UTILITY STREAM CROSSINGS: WHOSE PROBLEM IS IT AND WHO'S PAYING?

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ABSTRACT

Streams: A wonderful natural amenity, but often a costly headache for utility crossings. Crossing streams with utilities is inevitable. Unfortunately, stream locations are not permanent - over time streams erode and move, undermining support piers and manholes, uncovering pipe joints, and compromising the utility. The utility owner is forced to take measures to stabilize the stream; but is this money well spent? Is the stabilization, such as riprap carelessly placed on the banks, a "band aid" destined to be eroded away within another year and replaced again? Temporary solutions often don't work and can be more costly than well designed permanent solutions.

It could greatly benefit a water-sewer utility to coordinate with their storm utility or consultant to more permanently stabilize their utility crossings, preventing costly relapses of eroding banks around their water and sewer infrastructure. The cities of Greensboro and Winston-Salem have both seen the benefits of stabilizing their utility crossings with more permanent stream stabilization techniques. This paper will discuss case studies from these two communities in which natural stream channel design techniques were implemented with successful stabilization of water and sewer utilities. In addition this paper will highlight the implementation of a proactive utility crossing inspection program which can help eliminate and reduce emergency stabilization. Communication between water/sewer and storm utilities can help coordinate projects and funding opportunities.

KEYWORDS

Utility, streambanks, water, sewer, stormwater, erosion, restoration, stabilization

INTRODUCTION

Utility crossings at streams and waterbodies are an area of active concern for water/sewer utilities. All water or sewer systems will sooner or later, have to have a utility line near a waterbody, whether it is buried or aerial. Unfortunately, the very nature of a waterbody is its desire to move, through a constant series of erosion and accretion of sediment. Although normal and healthy for the waterbody, it can have a significant impact on utilities, as they become exposed and have their support systems damaged. In addition, the process is continual (like the constantly encroaching ocean), leaving a recurring cost associated with protecting our utilities.

So, the question remains, are we doing the right thing for our utilities? Could we do it better? Could we find a better way to fund the work?

There is a better way to approach this. It requires that we no longer think of stormwater utilities and water/sewer utilities as separate entities that do not impact each other. Rather, these entities can work together to find ways to utilize funding sources unique to each of them for the benefit of both. In addition our understanding of riverine hydrology can be used to our advantage, allowing better and more permanent design to aid in stabilizing water/sewer utilities, while improving the overall health of our waterbodies.

METHODOLOGY

Improving stream stabilization at a sewer/stream crossing is a two pronged approach; coordination of effort and improved design. Coordination of effort is really about the synergies of different organizations, allowing the most effective use of available funds. The improved design focuses on the research done over the years on erosion in streambeds, the interaction of piers and streambeds on destabilized banks, and approaches to minimize impacts and find long-term or permanent repairs.

Coordination Benefits

Coordination of a water/sewer utility with their storm utility could allow more permanently stabilized utility crossings, preventing costly relapses of eroding banks around their water and sewer infrastructure. A cohesive effort between water/sewer and stormwater utility providers could also increase efficiencies in an organization, allowing the most economical allocation of funds.

In many organizations (especially larger ones) it has been accepted as unfortunate, but not correctable, that one department might do work in a location and then find out months later, another department duplicated their efforts on another project at that location. Clearly, coordination of work would save money for an organization. Additionally, instead of spending a minimal amount on it for a temporary fix, it could be possible to pool the funds in order to do something more permanent that wouldn't require additional work in a few years.

There are many benefits to the coordination of water/sewer and stormwater within an organization. In addition to the ability to pool funds to do a better, long-term fix, there are funds available to stormwater groups from outside the organization, including:

- NC Clean Water Management Trust Fund (CWMTF)
- NC DWQ CG&L – Clean Water State Revolving Fund (CWSRF)
- NC Division of Soil and Water Conservation
- NC DWQ Section 319 Program
- US EPA
- NC Wetlands Restoration Program (EEP).

