width, helping to explain why small culverts narrower than the channel itself (i.e., a fast change in width) are often unstable areas prone to adjustments. The deposition and erosion that frequently occurs around such structures represent the stream's adjustment towards a minimization in the width change from point to point rather than all of the width change occurring suddenly at the culvert itself. The "rivers don't like fast changes" refrain for understanding equilibrium and identifying unstable areas along rivers even applies to rapid changes in bank composition between natural erodible soils and unerodible armored banks as discussed above when explaining why static channels do not represent an equilibrium condition.

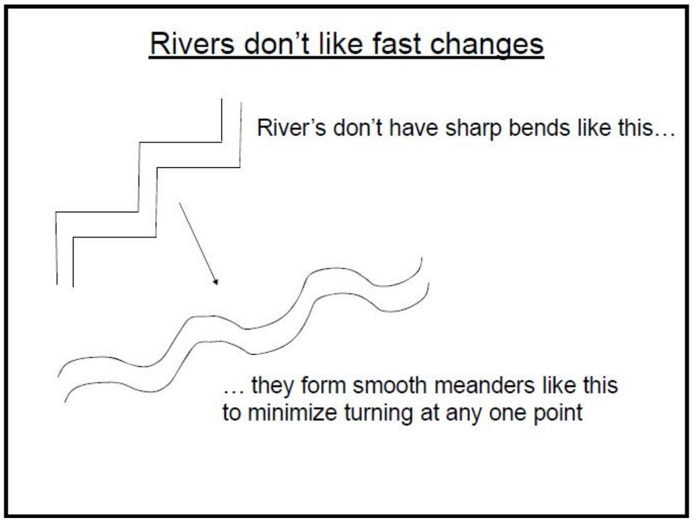

Figure 3. Rivers minimize change from one point to the next to achieve an equilibrium condition.

The principle of equilibrium and its value in anticipating where and how a channel might adjust through time largely applies only to what are referred to as "alluvial" channels. Alluvial channels have adjacent floodplains composed of sediment deposited by the streams themselves and, therefore, are able to freely adjust their dimensions, because these streams are able to transport the sediment composing the bed and banks of the channel. In contrast, "nonalluvial" channels do not have a floodplain along one or both banks and, thus, are unable to freely adjust their dimensions, because the bed and banks are composed of materials such as bedrock, boulders, or large cobbles that cannot be moved by the streams. Even if the sediment can be eroded, if one or both banks of a nonalluvial channel are very high the streams still cannot freely migrate given the volume of sediment that needs to be removed. The dimensions or form of a nonalluvial channel reflect the external constraints to the channel's adjustment and do not necessarily reflect a tendency towards the minimization of change – elimination of fast changes – characteristic of alluvial channels. The best way to appreciate the difference between alluvial and nonalluvial channels is to envision a nonalluvial bedrock channel with sharp right angle bends – a fast change – that follows the fracture patterns in the constraining rock rather than forming the smooth meanders typical of an alluvial channel in equilibrium. Although not as dramatic, the coarse sediment or high banks of nonalluvial channels may exert similar constraints on the shape of meanders (and other channel features). Nonalluvial channels also trend toward an equilibrium form, but unlike alluvial channels the equilibrium dimensions of such channels are less predictable and more dependent on the site specific conditions constraining the minimization of change (elimination of fast changes).

The above discussion on equilibrium and the difference between alluvial and nonalluvial channels is critical for appreciating the difference between the two schools of thought within the field of stream restoration: form-based restoration and process-based restoration. With form-based restoration the goal is to actively realign and reshape an unstable channel into the "form" (i.e., shape) of an equilibrium channel that would be expected to develop naturally in the absence of human impact. By doing this, the intention of form-based restoration is to "short circuit" a long period of channel instability that may threaten human infrastructure or cause unwanted downstream sediment loading as the river adjusts towards equilibrium. Determining what that equilibrium should be is often based on an analysis of the dimensions of "reference" streams located in watersheds relatively undisturbed by human influence. Form-based restoration is also referred to as "natural channel design", the term reflecting the intent to create a stream channel with the dimensions and form expected to develop under natural conditions.

