Retrofit Types

There are many types of stormwater retrofits that can be used to disconnect and reduce DCIA and provide other benefits as described earlier in this chapter. The major types of retrofits addressed in this Manual are described below.

Impervious Area Conversion

Impervious area conversion involves removing and replacing existing excess impervious surfaces (pavement, buildings, etc.) with pervious vegetated surfaces (lawn, meadow, woods) and restoring the pre-development infiltration rate and storage capacity (i.e., porosity) of the underlying soils. Conversion of the impervious surface to a vegetated pervious surface results in a reduction in runoff volume and pollutant loads and an increase in infiltration and groundwater recharge.

Opportunities to convert impervious surfaces to pervious surfaces are common on older, developed sites where historical development patterns and zoning or subdivision regulations dictated excessive amounts of impervious coverage associated with parking lots, roads, and buildings. These developments also typically pre-date regulatory requirements for stormwater quality controls, so much of the impervious area on these sites is often directly connected to the drainage system or surface waters (i.e., DCIA).

Common examples of impervious area conversion retrofits include:

- Eliminating unused or underutilized parking spaces in parking lots and replacing them with vegetation or for impervious area disconnection strategies (see discussion below).
- Reducing paved shoulder widths.
- Reducing lane widths (e.g., road diet with pavement removal).
- Replacing pavement in parking lot islands and medians with vegetation.
- Replacing the center portion of paved cul-de-sac bulbs with vegetation or structural stormwater BMPs (see discussion below).

Such conversions should not preclude roadway and parking lot design and safety standards.

The subgrade below pavement is often highly compacted, with low infiltration and water storage capacity, and lacking organic material in the soil structure to support vegetative growth. An important aspect of converting impervious surfaces to pervious vegetated surfaces is to ensure that the converted area has similar hydrologic functions and characteristics as a natural, undeveloped area in terms of runoff and infiltration. This typically requires modification of the soils beneath the previously paved surface to restore the pre-development infiltration rate and porosity (similar to that of the native underlying soils) and improve the soil quality to support vegetation. The subgrade should be treated by scarification, ripping (tilling), or use of a shatter-type soil aerator to a depth of 9 to 12 inches or more depending on site and soil conditions. A soil test by the University of Connecticut Soil Testing Laboratory, another university soil testing laboratory, or a commercial soil testing laboratory is recommended to determine the suitability of soils for plant growth and to classify the permeability (in terms of Hydrologic Soil Group) of the restored pervious area. Amendment with 2 to 4 inches of topsoil or organic material may be required to improve plant establishment or restore soil permeability.

Chapter 5 - Low Impact Development Site Planning and Design Strategies provides design criteria for impervious area conversion in the context of redevelopment projects. The design guidance in Chapter 5 is also applicable to stormwater retrofits.

Impervious Area (Simple) Disconnection

Impervious area disconnection, also called “simple disconnection,” involves re-directing stormwater runoff from impervious surfaces as sheet flow onto adjacent vegetated pervious surfaces where it has the opportunity for treatment and infiltration, as described further in Chapter 5 - Low Impact Development Site Planning and Design Strategies. For new development and redevelopment, impervious area disconnection is an important Low Impact Development (LID) site planning and design strategy. Impervious area disconnection is also a simple, low-cost stormwater retrofit technique by utilizing the existing vegetated areas (i.e., lawn, meadow, or woods) that are typically adjacent to impervious areas, such as roads, parking lots, and buildings, for stormwater management.

Common applications of impervious area disconnection retrofits include:

- Installing inlet curb cut openings to allow runoff from a roadway to sheet flow to an adjacent vegetated median.
- Installing inlet curb cut openings in a parking lot to allow runoff to bypass existing catch basins and sheet flow to vegetated areas around the perimeter of the lot. The existing catch basins in the parking lot can function as overflow structures to convey runoff in excess of the water quality storm.
- Grading an uncurbed parking lot towards a vegetated island.
- Disconnecting building roof downspouts from the drainage system to adjacent pervious areas.