These funds are meant to be used in areas that have water quality concerns within a watershed, such as a Total Maximum Daily Load (TMDL) for a pollutant. If a sewer crossing occurs in an area where there is a stream stabilization concern impacting water quality for sediment, phosphorous, nitrogen, etc., the repairs made to one could be coupled with the needed updates to the other. In addition to cost sharing for some of the work, the combined projects will allow a reduced total bid price because of the combined project and the potential for a better, more comprehensive result.

There are benefits to both water/sewer and stormwater utilities from these efforts. Stormwater will get a more competitive bid process and a final product that will reduce sediment entering the stream. The water/sewer division will be able to reduce sewer releases from compromised infrastructure, stabilize existing crossings, find a more permanent solution to sewer crossings, and access funds that would normally not be available for this work.

Design Improvement

The second, arguably more critical, prong to improving stream stabilization is better design. Frequently, the solution to erosion under and along an aerial sewer support or over a buried gravity line in the stream channel is to place riprap. Many times this may not address what is causing the erosion and only provides minimal thought to whether the solution is sufficient.

The standard approach to riprap is looking at a typical velocity in the stream bed and sizing the riprap to resist the sheer stress from the water movement. A slightly more detailed approach would be for the designer to consult the Erosion and Sediment Control Planning and Design Manual (2013) for the required design calculations. Although this is a good place to start, a more comprehensive approach can result in stabilization that is more appropriate and more permanent.

Depending on the sewer crossing type, it can be affected differently by erosion. A buried sewer crossing is impacted by transport of sediment from over the top, see Figure 1. Aerial sewer crossings are impacted by erosion of the streambed, bank incising, and erosion around the pipe supports. Figure 2 is an example of where both the pier has been undermined by erosion and the bank has been incised. This exposes more pipe in the streambank and increases the length of unsupported pipe. Figure 3 shows a location where the stream bed has eroded to the point where the length of unsupported pipe has become too long and a temporary solution has been applied to give added stability.

Understanding Your Waterbody

It is important to remember that waterbodies, by nature, will move. The natural state of a waterbody is to meander to find the path of least resistance. Even a perfectly straight waterbody will slowly begin to meander due to the erosive nature of water interacting with the soil and groundcover it encounters. On the outer edges of a bend, the velocity in the waterbody will be faster, causing erosion. On the inner edge, where the travel distance is shorter, the velocity will be lower and sediment deposition will occur. Over time, the location of the streambed will change. An example of this is seen in Figure 4. In the modern era, our tolerance for meandering streams can be limited due to the structures we build along them or over them. Understanding the nature of the waterbody and how and why it is impacting a structure is critical to finding a more permanent stabilization solution. It should be noted that a support present in a waterbody can become a source of erosion as well. Studies have shown that the impact of a pier in even relatively laminar flow will cause vortices behind the pier, increasing erosion around the structure. See Figure 5.

In order to design a stable solution for erosion impacts on gravity lines we need to understand the waterbody itself. According to Rosgen, 1996, the goal for stability is to find the natural state for the waterbody, or to find the state in which it can transport flow and sediment without change to dimension, pattern or profile. The focus in Rosgen's research was to find the state that restores the waterbodies natural function, rather than returning it to its pre-disturbance state, which is probably no longer possible.

This is, of course, is not an easy process; it requires (Rosgen, 1997):

- Determining the cause of the instability
- Determining the natural stable form
  - What is the appropriate stream type to valley type
  - What are the stable dimensions?
    - Width
    - Mean depth
    - Width/depth ratio
    - Maximum depth
    - Flood prone area width
    - Entrenchment ratio
  - What is the stable pattern?
    - Sinuosity
    - Meander wavelength
    - Belt width
    - Meander width ratio
    - Radius of curvature
  - What is the stable profile?
    - Mean water surface slope
    - Pool/pool spacing
    - Pool slope
    - Riffle slope.

This data is part of the "classification" of the stream. Knowing this information allows a stream to be classified as a stream type. Stream types are grouped based on erosion and deposition over time. In the southeast, many waterbodies were aggraded (experienced deposition) from many years of farming. Now these same areas are experiencing the impacts of highly developed watersheds, causing waterbodies to cut down into the same areas where deposition happened before. (Rosgen, 1997) This is the very action that is causing instability with current waterbodies and sewer stream crossings. A broad level of these stream classifications is shown in Figure 6.

