Water Quality Benefits of Daylighting Streams

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Executive Summary

Healthy headwater streams and their floodplains provide important ecological services. They effectively retain water, which decreases the magnitude of flood flows and the erosive energy of those floods. Small streams provide habitat for a diverse collection of organisms, from microorganisms and macroinvertebrates at the base of the food web to fish, birds, and other wildlife. Headwater streams and floodplains also provide conditions suitable for maintaining good water quality. These water quality benefits can include reduction of available nutrients, regulation of oxygen, pH, and temperature, and reduction of turbidity.

Many of these functions have been impaired by the development of towns and cities. Impervious surfaces, such as buildings, parking lots, and roads have increased the quantity and speed of water that runs off the land after a rainfall, and the quality of that runoff water diminished. These changes in runoff characteristics contribute to channel instability, loss of habitat, and lower water quality in stream systems. In some watersheds, discharges of industrial and municipal wastes also change the characteristics of streams. Perhaps the most extreme manipulation of the stream system associated with human development is the elimination of headwater streams altogether by placing them in pipes and burying them underground to increase the amount of developable land. While piping the drainage from a single small area may seem inconsequential, the net effect of this practice has been considerable. It has been estimated that small first and second order streams naturally made up over 70% of the stream miles in the United States. Recent studies have found that in some urban and suburban areas, more than 60% of these stream miles have been eliminated.

Restoring some of the ecological services of headwater streams through daylighting previously piped streams is an important tool in improving the health of river systems. The published literature highlights several factors that contribute to the overall effectiveness of streams in improving water quality. These factors include connectivity to a large vegetated floodplain, presence of woody debris and other types of large organic material, active exchange with the hyporheic zone, shade, contact with biofilms on stream bed and bank materials, and appropriate habitat for macroinvertebrates and fish. The design and implementation of daylighting projects should incorporate an understanding of these factors to maximize the ecological benefits of the projects. A well designed study to monitor the effects of a suburban stream daylighting project is very important in understanding the benefits of the project. Sample locations, monitoring frequency and duration, and parameter selection should be carefully considered to ensure that monitoring objectives are met.

Introduction

Headwater streams are naturally extremely abundant. These small first and second order streams had been estimated to constitute approximately 73% of the total stream channel length in the United States (Leopold, et al., 1964). However, many of these streams have suffered extensive damage over the past couple of centuries as a result of several urban, suburban, and rural practices.

In urban and suburban areas, many streams have been straightened, moved, or enclosed within pipes and buried to facilitate rapid removal of water from the landscape and increase the amount of developable land. Meyer and Wallace (2000) reported that by 1966 in the Rock Creek basin, in a portion of Maryland that is affected by Washington, DC urbanization, 58% of the stream miles in the watershed had been eliminated altogether as they were filled and replaced with stormwater pipes. In the Atlanta region, urban and suburban watersheds were found to have approximately 1/3 less stream miles than those in less developed watersheds. Elmore and Kaushal (2008) reported that within suburban areas outside Baltimore, Maryland, approximately 20% of all streams had been placed in pipes and buried, and 66% of all streams within Baltimore City had been placed in pipes and buried. Roy et al. (2009) performed an assessment of headwater streams in and around Cincinnati, Ohio, and estimated a loss of 93% of the ephemeral channel length and 46% of the intermittent channel length.

The consequences of the collective degradation and elimination of many of our headwater streams and their associated riparian areas is the reduction and even elimination of the ecosystem services that these systems provide. Perhaps the most obvious result is the loss of important physical habitat for a variety of fish, invertebrates, amphibians, reptiles, birds and mammals. However, the loss of these stream corridors also contributes to loss of water and pollutant retention and processing capacity of the headwater area. This loss negatively impacts the chemical, physical, and biological integrity of downstream waters, which can be reflected in water quality parameters often used to characterize some components of ecological integrity, including dissolved oxygen, nitrogen, phosphorus, suspended solids, pH and temperature.