The feasibility and success of impervious area disconnection depends on several factors including the ability to re-direct runoff from the impervious area to the pervious area (often requiring grading or a curb-cut), as well as the ability of the pervious area to disperse (via a level spreader) and infiltrate runoff for storm events up to the water quality design storm. Key characteristics of the receiving pervious area include:

- Ground slope.
- Soil infiltration capacity and depth to groundwater.
- Size of the pervious area relative to the size of the contributing impervious area.
- Density of vegetation.
- Use of devices such as level spreaders to disperse the discharge and provide sheet flow, as needed, to disperse the flow and avoid flow concentration and short circuiting through the pervious area.

Sites with flatter slopes, pervious soils, and a dense stand of vegetation are better suited for maintaining dispersed flow. Flows for larger storm events should bypass or exit the pervious area in a controlled manner.

Chapter 5 - Low Impact Development Site Planning and Design Strategies provides design criteria for impervious area disconnection focused on new development and redevelopment projects. The design guidance in Chapter 5 is also applicable to stormwater retrofits.

Modifying Existing Structural Stormwater BMPs

Existing stormwater BMPs and related stormwater infrastructure originally designed for conveyance and stormwater quantity control can be modified to improve pollutant and runoff reduction performance. Depending on site conditions, such enhancement may be more cost-effective than constructing new structural stormwater BMPs. These types of retrofits can include modification of existing BMPs and stormwater infrastructure that was not designed with stormwater quality in mind, as well as rehabilitation of existing functional stormwater BMPs to improve their performance.

Key considerations for identifying and evaluating the feasibility of these types of retrofits include:

- Will the retrofit meet the project objectives and qualify for retention and/or treatment credits by meeting the design requirements in this Manual?
- Is the retrofit feasible based on existing site conditions?
- Is the retrofit cost-effective when compared to other retrofit alternatives?

An evaluation of existing site conditions and the existing stormwater infrastructure is required to determine the need for modifications to the conveyance system, if the retrofitted system should be designed in an on-line or off-line configuration, and how these decisions may impact project feasibility and cost.

Common opportunities for modifying existing stormwater BMPs and related stormwater infrastructure for enhanced pollutant and runoff reduction performance include:

Detention Basin Retrofits

Traditional dry detention basins are effective for stormwater quantity control but provide very limited pollutant removal. Dry detention basins, which were commonly used as the sole stormwater management practice for many older developments, can be modified to function as dry extended detention basins, infiltration basins, stormwater ponds, or stormwater wetlands for more effective retention of stormwater and enhanced pollutant removal. This is one of the most common and easily implemented retrofits since it typically requires little or no additional land area, requires minimal or no earthwork, utilizes an existing facility for which there is already some resident acceptance of stormwater management, and involves minimal impacts to environmental resources.

Detention basin retrofits should result in improved pollutant and/or runoff volume reduction performance, without a significant reduction in stormwater quantity control performance. Some detention basin upgrades may result in a partial loss of flood storage and peak discharge control. Detention basin retrofits that result in reduced basin storage volume (e.g., conversion to stormwater wetlands or stormwater ponds) should include a hydrologic and hydraulic analysis of the existing system and proposed changes to ensure that the modified basin will continue to provide adequate stormwater quantity control and will not cause flooding or other undesirable conditions for adjacent infrastructure or site uses. The basin's total storage volume may need to be increased to offset loss of storage volume. If the existing basin is constructed with an earthen berm, the stability of the embankment should be also evaluated relative to the proposed modifications.

Conversion to Infiltration Basin. Detention basins that remain dry between storm events, are in well-drained soils, and have three feet or more of vertical separation between the bottom of the basin and the seasonal high groundwater table are good candidates for conversion to infiltration basins. The major benefit of this type of retrofit is retention of stormwater and the associated reduction in runoff volume and pollutant loads. Common modifications to convert detention basins to infiltration basins include:

- Conduct test pits or soil borings to confirm soil characteristics, depth to the seasonal high groundwater table, and depth to bedrock or other confining layer, and perform field infiltration testing consistent with the guidance in Chapter 10 - General Design Guidance for Stormwater Infiltration Systems.

