Complications With Urban Stream Restorations
Mine Bank Run: A Case Study

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Abstract

Natural stream restorations in general are difficult to design. There are numerous steps and calculations that must be made in order to mimic the properties of a stable, natural channel. The complexity of this process is increased for stream restorations in urban settings due to numerous constraints such as poor bankfull indicators, lack of reference reaches, numerous utilities, roads, and property lines, poor soils, flashy flows, and "hungry" water.

In order to demonstrate the complexity of urban stream restoration, Mine Bank Run, an urban stream in Baltimore County, Maryland, is used as a case study. Over the past 50 years Mine Bank Run's watershed has undergone extensive residential and commercial development. The rapid land use change caused dramatic increases in both the frequency and amount of stormwater discharge to the stream while at the same time decreasing the base flow. Severe channel degradation in the 1960's and 70's was countered by installing concrete flumes in the channel. During the 1990's portions of the concrete flumes had been lifted out of place by storm flows and were causing severe bank erosion.

Baltimore County realized that natural stream restoration would work best to stabilize the channel and retained Biohabitats, Inc. to design a natural channel restoration. The restoration reach included approximately 6000 feet of the upper most mainstem of Mine Bank Run and about 2000 feet of four tributaries.

Natural channel design relies heavily on bankfull or dominant discharge. Because of the degraded state of the existing channels, there were few reliable bankfull indicators. The limited field data was supplemented using discharge data from a hydrologic model, regional regression equation, and regional stream gage data. Planform geometry was limited in some reaches by the narrow (fifty feet) right-of-way or the close proximity of sewer lines. Rapid establishment of vegetation to stabilize newly graded slopes is extremely important for the success of stream restoration projects. Because many reaches of Mine Bank Run had been manipulated for utility installation or lined with concrete the native soils had been replaced with sand and gravel which was not conducive to plant growth.

These are just a few examples of the many constraints that complicate the design process of urban stream restorations. This case study will highlight the difficulties encountered.
with the restoration and discuss how they were handled and how they affected the success of the stream restoration.

Introduction

In the project area, Mine Bank Run drains 500 acres of fully developed (commercial, institutional, and residential) land in central Baltimore County, Maryland. It originates in the heart of Towson and flows north-east through residential communities and a business park to the downstream limit of the project at I-695 (Baltimore Beltway). From here, Mine Bank Run continues north-east to the Gunpowder River. The upper most end of the watershed had been developed since the 1800’s, but the majority of the watershed had been agricultural or forested land until the 1950’s when extensive development of the watershed began. By 1980 the watershed was fully developed.
This dramatic change in land use resulted in a dramatic change in the hydrologic inputs to Mine Bank Run. During the development of the watershed, most of the first order channels were placed in storm drain systems. At the same time a sewer line was installed along the channel – disturbing the riparian vegetation and floodplain of Mine Bank Run. The increase in impervious surfaces (roads, parking lots, roof tops, etc.) increased the volume and frequency of runoff reaching Mine Bank Run. Because the bankfull or channel-forming discharge had increased while at the same time the sediment supply from the watershed decreased, the channel responded by downcutting and widening. Essentially the channel’s cross sectional area needed to increase to accommodate the increased bankfull discharge. In addition, because the channel’s radius of curvature, meander wavelength, and belt width are related to the width of the channel, the entire planform of Mine Bank Run had to adjust. This type of adjustment results in severe erosion along outside meander bends which results in tree loss, property loss, and damage to infrastructure.

In response to the severe degradation taking place in the channel, Baltimore County installed concrete flumes in various locations in the upper end of Mine Bank Run. In one severe area a large concrete drop structure (six feet high, twelve feet wide, and twenty feet long) was installed in the channel to stop a large headcut from moving upstream. Eventually the concrete flumes began to degrade and sections of concrete were lifted out of place by storm flows. These displaced slabs created ever worsening erosion of the channel.

The failure of the concrete flumes prompted Baltimore County to try natural channel design to stabilize Mine Bank Run. Natural channel design utilizes fluvial geomorphic principles to guide the channel design process and natural materials such as rocks, logs, and plants for channel stabilization. Two main principles of natural channel design are the use of reference reach data to create a design model and bankfull discharge as the channel design discharge.