It is necessary to find a "reference reach," or a stream type that has the same valley type and watershed as the impacted stream classification. A similar analysis would be done on the reference reach and will be used as a blue print for what the impacted stream should be. Dimensionless ratios from the reference reach would then be applied to the impacted waterbody to determine adjustments needed for stabilization.

The steps of this analysis can include:

- Characterization of the waterbody
- Stability Examination/Nature of Instability
- Mitigation and/or restoration alternatives
- Mechanical or direct change in pattern, profile and/or materials (NRCS, 1997).

Besides changes in profile and sinuosity, in-stream structures can be used to adjust water velocity across the profile and run of the impacted waterbody. These in-stream structures can include:

- A-vane/cross vane
- J-hook vane
- Single arm vane
- Boulder clusters.

Examples of cross vanes and j-hooks are included in Figures 7 and 8, respectively.

In addition to the pattern changes and in-stream stabilization, these improvements would be coupled with stabilization of the newly designed banks of the waterbody. Techniques that can be used for this include:

- Root wads
- Boulder toe protection
- Imbricated stone
- Brush mattress
- Willow fascines
- Vegetated mechanically stabilized slopes (soil lifts)
- Matting.

Important techniques in utility work are the soil lift and the boulder toe. A soil lift is a vegetated “lift” or slope of soil. In order to stabilize this the soil “lifts” are wrapped in liners (NRCS, 2007). This is illustrated in Figure 9. Boulder toes are also a good way to stabilize a stream bank (see Figure 10). In this case, boulders are imbedded into the stream bed and are stacked in such a way as to allow a stable and fairly upright streambank. An example of a boulder toe installation is included in Figure 11. In both cases, a streambank is stabilized. It is less than a natural state, but if done properly, it will stabilize in an area where there isn’t sufficient space to lay back the streambank to a more natural state.

RESULTS

Case Study: Winston-Salem Stream Bank Repairs

The Winston-Salem Case study for stream bank stabilization included six locations in various tributaries throughout the City. One site within this area was Buena Vista Branch. Figure 2 is a photo of this area, consisting of a scour hole at the bottom of an exposed pier along the left bank of an aerial sewer line crossing. The stream was stable both laterally and vertically except for a washed out area which left the concrete pier suspended above the ground and water. Improvements consisted of replacing the existing pier, adding two j-hook boulder vanes along the left bank at the outside of the stream bend, and excavating the vertical banks to decrease bank slope. Container plants and live stakes were installed.

Figure 12 shows the reconstruction process and illustrates that the banks have been laid back and stabilized with matting and, downstream of the aerial crossing, a j-hook structure has been built upstream and downstream. These improvements have stabilized the velocity in the stream and reduced erosion around the pier. This also allows a pool to form under the aerial utility to better enable debris to move downstream without negatively impacting the aerial pipe. Figure 13 is the final product. With these improvements, it is not expected that erosive properties will damage the structure again and the stream has been returned to a natural state.

This project was funded through CWMTF for a TMDL for sediment in the watershed. The work allowed benefit to the stormwater utility provider, due to reduction of sediment added to the stream from erosion around the pier. The water/sewer utility was able to gain a more permanent stabilization of an aerial crossing within the same construction contract.

The total cost for the natural channel repairs came to $200k, or approximately $500/LF, which is generally typical for this type of work. The utility cost portion of the work across the six projects came to another $200k, for a total cost across all six projects of $400k.

Case Study: Greensboro Projects

South Buffalo Stream Restoration, Greensboro, NC

The South Buffalo Creek stream restoration was a large project. A portion of this work was located on a tributary entering South Buffalo Creek. In this area a buried 48-inch concrete sewer line had been exposed due to erosion of the streambed. The total work was a straight-forward project: In order to stabilize the stream bed a single cross-vase was added for grade and stream stabilization. This project was fully funded from the Stormwater Utility fund. It stabilized an area of erosion adding sediment to South Buffalo Creek and therefore benefited the Stormwater Department, while at the same time protected a Water/Sewer Department utility.

