C H A P T E R 2

# Low Impact Development Techniques

As described in Chapter 1, land development can have severe adverse stormwater impacts, particularly if the land is converted from woods, meadow, or other natural condition to a highly disturbed area with large percentages of impervious and non-native vegetated covers. Such impacts typically include an increase in stormwater runoff volume, rate, velocity, and pollutants and a corresponding decrease in the quality of runoff and stream flow. Frequently, management of these impacts has focused on collecting and conveying the runoff from the entire site through a structural conveyance system to a centralized facility (e.g., detention basin, wet pond) where it is stored and treated prior to discharge downstream. In effect, such practices first allow the adverse runoff impacts to occur throughout the site and then provide remedial and/or restorative measures immediately prior to releasing the runoff downstream.

Since the 1960s, the range of remedial measures provided in centralized treatment facilities has increased from merely 100-year peak flow attenuation to the range of peak flow, volume, and nonpoint source pollutant controls required by New Jersey's current Stormwater Management Rules at N.J.A.C. 7:8. This has required modifications to established methods of runoff computation and the development of alternative treatment methods to be used in centralized facilities.

However, with the increasing emphasis on nonpoint source pollution and concerns over the environmental impacts of land development, it has become necessary to develop effective alternatives to the centralized conveyance and treatment strategy that has been the basis for much of the stormwater management systems and programs in the state. New strategies must be developed to minimize and even prevent adverse stormwater runoff impacts from occurring and then to provide necessary treatment closer to the origin of those impacts. Such strategies, known collectively as Low Impact Development or LID, seek to reduce and/or prevent adverse runoff impacts through sound site planning and both nonstructural and structural techniques that preserve or closely mimic the site's natural or pre-developed hydrologic response to precipitation. Rather than responding to the rainfall-runoff process like centralized structural facilities, low impact development techniques interact with the process, controlling stormwater runoff and pollutants closer to the source and providing site design measures that can significantly reduce the overall impact of land development on stormwater runoff. As such, low impact development promotes the concept of designing with nature.

Effective low impact development includes the use of both nonstructural and structural stormwater management measures that are a subset of a larger group of practices and facilities known as Best Management Practices or BMPs. As noted above, the BMPs utilized in low impact development, known as LID-BMPs, focus first on minimizing both the quantitative and qualitative changes to a site's pre-developed hydrology through nonstructural practices and then providing treatment as necessary through a network of structural facilities distributed throughout the site. In doing so, low impact development places an emphasis on nonstructural stormwater management measures, seeking to maximize their use prior to utilizing structural BMPs.

Nonstructural BMPs used in low impact development seek to reduce stormwater runoff impacts through sound site planning and design. Nonstructural LID-BMPs include such practices as minimizing site disturbance, preserving important site features, reducing and disconnecting impervious cover, flattening slopes, utilizing native vegetation, minimizing turf grass lawns, and maintaining natural drainage features and characteristics. Structural BMPs used to control and treat runoff are also considered LID-BMPs if they perform these functions close to the runoff's source. As such, they are typically smaller in size than standard structural BMPs. Structural LID-BMPs include various types of basins, filters, surfaces, and devices located on individual lots in a residential development or throughout a commercial, industrial, or institutional development site in areas not typically suited for larger, centralized structural facilities.

Finally, low impact development promotes the view of rainwater as a resource to be preserved and protected, not a nuisance to be eliminated. For example, with low impact development, roof runoff can be captured and stored in rain barrels for plant watering or other uses. Runoff can also be directed to small on-lot bioretention or infiltration basins, also known as rain gardens, to provide both runoff treatment and landscape enhancements.

Unfortunately, low impact development techniques and strategies are considered by some to be applicable only to land development sites with limited impervious cover. However, it has been clearly demonstrated that low impact development techniques can be applied to virtually any development site, regardless of impervious coverage, to produce enhanced site designs and "lower" stormwater impacts.

The use of nonstructural and structural LID-BMPs can be a significant improvement over the more centralized approach to stormwater management traditionally used in New Jersey. Even in those instances where centralized structural BMPs are still required to fully provide downstream areas with effective pollution, erosion, and flood protection, LID-BMPs can help to reduce the number and/or size of such facilities, further reducing site disturbance. And, in certain instances, it may be possible to satisfy all stormwater management requirements through the use of nonstructural LID-BMPs alone, thereby eliminating the need for any structural BMPs. In all instances, specific site and downstream conditions must be evaluated to determine the range of standard and low impact development BMPs that can be utilized at a land development site.

It is also important to note that, since low impact development typically relies on an array of nonstructural and relatively small structural BMPs distributed throughout a land development site, ownership and maintenance of the various BMPs may be similarly distributed over an array of property owners. As such, it is vital to have public understanding of and support for the various LID-BMPs officially authorized for use in a particular municipality. Such understanding and support must include an appreciation for the role that the LID-BMPs play in the site's or watershed's stormwater management program and a commitment to preserve and maintain them. Additional information regarding this issue is presented in the *Additional Considerations* section below.

The use of both nonstructural and structural BMPs in low impact development is governed by certain principles, objectives and requirements. A discussion of each of these factors is presented below, along with details of each type of LID-BMP. It should be noted that, while consideration of nonstructural stormwater management techniques at land development sites is required by the NJDEP Stormwater Management Rules at N.J.A.C. 7:8, the NJDEP believes that effective, state-wide use of such practices can be best achieved through municipal master plans and land development ordinances that mandate specific LID goals and authorize the use of specific LID-BMPs. For this reason, the Stormwater Management Rules require municipalities to review their master plans and ordinances in order to incorporate LID practices into their land development regulations to the maximum extent practicable. A detailed discussion of the NJDEP Stormwater Management Rules is presented below, along with guidelines on the development of municipal LID regulations and the selection of practical and reliable LID-BMPs.

## Nonstructural Stormwater Management Strategies

As described above, effective low impact development includes the use of both nonstructural and structural stormwater management measures known as LID-BMPs. Of the two, nonstructural LID-BMPs play a particularly important role. The proposed NJDEP Stormwater Management Rules at N.J.A.C. 7:8 require in Section 5.2(a) that the design of any development that disturbs at least 1 acre of land or increases impervious surface by at least 1/4 acre must incorporate nonstructural stormwater management strategies "to the maximum extent practicable." Such a development is defined in the Rules as a "major development." As such, nonstructural LID-BMPs are to be given preference over structural BMPs. Where it is not possible to fully comply with the Stormwater Management Rules solely with nonstructural LID-BMPs, they should then be used in conjunction with LID and standard structural BMPs to meet the Rules' requirements.