**Description**

The project reach included approximately 6000 linear feet of mainstem channel and 2000 linear feet of tributary channels. The first step in the design process was to assess the existing conditions of all the stream channels in the project area. The assessment not only provided detailed descriptions and location of all channel problems, utilities, road crossings, and riparian vegetation but also included cross section and profile surveys for classification of reaches with the Rosgen classification system. Degraded, urban channels often do not clearly fall into a distinct channel type. For instance, over 1000 linear feet of Mine Bank Run was lined with concrete. Also, some reaches had entrenchment ratios and slopes of an F channel but the width/depth ratio of a C channel. While existing channel types were not always clear, existing valley conditions and site constraints, such as road crossings, parallel sewer lines, and private property, made it clear what proposed channel types should be designed. Reaches with slopes of 2% or greater would be designed as B channels (step/riffle/pool) and reaches with slopes less than 2% would be designed as C channels (riffle/pool). The last 500 feet of the mainstem
had to be designed as a Bc because the slope was less than 1% but the floodplain had been filled for development such that no floodprone area could be created without extensive grading and tree loss.

The success of a stream restoration design is almost entirely dependent on bankfull discharge and bankfull dimensions. Therefore, an integral part of the classification and design processes is identification of bankfull elevation and bankfull discharge. In stable channels there are usually well-defined features such as point bars and vegetation that indicate bankfull elevation. In degraded urban streams these indicators can be nonexistent. For instance on Mine Bank Run, the few point bars in the system had multiple flat surfaces that made it difficult to determine which surface represented a dominant discharge. These multiple surfaces formed because of the high variability of urban storm discharges and the large amount of fine sediment generated by the eroding channel.

The lack of clear bankfull indicators meant that other methods of estimating bankfull discharge had to be performed. These methods included modeling the watershed with TR-20 to compute 1 and 2 year peak discharges, estimating 2-year discharge with the USGS regression equation for the Maryland Piedmont, and computing 1.5 year discharges using Log Pearson flow frequency analyses of nearby gage stations. (At the time there were no regional curves available as another estimate of bankfull discharge.) All bankfull discharge estimates, including those determined from field cross sections, were compared by graphing discharge versus drainage area. The discharges computed using the USGS regression equation were used as bankfull discharge because they were very close to the average of all discharge estimates.

It might seem inappropriate to use a 2-year discharge estimate; however, it must be remembered that a majority of the gage data used to develop the USGS regression equation came from undeveloped watersheds. It is reasonable that a 2-year discharge from an undeveloped watershed is similar to a bankfull discharge in a developed watershed. We have also seen in our studies of urban streams that a 2-year, TR-20 discharge will occur about 2 times a year in an urban watershed. These discharges are reached during an intense thunderstorm rather than the 24-hour storm used in the TR-20 model.

Because there were no stable reaches in the project area, reference reaches had to be located and measured. The preferred reference reaches would be located in a fully developed watershed and situated in similar valley types with similar bed material. Mine Bank Run downstream of the project area was looked-at first but no stable reaches were found there. Many fully developed watersheds in Baltimore County were searched but no stable reaches were found. It was decided that a reference reach from White Marsh Run (a C channel) should be used even though the substrate was smaller. Reference reaches for a B step/pool and B riffle/pool systems had to be taken from less developed watersheds. While the watershed was not ideal, we were able to find systems with similar bed material and slope.
The measurements from the reference reaches gave stream parameters that could not be obtained in the study reach because of the severely graded nature of Mine Bank Run. These parameters included entrenchment ratio, width/depth, radius of curvature/width, meander length/width, pool depth/average depth, riffle slope, pool slope, run slope, glide slope, point bar slope, riffle length, pool length, step height, step length, and sinuosity.

With all the stream parameters known from the reference reaches, the restored reaches had to be designed within the site constraints. The most serious constraint was the sewer line that paralleled and crossed the stream over its entire length. This was a critical constraint because the sewer line could not be moved. Similarly there were four road crossings that could not be changed.

A more important constraint for the stream system was maintaining existing vegetation. Because vegetation is essential for bank stability, shade, cover, and food production it was important to save as much existing vegetation as possible, especially mature trees. All trees 12” diameter at breast height (dbh) or greater were surveyed and their locations mapped with existing topography, utilities, roads, and property lines.