Restoration and enhancement of headwater streams offers some promise for restoring some of the function of our headwater streams, including those functions that affect water quality of the stream system. By eliminating pipes and reconstructing more natural stream channels, streams can be reconnected to their floodplains and the matrix of gravel, sand, silt and organic material that make up the bed and banks. This increases pollutant removal and retention processes within those channels by increasing the retention time in the system and increasing interaction with biological components of the stream that retain and metabolize pollutants. It also increases water retention, which can decrease the erosive power of the creek downstream, increase channel stability, and thereby reduce sediment loads from those banks. Because sediment particles often have other pollutants, such as phosphorus, attached to them, this reduction in sediment load also often represents a reduction in other pollutant loadings.

In the following sections, we summarize the published literature related to water quality impacts of headwater stream elimination through replacement with stormsewer in semi-urban settings as well as the potential to improve water quality by daylighting such streams. We also offer some options for studying the water quality impacts of the Village of Sussex Spring Creek Daylighting project.

Ecological Functions of Headwater Streams

Though small and historically undervalued by human society, headwater streams and their riparian corridors perform very valuable functions in the river system that affect the ecological health of downstream waters. Important areas of a healthy headwater stream corridor include the riparian zone, the channel, and the hyporheic zone. Each of these areas stores water and facilitates interactions between biotic and chemical water components that transform and/or remove pollutants from the water.

The Riparian Zone. The riparian area adjacent to the stream is critical for capturing pollutants approaching the stream in stormwater runoff, providing shade to reduce temperature which increases oxygen capacity in the stream, stabilizing the channel banks with roots, and providing organic matter to the stream and floodplain. The floodplain soils provide a variety of conditions that promote biogeochemical processing, particularly when organic material is readily available. Numerous studies have documented the effectiveness of vegetated riparian buffers at capturing pollutants in stormwater runoff (Mayer et al., 2005, Lowrance et al., 1997, Bruland et al., 2004, Hunter and Faulkner, 2001, Hill and Cardaci, 2004, and Gift et al., 2010). Riparian pollutant removal has been found to be most effective where slopes are flat, stormwater crosses the riparian buffer as sheet flow, and vegetation is abundant. For increased denitrification, presence of organic matter and saturated anoxic soils enhance performance (Gift et al., 2010).

Riparian floodplains also effectively store flood waters and dissipate energy of flood waters, allowing slower, less erosive release to downstream channels. This allows sediment deposition in the floodplain during flooding and facilitates maintenance of stable channel beds and banks downstream. Together these functions are critical to controlling sediment loads to downstream waters. While sediment transport is a natural process in healthy stream systems, in many urban and suburban streams, high flood flow rates often erode a higher volume of sediment from the channel bed and banks than can be accommodated by the stream. This instability reduces the quality of the stream habitat for many macroinvertebrates and fish. These sediments also often have other pollutants, including phosphorus, attached to them, and the downstream export of those sediments can contribute to high loadings of these other pollutants.

The Channel. Vannote et al. (1980) presented the River Continuum Concept to describe the function of river systems from source to mouth. Although it is a general model, this concept offers a useful framework for considering the longitudinal connectivity of rivers and the importance of that connectivity to the processing of energy and nutrients delivered to the stream. Healthy headwater streams are typically shaded, and therefore primarily heterotrophic, receiving energy from the riparian area as coarse particulate organic matter, such as woody debris and leaf litter. This material is high in carbon, but relatively low in the macronutrients nitrogen and phosphorus (Mulholland, 2004). Aquatic microbial communities colonize this debris and pull nutrients from the water to build cell mass. The film of microorganisms, or biofilm, that forms adds nutritional value to the debris which is consumed by macroinvertebrate detritivores, particularly those in the shredder, grazer, and collector feeding guilds (Allen, 1995). Through this path, carbon and nutrients enter a complex food web made up of diverse organisms, including fish, reptiles, birds, and amphibians. Some of the carbon and nutrients are also broken down into fine particulate organic matter and mineralized nutrients that are available to the phytoplankton and zooplankton that make up the base of the food web in wider sections of the river downstream where more sunlight is available and the system becomes more autotrophic.

