

Ecologically Functional Stormwater Basin Retrofits

Meeting NPDES water-quality requirements in stormwater basins

By Joel P Thrash

Introduction

The requirement to meet post-construction stormwater-quality standards set forth by states and regulated municipalities under the auspices of the National Pollutant Discharge Elimination System (NPDES) Phase II program has become increasingly stringent—and for good reason. Inadequate stormwater management leaves a distinct, detrimental fingerprint on downstream water quality, urban flood control, and receiving stream stability in developing landscapes. Prior to NPDES stormwater regulation, stormwater runoff was locally managed for infrequent storm events. Multiple states have now adopted post-construction water-quality regulations to address both stormwater quantity and stormwater quality in equivalent realms. Post-construction stormwater requirements such as water-quality volumes regulate to the heart of the “first flush” concept by requiring detainment of runoff and pollutants that are generally discharged at their highest concentrations during the early stages of storm events. This article discusses how existing stormwater basins can be retrofitted to meet current standards and, more importantly, how ecological functionality can be incorporated into future stormwater management facilities to improve water quality, increase stormwater residency times, provide wetland/riparian habitat functions, and improve the economic and aesthetic value of land designated for stormwater management.

Comprehensive Stormwater Management: A Holistic Perspective

The correlation between stormwater generated from upland watershed urbanization and the degradation of downstream water resources is well documented (CWP 2003), and the results are alarmingly conclusive. Pollution loading, flash flooding, sedimentation, channel incisement, and fluvial instability are among the impacts commonly associated with magnified stormwater discharges to urban water resources (USEPA 2004). In most impaired urban watersheds, the recurrent problems associated with stormwater discharges are less dependent on physical, temporal, or spatial variables and more directly tied to insufficient regulation and non-comprehensive management planning. The impacts to water resources from impervious land conversion leave predictable signatures in water bodies nationwide. [Table 1](#) highlights some of the problems associated with inadequate stormwater management following urbanization.

The effects of urban development listed in [Table 1](#) are difficult to evaluate from a watershed perspective, but data collected from research professionals and empirical observations made by water-quality advocates are beginning to highlight the need for ecologically informed approaches to stormwater management with respect to water quality. The EPA has weighed in on these issues with NPDES Phase I and Phase II stormwater regulations; however, the specifics behind minimum control measures set forth in those regulations are intentionally left open-ended to regulated communities on everything from ordinances updates to best management practice (BMP) selection. For some municipalities and their elected officials, Phase II regulation is viewed as an opportunity to update local ordinances or enforcement measures and to invest in surface-water resources previously ignored at the local government level. For others, even within the same watershed, Phase II stormwater requirements are a necessary evil packaged and presented to citizens as six *de minimus* control measures mandated to them by the federal government. From both perspectives, short- and long-term economic growth associated with urban development is understandably of greater importance than the NPDES program and its potential ecological significance.

But even when the priority of individual community goals is justifiable, the lack of an investment in comprehensive planning to address urban hydrology, riparian resource protection, and water quality under the auspices of NPDES Phase II is not. The good news for water-quality professionals is that the fundamental disconnect between urbanization and water-resource management is closing with a new wave of NPDES post-construction regulations. In fact, avenues to incorporate innovative methods of resource protection, habitat restoration, and alternative BMPs are just beginning to be opened by the NPDES Phase II program. Stormwater basin retrofits, as described later in this article, are specific examples of how water-quality improvement projects can be completed under the umbrella of post-construction Phase II water-quality rules.

Post-Construction Phase II Water-Quality Regulations:

Looking Small at the Big Picture

From coast to coast, municipal separate storm sewer systems in the United States have been increasingly subjected to NPDES stormwater regulations mandated from the EPA to authorized states and ultimately to individual municipalities. Prior to NPDES regulation, stormwater regulations in both small and large municipalities varied greatly from the way stormwater detainment volumes were calculated to the way end users maintained their storm sewer systems. A common denominator across the country, however, was that stormwater basins were easily recognized as the best available flood control technology and regulations were generally derived in one way or another to address pre- and post-developed stormwater-quantity volumes and flow rates to and from stormwater basins. The Metropolitan Sewer District of Greater Cincinnati (OH), for instance, requires that detention facilities detain the difference in runoff volume from the predeveloped site over a 10-year event of one-hour duration and the post-developed site under a 25-year event of one-hour duration (MSD 2001). This is contained in regulations pertaining to combined sewer systems.