However, the equilibrium form of a stream that develops when human "stressors" (influences that cause a stream channel to adjust its dimensions) are still present will be different than the form that would develop under natural conditions with no human stressors. To be clear, an equilibrium condition is not necessarily synonymous with a natural condition – a fact that is not often appreciated by those involved in form-based restoration and natural channel design. The equilibrium dimensions of a channel change as the amount of water and sediment delivered to the stream changes; human stressors such as urbanization that increase runoff from roofs and paved areas are a common cause for channel adjustments leading towards a new and different equilibrium condition. If the human stressors present in a watershed are not addressed prior to or as part of a natural channel design project such projects are prone to failure as the idealized equilibrium natural form imposed on a stressed stream system will often unravel with the stream readjusting towards the actual equilibrium condition stable under the stressed condition (Figure 4). Over time, the erosion and deposition associated with adjustments due to, for example, urbanization will become less severe as the new equilibrium condition is reached, although the habitat degradation may be permanent as aquatic species obviously evolved in channels that were in equilibrium with natural conditions and not an urbanized environment.

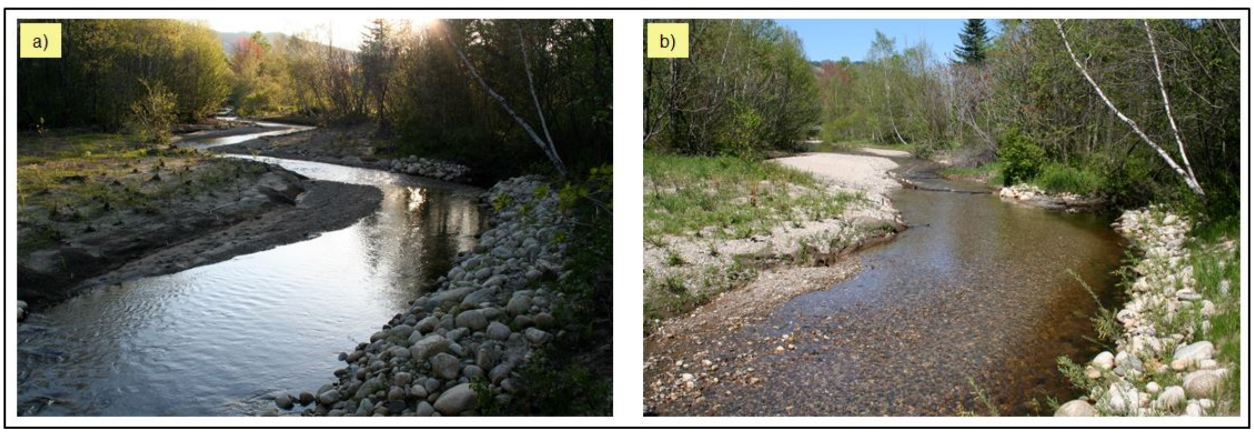

Figure 4. Form-based stream restoration project completed on Barker Brook in Newry, ME that a) created meanders based on reference conditions but b) straightened itself out in less than two years due to high sediment loads from upstream development.

Process-based restoration, in contrast, attempts to address the underlying stressors (or processes) causing the channel instabilities to be addressed by the restoration. After the stressor is removed, the stream is allowed to adjust towards a more natural equilibrium condition such that the amount of channel instability subsides while aquatic habitat is enhanced. Typical process-based restoration projects include such projects as: 1) resizing undersized bridges and culverts to ensure they span more than the natural channel's width (as narrow structures typically cause significant deposition upstream and channel incision and bank erosion downstream); 2) reforming meanders on artificially straightened and channelized streams by constructing log jams on the margins of the channel (Figure 5) so flow is diverted around these structures to create a sinuous flow path that is, ultimately, more stable than the straightened channel, and 3) removing or setting back levees on the river bank so flood flows can once again access (portions of) the floodplain and reduce erosive flow velocities in the channel. These projects must be done with care to avoid conflicts with human infrastructure but can and have been completed in urban settings (e.g., see Figure 1). Process-based restoration projects are often less disruptive, less costly, more sustainable, and more effective than form-based restoration projects, because the ultimate cause of the channel instability is removed.

Figure 5. A meander developed around a marginal log jam constructed on an artificially straightened section of Nash Stream in Coös County, NH.