Ardmore Stream Restoration, Greensboro, NC

The Ardmore stream restoration was another project driven by and funded by the Stormwater Utility Fund. In this case there was incising of the stream banks in a confined area with no ability to bench or lay back the streambeds. When Stormwater reviewed this condition, they realized that some parallel water/sewer utilities could become exposed, if the incising was allowed to continue. To avoid this, the Stormwater Department coordinated their work with the Water/Sewer Department and by using soil lifts and boulder toes, were able to stabilize an incised streambank in a very tight area and protect the nearby utilities.

DISCUSSION

Lessons Learned

In most cases it was recognized that doing this work under drought conditions was a great benefit for the construction in the streams. When there isn't a drought condition to expose the streambed, construction during the fall and winter is beneficial. However, if there will be cast-in-place concrete used on the job, timing of this work needs to be considered. Additionally, there is always the possibility that, during dry times, what is seen as typical (or the stream's "classification") could look different between design phase and construction phase. Since drought or cold could have a negative impact on plantings, care should be taken with the planting material selection and careful consideration given to plant warranties.

During these experiences, the most important lesson learned is that the interaction between the Water/Sewer Department and Stormwater Department is essential to saving utilities, minimizing costs, and improving the health of the waterbodies. The ability to use funding from the stormwater utilities department as well as the many other fund sources associated with stream work would benefit the water/sewer department.

Lastly, it became obvious that proactive utility crossing inspection program would benefit both utility departments. Such a program would allow:

- Elimination and/or reduction of emergency stabilization situations.
- Eliminate wasted money on solutions that aren't permanent
- Reduce potential for sanitary sewer releases to streams
- Improve maintenance (e.g. identify damage such as trees hung on aerial lines).

CONCLUSIONS

Our approach to stabilization of water/sewer utilities near or crossing streambodies has evolved. It is apparent that the standard approach over the years hasn't always taken into account all aspects of sustainable design, funding, and maintenance practices. There is an oft used quote, "The definition of insanity is continuing the same practice and expecting different results". Although attempting stabilization is hardly pointless, it is time we recognize new approaches.

As addressed in this paper, there is a benefit to water/sewer and stormwater utilities working together. In addition to coordination of effort eliminating cross-purpose projects, each utility will benefit in other ways. Water/sewer providers can expand funding options and use stormwater knowledge to improve stabilization and stormwater utility providers have the ability to get better pricing through combined contracts with water and sewer work.

In addition, it is time for utilities to take a more proactive approach to erosion at stream crossings. Rather than waiting for something catastrophic to happen and potentially not be noticed for some time (collapsed aerial crossing), it is proposed that the better approach would be an on-going inspection of utility crossing locations. A listing of all utility crossings that are inspected on a regular basis for stability could then be cross-checked with a list of stormwater projects that are needed. The combined urgency of both utilities can then be used to prioritize the project work schedule.

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Figure 1. Exposed Pipe in Streambed


Figure 2. Scour Under a Support

Figure 3 Bank Scour Causing Un-supported Lengths of Aerial Pipe

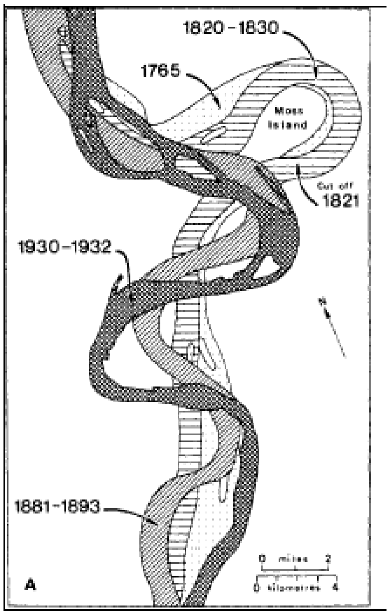


Figure 4 A section of the Mississippi River from 1765-1932, (U.S. Department of Transportation, 2012)