Despite traditional approaches to post-developed stormwater management, advances in research and regulation suggest that it is the small storms, not just large ones, that play a convincing role with respect to urban hydrology and receiving-water quality. The notion that post-developed water quantity and water quality are strongly correlated to smaller or “critical” storms is so evident that the two concepts are being intrinsically merged within new federal stormwater guidelines and further reinforced at the state level. In North Carolina, for example, statewide post-construction stormwater general permitting requires hydrologic control and water-quality treatment [85% of total suspended solids (TSS)] of the difference in pre- and post-development runoff volumes for, at a minimum, the one-year, 24-hour storm (North Carolina DENR 2005). Furthermore, a model ordinance for municipalities developed within that state reflects this post-construction requirement and appropriately requires runoff volumes from project sites to be drawn down over the span of 24 to 120 hours (Kane and Whisnant 2005).



Concrete gutter removal was one aspect of Ohio's first detention basin retrofit.

impervious land conversion (Konrad 2003). When a drainage area is subjected to urbanization, the resultant annual increase in magnitude from small flood events can be significantly greater than large flood events (Konrad 2003). For example, 10-year, 50-year, and 100-year storms result in flooding regardless of watershed land uses, but when regulations are designed to hold back only runoff generated from the 10-year or 25-year storm, the more frequent storm events (one month, six months, one year, and two years) are magnified in greater proportion by watershed urbanization and ultimately passed through a storm sewer system without detention or water-quality treatment (Figure 1).



A water control device on an existing detention basin outlet

nation's leading nonpoint-source pollutant, undetained stormwater discharges that result in concentrated tailwater flows and sediment transport at the bankfull width may be as or more important in addressing turbidity and TSS than the sediments associated with upland land disturbances like farming or construction. Preventing magnification of stream flows at the bankfull width and subsequent fluvial instability can be addressed by adopting regulations that focus on detaining flow generated from smaller storms.

The third and most overwhelming problem with managing and regulating only large, infrequent storm events is that pollutant attenuation and treatment is minimal. The notion that pollutants associated with stormwater runoff are generally mobilized during the initial stage of a storm event is known as the first-flush concept. This phenomenon is generally defined as the initial period of stormwater runoff during which the concentration of pollutants is substantially higher than the later part of a storm event (Deletic 1998). Understanding the first-flush concept and the interaction of pollutants with small storms and the early parts of larger storms is critical in designing proper treatment systems, especially with the more stringent water-quality components set forth in NPDES Phase II. Certain types of pollutants such as heavy metals, organics, oils and greases, particulate matter from tires, sediment, chemical oxygen demand (COD), and polycyclic aromatic hydrocarbons (PAHs) have been connected to the first flush (Deletic 1998, and Lee et al. 2002) (Figure 2).

Detaining runoff associated with smaller storm events in addition to incorporating structural or nonstructural treatment practices proves to be the most effective method by which stormwater pollution can be managed and minimized.

A Realistic Solution

The big picture is that Mother Nature provides a clear illustration that the best way to manage precipitation and runoff is attenuation and slow release over time. These concepts are encapsulated in the North Carolina model ordinance; however, large-storm, quantity-based ordinances and stormwater management approaches that attempt to rush stormwater away from developed areas as highlighted by the City of Cincinnati above (and duplicated by thousands of municipalities across the United States) are directly opposite of nature's approach to stormwater management. Recognizing the importance of small storms in urban watershed hydrology and encouraging the attenuation of water at its source through proactive stormwater management planning and BMP selection are the best ways to conserve water quality in urbanizing watersheds. Ignoring small storms and source attenuation, particularly at the local and individual project level, results in three oft-ignored yet interconnected problems for municipal stormwater programs: localized flooding, fluvial instability, and pollution loading.

