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Incorporating Green Infrastructure Concepts into Total Maximum Daily Loads (TMDLs)

Overview

Throughout the U.S. there are thousands of waters listed for water quality impairments associated with discharges of urban and suburban stormwater. In addition to delivering pollutant loadings to receiving waters, the volume and energy of stormwater discharges can cause physical changes to surface water resources. Use of Green Infrastructure and Low Impact Development to manage stormwater can reduce pollutant inputs and help restore and maintain the natural hydrology in a watershed. The purpose of this fact sheet is to summarize how Green Infrastructure/Low Impact Development (GI/LID) practices can be incorporated into Total Maximum Daily Loads (TMDLs), and to show how these concepts have been applied in two recent TMDLs.

What is Green Infrastructure/ Low Impact Development?

Green Infrastructure (GI) and Low Impact Development (LID) are terms used to describe stormwater management approaches and practices that can be used to eliminate or reduce urban runoff and pollutant loadings by managing the runoff as close to its sources as possible. A collection of small-scale practices, linked together on a site, is used to reduce the impacts of development and redevelopment activities on water resources by maintaining or replicating the predevelopment hydrology of the site. This is achieved through the onsite infiltration, evapotranspiration, and/or reuse of rainwater. Examples of GI/LID practices are rain gardens, vegetated swales, pervious pavements, and green roofs.

How can a TMDL include GI/LID?

A TMDL report is a plan that calculates the maximum amount of pollutants an impaired water body can receive and still meet water quality standards. Once these pollutant "budgets" or allocations are calculated, they can then be translated into management actions that are implemented through permitting and/or non-regulatory programs. Currently there are thousands of 303(d) listed waters for stormwater-source pollutants such as pathogens, nutrients, sediments and metals. In addition, many listed waters have degraded habitat and/or impaired biological communities which are related to changes to natural hydrology that have occurred as development has taken place. This development often is associated with greater areas of impervious surfaces, resulting in increased stormwater volumes and velocities, which are highly erosive and degrade stream and lake habitats. As land use increasingly becomes more urbanized, waterbody impairments from stormwater sources likely will increase, requiring additional TMDLs. Incorporating GI/LID into TMDLs can point the way toward implementation actions that can reduce stormwater runoff loads and erosive effects, and help meet pollutant loadings identified in the TMDL. Two components of a TMDL can include a discussion of LID practices, where appropriate: *Future Growth, and TMDL Implementation Plans.*

Future Growth

USEPA's regulations at 40 CFR §130.2(i) and §130.7 define a TMDL as the sum of wasteload allocations (WLAs) for point sources plus load allocations (LAs) for nonpoint sources plus a margin of safety (MOS) to account for uncertainty. Mathematically, this is:

$$TMDL = \sum(WLA) + \sum(LA) + MOS$$

WLAs are loads allotted to existing and future point sources and LAs are loads allotted to existing and future nonpoint sources, plus loads from natural background. Future growth allowances in TMDLs account for increased pollutant loadings, and can be included as an allocation of pollutant loads from new sources expected in the future. For instance, in areas where land use changes are anticipated, TMDLs can include a reserve for future growth, which can be a separate element in the mathematical expression above, or included in WLAs or LAs. For example, if the population being served by a municipal wastewater treatment plant is expected to grow, the volume of the discharge from the WWTP would grow commensurately. In a case like this, the TMDL might include a future growth allocation for the WWTP discharge reflecting expected population growth.

A future growth allocation can also be included in the TMDL for stormwater discharges if significant land use changes are expected to occur in the drainage area. For example, if open space and farmland are predicted to be converted to residential and industrial land uses, there will be more imperviousness in the drainage area. The volume of stormwater and the pollutant loadings for many constituents will increase when the development occurs. In situations such as this, the TMDL can include a future growth allocation for the expected increases in stormwater discharges.

A future growth allocation for stormwater will typically reflect at least two factors:

1. The extent of new development (future growth), i.e., how much land area will convert from open space or agricultural uses to more intensive land uses.
2. The design of the new development areas -- will conventional development practices be implemented, or will GI/LID practices be widely implemented?