More precisely, to achieve the Rules' design and performance standards, Subchapter 5 of the NJDEP Stormwater Management Rules requires the maximum practical use of the following nine nonstructural strategies at all major developments:

1. Protect areas that provide water quality benefits or areas particularly susceptible to erosion and sediment loss.
2. Minimize impervious surfaces and break up or disconnect the flow of runoff over impervious surfaces.
3. Maximize the protection of natural drainage features and vegetation.
4. Minimize the decrease in the pre-construction "time of concentration."
5. Minimize land disturbance including clearing and grading.
6. Minimize soil compaction.
7. Provide low maintenance landscaping that encourages retention and planting of native vegetation and minimizes the use of lawns, fertilizers, and pesticides.
8. Provide vegetated open-channel conveyance systems discharge into and through stable vegetated areas.
9. Provide preventative source controls.

In addition, Subchapter 5 further requires an applicant seeking approval for a major development to specifically identify which and how these nine nonstructural strategies have been incorporated into the development's design. Finally, for each of those nonstructural strategies that were not able to be incorporated into the development's design due to engineering, environmental, or safety reasons, the applicant must provide a basis for this contention.

While the nonstructural stormwater management strategies listed above represent a wide range of both objectives and practices, Strategies 1 through 8 can be directly addressed through the use of specific nonstructural LID-BMPs that can be grouped into four general categories:

1. Vegetation and Landscaping;
2. Minimizing Site Disturbance;
3. Impervious Area Management; and
4. Time of Concentration Modifications.

Information on the specific nonstructural LID-BMPs included in each of these categories is presented below. A Nonstructural Stormwater Management Checklist is provided in Appendix A to assist applicants and reviewers in demonstrating that the Stormwater Management Rules' nine nonstructural stormwater management strategies have been utilized throughout the land development site to the maximum extent practicable.

Prior to utilizing any of the specific nonstructural LID-BMPs described below, applicants are urged to review the land development regulations of the municipality and/or agency from which they are seeking development approval. Despite low impact development being a relatively new aspect of stormwater management, many municipalities and agencies have already incorporated low impact development goals and strategies into their own regulations and, with the advent of the NJDEP Stormwater Management Rules, those that haven't will be required to do so. Therefore, additional nonstructural strategies and/or specific nonstructural LID-BMPs aside from those described in this chapter may have already been incorporated into a municipality's land development regulations or will be in the near future. In light of the site specific nature of LID-BMPs, these regulations may also discourage or prohibit the use of specific LID-BMPs for engineering, safety, or maintenance reasons. Consideration should also be given to having a pre-design meeting and/or site walk with pertinent regulators and technical reviewers to review local regulations and optimize the site's nonstructural stormwater management design.

Finally, engineers and site designers should recognize the importance of accurately computing existing or predeveloped runoff at a land development site. While this is an important computation at all development sites, it is particular important at those sites where nonstructural LID-BMPs will be utilized. This is because, to a large degree, these nonstructural measures will utilize and/or mimic the predeveloped site's rainfall-runoff response. As such, accurate computation of predeveloped hydrologic conditions is vital to successful LID-BMP use. It is recommended that engineers and site designers consult with regulatory entities, such as the State, municipality, or local soil conservation district, regarding predeveloped hydrologic conditions.

# 1. Vegetation and Landscaping

As a nonstructural LID technique, the management of existing and proposed vegetation at a land development site can significantly reduce the site's impact on downstream waterways and water bodies. As discussed in detail in Chapter 5, pervious vegetated areas reduce runoff volumes and peaks through infiltration, surface storage, and evapo-transpiration. Vegetated areas also provide a pervious surface for groundwater recharge, particularly during dormant or non-growing seasons. In addition, vegetation can remove pollutants from the runoff flowing through it through both filtration and biological uptake.

Information regarding three key nonstructural LID-BMPs that utilize vegetation and landscaping to manage stormwater runoff are presented below. A review of this information demonstrates how the features of all three are closely inter-related.

## A. Preservation of Natural Areas

The preservation of existing natural vegetated areas is a nonstructural LID-BMP that must be considered throughout the design of a land development. This is especially true for areas with significant hydrologic functions such as forested areas, riparian corridors, and high groundwater or aquifer recharge capabilities. When applying for development approval from a regulatory agency or board, a plan showing natural vegetated areas on the pre-developed site, along with a narrative and photographs describing each area's vegetated and hydrologic characteristics, should be included in the application package. The narrative should also discuss the alternatives and choices made to preserve the natural vegetated areas.

In addition to identifying natural areas to be preserved at a development site, specific legal and/or procedural measures must be specified to ensure that such areas remain preserved in the future. This may include the establishment of easements or deed restrictions on specific portions of a parcel or lot that prohibit any disturbance or alteration. Other measures may not designate a particular portion of a parcel or lot but instead mandate through deed restrictions that an overall percentage of the parcel or lot must remain in natural, vegetated cover. This method allows greater flexibility but can be used only where the exact location of the preserved natural area is not critical to the success of the development's stormwater management system. In either case, the amount of natural area to be preserved must be the maximum amount feasible.

## B. Native Ground Cover

Research has demonstrated that areas covered with turf grass typically generate more runoff than other types of vegetation. This is especially true when comparing grass areas with naturally wooded areas or forests. Therefore, in keeping with the goals of nonstructural LID-BMPs contained in the NJDEP Stormwater Management Rules, the amount of lawns and other grass areas at land development sites should be minimized. Instead, alternative vegetation, particularly native plants, should be used to revegetate disturbed site areas.

The use of native plants can provide a low-maintenance alternative to turf grass, resulting in lower fertilizer and water needs. The use of native ground cover, shrubs, and trees instead of turf grass can create infiltration characteristics similar to those of natural areas. These plants can also provide better habitat and create food sources for songbirds and small animals. Native landscaping can also be used to provide property screening, summer shade, and year-round landscaping interest.

In addition to revegetating site areas disturbed by construction, native plants can be used to improve or enhance the hydrologic characteristics of existing site areas. Such areas may include existing agricultural fields, developed areas, access roads, and other previously disturbed portions of the site as well as degraded natural areas. Naturally wooded areas or forests should also be restored or reestablished at land development sites wherever practical. This is also consistent with the goals of nonstructural LID-BMPs. In doing so, it is often necessary to provide stable interim vegetative cover in such restored areas.

In selecting native vegetation, consideration should be given to height, density, and other growth patterns, visual appearance, anticipated use of the planted area, and fertilizer, irrigation, and other maintenance needs. Additional information on native vegetation and landscaping is presented in Chapter 7.

## C. Vegetative filters and Buffers

Both native ground cover and grass areas can provide a vegetated buffer to help filter stormwater runoff and provide locations for runoff from impervious areas to re-infiltrate. As described above, water flowing as sheet flow across a vegetated area is slowed, filtered and, depending on soil conditions, given the opportunity to re-infiltrate into the soil. Dense vegetative cover, long flow path lengths, and low surface slopes provide the most effective vegetated filters. Maximizing the use of such nonstructural LID-BMPs helps demonstrate compliance with the nonstructural stormwater management requirements of the NJDEP Stormwater Management Rules.