- Till or scarify the bottom of the existing basin to restore soil infiltration capacity or excavate and replace the existing soil with a more uniform, permeable soil or engineered soil media.

- Modify the existing outlet structure by plugging or capping the low-level orifice and creating a new raised orifice to retain and infiltrate the Required Retention Volume, while maintaining a high-level overflow or orifice for stormwater quantity control and to convey flows for larger storms.

- Incorporate pretreatment (e.g., sediment forebays) at basin inlets.

- Revegetate the bottom of the basin to stabilize the basin surface and to establish a healthy vegetative root system, which helps maintain soil infiltration capacity.

Refer to the Infiltration Basin section in Chapter 13 and Chapter 10 - General Design Guidance for Stormwater Infiltration Systems for additional design guidance.

Conversion to Stormwater Pond or Stormwater Wetland. Detention basins that tend to remain wet between storm events, are in poorly drained soils, or have minimal vertical separation between the bottom of the basin and the seasonal high groundwater table are ideal for conversion to wet stormwater ponds or stormwater wetlands. This type of retrofit can significantly improve the pollutant removal performance of the basin by introducing additional pollutant removal mechanisms associated with a permanent pool of water and wetland vegetation. Common modifications to convert detention basins to wet stormwater ponds or stormwater wetlands include:

- Conduct test pits or soil borings to confirm soil characteristics, depth to the seasonal high groundwater table, and depth to bedrock or other confining layer consistent with the soil evaluation guidance in Chapter 10 - General Design Guidance for Stormwater Infiltration Systems.

- Modify the existing outlet structure by plugging or capping the low-level orifice and creating a new raised orifice to maintain a permanent pool of water and support wetland vegetation, while maintaining a high-level overflow or orifice for stormwater quantity control and to convey flows for larger storms.

- Excavate the basin bottom to intercept the groundwater table and create more permanent pool storage.

- Add gravel and underdrain piping if converting the basin to a subsurface gravel wetland.

- Increase the flow path from inflow to outflow and eliminate short-circuiting by using baffles, earthen berms, or micro-pond topography to increase residence time of water in the pond and improve settling of solids.
- Replace paved low-flow channels with meandering vegetated swales.
- Provide a high flow bypass to avoid resuspension of captured sediment/pollutants during high flows.
- Incorporate stilling basins at inlets and outlets and pretreatment (e.g., sediment forebays) at basin inlets.
    - Regrade the basin bottom to create a wetland area near the basin outlet or revegetate parts of the basin bottom with wetland vegetation to enhance pollutant removal, reduce mowing, and improve aesthetics.
    - Create a wetland shelf along the perimeter of a wet basin to improve shoreline stabilization, enhance pollutant filtering, and enhance aesthetic and habitat functions.
    - Create a low maintenance "no-mow" wildflower ecosystem in the drier portions of the basin.

Refer to the Stormwater Pond BMPs and Stormwater Wetland BMPs sections in Chapter 7 for additional design guidance.

Drainage Channel Retrofits

Conventional grass swales and ditches that were constructed primarily as surface stormwater drainage channels provide little if any pollutant removal and limited or no infiltration and volume reduction. Drainage channels are common along some roads and highways or as perimeter features around parking lots. Drainage channels can be modified to reduce flow velocities; create opportunities for ponding, infiltration, and establishment of wetland vegetation; and enhance pollutant removal.

Grass swales and ditches can be converted to wet or dry water quality swales, or linear bioretention systems (i.e., bioswales). Similar to detention basins, the most appropriate retrofit approach depends largely on the soil and groundwater conditions at the site. Drainage channels located in well-drained soils with adequate vertical separation to the seasonal high groundwater table are ideal for conversion to dry water quality swales or linear bioretention, while drainage channels in poorly drained soils and shallow groundwater are better suited for conversion to wet water quality swales.