In some instances, integrating both process-based and form-based elements into the same restoration project can be valuable. A prime example of a combined approach is associated with removing older dams that no longer serve their original purpose, present a hazard as they deteriorate and become unsafe, and continue to obstruct fish passage. Removing the dam itself restores natural processes, while excavating a new channel based on the expected equilibrium condition in the former impoundment area upstream can prevent large amounts of sediment stored behind the dam from moving downstream. Since the cause of channel instability, the dam, is removed (the process-based portion of the project), the form-based portion of the project (creating the new channel in the impoundment) has a much greater likelihood of success.

Comments on the County Proposal

The County's proposal for restoration of Goodman and Brickelmaier Parks is a form-based restoration project based on natural channel design principles (Stantec, 2018; Rosgen, 1996). The primary objective of the County's restoration effort is to reduce downstream sediment and nutrient loading to Chesapeake Bay by eliminating the channel incision and bank erosion currently observed along portions of the two streams that are considered to be significant sources of sediment and associated nutrients. This objective and secondary objectives to improve habitat and reduce hazards are certainly laudable and worth pursuing. To fulfill these objectives, the County's restoration design calls for a complete reshaping and realignment of the streams in both parks in an effort to create channel dimensions that match reference conditions and are expected to form under natural conditions (Stantec, 2018). The existing channels will be partially, or in some cases, completely filled up to depths exceeding 12 feet, while a new channel will be created by either reshaping the existing channel or completely excavating a new channel across the existing floodplain or side slopes (Stantec, 2020). Not only will a considerable amount of sediment be imported to the site to achieve the filling, a large amount of the native soil and vegetation will be disturbed to excavate the new (or reshape the existing) channel, form a new narrow floodplain bench, and regrade the valley slopes.

Ideally, the whole scale realignment of the channel is intended to create a stable natural channel in equilibrium where far less bank erosion and channel incision (producing large volumes of sediment that could be transported downstream) takes place. However, Fairfax County has indicated that the reference equilibrium conditions cannot be created within the County's easement and without far more extensive disruption to the surrounding landscape (Fellows, 2020). In recognition that the stable natural equilibrium dimensions will not be achieved with implementation of the project plans, large portions of the channels' bed and banks will be lined and armored with large rock to prevent bank erosion and channel incision that would cause adjustments in the shape and position of the new channel. This armoring is necessitated because the equilibrium dimensions of the channel will not be created as intended and the realigned and reformed channels will be inherently unstable and prone to erosion.

The justification for the extensive alteration of the channels appears based on comparisons in the dimensions between the Hollin Hills streams and an amalgamation of conditions observed on multiple "reference" streams, some in other states. For example, the dimensions of meanders are a typical parameter considered in natural channel design. For the streams in the two Hollin Hills parks, the meanders were considered tighter in comparison with reference conditions, so the design envisions creating more open meanders (Stantec, 2018). Creating meanders of a different shape necessitates the proposed realignment and reconfiguration of the channel. Similarly, the cross sectional area and other dimensions of the channels are to be adjusted to further match the "reference" conditions. This will require the filling of incised portions of the stream and its widening to establish a channel cross section that the County presumes mimics an equilibrium condition (Figure 6).