Vegetative filters and buffers can be created by preserving existing vegetated areas over which runoff will flow or by planting new vegetation. Vegetative filters located immediately downstream of impervious surfaces such as roadways and parking lots can achieve pollutant removal, groundwater recharge, and runoff volume reduction. Vegetated buffers adjacent to streams, creeks, and other waterways and water bodies can also help mitigate thermal runoff impacts, provide wildlife habitat, and increase site aesthetics. Further information and detailed design procedures for vegetative filters are presented in Chapter 9.

## 2. Minimizing Land Disturbance

Minimizing land disturbance at a development site is a nonstructural LID-BMP that can be used during all phases of a land development project. Similar to the preservation of natural areas (see *1. Vegetation and Landscaping* above), minimizing land disturbance can help reduce post-development site runoff volumes and pollutant loads and maintain existing groundwater recharge rates and other hydrologic characteristics by preserving existing site areas. However, as a strategy, minimizing land disturbance can also be applied during a project's construction and post-construction phases.

Minimum disturbance begins during the project's planning and design phases by fitting the development into the terrain, as opposed to changing the terrain to fit the development. Also known as site fingerprinting, minimal disturbance techniques are first applied during the planning and design stages to evaluate existing site characteristics and constraints. The goal of this process is to limit clearing, grading, and other land disturbance necessary for buildings, houses, roadways, parking lots, and other proposed features and facilities. Roadway and building patterns that match the existing land forms and limit the amount of required clearing and grading should be chosen.

Site-specific conditions such as slope, soil type, drainage area, and other site conditions and constraints must be considered, including the identification of effective groundwater recharge and runoff storage areas. Wherever feasible, development should be concentrated on soils with low permeability rates to minimize the increase in runoff and to retain high permeability areas for groundwater recharge. The selection of the location of the development due to the soil type can have a significant impact on the resulting increases in runoff. Existing runoff storage areas should also be preserved to help retain the site's hydrologic character. Strict adherence to a minimum land disturbance strategy during a development's planning and design stages can also be an effective way to minimize soil compaction at those sites where there is a potential for it to occur.

In addition, the identification and evaluation of site constraints such as wetlands, Karst topography, and floodplains are critical to the effective implementation of LID designs. For example, additional analysis and provisions are applicable for development in Karst areas. It is interesting to note that the New Jersey Geological Survey's recommendations for Karst areas presented below are very similar to those for low impact development:

1. Do not concentrate flows.
2. Minimize grading.
3. Build within landscape (design around existing topography).
4. Do not alter natural drainage areas.
5. Minimize the amount of imperviousness.
6. Increased structural loads at the site can contribute to ground failures.
7. Changes to existing soil profile, including cuts, fills, and excavations, should be minimized.

Additional information on development in Karst areas can be found in Appendix A-10 of the New Jersey Department of Agriculture's Soil Erosion and Sediment Control Standards or from either the State Soil Conservation Committee (SSCC) at (609) 292-5540 or the New Jersey Geological Survey (NJGS) at (609) 292-2576. Information may also be available from the local Soil Conservation District or municipal engineer.

As noted above, land disturbance can also be minimized during a project's construction and post-construction stages. For example, during a development's construction phase, construction areas, access roads, and material and equipment storage areas can be minimized and strictly regulated. In addition, lighter-weight, rubber-tired construction equipment can be used whenever possible, with their movements limited to a few repetitive routes. Construction can also be phased to minimize the site area that will be disturbed at any given time. To help ensure compliance, such practices and requirements should be included in soil erosion and sediment control plans, construction plans, and contract documents.

Following construction, limits can be placed on the expansion of homes, buildings, driveways, parking, and other disturbed areas through deed restrictions, approving resolutions, owners' agreements, and zoning ordinances. Specific portions or percentages of a parcel or lot can be designated to remain undisturbed through deed restrictions or easements. As such, it can be seen that minimizing land disturbance should not only be one of the first nonstructural LID-BMPs applied to a land development's design, but it should also be continually reapplied throughout the life of the project.

It should also be noted that, in addition to the measures described above for minimizing soil compaction, measures can be taken to remediate a soil compaction problem. If compaction should be a problem, the Standards for Soil Erosion and Sediment Control in New Jersey recommends that, prior to topsoil and seed application, the surface of all compacted areas be scarified 6 to 12 inches.

## 3. Impervious Area Management

Impervious areas in a watershed have been cited in studies as an indicator of stream health. Increases in watershed imperviousness have been linked in these studies to degradation of water quality, especially in areas where the impervious surface is directly connected to a water body. Increases in impervious cover in a watershed can be directly correlated to increased runoff volumes and rates as well as waterway velocities, erosion, and flooding. Impervious areas can also accumulate nonpoint source pollutants that can significantly impact waterways when washed off by runoff.

Fortunately, comprehensive management of impervious areas at a land development site can help reduce the impervious area impacts described above. This section discusses the nonstructural LID-BMPs that can reduce the volume and peak rate of runoff from impervious surfaces by limiting their total area or disconnecting them from the site's stormwater conveyance system. Reductions in impervious area translate into more surface storage, infiltration and groundwater recharge, less stormwater runoff, and reduced storm sewer construction, maintenance, and repair costs. It is important to note that all reductions in the amount and dimensions of impervious surfaces at a land development site must also recognize safety and the level of use of the impervious surfaces.

### A. Streets and Sidewalks

**Street Widths:** Street widths are typically based on traffic density, emergency vehicle movement, and the need for roadside parking. Street widths in residential areas are specified in Subchapter 4: Streets and Parking of the Residential Site Improvement Standards at N.J.A.C. 5:21 (RSIS). In such developments, efforts should be made to utilize the minimum pavement or cartway width consistent with the Standards. Similarly, in all other development types, the widths of all streets should be evaluated to demonstrate that the proposed width is the narrowest possible consistent with safety and traffic concerns and requirements.

**Street Features:** The design of certain streets or portions thereof may include features or areas that can be covered with pervious material, landscaped, and/or designed to receive runoff. For example, traffic calming measures such as circles, rotaries, medians, and islands can be vegetated or landscaped. Such features reduce the amount of impervious cover and provide an opportunity to store and possibly infiltrate runoff from adjacent impervious street surfaces. When curbs are necessary to maintain traffic safety and/or meet existing regulations, street runoff may be directed to these features through curb cuts.

**Sidewalks:** Sidewalk requirements within residential areas are also specified in Subchapter 4 of the RSIS and are based on the street type and development intensity. Municipal regulations often dictate the requirements for sidewalks in non-residential development to provide safe pedestrian movement. Pedestrian traffic patterns considered when determining the placement of sidewalks include the presence of schools, shopping centers, recreational facilities, handicap access, and public transportation facilities. Sidewalks can be made of pervious material, such as porous pavement or concrete, or designed to provide runoff storage and infiltration in their stone base. Where impervious material is used, sidewalks can be disconnected from the drainage system, which allows some of the runoff from them to re-infiltrate in adjacent pervious areas. Additional details regarding unconnected impervious surface is presented below.