The Hyporheic Zone. The hyporheic zone, which includes the porous substrate below and adjacent to the stream where groundwater mixes with surface water, is an important environment for chemical, microbial and physical processes. Surface water enters the hyporheic zone in downwelling areas, bringing pollutants, nutrients, oxygen, and carbon in contact with microbial communities and variable conditions that promote precipitation and biological processing (Hester et al., 2010). Water flowing through the hyporheic zone has a longer retention time in a stream reach than water flowing above the bed in the channel. This allows time for biologic and chemical processes to take place before water is removed to downstream reaches. The effective storage represented by this longer retention time together with storage in backwater eddies and pools is referred to as the transient storage of the stream. The effects that the channel and the hyporheic zone of a stream have on specific pollutants can be difficult to separate, so in many cases the overall effect of these areas is characterized together.

Nutrient Cycling in Streams. Nutrient cycling in streams is the process of nutrient uptake by organisms and subsequent release at a later time, and often further downstream. This uptake and storage of nutrients in desirable forms of biomass, such as fish, macroinvertebrates and riparian vegetation, effectively reduces the quantity of nutrients available for less desirable biomass, such as algal blooms. Additionally, some processes in floodplains and within the hyporheic zone of streams permanently remove some forms of nutrients from water. Specifically, nitrate can be converted to nitrogen gas and permanently lost to the atmosphere if anoxic and other conditions supporting denitrification are available. Phosphorus can be removed if it is adsorbed onto sediment particles that become deposited on the floodplain, or if it precipitates as a solid in the presence of iron or aluminum. However, phosphorus in particulates can be re-released, and therefore, is not permanently removed.

Hammer et al. (1999) reviewed literature and data for Ohio streams to assess the relationship between nutrients, habitat and aquatic life. They noted that improved habitat can facilitate assimilation of nutrients and reduce downstream impacts of nutrient loads by storing nutrients in plant and animal biomass. They cited studies that found a correlation between low total phosphorus concentrations and high quality habitat. This correlation does not imply that the high habitat quality causes the low phosphorus concentrations, but they noted that the delivery of phosphorus to streams, the rate at which phosphorus is processed in the stream, and the amount of phosphorus available in the water column is affected by the condition of the riparian zone and instream habitat. They also noted that aquatic organisms that are found in streams with better habitat are more efficient at processing the coarse particulate organic matter that enters streams such that phosphorus is efficiently converted into desirable aquatic biomass rather than undesirable algal blooms.

Much of the research on nutrient cycling has included measurements of uptake rate, the rate at which nutrients are taken out of the flowing water column (mass/time), and uptake length – the distance along the stream that is typically traveled by a nutrient before it is taken out. Many of these studies have concluded that the uptake and retention of nutrients in headwater streams is significant. Peterson, et al. (2001) reviewed studies from 12 different headwater streams across the United States and found that the most rapid uptake and transformation of inorganic nitrogen occurs in the smallest streams. The uptake of ammonium occurred within tens to hundreds of meters in small streams and uptake of nitrate required approximately 5 to 10 times the distance required for ammonium. They also found that during seasons of high biological activity, reaches of headwater streams exported less than half of the input of dissolved inorganic nitrogen from their watersheds. Ensign and Doyle (2005a) reviewed published studies of nutrient spiraling in streams and noted that average uptake lengths for ammonium and phosphate were comparable (86 m and 96 m respectively) but significantly shorter than the uptake length for nitrate (236 m). Arango, et al. (2008) compared the nitrogen uptake and microbial nitrogen transformation in streams at several sites on the Kalamazoo River in Michigan and found that nitrogen loss through nitrification and denitrification were an order of magnitude less than whole stream nitrate uptake. Mulholland (2004) also found that instream uptake of nutrients is substantial in headwater streams in a forested watershed in Tennessee. He found that instream processes, such as biotic uptake and physical-chemical adsorption and precipitation, resulted in retention of approximately 20% of the nitrate and 30% of the soluble reactive phosphorus that entered the stream annually with highest uptake rates occurring in November when coarse particulate matter inputs (leaves) were high. Tracer tests indicated that much of the nitrogen sequestered was retained within biomass for over 6 months. Withers et al. (2008) reviewed several studies and concluded that there is a high capacity for headwater streams to retain phosphorus, particularly during low flow conditions, thereby acting as a buffer for downstream waters. They also noted that because headwater streams have high benthic area to water volume ratios, they have the greatest potential for physical-chemical and biological phosphorus retention at the benthic interface.