In determining a future growth allocation for stormwater in a TMDL, population projections and land use plans can be used to estimate the future growth, and pollutant loadings associated with the future development can be estimated using various modeling tools. Typically, what will be seen is the future growth allocation for stormwater will be lower if GI/LID practices are implemented. If the future growth allocation for stormwater can be reduced by planning for GI/LID practices, this may create opportunities to increase other allocations in the TMDL and still meet overall pollutant reduction targets.

Implementation Plans

TMDL Implementation Plans (IP) describe the management actions that can be adopted to reduce pollutant loadings to meet the water quality targets identified in the TMDL. Although there are no federal requirements that IPs be part of a TMDL, many states do require them and/or include some implementation information in the TMDL. The IP specifically can discuss what LID/Green Infrastructure practices can be incorporated into both regulatory and non-regulatory programs. For example, the implementation plan can show how storm water NPDES permits can include performance standards for current sites [e.g. retrofits] or could incorporate specific practices to reduce future pollutant loadings.

Another example is that NPDES stormwater permits for construction sites could establish post-construction requirements for groundwater recharge in a watershed impaired by stormwater discharges and changes to hydrology. Such permit provisions could require sites to plan for and implement GI/LID practices as development takes place. The construction general permit for construction sites in the Big Darby Creek watershed in Ohio is an example of a NPDES permit that includes groundwater recharge requirements. See http://www.epa.state.oh.us/dsw/permits/GP_ConstructionSiteStormWater_Darby.html.

Where a TMDL includes a future growth allocation for stormwater that reflects widespread GI/LID implementation, the mechanisms through which GI/LID implementation will occur might also be described in the Implementation section. For example, local jurisdictions can establish requirements/standards for GI/LID implementation in local codes and ordinances. The Conservation Design ordinance adopted by the Village of Homer Glen (Illinois) is an example of a local ordinance that will reduce stormwater volumes and pollutant loads from areas where new development occurs. See http://www.homerglen.org/regulations/ConservationDesign.htm.

TMDL Case Studies

The following section provides information on two case studies where the hydrology of the watershed was specifically addressed as part of the TMDL: Olentangy River, Ohio and Barberry Creek, Maine. Their TMDL implementation plans include implementation of GI/LID practices as new development takes place (Olentangy River example) and retrofits of existing areas to build in GI/LID practices and reduce the functional imperviousness of the drainage area. The two TMDLs described below are:

The Olentangy River TMDL identifies the management of stormwater quantity and quality in developing areas as an important step to preserving natural stream function through channel protection, and restoring stream habitat in agricultural areas. Several sections of the TMDL describe implementation of Green Infrastructure/Low Impact Development measures to restore/maintain natural hydrology.

The Barberry Creek TMDL addresses the problem of metals from stormwater runoff through the reduction of impervious cover. The implementation section contains discussion about LID-oriented best management practices that take three forms: general stream restoration techniques, disconnection of impervious surfaces, and conversion of impervious surfaces to pervious surfaces.

These TMDLs are summarized in the table below and discussed in detail in the following pages.

Table 1: Summary of TMDL Case Studies

	Olentangy River, OH TMDL	Barberry Creek, ME TMDL
Pollutants/pollution of concern	-Impaired for Aquatic life use and Recreational uses. -Causes of impairment: siltation, nutrient enrichment, habitat and flow alteration, and pathogens. -Instream targets: Total Suspended Solids, Total Phosphorous, and Fecal Coliform. -Stream geomorphology and floodplain targets were also established in the TMDL.	-Impaired for Aquatic life uses. Percent Impervious cover used as surrogate for complex aquatic life stressors. -Pb and Zn used as surrogate measures for an array of metals in stormwater runoff.
Major sources associated with impairment	**Point Sources:** Phase II MS4s, 32 minor, and 14 miscellaneous **Nonpoint Sources:** -unregulated stormwater -Channelization (for drainage improvement)	**Point Sources:** City of South Portland regulated under MS4 stormwater general permit **Nonpoint Source:** Unregulated stormwater
Impacts	-Runoff from agriculture resulting in high nutrient and pathogen loadings -Channelization leading to habitat degradation and sedimentation -Changing land cover resulting in altered hydrology and poor habitat	-Impaired stream habitat and low baseflow were identified as aquatic life stressors -Runoff leading to loadings of an array of metals to the waterbody
LID Practices Proposed	-Reduction of impervious cover -Various stormwater abatement techniques for individuals and businesses to reduce flow	-Implementation of BMPs for stream restoration techniques -Disconnection of impervious surfaces -Conversion of impervious surfaces to pervious
Method of LID Implementation	-Revisions to construction permit and future general stormwater permit -Incentives and market-based programs to encourage onsite stormwater management	-Abatement measures implemented under an adaptive management approach. -BMPs implemented through a phased program focusing on sensitive areas first.
Sections of TMDL containing LID Discussion	Section 9: Water Quality Improvement Strategy (Implementation Plan)	Section 7: Implementation Plan