## B. Parking and Driveway Areas

Similar to street widths, the size of parking areas and driveways contributes to the total amount of impervious surface at a development site. In New Jersey, parking area and driveway requirements are typically mandated by municipal regulations and, in the case of residential areas, the RSIS. In Section 4.14, the RSIS states:

> *Alternative parking standards… shall be accepted if the applicant demonstrates these standards better reflect local conditions. Factors affecting minimum number of parking spaces include household characteristics, availability of mass transit, urban vs. suburban location, and available off-site parking resources.*

As such, the RSIS provides flexibility in selecting parking and driveway size, provided that supporting local data is available.

The RSIS further states:

> *When housing is included in a mixed-use development, a shared parking approach to the provision of parking shall be permitted.*

From the above, it can be seen that a mix of residential and nonresidential uses at a development site can share parking areas, thereby reducing the total parking area and impervious cover. The RSIS also allows a reduction in the standard 18 foot parking space length provided that room is provided for overhang by the vehicle. The overhang area can then be vegetated to further reduce (and possibly help disconnect) impervious surfaces. Non-residential developments can use these same ideas where permitted by local regulations.

At all development sites, consideration should be given to constructing some or all driveways and parking areas from pervious paving material. This is particularly true for overflow parking areas as well as driveways (and other access roadways) that are used relatively infrequently by maintenance and emergency vehicles. See below and Chapter 9 for more information on pervious paving materials. Parking can also be located underground or beneath buildings, which can help reduce the site's overall impervious coverage. Finally, parking decks can reduce overall impervious coverage by concentrating the total required parking area into a smaller footprint.

## C. Pervious Paving Materials

Pervious paving materials can be used at many site locations to replace standard impervious pavement. These locations may include parking spaces, driveways, access roadways, and sidewalks. Pervious material can include pavers (interlocking concrete blocks or bricks), porous pavement (concrete or asphalt), gravel, and reinforced lawn. While brick pavers, concrete block pavers, and gravel are themselves impervious, their use can reduce impervious areas by providing gaps between individual pieces through which runoff can reach a pervious base course and/or subsoil. Turf blocks (open cells made of concrete, plastic, or composite materials that are filled with soil and planted with grass) may also be utilized to replace traditionally paved areas. Porous concrete and porous asphalt are generally considered fully pervious and may be viable options for areas that need to be fully paved. Municipal regulations must be reviewed to determine whether the use of pervious paving materials is permissible at a development site. It may also be appropriate to discuss the use of pervious paving materials with local officials and Soil Conservation Districts.

In selecting the type of pervious paving material to be used at a development site, consideration must be given to anticipated character and intensity of use of the material's surface. This will include the type, weight and size of vehicle, and the traffic rate and frequency. For example, due to their non-monolithic character, pavers, turf blocks, and gravel can achieve significant infiltration but may not be able to withstand regular traffic loads. As such, these materials may be more appropriate for overflow parking areas and emergency or maintenance access roads. Since its monolithic character is similar to standard impervious paving, porous pavement will have more general use, provided that adequate subsurface drainage is available. In all cases, consideration must be given to the effects of snow plowing and other maintenance activities. Additional information regarding pervious paving is available in Chapter 9.

## D. Unconnected Impervious Areas

Unconnected impervious areas are impervious surfaces that are not directly connected to a site's drainage system. Instead, runoff from an unconnected impervious area is allowed to sheet flow from the impervious area across a downstream pervious surface, where it has the opportunity to re-infiltrate into the soil, thereby reducing the total runoff volume. An unconnected impervious surface may be on-grade (e.g., a parking lot) or above-grade (e.g., a roof). While impervious area disconnection is most applicable to low density development where pervious open space is readily available to accept impervious area runoff, opportunities to utilize unconnected impervious area can usually be found even at highly impervious development sites.

In most circumstances, impervious areas can be considered unconnected under the following conditions:

1. All runoff from the unconnected impervious area must be sheet flow.
2. Upon entering the downstream pervious area, all runoff must remain as sheet flow.
3. Flow from the impervious surface must enter the downstream pervious area as sheet flow or, in the case of roofs, from downspouts equipped with splash pads, level spreaders, or dispersion trenches that reduce flow velocity and induce sheet flow in the downstream pervious area.
4. All discharges onto the downstream pervious surfaces must be stable and nonerosive.
5. The shape, slope, and vegetated cover in the downstream pervious area must be sufficient to maintain sheet flow throughout it length. Maximum slope of the downstream pervious area is 8 percent.
6. The maximum roof area that can be drained by a single downspout is 600 square feet.

Methods to compute the resultant runoff volumes and peak runoff rates from unconnected impervious areas are presented in Chapter 5 of this manual. This includes parameters and procedures for determining the effective size of the downstream pervious area that receives the runoff from an unconnected impervious area.

Curb requirements included in the RSIS and many municipal regulations are often cited as a limiting factor in the use of unconnected impervious areas. However, residential curb requirements in the current RSIS provide flexibility to limit curbing, and also allow the use of curb cuts to disconnect impervious areas. The RSIS states in Section 4.3 (d):

> *Curb requirements may be waived by the appropriate municipal approving agency, and shoulders and/or drainage swales used when it can be shown that: shoulders are required by CAFRA; soil and/or topography make the use of shoulders and/or drainage swales preferable; and/or the community desires to preserve its rural character by using shoulders and/or drainage swales instead of curbs.*

In addition, the top of the curbing may be set level with the impervious and downstream pervious surfaces to allow sheet flow from one to the other. Similar opportunities to use level curbs and/or curb cuts may also exist at nonresidential developments.

**It is important to note that, in designing and utilizing unconnected impervious areas, consideration must be given, on a case-by-case basis, to sensitive or limiting geographic conditions such as Karst topography and rough, irregular topography.**

## E. Vegetated Roofs

Vegetated roofs, also known as green roofs, are an innovative way to reduce impervious surfaces at development sites in New Jersey. They have been used successfully in several European countries, including Germany. A vegetated or green roof consists of a lightweight vegetated planting bed that is installed on a new or existing roof. This enables the roof to retain precipitation on and within the planting bed and on the surface of the vegetation. This stored water is later released through evapotranspiration, thereby reducing the volume of runoff from the roof. The exact amount of rainfall storage (and runoff reduction) will depend upon the depth and porosity of the planting bed and, to a lesser degree, the type and density of vegetation.

Vegetated roofs can be implemented using specialized commercial products. A common arrangement consists of an impervious synthetic underdrain system that allows drainage of water from the roof surface (known as a geomembrane) and a 1 to 6-inch thick layer of lightweight planting media. The type of vegetation to be used should be based on access and maintenance requirements and secondary uses of specific roof areas. Except for periodic fertilization and watering, a meadow-like planting of perennial plants can require minimal maintenance.