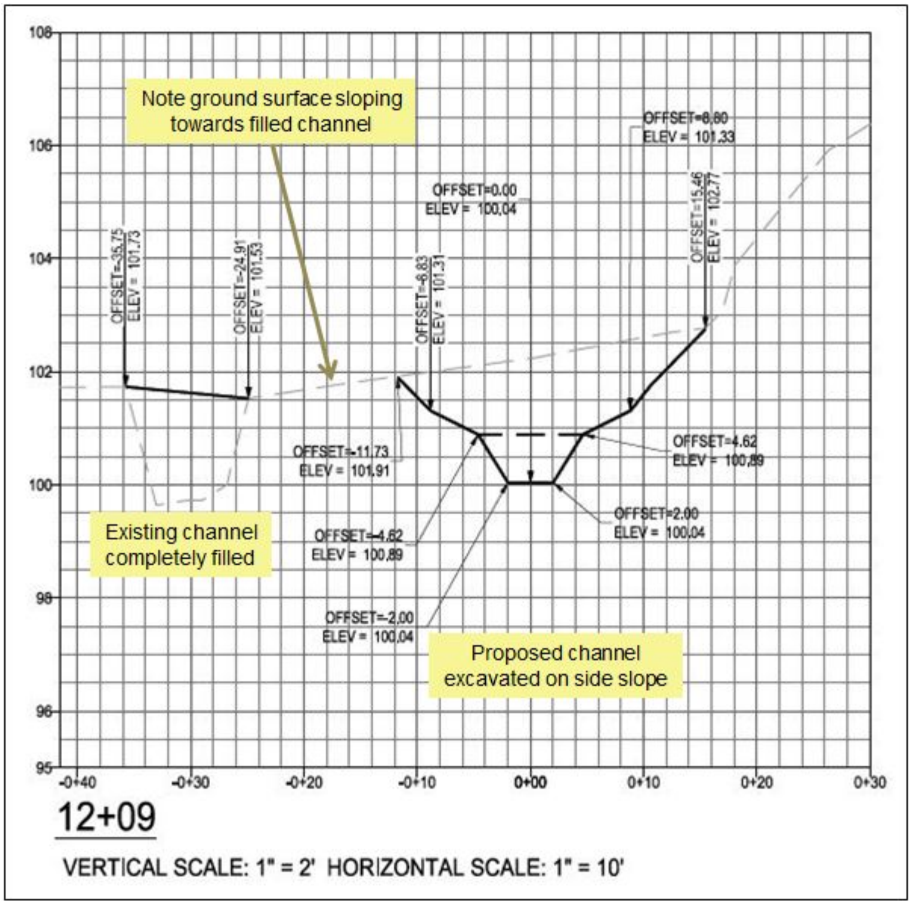

Figure 6. Cross section 12+09 from Stantec (2020) shows filling of existing channel and excavation of a new channel. Difference in top elevations of the banks of the two channels could lead to unraveling of the project (see text for further explanation).

The proposed filling of existing channels and excavation of new channels creates unintended conditions that could potentially jeopardize the success of the project. Note on Figure 6 how the top elevation of the banks of the proposed channel will be higher than the existing channel to be infilled. This creates an "avulsion" risk where flow spilling out of the new channel during a flood would flow towards and become concentrated in the area of the lower infilled channel, allowing the fill to be washed away and the stream to rapidly migrate back to its old position. This rapid shift in channel position (known as an avulsion) will initiate erosion upstream as the entire stream regrades to the lower level, transporting additional sediment towards Chesapeake Bay – counter to the project's primary objective. Therefore, minor grading issues (only 0.5 feet as displayed in Figure 6) – even if constructed as specified – could potentially lead to an unraveling of the project. While armoring the project with large rock could potentially forestall an avulsion from occurring for many decades, the risk would remain "frozen" on the landscape, so does not truly represent stream restoration that is sustainable, creates an equilibrium condition, and avoids upstream and downstream impacts.

As a fluvial geomorphologist with a PhD in the field and over 25 years of research and work experience on stream restoration projects, I have several significant additional concerns with the County's proposed design that are detailed below:

1) The primary objective of the proposed restoration is to reduce downstream sediment and nutrient loading to Chesapeake Bay. In contrast, the intent of natural channel design projects, as proposed for Goodman and Brickelmaier Parks, is to more efficiently transport sediment through the restored stream reach (Rosgen, 1996). These two objectives are inconsistent with each other – the proposed restoration solution, even if performing as intended, will not achieve the stated objective. Restoration techniques leading to greater, yet evenly distributed, sediment storage – not more efficient sediment transport towards the Bay – would be better aligned with the stated project objective. Short circuiting the process of channel evolution that ultimately leads to an equilibrium condition by immediately imposing on the streams the final assumed equilibrium condition will fill the available sediment storage space (see filled existing channel in Figure 6) with sediment to be, at least in part, imported by truck into the site. Importing presumably non-cohesive erodible loam to the site to reduce sediment loading downstream is incongruous. Why would a restoration project intended to reduce downstream sediment loading make more sediment available for downstream transport? In short, why add sediment to reduce sediment? Streams trend towards an equilibrium condition but allowing the processes that will lead towards equilibrium (e.g., infilling of the incised channel through sediment storage) to progress naturally are just as important as the end stage the County proposes to impose immediately through form-based restoration. The process is important, if not essential, for the full restoration of the entire watershed from Hollin Hills to Chesapeake Bay!
2) The form-based restoration design using "reference" conditions from, presumably, alluvial channels are not completely appropriate for use on the streams in Goodman and Brickelmaier Parks that have both alluvial and nonalluvial reaches (Figure 7). This distinction is critical as the tight meanders of the existing channel are considered in the County's design to represent an unstable condition that needs to be realigned, but in actuality these tight meanders may represent the equilibrium condition for nonalluvial sections of the streams. The banks of alluvial channels are typically composed of easily erodible loam (an admixture of sand, silt, and clay) allowing more open meanders to develop whereas the banks of nonalluvial channels may be composed of more resistant materials that deflect flow away from a straighter path and allow tighter meanders to form. In the case of the Hollin Hills parks, the nonalluvial banks are likely resistant to bank erosion due to a composition of both cobbles deposited by the ancestral Potomac River and cohesive clay developed over tens of thousands of years of soil formation (Figure 8; Terracon, 2018). This is not to say the nonalluvial banks don't erode, but they likely erode more slowly with the greater resistance to erosion leading to the formation of tighter, yet stable, meander dimensions. In the County's restoration design, a uniform meander dimension appears to have been applied along the full length of the streams without any distinction made between alluvial and nonalluvial reaches of the stream where the meander dimensions would be expected to vary naturally;