Case Study 1: The Olentangy River Watershed TMDL, Ohio (2007)

TMDL Background
The Olentangy River, located in central Ohio, is approximately 93 miles long with a drainage area of 536 square miles. The river was listed based on impairments to aquatic life use and recreation. Land use primarily includes agricultural land interspersed with suburban urban areas that are rapidly being developed. The Olentangy River watershed flows across Ohio's first and sixth most rapidly growing counties, and coincides with Exceptional Warmwater Habitat reaches and the State Scenic River portion of the mainstem. Key future threats to the river are conversion of farm land to suburban and commercial land uses, especially in Delaware County.

A TMDL was required because portions of the Olentangy River and its tributaries do not attain their beneficial use designations for aquatic life and recreation. TMDL allocations were developed for (1) fecal coliform to address recreational use impairment; and (2) total phosphorus, total suspended solids (a surrogate for sedimentation), and habitat to address aquatic life use impairment. Although no allocations were developed for parameters related to stream geomorphology, floodplain area or hydrology, the TMDL report described how these factors related to attaining water quality standards. The Olentangy River TMDL identified managing stormwater quality and quantity in developing areas as an important step to preserving natural stream function through channel protection, and restoring stream habitat in agricultural areas. In the Olentangy River watershed, the City of Powell, Orange and Liberty townships and Delaware County are designated Phase II MS4 communities and have initiated stormwater programs which included construction site permitting and inspections, good housekeeping training, and public outreach and education.

Following are excerpts from the TMDL that discuss the hydrology of the watershed and the need for GI/LID practices. The full TMDL is available at:
http://www.epa.state.oh.us/dsw/tmdl/OlentangyTMDL_final_aug07.pdf

Section 9: Water Quality Improvement Strategy
Section 9.1.2. Habitat
Developing Areas
The most serious threat to channel stability, and possibly overall water quality and biological integrity, in the Olentangy River watershed is the rapid conversion of forest and/or agriculture land uses to residential, commercial, and industrial uses. Numerous scientific studies show that increasing impervious cover in a watershed (i.e., through development) is commensurate with the degradation of water quality and biological communities (Booth et al., 2005; Brabec et al.,2002; Roy et al., 2003; Roy et al., 2006; Morgan and Cushman, 2005).

This type of land use conversion substantially increases the volume of runoff, which is eventually routed to the stream system. Ultimately the sediment transport capacity of the system increases resulting in more channel erosion and instability (Booth, 2005). The resulting morphology provides poor habitat and may have a reduced capacity for nutrient assimilation (Walsh et al., 2005). Higher runoff volume increases pollutant loading (e.g., nutrients, metals, salts, pesticides, sediment). Additionally stream temperatures can be raised when runoff is heated by impervious surfaces such as asphalt and concrete or while residing in detention basins. Temperature increases reduce dissolved oxygen concentration and create stressful *conditions for aquatic biota (Ward, 1992; Cossins and Bowler, 1987)***…**