There are several factors that can affect the efficiency of nutrient uptake in streams, including presence of coarse woody debris and vegetation, active hyporheic exchange, extended retention time of stream water in transient storage, and contact with biofilms. Ensign and Doyle (2005b) studied the impact of in-channel flow obstructions such as vegetation and coarse woody debris on transient storage retention of nutrients in coastal plain streams in North Carolina. They found that vegetation and woody debris removal reduced the transient storage considerably (61% and 43% in an agricultural stream and a channelized, forested, blackwater stream, respectively). The reduced transient storage also corresponded with significant decreased ammonium and phosphate uptake in the forested stream. These results led them to conclude that nutrient uptake in the forested stream was enhanced by biofilms on debris within the channel and extended retention time of stream water in contact with those films through temporary storage caused by debris. Mulholland et al. (1997) compared two streams, one with much larger transient storage in the hyporheic zone, and found that the phosphorus uptake rate in the stream with the greater transient storage was 2.6 times greater than the phosphorus uptake rate in the stream with less storage. The uptake length was 5 times longer in the stream with less storage.

As described above, much of the published research on water quality impacts of headwater streams, their destruction and subsequent rehabilitation, has involved nutrient cycling. This is perhaps due to the prevalence of nutrients in our surface waters, the negative impact of this excess, and the complexity of nutrient cycling in river systems. However, nutrient availability and uptake in stream also affects other water quality parameters. Nutrients contribute to high primary productivity, which increases photosynthesis when light is present and increases respiration during dark hours. This results in removal of carbon dioxide from the water and delivery of oxygen to the water during the day, and a removal of oxygen and delivery of carbon dioxide at night. Carbon dioxide combines with water to form acid, affecting the pH of the water. Therefore, where high nutrient concentrations contribute to high primary productivity in the stream, high pH and high oxygen levels are observed during the day and low oxygen concentration and low pH at night. Sometimes these swings are dramatic, resulting in conditions unsuitable to support diverse aquatic life.

Effect of Urbanization and Suburbanization on Water Quality Attenuation by Streams

Urban and suburban development of a watershed has dramatic effects on the stream system. Streams in urbanized watersheds often experience compressed hydrographs after storms, increased peak floods, elevated concentration of nutrients and contaminants, altered channel morphology, and reduced quality of biotic assemblages (Walsh et al., 2005). In the most extreme case, in which a stream is buried in a pipe, the stream is completely disconnected from its hyporheic zone and its floodplain. All of the functions previously provided by the hyporheic zone and floodplain, which are described in the previous section, are eliminated altogether.

Several researchers have studied the impact of urbanization on nutrient dynamics. Groffman et al. (2003) studied two urbanized streams in Baltimore, Maryland, and Paris, France, and noted that the impervious surfaces and piped storm drainage reduced infiltration in the watershed, which contributed to a decrease in the groundwater elevations. The high peak flows resulting from piped storm drainage also contributed to incision of the stream bed. The lower stream bed elevation allowed groundwater drainage into the stream at lower elevations which further lowered the groundwater elevation. This caused a condition they referred to as riparian hydrologic drought as floodplain soils dried out, increasing the nitrification potential but decreasing denitrification, leading to an increased export of nitrate to the stream system. Claessens et al. (2010) noted that the interactions between flow conditions and organic debris account for seasonal and longitudinal differences in ammonium uptake and that urbanization affects both of these factors. They further observed that much nutrient processing occurs in hyporheic zones and urbanization reduces hyporheic exchange. Mayer et al. (2010) found that even in urban streams, there is potential for denitrification, and hotspots of denitrification may exist where carbon is available and residence time is high. However many urban and suburban streams lack these components because the riparian vegetation has been removed and stormwater conveyance efforts have decreased water residence time in the system. Grimm et al. (2005) measured the impact of hardening channels in urban and suburban areas as it affects nitrate uptake lengths and found that uptake lengths increased from 70 – 90 m for unaltered streams to 800 – 1200 m for concrete channels.