Figure 7. Sections of the Hollin Hills parks are alluvial (left) while others are nonalluvial (right). Note high sloping banks confining flow in the nonalluvial section while the low banks in the alluvial section allow flows to spread out on the floodplain.

Figure 8. Nonalluvial soils in Hollin Hills parks composed of cobbles and red clay are likely less erosive than alluvial soils elsewhere in the parks. Downstream view of stream in Brickelmaier Park just downstream of Martha's road culvert.

3) The "value" of Fairfax County's stream restoration projects is largely measured by the extent to which sediment and nutrients are prevented from reaching Chesapeake Bay. The method used to quantify this "value" is based on estimates of how much erosion is prevented from occurring by the bank stabilization presumed to result from stream restoration and, in the case of the proposed Hollin Hills parks projects, relies on the mapping of existing erosion at the restoration site and application of erosion rate curves established from long-term monitoring of streams from other areas. Mapping of erosion in the Hollin Hills parks occurred on a single day in August 2018 and the erosion rates drawn from curves established in North Carolina and another one developed by the U/S. Fish and Wildlife Service (Stantec, 2019). The use of two curves allowed for two estimates of the weight of sediment and nutrients that will be prevented from reaching Chesapeake Bay if the project is implemented. Stantec (2019) provides little documentation of the erosion curves used but an online search indicates the North Carolina curve is based on streams in that state's piedmont region (Web citation 2) while the USFWS curve was developed from streams in Washington, D.C. (Web citation 3). The degree to which the Hollin Hills streams match the conditions of the streams on

which the erosion rates were established is not provided. The two estimates based on the erosion curves developed in different areas vary by more than 100 percent (Stantec, 2019), suggesting the erosion curves were developed on streams with widely varying characteristics. Without information comparing the characteristics of the Hollin Hills streams with those used to create the erosion curves, the estimates for Goodman and Brickelmaier parks must be considered unreliable. Stantec (2019) recommends using only 50 percent of the estimated values in determining the "credit" Fairfax County should receive for preventing sediment and nutrients from entering the Bay. While this would appear to represent a conservative decision in light of the uncertainties with the erosion curves used, the stated reason for reducing the estimated total by 50 percent is that the "projects will not be 100% effective in stream bank erosion" (Stantec, 2019, p. 3), suggesting the project designers themselves question the project's long-term effectiveness and sustainability;