*A hydrologic regime that approximates that of pre-development conditions is important for protecting water quality and aquatic biological communities (Roy et al., 2006)***…** *Approximating the pre-development hydrology is not likely to be achieved with centralized controls (i.e., end of pipe retention/detention basins). However, onsite retention and infiltration is a realistic and potentially effective way to accomplish this (Andoh and Declerck, 1997). With an onsite approach, stormwater is managed near the area generating the runoff and infiltration is maximized. Onsite stormwater management contrasts with centralized systems that collect runoff over a broad area, provide relatively little opportunity for infiltration and consequently must manage very large volumes. Individual onsite controls operate on a small scale but systems are distributed to act collectively in managing runoff across a large area. Incentives, utilities and/or market based programs should be explored as a means to achieve more effective and ecologically meaningful stormwater management. Parkyn et al. (2005) provide an analysis of options for addressing stormwater management in an environmentally and economically sustainable manner.*

Onsite, or decentralized, stormwater management increases infiltration and reduces runoff generation by decreasing imperviousness. This is accomplished through appropriate planning, such as that used for Low Impact Development (LID). Low Impact Development is based on maximizing contiguous open space, protecting sensitive areas, namely floodplains and wetlands, and preserving existing vegetation (especially trees). Web based resources for LID include: www.lowimpactdevelopment.org/. In a Low Impact Development, houses are located relatively closer to one another, roadways are narrower, and bio-retention and infiltration techniques are used. LID reduces runoff and can provide cost savings in stormwater infrastructure. Additional non-environmental benefits include a greater than average increase in property values.

…

Watersheds that retain relatively large areas of forest are able to better mitigate the impacts of increasing imperviousness than those with little forest cover (Brabec et al., 2006, Booth, 2005). The procurement of conservation easements, and the establishment of parkland and nature preserves can help retain some of the existing forest cover as well as facilitate the conversion from open land to forest. Although land preservation alone is not likely to occur at a level necessary to mitigate development impacts, it will augment other measures that are taken (e.g., LID and/or discrete onsite stormwater management).

Stormwater abatement techniques that are employed in commercial developments and on individual residences (i.e., that are not a part of a LID) will provide protections to water quality. In particular, parking lots often account for a very high proportion of the impervious surfaces in urban watersheds. According to the University of Connecticut Extension, impervious cover associated with automobile traffic accounts for a significant proportion of the total impervious cover in a given watershed (http://nemo.uconn.edu/).

At the scale of individual residences or business stormwater abatement techniques can be used that include diverting drainage from rooftops, driveways, and other impervious surfaces away from a centralized collection system (e.g., outlets to either curb-and-gutter drains or stormwater sewer lines) and to permeable areas that can provide infiltration and/or temporary storage. Minimizing the extent of impervious surfaces by limiting their size or substituting them *with permeable surfaces will also increase infiltration and detention for a given property. Outreach and education activities are likely to result in some increase in this type of voluntary action taken by watershed residents, however to what extent would be very difficult to predict. Outreach efforts that include landscape design and construction companies may also be beneficial as they can present options for enhanced stormwater management to their prospective clients.*

Excerpt from Section 9.2 Implementation Recommendations by Sub-watersheds
9.2.3. Lower Olentangy
<u>Point Sources</u>
Threat to Resource Quality from Development
To protect against the degradation of water quality in one of the nation's most rapidly developing areas, the Ohio EPA recommends that general stormwater permits for construction activities be revised for the Delaware County and the uppermost Franklin County portion of the watershed downstream of the Delaware Reservoir. It is recommended that the NPDES General Permit for Storm Water Associated with Construction Activity Located within Portions of the Olentangy River Watershed include additional requirements, beyond the current statewide construction storm water general permit requirements. The additional requirements should include requiring submittal of the storm water pollution prevention (SWP3), riparian setback requirements and more stringent sediment and erosion controls which include performance standards.

Regional planning and local zoning authorities should adhere to the principals of Low Impact Development and encourage land preservation. Additionally, onsite stormwater management should be encouraged and incentives, utilities and/or market based programs should be explored as a means to achieve this.