First and foremost, small storms predominately contribute to local flooding. Research has demonstrated that the effects of smaller, more frequent storm events are greatly magnified, up to an order of magnitude, by urbanization and

Considering the thousands of existing stormwater management facilities (i.e., detention basins) within urban landscapes nationwide, the most common storm events are not detained and often result in concentrated stormwater discharges to our communities' streams and wetlands. Termed the “goes-in, goes-out” effect, this scenario is greatly amplified by municipalities that fail to set pretreatment goals or that require structural improvements like concrete gutters in their stormwater management systems, leaving no chance for detention or water-quality attenuation of small storm events.

Secondly, large, quantity-based stormwater management approaches result in more severe streambank erosion and channel incisement. When runoff emanating from smaller, more magnified small storm events is not detained and quickly passes through a storm sewer system, the resultant tailwater flows in the receiving water body are elevated. In urban stream systems, this means bank erosion and fluvial instability are expected results of outdated regulations. Research by Peter Whiting at Case Western Reserve University in Cleveland, OH, is demonstrating that up to 45% to 65% of all sediment in some streams can be chemically traced to the streambanks themselves (Whiting 2006). With sediment identified as the

The perfect solution to problems associated with urban runoff, flooding, water quality, stream stability, low-maintenance BMPs, and economic feasibility is not simple. From a regulatory standpoint, the NPDES program has attempted to level the playing field and multiple states have now adopted post-construction water-quality regulations to address both stormwater quantity and stormwater quality in equal measure. In Ohio, for instance, the Ohio EPA's NPDES stormwater program defines a post-construction water-quality volume (WQv) as the first 0.75 inch of precipitation over a constructed drainage area and factors in appropriate runoff coefficients to determine a WQv that must be detained and released within 24 to 48 hours (Ohio EPA 2003). Post-construction stormwater requirements such as these regulate to the heart of the first-flush concept by requiring detainment of runoff and pollutants that are generally discharged at their highest concentrations during the early stages of storm events.

Although water-quality regulations like these are intentionally left open-ended in terms of structural versus natural BMP selection, opportunities to incorporate ecologically informed stormwater management planning exist under the Phase II umbrella. JF New & Associates, with offices in five Midwestern states, advises its clients to not only meet but exceed compliance expectations by presenting opportunities for innovative ecological solutions that address water quality, restore habitat, and improve aesthetics. Phase II stormwater rules provide the ideal framework for turnkey ecological solutions.

Retrofits: A New Way to Green Up Existing Basins

Onsite stormwater basins continue to be the most common stormwater management facility and BMP employed in residential and commercial developments nationwide, and they present an opportunity to serve multiple purposes: construction-site sediment control, flood control, and water quality. Regulations generally encourage using basins for dual purposes—sediment control facilities during construction and flood control facilities after construction—but even the most proactive communities have difficulties implementing and maintaining stormwater basins for post-construction water quality and ecological functionality.



By this Ohio project's end, more than 3,500 wetland and prairie plant plugs and 60 pounds of native seed mixes have been installed.

Throughout the country, JF New is demonstrating that impacts associated with traditional approaches to stormwater management are not irreversible. In southwest Ohio, we are demonstrating that even the oldest, most mundane systems in a developed area can be converted from dry-bottom, concrete-gutter-lined eyesores to ecological amenities. This conversion is happening elsewhere as well. Partnerships among local and state governments, watershed groups, academia, and private developers are beginning to "retrofit" past mistakes one dysfunctional basin at a time.

The following case studies of JF New projects from southwest Ohio represent two very different approaches that have yielded similar results with the mutual goal of restoring ecologically significant segments of riparian corridor. Both of these examples are located in urban landscapes and utilize innovative water-quality designs to meet current standards; furthermore, both examples serve as pioneering models that will educate the local development community while heightening public perception of water resources.