When designing new systems or converting existing roofs to green roofs, adequate capacity and easy access to gutters, underdrains, downspouts, and other components of the roof's drainage system must be provided. Clogging of underdrains must be prevented through a combination of sound design and regular inspection and maintenance. Overflows must also be provided to address drainage system malfunctions and rainfalls that exceed the system's design storm. Green roofs will be most effective during the spring and summer growing season, with somewhat reduced effectiveness during the late fall and winter months. Depending on the type of vegetation selected and the amount of rainfall, there may be a need for occasional watering and perhaps fertilization of the vegetative cover. Therefore, special provisions must be provided to readily enable such activities.

The structural integrity of the roof and the building must support any loading resulting from the vegetation, soil, and rainfall stored in the rooftop. In general, the slope (horizontal to vertical) of the roof can vary between 12:1 and 4:1. Steeper roofs will usually require erosion protection to hold the planting media in place at least until the plants become established. The roof slope must not exceed 1:1. Relatively flat roofs require an underdrain layer, while steeper roofs can drain by gravity.

## 4. Time of Concentration Modifications

Time of concentration (Tc) is technically defined as "the time for runoff to travel from the hydraulically most distant point of the watershed to a point of interest within the watershed."[1] Stated more simply, it represents the time needed to drain runoff from an area. Changes in peak flow result from changes in Tc from drainage areas, with longer times yielding smaller peak runoff rates and shorter times causing greater ones. Site factors that affect a drainage area's time of concentration include flow length, flow regime, surface roughness, channel shape, and slope.[2] Typically, land development modifies most if not all of these factors in ways that cause the time of concentration of a drainage area to be shorter (and, therefore the peak runoff rates to be greater) after development than prior to development.

However, during site design, it may be possible to avoid or minimize this decrease in time of concentration by controlling the various site factors that affect it. Considerations for three factors are presented below. In reviewing these considerations, it must be remembered that, although the time of concentration of a drainage area is computed for a specific flow path (as determined by the technical definition above), it is actually a representative time for an entire drainage area. As such, the modifications discussed below that pertain to sheet flow from a drainage area to a more defined conveyance system (such as a channel or storm sewer) must not only be applied along the specific Tc route, but throughout the entire area where the sheet flow is occurring.

For certain areas in New Jersey, such as those with Karst topography, the flat topography of the Pinelands and shore areas, and the rough terrain of the northwest, the development of a time of concentration may be difficult. In such cases, the designer should confer with the applicable review agencies in order to develop a representative Tc route and time.

### A. Surface Roughness Changes

Based upon hydraulic theory, surface roughness coefficients used in sheet flow computations are based on the land cover of a drainage area, with areas of dense vegetation having generally higher coefficients (and longer times of concentration) than smoother surfaces such as paved or grassed areas. This surface roughness can also vary with season and degree of maintenance, particularly for turf grass areas. Therefore, site designers should preserve existing native vegetation or use native plants to restore disturbed areas (as discussed above in *1. Vegetation and Landscaping*) in order to increase surface roughness and time of concentration, and consequently reduce the peak flows from a drainage area.

### B. Slope Reduction

As noted above, ground slope is another important factor in determining a drainage area's time of concentration and peak discharge. Reducing slopes in graded areas can help minimize Tc reductions and peak flow increases. In addition, terraces and reduced slope channels can be constructed on a sloping area to provide additional travel time. Terraces can also be used to redirect runoff to flow along rather than across the slope, decreasing the slope and increasing the flow length and, subsequently, the time of concentration. Care should also be taken to ensure that the grading of vegetated areas is sufficient to allow for positive drainage as required by local or state regulations, particularly adjacent to buildings and other structures.

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[1] USDA Soil Conservation Service Technical Release 55, June 1986, Urban Hydrology for Small Watersheds.

[2] Ibid.

### C. Vegetated Conveyance

The use of vegetated conveyance measures such as channels and swales can increase the surface roughness along the Tc flow path and increase the overall Tc. Grade stabilization structures can also be added to further decrease the flow velocity. In addition, vegetated channels can provide opportunities for runoff treatment, runoff infiltration, and groundwater discharge. Such measures can replace conventional storm sewer systems in small drainage areas. Site specific conditions such as slope, soil type, drainage area, and site constraints must be considered in the design of a vegetated channel or swale. Additional requirements are presented in the Standards for Soil Erosion and Sediment Control in New Jersey. The local Soil Conservation District will review the project to ensure stability.

In designing vegetated conveyance measures, care should be taken to protect transitions to and from culverts from erosion caused by flow acceleration and turbulence. In addition, vegetated channels and swales should be constructed only in areas with sufficient sunlight to adequately maintain vegetation. The channels must also be able to drain and dry out between storm events. As an alternative to grasses, the channel could be planted with ground covers that tolerate frequent short-duration flooding. The vegetation must be tolerant of the hydrologic regime associated with the channel.

In the design of any site features to control or modify time of concentration, it should be noted that the effectiveness of the design may vary with runoff rate and, therefore, storm frequency. As a result, modifications to such factors as slope or surface roughness may have a significant effect on the time of concentration for a one-year storm event, but little or no effect on a larger 10 or 100-year event. Therefore, it may be necessary (and even prudent) to vary Tc with storm frequency, utilizing the longer one for the frequent events associated with stormwater quality and the shorter (and more conservative) one for the more extreme erosion and flood control storms. Care should also be taken when analyzing a time of concentration to ensure that the watershed it represents is relatively homogenous. Otherwise, the drainage area may need to be divided into subareas with a separate Tc computed for each.

## Structural Stormwater Management Measures

In addition to the nonstructural LID-BMPs presented in the previous section, structural stormwater management measures can also be used to implement low impact development. Known as structural LID-BMPs, these structural measures are identified as low impact BMPs by storing, infiltrating, and/or treating runoff close to its source. Unlike typical structural BMPs that are centrally located along a site's drainage system, structural LID-BMPs are normally dispersed throughout a development site and, like the nonstructural LID measures discussed above, provide ways to more closely mimic the site's predeveloped hydrology than standard structural BMPs.

As structural facilities, however, the configuration, operation, and maintenance of structural LID-BMPs are similar to standard structural BMPs, although their location closer to the runoff source typically allows them to be smaller in size. An example of this relationship is the use of bioretention basins as structural LID-BMPs in a residential subdivision. Also known as raingardens, they are typically located on each lot in the subdivision and, as such, each receives considerably less runoff than would a single, centralized bioretention basin. Nevertheless, similar to the centralized bioretention basin, each basin would be designed and constructed in accordance with the technical standards presented in Chapter 9. Designers should take care to ensure that sufficient setbacks are provided to protect adjacent structures from impacts due to the anticipated functioning of LID-BMPs.