4) The County's proposal to realign the stream channel appears is intended to reduce bank erosion as a means of reducing downstream sediment and nutrient loading. Very little information is provided on the cause of the existing bank erosion and channel incision other than referring to "high velocity stormwater runoff" (Stantec, 2018, p. 5.27). The County acknowledges that "no source controls will be added in the near future which could reduce the runoff to the channels in Goodman and Brickelmaier Parks" (Fellows, 2020). If the upstream stressors (i.e., excess and concentrated runoff from homes, roads, and culverts) resulting in channel instability in the parks are not addressed, then, as discussed above, the proposed form-based restoration will be prone to unraveling. Realigning the channels in Goodman and Brickelmaier Parks to match a presumed natural equilibrium condition can be sustained only if the upstream human stressors are simultaneously addressed. Otherwise, the realigned channel will have a tendency to revert back to the existing condition as the streams seek equilibrium with the remaining human stressors in the watershed.
5) The County appears to tacitly acknowledge the project's risk of unraveling by proposing to armor much of the bed and banks of the channel with large rock to be imported into the site. Armoring the channel creates a static channel that, as discussed above, does not represent a channel in equilibrium even if all the dimensions match the "reference" equilibrium conditions. In fact, the County acknowledges that creating a stable channel using natural channel design to match natural reference conditions is not possible at Goodman and Brickelmaier Parks because doing so "would mean an astounding amount of land would need to be cleared, more tree and soil removal, a longer construction window and bringing the stream and floodplain closer to the private homes" to create "soft enough curves [that] wouldn't even need wood armoring" to prevent erosion (Fellows, 2020). The armoring is thus required to prevent erosion along what the County admits will not be in equilibrium with natural conditions. Armoring a channel should not be confused with stream restoration. Channel armoring is better described as channelization – a river management practice long shunned by EPA and other agencies because such channelization increases downstream sediment loading (Brookes, 1985), degrades aquatic habitat (Lennox III and Rasmussen, 2016), and exacerbates flooding and erosion (Shankman and Samson, 1991). This is not what natural channel design is intended to do – natural channel design is meant to create a stable channel where the potential for erosion and degradation has been minimized not amplified. While armoring

may temporarily freeze a channel's instabilities in place, perhaps preventing the negative consequences of channelization from being expressed for years or even decades, the county's plan to armor the channel will not restore natural conditions as intended (have you seen a natural armored channel in Fairfax County?) and ultimately could worsen downstream sediment loading, habitat degradation, and flooding and erosion hazards.

An Alternative Process-Based Concept

Given the above serious issues associated with the County's proposed restoration design, what alternatives are available to more effectively, safely, and sustainably reduce downstream sediment loading? Drawing from my over 25 years of experience of studying rivers and involvement with stream restoration projects, I would like to propose a process-based restoration concept for the streams in Goodman and Brickelmaier Parks that I believe would address Fairfax County's primary objectives for completing the restoration with minimal disturbance to the physical landscape and residents of Hollin Hills. Instead of focusing on the erosion that produces the sediment, another option, more consistent with equilibrium principles, is to encourage the storage of sediment along the streams in Hollin Hills, providing an alternative approach of preventing sediment and associated nutrients from reaching Chesapeake Bay. The complete elimination of erosion along a stream as envisioned in the County's plan is, actually, antithetical to the principle of equilibrium where a balance between erosion and deposition must be achieved to maintain the continuity of sediment transport. To reduce sedimentation and nutrient loading in the Bay, the objective should be to evenly distribute sediment along the length of the stream – minimizing the amount of deposition at any one point. Sedimentation only becomes problematic, even in the Bay, when it occurs rapidly and is focused over a small area. The goal of restoration, then, should not be to eliminate erosion entirely – although some bank stabilization may certainly be warranted – but rather to store the eroded sediment. Skalak and Pizzuto (2010) demonstrated that fine sediment and organic matter can remain in storage for decades behind large woody debris in rivers, significantly reducing the annual sediment load moving downstream.

An excellent method for encouraging the storage of sediment with minimal distrubance along a stream in temperate climates, such as Virginia, is by adding wood to the stream. Using wood as a key element of stream restoration projects is gaining wider acceptance around the country (Reich et al., 2003), including in urban and suburban settings such as Hollin Hills (Web citation 4). Where considerable sediment is available due to erosion, wood can result in rapid and significant sediment storage (Figure 9) that persists long enough to revegetate and reestablish floodplain function (Figure 10).

Figure 9. Wood addition projects on small streams in Green Mountain National Forest, Vermont taken a) one year after project completion and b) 20 years after project completion (arrows at edge of channel prior to wood addition). Note considerable sediment storage following one year and how in 20 years a revegetated floodplain developed as the channel narrowed.