Case #1: Upper Mill Creek Riparian Restoration and Stormwater Wetland Enhancement Project, Beckett Ridge PUD, West Chester, OH

Made possible by a Five-Star Restoration Grant funded by the National Association of Counties, the Butler County (OH) Soil and Water Conservation District (SWCD) and JF New successfully installed the first stormwater detention basin retrofit of its kind in Ohio. The project involved the conversion of a 1.1-acre dry-bottom detention basin situated along 420 linear feet of degraded riparian corridor into a fully functional ecological system capable of meeting water-quality and flood control concerns. Sited along a sensitive reach of headwater stream in a rapidly developing suburban watershed, the barren and concrete-gutter-lined stormwater facility was transformed from a local eyesore covered in unmanaged, invasive vegetation to a local prototype for open space and stormwater management. The stormwater wetland system was designed to detain smaller storm events generated from 25 acres of upland residential and golf course property. The project successfully utilized the existing basin footprint to provide continued peak flow control; however, it was retrofitted using the Ohio EPA's WQv model to treat stormwater pollutants and provide water-quality attenuation.

The project consisted of three key phases: design, restoration, and monitoring. First, the existing detention basin was redesigned to be a wetland extended-detention water-quality basin. This involved the transformation of degraded riparian land into a fully functioning system with wetland components, principally to provide habitat and treat upland runoff before it entered the Upper Mill Creek. It was determined that 0.48 acre-foot of water was required to meet the Ohio EPA's post-construction WQv requirement. Because the existing basin merely provided flood control detainment of runoff from the predeveloped 10-year storm, the design plan was developed to incorporate the water-quality volume in addition to flood control volumes utilizing a combination of stormwater wetland features (Figure 3).

These features included microtopographical adjustments within the basin, specifically depression swales and micropools to increase stormwater residency time, earthen baffles to separate inflow from outflow, and forebays to collect sediment at stormwater entrance points. The project also involved invasive species (bush honeysuckle) eradication, concrete-gutter removal, a water control structure implement on the existing outlet, and most importantly a native vegetation planting plan customized to the various hydrologic regimes within the system. The final design was approved by the Ohio EPA and the Ohio Department of Natural Resources and constructed in the spring of 2006. At project's end, more than 3,500 wetland and prairie plant plugs and 60 pounds of native seed mixes were installed by a collaborative effort of volunteers and interested stakeholders.

To evaluate the efficiency of the system and its assimilation of pollutants following storm events, Butler SWCD and Miami (OH) University enacted a volunteer water-quality monitoring program. The results of the water-quality monitoring program in the basin and the receiving stream will be an invaluable data source used to educate local decision makers, developers, and engineers on this type of alternative BMP to improve water quality from sites in their communities. Preliminary results comparing data collected before, during, and after the

project suggest that the system is functioning (Table 2); however, conclusive results documenting before- and after-retrofit conditions and comparison of those results with those from other, non-restored basins are expected to be published by Miami University and disseminated by Butler SWCD over the next few years.

Serving as a more natural method to treat nonpoint-source runoff and protect receiving stream quality, this project also provided a local example as to the type of water-quality and flood control BMP that can be selected with appropriate education and partnerships for future development in the Mill Creek watershed. The Mill Creek is listed as a 303(d)-impaired watershed due to pollution, in part, associated with the urban and suburban land uses that dominate the watershed. Project partners included Butler SWCD, JF New, Miami University's Institute of Environmental Sciences, Beckett Ridge HOA, Butler County Stormwater District, Mill Creek Watershed Council of Communities, Ohio-Kentucky-Indiana Regional Council of Governments, and the Ohio Department of Natural Resources (Division of Soil and Water Conservation).

Case #2: Section 401 Water-Quality Certification, Hormel Foods Facility, Dayton Distribution Center, City of Dayton, OH

Prompted by mitigation and corrective action requests from the US Army Corps of Engineers and the Ohio EPA, Hormel Foods and the City of Dayton, OH, worked with JF New to correct unanticipated stream mitigation failures associated with magnified stormwater discharges to regulated waters in the Wolf Creek watershed. Although this project was more regulatory driven, a similar approach was employed, converting an approximately 200,000-cubic-foot dry-bottom detention basin to a compliant water-quality basin using wetland extended-detention principles to treat pollution and attenuate peak discharges.

Although the design approach was similar to the previous project, the Hormel Foods stormwater basin retrofit presented a different set of design variables. Most notably, the Hormel Foods facility contained a much smaller drainage area, 9 acres as opposed to 25, but the drainage area was dominated by nearly 100% impervious surface coverage. This resulted in a much shorter time of concentration and much larger flow rate discharging from the system. When the original detention basin was constructed, water-quality goals were not considered, and the basin met only basic flood control requirements. However, to meet the 0.50-acre-foot WQv requirement needed for the system, JF New determined that additional storage area was required.