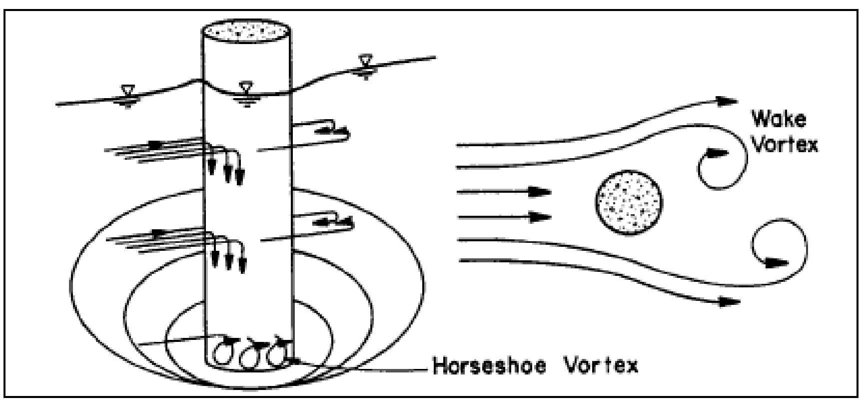


Figure 5. Representation of Scour at a Cylindrical Pier (Circular No. 18, 2012)

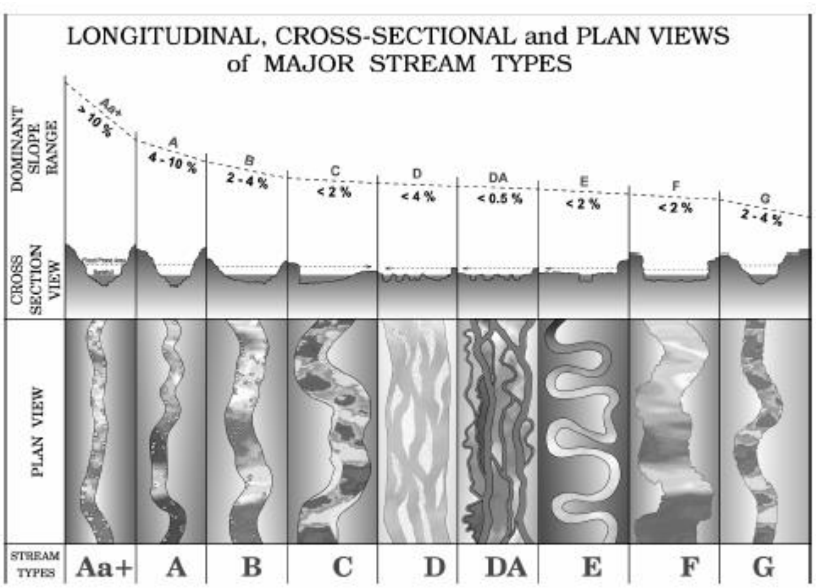
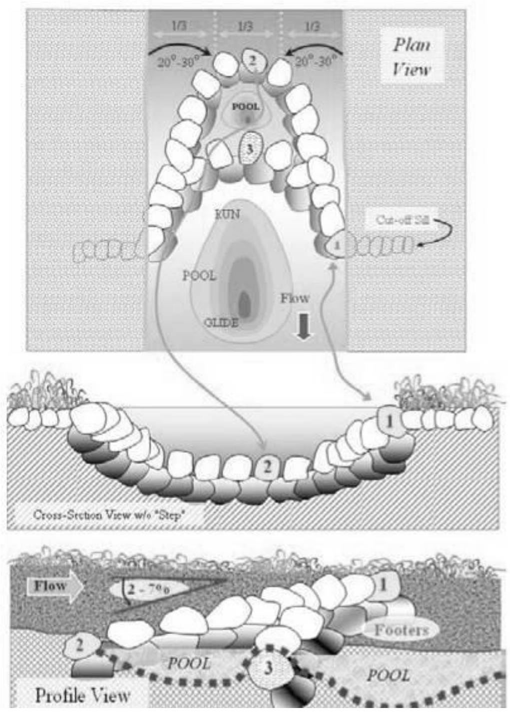


Figure 6. Stream Classification (Rosgen, 1994)