Adding wood along the full length of the stream channels in Goodman and Brickelmaier Parks, perhaps in greater densities just downstream of areas exhibiting the greatest erosion and instability, would allow the resulting stored sediment to be more evenly distributed as expected along a stable stream in equilibrium. The storage of sediment in the channel would elevate the incised stream bed and eventually allow flood flows to more frequently spread out onto the floodplain, leading to even further sediment storage. In other words, let wood trap and store sediment already moving downstream towards the Bay to fill the incised channels rather than importing sediment to the site to do the same – sometimes the processes leading to equilibrium may be more important than the end channel form itself. In addition, wood in streams is associated with higher quality aquatic habitat and reduces the velocity of stormwater flows such that bank stability will improve over time and less sediment will be produced overall even if local scour around wood structures does occur. Wood can also be used to stabilize eroding banks directly as is already envisioned in the County's restoration plan along some banks.

A number of details would need to be considered in a thorough design phase of a wood additions project such as the size, length, orientation, density, and grouping of logs and tree tops. Perhaps of greatest concern is the need to ensure public safety by securing and anchoring the wood in place so culverts, for example, are not plugged by logs floating downstream. Safety concerns are a serious issue associated with all wood addition projects, but are not insurmountable as the County's use of wood in their design proposal attests.

The cost of wood additions would be significantly less than the County's form-based restoration proposal and would require much less time and disturbance to complete, because the channel realignment and the importation of boulders and sediment required in the County's form-based restoration design would no longer be needed. While live trees near the bank can sometimes be directionally felled to fall in the stream channel, trees for a wood addition project in Hollin Hills would likely be brought in from elsewhere given the narrowness of the parks and limited number of trees available. Grip hoists and other hand equipment could be used to carry and maneuver the trees into place, even in steep narrow settings, to avoid the need for heavy equipment and removal of live trees for access. Restoration through wood additions would be completed in the existing channel, so no realignment or infilling of the channel as envisioned in the County's plan would be required. Although simple and relatively inexpensive to complete, the benefits of such projects are realized quickly (Figure 9a) and persist for decades (Figure 9b).

The concept of adding wood to the streams in Goodman and Brickelmaier Parks is a potential win-win scenario. The value of wood addition in terms of reduced sediment loading to Chesapeake Bay, the major driver of the Hollins Hills restoration, could be measured in terms of volumes or pounds of sediment stored in the stream channels and on the reconnected portions of the floodplain. This metric would be similar to that used by the County to estimate how much sediment will not enter the streams from eroding banks that are to be stabilized. The County can thus continue to gain stormwater credits and demonstrate to the EPA that sediment and nutrient loading downstream is being minimized – all with minimal disruption to the neighborhood and at a greatly reduced cost.

Although the added wood will decompose over time, this can be slowed when and where rot-resistant species are used, the wood remains wet, or the wood becomes buried in the accreting sediment. If some logs deteriorate and stored sediment released, the amount of sediment moving downstream will be minimal and potentially captured by other log structures further downstream. If the original wood additions last long enough to be replaced by trees naturally falling into the channel and for vegetation to become established on and stabilize the sediment accumulating behind the log structures (Figure 9b), project sustainability will be ensured and the impacts of sedimentation to downstream receiving waters (i.e., Chesapeake Bay) minimized for decades to come despite the eventual decomposition of the initial log structures.

Conclusions

The form-based restoration plan developed by Fairfax County for Brickelmaier and Goodman Parks in the Hollin Hills neighborhood runs counter to the stated objective of reducing downstream sediment loading to Chesapeake Bay. The principles of natural channel design utilized in developing the plan are predicated on the concept that the restored channels remain stable by transporting through the channel all of the sediment entering the channel – in other words, the proposed designed will more efficiently move sediment towards Chesapeake Bay. Furthermore, to achieve the channel form envisioned in the design will require the importation of large volumes of sediment to fill in deeply incised portions of the channel, thereby adding sediment to a system where the restoration is meant to reduce sediment available for downstream sediment transport. Simply put, why is the County adding sediment to reduce sediment?

An alternative process-based approach has a much greater likelihood of meeting the County's objective of reducing downstream sediment loading at minimal cost to the County and disruption in the neighborhood. Wood is a natural feature in the parks and can be added to the streams in an effort to store sediment before moving downstream towards Chesapeake Bay. The headwater settings of these streams are excellent candidates for restoration, as stated and understood by the County, precisely because of their potential for sediment storage. Importing large volumes of sediment to construct a design channel that more efficiently moves sediment downstream does not make use of the potential benefits of focusing on headwater streams. Better to encourage sediment storage in these streams to buffer the impacts of upland developments and enhance, through wood additions, the natural processes that will ultimately lead to streams in equilibrium with the developed watersheds rather than trying to freeze in place with rock armor a channel designed to be in equilibrium with a natural undisturbed setting that no longer exists in Hollin Hills or Fairfax County more broadly.