Coupling the decreased efficiency of nitrogen removal and phosphorus uptake of individual streams with the dramatic elimination of streams in urban areas described in the introduction, it is clear that urbanization and suburbanization can substantially reduce retention and processing of nutrients. The implication of this reduction in retention is that more nutrients remain in the water column longer and are more rapidly delivered downstream. If restoration activities can reverse some of this effect, more nutrients may be bound in desirable cell mass in headwater streams. Additionally, daylighting streams by removing pipes to reconnect flowing water to a hyporheic zone and a floodplain will increase water retention to improve channel stability, reducing sediment erosion downstream. Because sediment particles often have phosphorus adsorbed to them, the reduction in sediment erosion can also reduce the phosphorus load to the stream.

Prospect for Improvement through Physical Enhancement

The impact of stream enhancement on water quality parameters is site specific and dependent on many variables. If there are current instream scour problems in the stream system downstream of a proposed project, some of these problems can be alleviated if additional floodwater storage in a restored floodplain is coupled with appropriate upland stormwater management. Grade control structures in the enhanced reach can preclude headcuts from progressing upstream and can thereby minimize additional sediment loading. Temperature and dissolved oxygen problems can be improved through increased shading with trees and increased air-water interaction at created riffles.

Several studies have been conducted in recent years to better understand the impact that enhancement projects have on nutrient dynamics. Buckaveckas (2007) studied water velocity, transient storage, and nutrient uptake in a channelized Kentucky stream for 2 years prior to and for 2 years after the implementation of a restoration project. He found that in the restored channel, travel time through the channel increased 50% due to a combination of slower velocity and increased channel length associated with meandering. The uptake rate coefficients for nitrogen and phosphorus were 30 and 3 times higher, respectively, in the restored stream compared to the channelized stream.

Multiple researchers have found positive correlations between increased use of organic matter in restoration activities, including vegetation and woody debris, and increased denitrification. Roberts et al. (2007) found that coarse woody debris added to streams near Columbus, OH, provided increased transient storage in the stream and increased ammonium uptake. Gift et al. (2010) measured root biomass, soil organic matter and denitrification potential in degraded, restored, and reference riparian zones in Baltimore, MD. They found that there were strong correlations between root biomass and soil organic matter and between soil organic matter and denitrification potential, which lead them to conclude that establishing deep rooted vegetation is likely particularly important for increasing denitrification. Groffman et al. (2005) found that constructed debris dams have high denitrification potential in urban streams due to the high organic content and the anaerobic microhabitats caused by microbial respiration. They found that denitrification rates were low in pools, riffles and gravel bars, but they hypothesized that these features may still be very important for denitrification due to the relatively large area occupied by them. Walsh et al. (2005) also suggested that debris dams could be hot spots for denitrification in urban streams.

Other studies were designed to determine the opportunity for and effects of re-establishing connectivity to floodplains and hyporheic zones. Kasahara and Hill (2006) found that hyporheic exchange can be increased through construction of riffles. Kaushal et al. (2008) studied the effect of reconnecting a stream to an active floodplain and found that riparian areas with connected floodplains had higher rates of denitrification than areas where there was not a connected floodplain. They also found that denitrification was highest where banks were lowest.

Craig et al. (2008) identified several strategies for increasing nitrogen removal through stream restoration projects. The strategies included increasing carbon availability and organic matter storage, increasing contact with benthos by increasing surface area to volume ratios and/or increasing hydraulic retention, and increasing connectivity between streams and floodplains. They referenced other studies and estimated that restoration could account for nitrogen removal rates of 2 – 35 mg $N/m^2/day$.