Using a combination of stormwater BMPs, including reinforced vegetated inlet swales, micropools, flow separation baffles, and water control structures, the basin was redesigned and complemented by a native vegetation planting plan customized to hydrologic regime. The project also required the establishment of an approximately 4,500-square-foot rain garden and water-quality treatment cell in a previously mowed open area to meet additional WQv requirements. Additional highlights of the project installation were vegetation (fescue) eradication, basin sideslope stabilization, and upland prairie installation. In all, 4,000 native wet to mesic plant plugs and 80 pounds of native seed mixes were installed to provide ecological functionality and water-quality treatment within the system.

The resultant water-quality impacts to the receiving stream were immediate. Within six months after construction, a silt-deposition bar within the mitigated stream channel was reduced and hydrocarbons generated from truck traffic were eliminated from the Wolf Creek tributary. Considering the bigger picture, JF New determined that 91% of runoff from the most frequent storm events documented by the Miami Conservancy District rainfall gauging stations over the past 10 years would be completely detained and treated in the retrofitted basin before discharging to the mitigated stream channel in the future. In addition to exceeding regulatory concerns, the aggressive approach undertaken by Hormel Foods and the City of Dayton on this project exemplifies the type of BMP needed to preserve local hydrology and conserve water quality for future development projects.

Other Stormwater Basin Retrofit Measures Using Green BMPs

Stormwater basins present an opportunity for developers, engineers, and municipal stormwater managers to incorporate aesthetically pleasing and ecologically mindful components of watershed protection and post-construction stormwater-quality regulations into their projects. Water-quality improvements in developed watersheds may only be possible through correcting or retrofitting problematic areas where pollution-laden discharges are known. Whether stormwater basin systems are specified for future projects or already in place for municipal stormwater management in developed areas, there is a number of methods by which improvements to the status quo can be made.

In terms of vegetation establishment, wet (retention) basins and dry (detention) basins offer different possibilities to improve habitat function, aesthetics, and, ultimately, water quality. In dry basins, for instance, planting plans and seed mixes need to be customized to hydrologic regime and must include triannual maintenance. For wet basins, vegetation selection needs to be based on expected pool depths and account for fluctuations in fringe water levels. Below are a few methods by which native vegetation can be installed in existing stormwater systems



Hormel Foods' original detention basin met only basic flood control requirements.



Redesigning the basin included the establishment of a 4,500-square-foot rain garden.



Fescue eradication and sideslope stabilization are key benefits of the finished project.

to improve habitat and add post-construction water-quality value:

Shoreline plantings in existing retention (wet) ponds (Figure 4)
Emergent wetland/littoral shelves in retention ponds
Floating islands in wet ponds
Wet to mesic plug and seed installation in detention (dry) ponds
Water control devices on existing detention basin outlets

Conclusion

This article demonstrates how grandfathered stormwater basins can be retrofitted to meet current standards and how ecological functionality can be incorporated into existing systems to improve water quality, increase stormwater residency times, provide wetland/riparian habitat functions, and improve the economic/aesthetic value of open space designated for stormwater management. The necessary water-quality improvements and source-attenuation measures directly and indirectly promoted through the NPDES Phase II program are well understood, and the possibilities for implementation are limited only by the creativity of municipalities to incorporate them. Only through proactive ordinance adjustment, comprehensive stormwater management planning, and maintenance protocols can communities expect to see ecological stormwater BMPs such as rain gardens, bioretention basins, wetland stormwater treatment, and green roofs in their communities. While water-quality improvement projects and habitat restoration can be completed under the auspices of Phase II post-construction regulations, the future of ecologically friendly and alternative BMPs lies in planning and endorsement of such practices at the local level in projects that are yet to come. By aggressively correcting the mistakes of stormwater management practices in the past, water-quality retrofit projects are a small step forward in a larger nationwide effort to foster and facilitate new, more sustainable standards of alternative BMPs that promote stormwater attenuation and water-quality protection in the future.

Topics: [BMP Post Construction](#), [Project design](#), [Regulatory issues](#)