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<u>Case Study 2: Barberry Creek TMDL, Maine (2007)</u>

TMDL Background
Barberry Creek, located just south of Portland, Maine, was listed as impaired for non-attainment of Maine's Class C aquatic life standards. Maine concluded that impairments were due primarily to a combination of pollutant (metals) and non-pollutant (stream habitat and low baseflow) stressors related to stormwater runoff from developed areas. The major sources of stormwater are from the City of South Portland, regulated by Phase II MEPDES stormwater general permit, and overland runoff from a highly urbanized drainage area. The TMDL calculated the total extent of impervious cover (%IC) in the watershed as a surrogate for the complex mixture of pollutant and non-pollutant aquatic life stressors which are attributable to stormwater runoff from developed areas. The current extent of impervious cover in the Barberry Creek watershed is estimated at 23% IC. The TMDL sets a target of 12% impervious cover to guide implementation efforts. The TMDL also identified pollutant-specific loadings of Pb and Zn as surrogates for numerous metals found in stormwater runoff.

The full Barberry Creek TMDL document is available at: http://mainegov-images.informe.org/dep/blwq/docmonitoring/impairedwaters/TMDL/2007/barberry_ck_rep.pdf

Excerpts from Section 7: Implementation Recommendations:
Stormwater effects can be lessened, water quality improved, and impairments curtailed by implementing best management practices (BMPs) and remedial actions in a cost-effective manner using the following adaptive management approach:

- *Implement BMPs strategically through a phased program which focuses on getting the most reductions, for least cost in sensitive areas first (for example, begin with habitat restoration, flood plain recovery, and treatment of smaller, more frequent storms);*
- *Monitor ambient water quality to assess stream improvement;*
- *Compare monitoring results to water quality standards (aquatic life criteria);*
- *Continue BMP Implementation in a phased manner until water quality standards are attained.*

Generally speaking, these abatement measures can take one of three forms: they can consist of general stream restoration techniques (including flood plain and habitat restoration), they can disconnect impervious surfaces from the stream, or they can convert impervious surfaces to pervious surfaces. In general, practices that achieve multiple goals are preferred over those that achieve only one goal (ENSR 2005). For example, installing a detention basin along with runoff treatment systems provides more effective abatement of stormwater pollution than installing detention BMPs alone. Because of the effort and cost involved in implementing these BMPs, a long-term strategy can be used to achieve water quality standards. For example, lower cost general stream restoration techniques that lessen stormwater effects immediately can be implemented in the short-term to initiate stream recovery…

The following three sections list the options available for BMPs aimed at stream restoration techniques, and disconnection and conversion of impervious surfaces. Because many factors must be considered when choosing specific structural BMPs (e.g., target pollutants, watershed size, soil type, cost, runoff amount, space considerations, depth of water table, traffic patterns, etc.), the sections below only suggest categories of BMPs, not particular types for particular situations. Implementation of any BMPs will require site-specific assessments and coordination among local authorities, industry and businesses, and the public…

In summary, implementation of remedial measures will occur under an adaptive management approach in which certain measures are implemented, their outcome evaluated, and future measures, selected so as to achieve maximum benefit based on new insights gained. The order in which measures are implemented should be determined with input from all concerned parties (e.g., city, businesses, industry, residents, regulatory agencies, watershed protection groups). It is suggested that the City develop implementation recommendations by the end of 2006 and present them to the watershed stakeholders, the Cumberland County Soil and Water Conservation District, and MDEP. In the annual report required each year by the MEPDES stormwater general permit (MS4), the City should highlight its efforts to meet the wasteload allocation of this TMDL.

<u>General Stream Restoration Techniques</u>

- *Encouraging responsible development by promoting Smart Growth or Low-Impact Development guidelines and the use of pervious pavement techniques will minimize overall effects of urbanization.*

- *Reducing new impervious cover by promoting shared parking areas between homes or between facilities that require parking at different times will reduce impacts related to impervious surfaces. Lowering minimum parking requirements for businesses and critically assessing the need for new impervious surfaces will have the same effect.*