References Cited

Bernhardt, E.S., Palmer, M.A., Allen, J.D., Alexander, G, Barnas, K., Brooks, S., Carr, J., Clayton, S., Dahm, C., Follstad-Shah, J., Galat, D., Gloss, S., Goodwin, P., Hart, D., Hasset, B., Jenkins, R., Katz, S., Kondolf, G.M., Lake, P.S., Lave, R., Meyer, J.L., O'Donnell, T.K., Pagano, O.L., Powell, B., and Suddeth, E., 2005, Synthesizing U.S. river restoration efforts: Science, v. 308, p. 636-637.

Brookes, A., 1985, River channelization: traditional engineering methods, physical consequences, and alternative practices: Progress in Physical Geography, v. 9, p. 44-73.

Fellows, M., 2020, Comments posted to the Hollin Hills Forum by Alan Warshawer on February 26, 2020 at 2:53 pm.

Field, J.J., 1997, Channel modifications along an artificially constructed channel designed to provide salmon habitat: *In*, Wang, S.S., Langendoen, E.J., and Shields, Jr., F.D., Eds., Management of Landscapes Disturbed by Channel Incision, p. 822-827.

Lennox III, P.A., and Rasmussen, J.B., 2016, Long-term effects of channelization on a cold-water stream community: Canadian Journal of Fisheries and Aquatic Sciences, v. 73, p. 1530-1537.

Miller, J., and Kochel, R.C., 2010, Assessment of channel dynamics, in-stream structures and post-project channel adjustments in North Carolina and its implications to effective stream restoration: Environmental Earth Sciences, v. 59, p. 1681-1692.

Reich, M., Kershner, J.L., and Wildman, R.C., 2003, Restoring streams with large wood: a synthesis: American Fisheries Society Symposium 37, 12 p.

Rosgen, D.L., 1996, Applied River Morphology (Second Edition): Wildland Hydrology, Pagosa Springs, Colorado.

Shankman, D., and Samson, S.A., 1991, Channelization effects on Obion River flooding, western Tennessee: Water Resources Bulletin, v. 27, p. 247-254.

Skalak, K., and Pizzuto, J., 2010, The distribution and residence time of suspended sediment stored within the channel margins of a gravel-bed bedrock river: Earth Surface Processes and Landforms, v. 35, p. 435-446.

Stantec, 2018, Design report (Pre-design) Paul Spring Branch Segment at Hollin Hills: Unpublished report prepared for Fairfax County Stormwater Planning Division, 42 p.

Stantec, 2019, Paul Spring Segment 2 at Hollin Hills stream restoration and design services: Task L estimation of sediment erosion rate, nutrient loading, and stream restoration efficiency: Unpublished memo to Meghan Fellows, Fairfax County, Virginia, 61 p.

Stantec, 2020, Paul Spring Segments 1 & 2 @ Hollin Hills stream restoration construction plan: County of Fairfax, Virginia, 62 sheets (stamped by Megan McCollough on January 29, 2020).

Terracon (Terracon Consultants, Inc.), 2018, Geotechnical engineering report: Paul Springs Branch Segment 2 at Hollin Hills, Alexandria, Fairfax County, Virginia: Terracon Project No. JD 185215 prepared for Stantec, 82 p.

Thompson, D., 2005, The history of the use and effectiveness of instream structures in the United States: Humans as geologic agents: Reviews in Engineering Geology. v. 16, p. 35-50.

Web citations

Web citation 1: https://dec.vermont.gov/watershed/rivers/river-corridor-and-floodplain-protection/geomorphic-assessment

Web citation 2: https://www.agriculturejournals.cz/publicFiles/58_2018-SWR.pdf

Web citation 3: https://cdn.ymaws.com/www.vwea.org/resource/collection/C560DED3-7431-43D8-AFE3-9008EDA766DD/6-Mark_Secrist,_US_Fish_and_Wildlife_Service_H.pdf

Web citation 4: https://www.redmond.gov/DocumentCenter/View/4053/Large-Woody-Material-Enhancement-in-Urban-Streams-2007-PDF