An understanding of stream restoration principles and processes is important to effectively incorporate these elements into a stream daylighting design project. The conditions that sustain riffles and pools must be understood and incorporated into the design to ensure that the pools do not fill with sediment over time, which would diminish their effectiveness at promoting hyporheic exchange. Careful analysis of the hydrology and hydraulics of the stream channel is necessary to establish an effective channel geometry and floodplain elevation to ensure that the benefits of floodplain connectivity are maximized. Experience incorporating wood structures into stream enhancement projects is important to ensure that the wood structures remain in place and are self sustaining. Plant species selected for the riparian plantings should provide shade, a deep dense root zone, and a renewable source of woody and leafy debris to provide a long term source of carbon both within the channel and within the floodplain soils.

Opportunities and Challenges for Monitoring Benefits of Daylighting Projects

Monitoring the effects of restoring urban streams is critical to continuing to improve the health of headwater streams. There are several important considerations associated with designing and interpreting the results of such a water quality monitoring study.

Monitoring Locations. With any stream monitoring study, it is important to establish a good control system to which results can be compared. For example if the study is set up to compare conditions in the stream before the enhancement project and conditions after the project, ideally there should be no other changes in the watershed and the weather conditions during the study periods should be nearly identical. This sometimes requires several years of frequent monitoring both before and after the project is constructed to find a few windows of time that experienced similar rainfall, temperature, and daylight. Changes to the watershed and differences in weather conditions during the study periods need to be taken into account when comparing monitoring results before and after a daylighting project is implemented.

If the study is designed to compare water quality parameters in the water flowing into the project area and water quality parameters in water flowing out of the project area, it is important to define and monitor all of the inflow and outflow points. In an urban headwater stream, there is not only water flowing into the stream from the stream reach immediately upstream, but there can also be significant sheet flow from the adjacent upland areas and shallow base flow through the adjacent floodplain soils. As described above, many of the benefits of a healthy headwater stream are provided in these riparian areas. Therefore, flow into and out of this area is important to capture in describing the success of the project.

Monitoring Frequency. Another consideration with all water quality monitoring is timing. The common methods for monitoring water quality include (1) collection of single grab samples and analyzing them at a laboratory, (2) collection of multiple samples over a period of time using an automatic sampler and analyzing them individually or compositing the sample and only analyzing the composite, and (3) installing a probe with a data logger than measures water quality parameters semi-continuously in the stream and stores the results. The results of collecting and analyzing single samples at one point in time do not provide information about the quality of the water before or after that point. Unless frequent monitoring is conducted, the investigator cannot be sure that the samples collected reflect peak concentrations of pollutants, average concentrations, or low concentrations. During runoff events in urbanized areas, stream flow and pollutant concentrations can change very rapidly, and unless automatic samplers are deployed, it is unlikely that grab samples will be comparable upstream and downstream. Therefore, the best way to understand the range of conditions in the stream or calculate pollutant loads is to use flow compositing samplers or datasondes with semi-continuous data loggers deployed in the stream for long periods. Biological monitoring is also a very effective means of assessing overall stream quality over a period of time using relatively few samples.

Monitoring Parameters. In choosing parameters to monitor, several factors should be considered, including the likelihood of impact of the project on the parameter, cost of monitoring, and reliability of monitoring methods. As described in previous sections, a stream daylighting project may affect temperature, dissolved oxygen, pH, and nutrient concentrations. If the daylighting project also improves stability of the channel downstream of the project, it may also affect the turbidity. If the rehabilitated riparian area provides a filtration of stormwater runoff that previously was piped to the stream, it may also reduce some types of dissolved materials, thereby reducing conductivity.