<u>Disconnection of Impervious Surfaces</u>

- *Channel runoff from large parking lots, roads or highways into*
    - *Detention/retention BMPs (e.g., dry/wet pond, extended detention pond, created wetland), preferably one equipped with a treatment system;*
    - *Vegetative BMPs (e.g., vegetated buffers or swales);*
    - *Infiltration BMPs (e.g., dry wells, infiltration trenches/basins, bio-island/cells);*
    - *Underdrained soil filters (e.g., bioretention cells, dry swales).*
- *Guide runoff from paved driveways and roofs towards pervious areas (grass, driveway drainage strip, decorative planters, rain gardens).*
- *Remove curbs on roads or parking lots.*
- *Collect roof runoff in rain barrels and discharge into pervious areas.*

<u>Conversion of Impervious Surfaces</u>

- *Replace asphalt on little-used parking lots, driveways or other areas with light vehicular traffic with porous pavement blocks or grass/gravel pave.*
- *Replace small areas of asphalt on large parking lots with bioretention structures (bio-islands/cells).*
- *Replace existing parking lot expanses with more space-efficient multistory parking garages (i.e., go vertical).*
- *Replace conventional roofs with green roofs.*

These options for conversion of impervious surfaces also provide for a virtual elimination of runoff during light rains (which account for the majority of runoff events), reduction in peak discharge rate and volume during heavy rains, filtration of some pollutants, and improvement in groundwater recharge.

Key Resources

US EPA's Green Infrastructure (GI) Webpage
Summarizes common Green Infrastructure approaches and key resources for research, funding and partnerships.
(http://cfpub.epa.gov/npdes/home.cfm?program_id=298)

EPA's Low Impact Development (LID) Webpage
Provides comprehensive list of LID-related resources
(http://www.epa.gov/nps/lid/)

EPA's Sustainable Infrastructure for Water and Wastewater Webpage
Provides information and resources on EPA's Sustainable Infrastructure Initiative
(http://www.epa.gov/waterinfrastructure/)

Low Impact Development Center
Dedicated to research, development, and training for water resource and natural resource protection issues. The Center focuses specifically on furthering the advancement of Low Impact Development technology.
(http://www.lowimpactdevelopment.org/)

Stormwater Manager's Resource Center
Designed specifically for stormwater practitioners, local government officials and others that need technical assistance on stormwater management issues.
(http://www.stormwatercenter.net/)

The Conservation Fund and USDA Forest Service Green Infrastructure Webpage
A comprehensive website that covers a wide variety of green infrastructure topics, including funding opportunities, case studies, and publications.
(http://www.greeninfrastructure.net/)

Rooftop to Rivers: Green Strategies for Controlling Stormwater and Combined Sewer Overflows
(http://www.nrdc.org/water/pollution/rooftops/rooftops.pdf)

US EPA fact sheet on Incorporating Environmentally Sensitive Development into Municipal Stormwater Programs
This fact sheet is intended to assist local stormwater managers who wish to encourage or require green infrastructure practices to meet stormwater goals.
(http://www.epa.gov/npdes/pubs/region3_factsheet_lid_esd.pdf)

Low Impact Development: Technical Guidance Manual for Puget Sound
This guidance manual, developed by the Puget Sound Action Team and Washington State University, is designed to provide stormwater managers and site designers with a common understanding of low impact development/green infrastructure goals and objectives. It includes technical specifications for individual practices as well as research data related to those practices.
(http://www.psat.wa.gov/Publications/LID_tech_manual05/lid_index.htm)

US EPA's Using Smart Growth Techniques as Stormwater Best Management Practices
Reviews nine common smart growth techniques and examines how they can be used to prevent or manage stormwater runoff.
(http://www.epa.gov/smartgrowth/pdf/sg_stormwater_BMP.pdf)

US EPA Reducing Stormwater Costs through Low Impact Development (LID) Strategies and Practices
This report provides information to cities, counties, states, private-sector developers and others on the costs and benefits of using Low Impact Development (LID) strategies and practices to help protect and restore water quality.
(http://www.epa.gov/owow/nps/lid/costs07/)

Hipp, J. Aaron; Ogunseitan, Oladele; Lejano, Raul & Smith, Scott. **Optimization of Stormwater Filtration at the Urban/Watershed Interface.** Environmental Science & Technology 8/1/2006, Vol. 40, Issue 15, pp. 4794-4801.

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