The design of the restoration reach had to take all of these constraints into consideration. Therefore it was not always possible to utilize reference reach parameters in the design. For instance, the lower reach of the project (just upstream of 1695) had a slope of less than 1%, but the existing site constraints did not allow for the design of proper meanders or point bars. This reach had to be designed as a Bc for which there was no reference reach data. A similar situation occurred about 2000 feet downstream from the project start. In this case a narrow drainage easement (about 50') did not allow appropriate belt width and thus a Bc had to be designed where a C should have been.

In the reaches where concrete channel had been installed, the slope and narrow valleys predicated a B channel with step/pool and riffle/pool geometry. An unanticipated complication in these reaches was the poor soil conditions. Because these reaches had been so manipulated by the installation of the sewer line and the concrete channels, the soils contained little if any organics. It had been decided by the County to salvage existing topsoil rather than incur the expense of importing topsoil. This was okay for most of the project reach but because the disturbed areas were kept to a minimum in order to save existing vegetation little topsoil was salvageable. Also in order to limit disturbance and thus keep sediments from entering the stream it was not possible to salvage topsoil from another reach. The poor soils made it difficult to establish grasses to provide erosion control and saving the mature trees provided too much shade for bioengineering to establish. Even with soil stabilization matting, the bare soils easily eroded during out-of-bank flows.

Out-of-bank flows occur more often than expected (about once a year) due to the high imperviousness of the watershed. The large impervious areas produce substantial volumes of runoff very quickly during high intensity thunderstorms. The efficient storm drain system delivers all the thunderstorm runoff directly to Mine Bank Run. These high
discharges, while short in duration, are erosive to soils that have not yet established vegetation.

Particularly susceptible to erosion are the contacts between hard structures (rock or logs) and soil. Sandy and gravelly soils do not compact well and do not allow good vegetation growth. Therefore flowing water easily erodes the soil from the contact areas. Once erosion has started it creates a depression that is more accessible to water and more susceptible to erosion.

Erosion will also occur in the channel because water discharged from the storm drain system is carrying very little sediment. Therefore the water has more capacity to entrain sediments. The clean or “hungry” water occurs because a developed watershed with a large amount of impervious surfaces does not produce very much sediment. This phenomenon of “hungry” water is exasperated in Mine Bank Run because the upper most reach that receives the first contribution of clean water is a steep, narrow valley. This increases the appetite of the “hungry” water.

Conclusion

Natural channel design relies on bankfull discharge, reference reach data, and vegetative stabilization. In urban streams, such as Mine Bank Run, these three critical elements may be difficult to achieve. Highly degraded urban systems often do not have bankfull indicators from which to compute bankfull discharge; therefore, other less reliable means of computing bankfull discharge must be employed. Because the hydrology of a developed watershed is so different from that of an undeveloped watershed, a reference reach for an urban stream should be located in an urban watershed. It has been our experience that reference reaches are extremely difficult to find in urban watersheds because the stream channels in urban watersheds have been degraded by the urban hydrology or have been altered during the development process. This means that reference reaches must be located in less developed watersheds where the stream channel does not experience the intensity of an urban runoff event. The stream channel in an undeveloped watershed is not constrained by utilities, roads, and property lines. Even with a good reference reach it is often difficult to utilize the reference data within the site constraints. Also, most streams in undeveloped watersheds do not experience “hungry” water. This phenomenon of sediment-deprived water from impervious surfaces and storm drain systems undoubtedly affects the erosion capacity of the urban system. Natural channel design in urban streams often utilize hard structures, such as boulder bank and rock grade controls, in order to protect utilities, roads, and private property. However, vegetation is an extremely important component of natural channel design. Unfortunately the soils along urban streams may not be conducive to plant growth. Utility installation and other manipulations of the channel often mean removal of topsoil or even replacement of soil with sand and rock material. The case study of Mine Bank Run, which faced all of the above difficulties, shows how the restoration of an urban stream can be complicated by the very nature of the urban system. It also shows that even with these complications, natural channel design techniques can be successfully utilized on an urban stream.