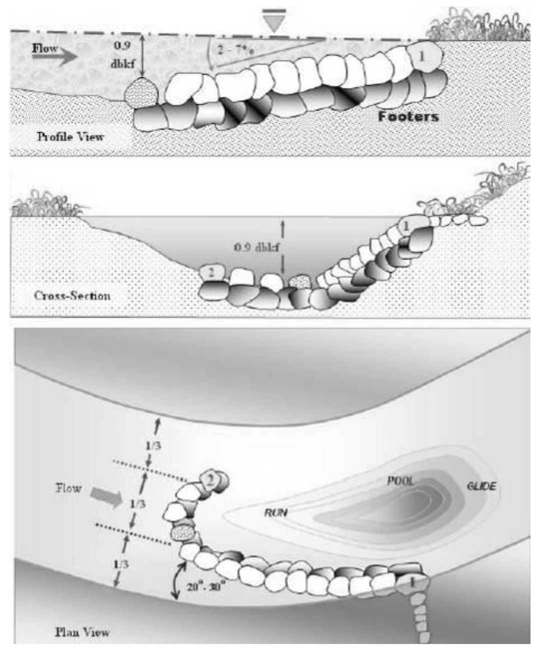


Figure 7. Example of a Cross Vane, (NRCS, 2007) Figure 8. Example of a J-hook Vane Structure (USDA, 2007)

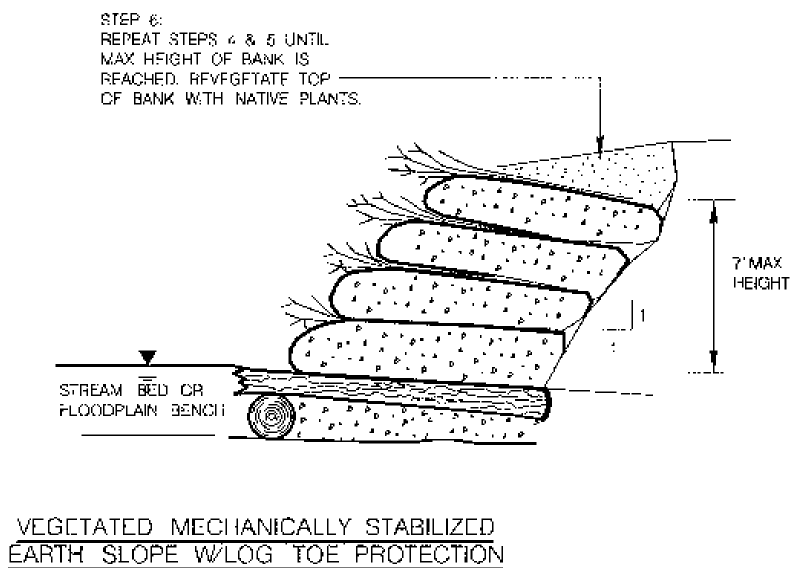


Figure 9, Detail of a Soil Lift

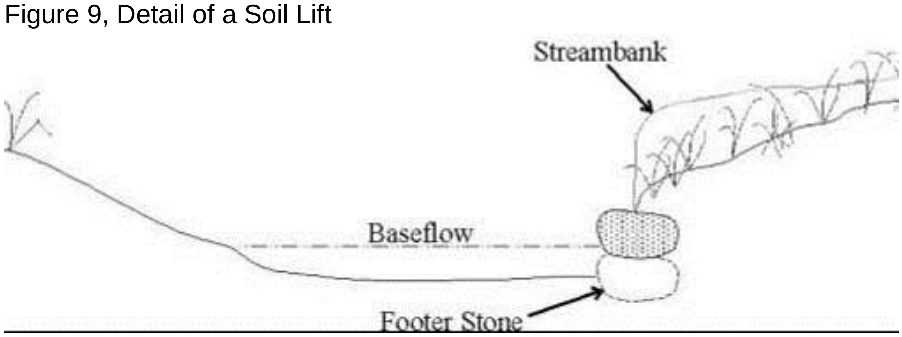


Figure 10, Detail of a Boulder Toe

Figure 11. Streambank Using a Boulder Toe for Stabilization

Figure 12. Buena Vista Ranch, During Reconstruction

Figure 13. Buena Vista After Reconstruction