The integration of bioretention basins and other structural BMPs throughout a development site can be viewed as applying low impact development techniques. Many standard BMPs can be done at an LID scale. Drywells, infiltration systems, bioretention basins, and both surface and subsurface detention basins can all be downsized to address stormwater runoff close to its source, as opposed to a centralized location at the end of a stormwater collection and drainage system. Detailed design, construction, and maintenance information on various structural BMPs is presented in Chapter 9.

## Preventative Source Controls

The most effective way to address water quality concerns is by preventing pollutants from being part of stormwater runoff. Pollution prevention techniques should be incorporated into site designs, especially at commercial and light industrial sites, to minimize the potential impact those activities may have on stormwater runoff quality. Preventative source controls, while more limited, can also be applied in residential development, particularly in preventing floatables (trash and debris) from entering storm sewer drainage systems.

Preventative source controls can prevent the accumulation of trash and debris in drainage systems by providing trash receptacles at appropriate locations throughout the site. The benefits are realized only if regular trash collection is provided; this should be included as part of the site maintenance plan. The installation of litter fences, especially at commercial properties, to prevent the blowing of litter off the site is another measure that addresses the accumulation of trash and debris. At industrial/commercial sites, maintenance plans should include regular sweeping or manual collection of litter. In residential developments, the inclusion of "pet waste stations" in the site design of dense housing developments such as apartment, townhouse and condominium communities prevents pollutants from entering the stormwater system. Pet waste stations should include bags for picking up pet waste and containers for pet waste disposal. Providing these stations will increase the likelihood that pet waste is properly disposed and prevent it from being washed into streams as part of stormwater runoff.

Site design features can also prevent the discharge of trash and debris into receiving streams. Storm drain inlets, trash racks, or structural BMPs are types of features that prevent the discharge of trash and debris. The New Jersey Pollutant Discharge Elimination System stormwater general permits issued under the Municipal Stormwater Regulation Program provide information on storm drain inlets that are designed specifically to prevent the discharge of large trash and debris from drainage systems by reducing the size of each individual clear space in both the grate and curb opening. Where allowed and consistent with the design standard, alternative devices may be substituted for these storm drain inlets.

Some site design features help to prevent or contain spills and other harmful accumulations of pollutants at industrial or commercial developments. These include roofs, overhangs, knee walls, berms, secondary containment, stormwater diversion devices, oil/grit separators and other manufactured treatment devices, and indoor storage. Specifically, berms and secondary containment can contain spills of fuels or other chemicals, and roofs and walls can prevent or minimize exposure of stormwater to activities and materials such as fueling and maintenance, trash, waste motor oil, storage or handling of landscape and garden chemicals (including fertilizers and pesticides) at retail stores, and storage or handling of raw materials, intermediate products, final products, and by-products at warehouses or manufacturing plants. Stormwater diversion devices, such as curbing and berms, can divert stormwater away from areas where it may come into contact with materials or activities that could affect stormwater quality. Oil/grit separators and other manufactured treatment devices may contain certain spills and treat stormwater that has come into contact with spills or residual material from spills. Also, the inclusion in the site design of adequate indoor storage of raw materials, intermediate products, final products, and by-products at commercial and industrial sites is the best method for preventing potential stormwater quality issues.

## Stormwater as a Resource

Stormwater runoff from precipitation is often viewed as a nuisance. However, an increase in stormwater runoff is an indicator of reduced infiltration and recharge to groundwater. As such, this negative view of stormwater runoff must be corrected to more accurately consider stormwater as a resource vital to achieving more sustainable development.

For example, stormwater runoff from roofs can be captured for future re-use using a variety of collection and storage devices. These systems can be installed above or below ground. Above ground systems could be simple rain barrels that overflow onto a splash pad. Underground systems may be concrete structures requiring a pump to empty them or, if the topography allows it, they may drain by gravity. The size of this BMP depends on the contributing roof area. In commercial or high-density residential applications, roof water cisterns can be incorporated into landscaping features such as water fountains and ponds. Where space permits, underground cisterns can discharge to an infiltration trench.

It is important to note that all collection and storage devices must be emptied between storm events in order to be considered effective in reducing site runoff volumes. In addition, the total system storage volume must be evaluated to determine its effectiveness as a runoff volume control measure. Nevertheless, re-use of the collected stormwater in place of potable water from an onsite well or public water supply will help minimize the site's over environmental impacts, reduce site operating costs, and help achieve a more sustainable environment.

## Additional Considerations

As described above, low impact development typically relies on an array of nonstructural and relatively small structural BMPs distributed throughout a land development site to manage stormwater runoff quantity and quality. This distributed approach to stormwater management contrasts with the more traditional use of centralized stormwater facilities in New Jersey. However, as discussed briefly at the beginning of this chapter, this distributed approach means that the responsibility for successful operation and maintenance of the various LID-BMPs will not be centrally located at a municipality or other government entity. Instead, such responsibility will be distributed over a variety of property owners with varying interests, knowledge, abilities, and resources. As such, it is vital to have public understanding of and support for the various LID-BMPs that a municipality authorizes for use in its stormwater management program and land development regulations. Such understanding and support must include both an appreciation for the necessary role that the LID-BMPs play in meeting a development site's stormwater obligations and a strong, enforceable commitment to preserve and maintain them.

This is particularly true for nonstructural LID-BMPs, which may rely on such techniques as preserving existing or planting new vegetation, minimizing building footprints, and limiting lot impervious cover and/or disturbance limits to effectively manage stormwater runoff and prevent downstream environmental and property damage. The Stormwater Rule at Section 5.3(c) requires the deed restriction of LID-BMPs since such practices may not be readily recognized by property owners as stormwater management measures or facilities, and they may be more prone to neglect, abandonment, or removal than centralized structural BMPs unless the property owners fully recognize, understand, and support their use.

Similar problems may also arise with structural LID-BMPs which, due to their smaller size and their location on individual lots much closer to homes than larger, centralized facilities, may be overlooked as vital stormwater management measures and similarly neglected or abandoned. In the worst case, a resident or property owner may remove a vital structural LID-BMP located on their property. Such action may occur due to an alternative need for the land (e.g., house addition, driveway expansion, storage shed), adverse aesthetic impacts, or excessive maintenance demands. Regardless of the reasons, a municipality may find it extremely difficult to have the eliminated LID-BMP either restored or replaced by a centralized facility.

Therefore, it is vital that each municipality critically evaluate the range of available nonstructural and structural LID-BMPs presented in this manual and elsewhere and authorize the use of only those that they can rely on to be properly operated, maintained, and preserved by their residents, property owners, and municipal employees. Failure to achieve such acceptance, operation, and maintenance can lead to flooding, erosion, and runoff pollution; damage to downstream waterways and property; and threats to public safety.