Several parameters can be monitored easily, affordably, reliably, and semi-continuously using multi parameter probes with dataloggers. The most common probes include temperature, dissolved oxygen, conductivity, pH, redox, depth, and turbidity. Additional probes have become available for monitoring ammonia, nitrate and chloride, but some of these probes have received mixed reviews. Monitoring most other parameters requires laboratory analysis of samples collected either at a single time, or samples collected at intervals and composited to determine average concentrations over a period. Typically, automatic samplers are used if multiple samples are desired over a short time period, such as during a storm, or if composite samples are desired. Given the cost and time required for laboratory analysis for each individual data point acquired and the large number of samples required to draw conclusions in stream water quality studies, parameters that require laboratory analysis should be chosen carefully.

One parameter for which reliable unattended probes are not available is phosphorus, but there is great interest in phosphorus concentrations and dynamics in Wisconsin streams. While there have been very encouraging findings regarding phosphorus uptake rates and uptake lengths in the literature, studies typically did not report significant net reductions in phosphorus between upstream and downstream measurements across restored reaches. Mulholland et al. (1997) reported little change in soluble reactive phosphorus between upstream and downstream monitoring locations on two streams in Tennessee and North Carolina and suggested that remineralization of phosphorus was balanced with uptake. However, other researchers have suggested that although most phosphorus uptake within streams is released back into the water column eventually, the temporary uptake and storage can provide important buffering to reduce peak concentrations. Documenting this type of buffering would require frequent monitoring, and unfortunately, there is not a well established probe at this time for measuring in-situ concentrations. In the absence of such a device, studies must rely on large numbers of grab samples taken with a frequency that can describe phosphorous concentrations before, during, and following storm events over the course of several seasons.

Many of the studies in the literature employed isotope tracers of phosphorus and nitrogen. Discernable from native phosphorous and nitrogen, these isotopes are added to streams and track uptake and release rates within a given stream length. If information on the impact of the project on nutrient cycling parameters is desired, a tracer study is the best method.

Recommendations for Spring Creek Daylighting Project

Given the ease and relative cost-efficiency of deploying multi-parameter probes described above, deploying probes both upstream and downstream of the project for multiple years prior to and after implementation would be a sound approach to monitoring. This combines the advantages of both the before-after study design and the inflow-outflow design. If there are significant changes in the watershed apart from the daylighting project, they should be reflected in the upstream data that can be used to normalize the downstream data. The reach is relatively short, and therefore, inflow into the reach from the adjacent parking lot should be small compared to inflow from upstream. It may be possible to ignore the affects of this inflow. However, if budget permits and if significant stormwater outfalls are routed into the project area from the adjacent lands, probes can be used to monitor the inflow quality at these points as well.

The standard parameters of dissolved oxygen, temperature, pH, conductivity, and turbidity all have potential for change due to the project. Dissolved oxygen and pH will be affected by more contact with the atmosphere and by altered biotic activity. Temperature may be affected by more exposure to sunlight, increased contact with the atmosphere, and removal of asphalt from above the stream. Conductivity may be affected by buffering the stream from road surfaces that receive deicing materials in the winter. Turbidity may be affected by particle trapping in the riparian area during runoff events. Additional inquiries should be made into the reliability of ammonia and nitrate probes. These parameters will likely be affected (though the magnitude of the effect may be small) by the project. If probe technology allows for accurate measurement, a stage recorder should be added to record stream discharge and provide data to calculate pollutant loads.

Depending on budget available for monitoring, laboratory analysis of phosphorus species and nitrogen species, if probes are determined to be unreliable, might also provide good information. However, it is likely that very frequent monitoring would be required to understand how these parameters are affected by the project. Additionally, tracer studies could provide information on nutrient cycling in the stream, though it may be difficult to predict the impact that these changes in cycling will have on downstream waters. Partnering with a research institution may be an efficient way of assessing these more labor intensive parameters.

Perhaps the most important monitoring that should be conducted within and near the project area are biological assessments. Bioassessments have the advantage of integrating conditions of the stream over long periods of time and reflecting stream quality in the biotic assemblages present in the system at any given time. Overall stream health can be gauged by this assessment, often at a reach scale, but quantitative data related to specific increases or decreases in rates or metrics cannot be obtained.

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