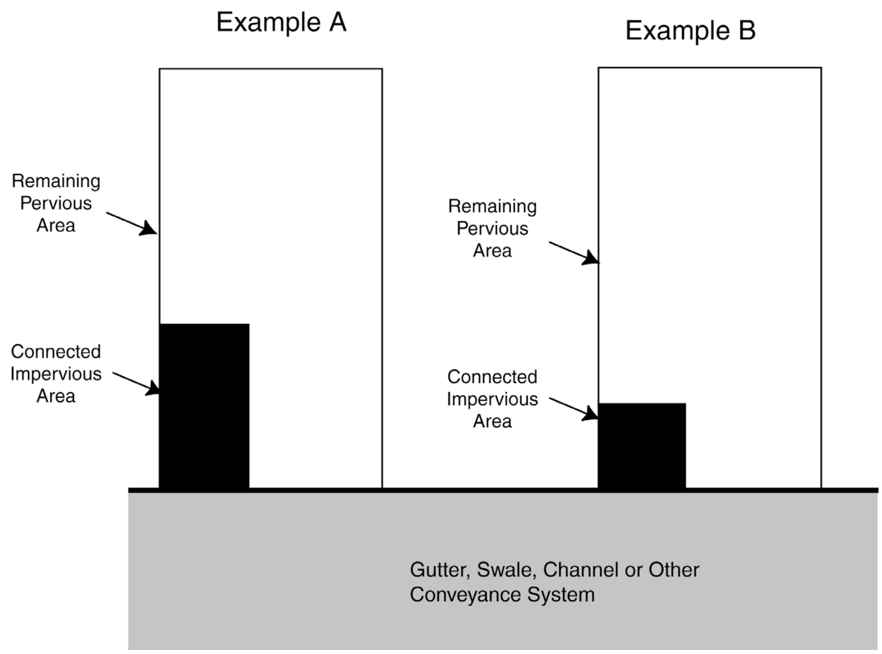
To assist in this evaluation, physical details and operation and maintenance requirements for a range of structural BMPs are presented in Chapter 9.

When evaluating LID-BMPs for authorization and incorporation into their land development ordinances and standards (as required by the NJDEP Stormwater Management Rules), a municipality should consider the following:

1. Permitting the use of certain LID-BMPs to manage the runoff from small, frequent storm events (such as those required by the NJDEP Stormwater Management Rules for groundwater recharge and stormwater quality), but prohibiting their consideration when addressing erosion and flood control requirements that typically involve larger, less frequent but more hazardous events. For example, a municipality may allow a site designer to use rain barrels and/or small, on-lot infiltration basins (also known as raingardens) to meet groundwater recharge and stormwater quality requirements, but may also require that such measures be ignored when meeting erosion and flood control standards.
2. Requiring deed restrictions or adopting ordinances that prohibit the alteration or elimination of on-lot LID-BMPs approved for use at a land development and officially identified as such. Such restrictions and ordinances should clearly define the right of the municipality to restore such LID-BMPs and the means by which it will be accomplished and financed.
3. Requiring deed restrictions or adopting ordinances that require land owners to properly maintain structural LID-BMPs located on their properties.
4. Requiring signage of LID-BMPs to indicate their function and use.
5. Preparing leaflets, brochures, and/or manuals for property owners on the function and importance of LID-BMPs and their maintenance and preservation. Similar efforts targeting such activities as proper septic system operation, recycling, lawn fertilization, and pet waste disposal have proven successful in many municipalities. Soil test kits and information regarding lawn fertilization are available for homeowners from the Rutgers Cooperative Extension.

# Low Impact Development Example Calculations

**Figure 2-1: Schematic of Lot with Connected Impervious Areas**




## Reduction of Runoff Volumes Due to Reduced Impervious Surfaces

Note: The computations were done by evaluating the runoff from the pervious and the impervious areas separately, and summing the volumes.

### Example A

Given: A 32670 sf lot with 27470 sf lawn, HSG "B", CN = 61, 5200 sf impervious surface, CN = 98.
No impervious cover is disconnected
$P_2$ = 3.3 inches, $P_{10}$ = 5.2 inches, and $P_{100}$ = 7.5 inches

From the NRCS Runoff Equation, the following runoff volumes are generated:

2-year = 2444 cf
10-year = 5567 cf
100-year = 10175 cf

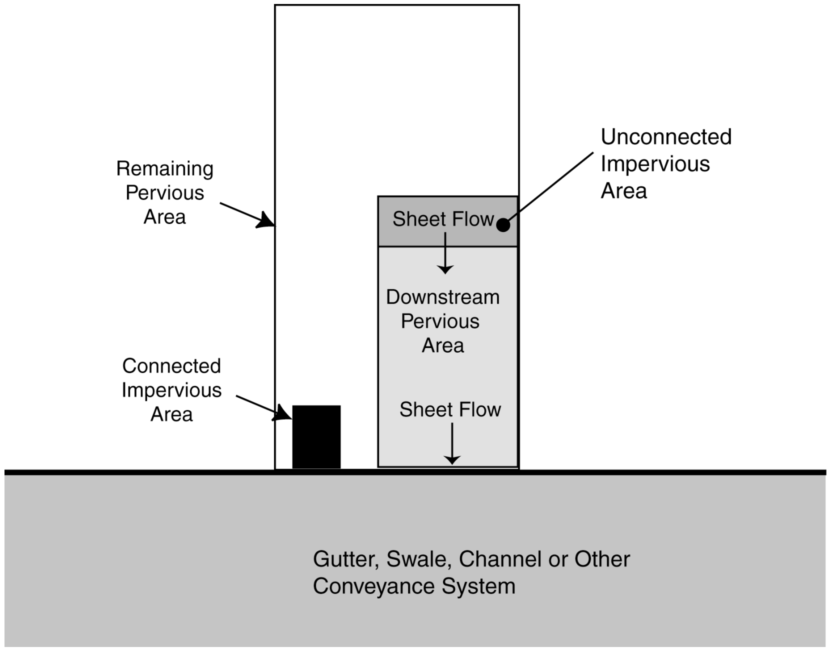
### Example B

Given: A 32670 sf lot with 29870 sf lawn, HSG "B", CN = 61, 2800 sf impervious surface, CN = 98.
No impervious cover is disconnected
$P_2$ = 3.3 inches, $P_{10}$ = 5.2 inches, and $P_{100}$ = 7.5 inches

From the NRCS Runoff Equation, the following runoff volumes are generated:

2-year = 1927 cf
10-year = 4872 cf
100-year = 9336 cf

**Figure 2-2: Schematic of Lot with Connected and Unconnected Impervious Areas**




## Changes in Runoff Volumes Due to Disconnection of Impervious Surfaces

### Example C

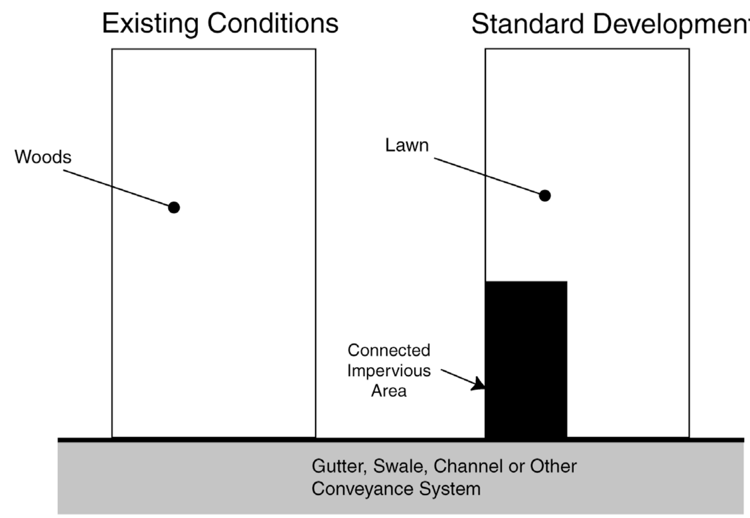
Given: A 32670 sf lot with 29870 sf lawn, HSG "B", CN = 61, 2800 sf impervious surface of total impervious area, CN = 98.
2000 sf of impervious area discharges to 8900 sf of lawn, and 800 sf impervious area is directly connected
$P_2$ = 3.3 inches, $P_{10}$ = 5.2 inches, and $P_{100}$ = 7.5 inches

**NRCS Method:
2-year = 1625 cf
10-year = 4515 cf
100-year = 8947 cf

Two-Step Method (discussed in Chapter 5):
2-year = 1650 cf
10-year = 4580 cf
100-year = 9055 cf

**Note: The computations were done by evaluating the runoff from the pervious, impervious, and unconnected impervious areas separately, and summing the volumes. The equation for Figure 2-4, shown in Appendix F of the USDA Urban Hydrology for Small Watersheds, was used for the volume of unconnected impervious areas.

**Figure 2-3: Schematic of Existing Lot and Standard Development Lot**




## Comparison of Changes in Runoff Due to Low Impact Development Techniques

### Predeveloped Condition

0.75 acre lot
20,650 sf woods, HSG "B"
12,020 sf woods, HSG "C"
$P_2$ = 3.3 inches, $P_{10}$ = 5.2 inches, and $P_{100}$ = 7.5 inch

Tc = 0.52 hours
125 lf sheet flow, 1.3% slope, n = 0.40
135 lf shallow concentrated flow, 1.4% slope, unpaved

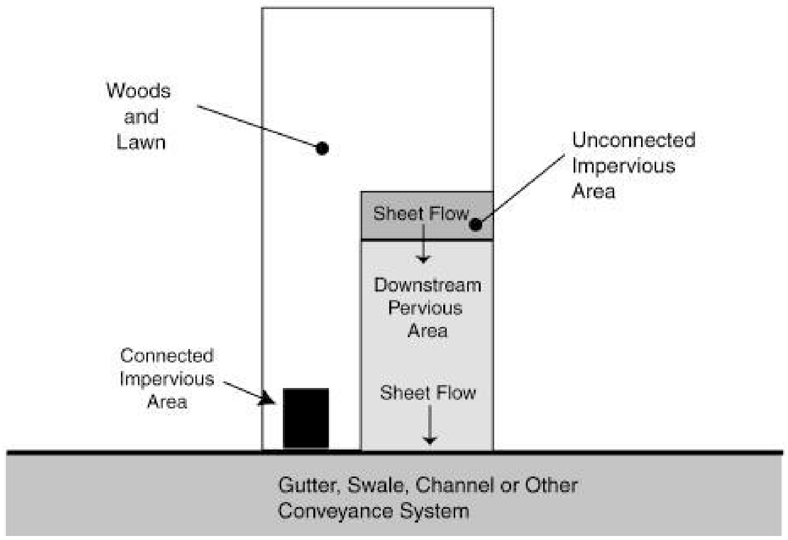
### Postdeveloped Condition (Standard Development Lot)

0.75 acre lot
5200 sf of total impervious area, directly connected, Tc = 0.1 hours
$P_2$ = 3.3 inches, $P_{10}$ = 5.2 inches, and $P_{100}$ = 7.5 inch

Vegetated Area, Tc = 0.32 hours
125 lf sheet flow, 1.6% slope, n = 0.24
135 lf shallow conc flow, 1.4% slope, unpaved

| Area (sf) | Land Use | HSG |
|---|---|---|
| 17214 | Lawn (good condition) | B |
| 10256 | Lawn (good condition) | C |
| 3436 | Impervious (directly connected) | B |
| 1764 | Impervious (directly connected) | C |

## Figure 2-4: Schematic of Lot With LID Techniques




## Postdeveloped Condition (With LID Techniques)

0.75 acre lot, 2800 sf of total impervious area

800 sf of impervious area, directly connected, Tc = 0.1 hours

2000 sf of impervious area, unconnected, discharging to 8906 sf of lawn

$P_2$ = 3.3 inches, $P_{10}$ = 5.2 inches, and $P_{100}$ = 7.5 inch

Nonstructural stormwater management strategies used: minimized land disturbance; minimized compaction; maximized the protection of vegetation; minimized the decrease in post-development time of concentration through retaining existing wooded area; and minimized and disconnected impervious cover.

Vegetated Area, Tc = 0.52 hours

125 lf sheet flow, 1.3% slope, n = 0.40

135 lf shallow conc flow, 2.1% slope, unpaved

| Area (sf) | Land Use | HSG |
|---|---|---|
| 17524 | Woods (good condition) | B |
| 1564 | Lawn (good condition) | B |
| 1876 | Lawn (good condition) | C |

Unconnected Impervious Area, Tc = 0.23 hours

100 lf sheet flow, 2.1% slope, n = 0.24

Note: The time of concentration was developed from the receiving pervious area alone.

| Distribution of Pervious Areas Receiving Unconnected Impervious Area Runoff | | |
|---|---|---|
| **Area (sf)** | **Land Use** | **HSG** |
| 1562 | Lawn (good condition) | B |
| 7344 | Lawn (good condition) | C |

## Peak Flow Rates and Volumes

| | Existing Conditions | Proposed Conditions (Standard Development) | Proposed Conditions (Nonstructural Stormwater Management Strategies) | |
|---|---|---|---|---|
| | | | Two-Step Method | NRCS Method |
| 2-year | 0.15 cfs<br>0.030 ac-ft | 0.48 cfs<br>0.067 ac-ft | 0.29 cfs<br>0.043 ac-ft | 0.27 cfs<br>0.041 ac-ft |
| 10-year | 0.62 cfs<br>0.093 ac-ft | 1.18 cfs<br>0.150 ac-ft | .81 cfs<br>0.116 ac-ft | .78 cfs<br>0.109 ac-ft |
| 100-year | 1.35 cfs<br>0.192 ac-ft | 2.19 cfs<br>0.261 ac-ft | 1.61 cfs<br>0.214 ac-ft | 1.58 cfs<br>0.211 ac-ft |

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