Conversion to Dry Water Quality Swale or Linear Bioretention. This type of retrofit can significantly improve the retention, infiltration, and volume reduction benefits of drainage channels. If the soils are not conducive to infiltration, the drainage channel can be converted to a lined bioretention system with an underdrain to improve the treatment effectiveness of the channel. Common modifications to convert conventional grass swales and ditches to dry water quality swales or linear bioretention systems include:

- Conduct test pits or soil borings to confirm soil characteristics, depth to the seasonal high groundwater table, and depth to bedrock or other confining layer, and perform field infiltration testing consistent with the guidance in Chapter 10 - General Design Guidance for Stormwater Infiltration Systems.
- Conduct minor grading and/or reshaping of the channel cross section.
- Excavate and replace the existing soil with engineered bioretention soil media.
- Incorporate pretreatment (e.g., sediment forebays) at inlets to the channel.
- Add check dams.
- Add underdrain if necessary.
- Establish a dense vegetative cover or adequately stabilized landscaped surface throughout the channel to promote pollutant removal and infiltration.

Refer to the Dry Water Quality Swale and Bioretention sections in Chapter 13 for additional design guidance.

Conversion to Wet Water Quality Swale. This type of retrofit can significantly improve the pollutant removal performance of the drainage channel by introducing additional pollutant removal mechanisms associated with a permanent pool of water and wetland vegetation. Common modifications to convert conventional grass swales and ditches to wet water quality swales include:

- Conduct test pits or soil borings to confirm soil characteristics, depth to the seasonal high groundwater table, and depth to bedrock or other confining layer consistent with the soil evaluation guidance in Chapter 10 - General Design Guidance for Stormwater Infiltration Systems.
- Conduct minor grading and/or reshaping of the channel cross section.
- Modify or install an outlet structure to maintain a permanent pool of water and support wetland vegetation or excavate the channel bottom to intercept the groundwater table.
- Incorporate a high-level overflow or orifice in the outlet structure for stormwater quantity control and to convey flows for larger storms.
- Incorporate pretreatment (e.g., sediment forebays) at inlets to the channel.
- Add check dams.

- Plant with emergent wetland plants.

Refer to the Wet Water Quality Swale section in Chapter 13 for additional design guidance.

Note that these drainage channel retrofits are only applicable to man-made stormwater conveyances and should not be implemented within natural stream channels or regulated wetlands or watercourses.

Bioretention System Retrofits

Many existing bioretention systems constructed in the past 20 years were based on older, outdated designs. While these systems may still function adequately, their treatment and infiltration/retention performance may be improved by incorporating relatively simple modifications that reflect current state-of-the-practice for bioretention system design. These design modifications are part of the standard design guidance for new bioretention systems as presented in the Bioretention section of Chapter 13.

Internal Water Storage. For systems with an underdrain, modify the underdrain outlet structure to incorporate an upturned outlet (using an elbow or capped “T” pipe) to create a thicker saturated zone (also called an Internal Water Storage zone or Internal Storage Reservoir) that extends into the bottom of the bioretention soil media. This type of underdrain configuration increases infiltration and evapotranspiration and enhances removal of nitrogen through the creation of an anaerobic or anoxic Internal Water Storage zone. The combined volume reduction and nitrogen treatment benefits of this modification can result in significant nitrogen load reductions. The upturned pipe should be located inside the outlet structure, if possible, to facilitate maintenance access.

Filter Media Amendments. Many of the earlier bioretention system designs incorporated compost as the organic component of the bioretention soil mix. Compost-based bioretention soil mixes have been shown to export nutrients and are therefore no longer recommended. The soil media in aging bioretention systems that receive heavy pollutant loads may be beyond its useful life in terms of pollutant removal. In these instances, bioretention systems can be modified by amending the bioretention soil to enhance pollutant removal, particularly phosphorus removal, and extend the life of the bioretention soil media. Organic matter (sphagnum peat moss or wood derivatives such as shredded wood, wood chips, ground bark, or wood waste) can be mixed into the existing bioretention soil layer. Other soil amendments such as zerovalent iron and/or drinking water treatment residuals (alum) may be used to further enhance phosphorus sorption. This is an emerging area of research and practice that includes fungal mycelium, biochar, and other innovative filter media amendments.

Forebays. Sediment forebays and similar pretreatment measures not only facilitate bioretention maintenance but have also been shown to be effective for removal of phosphorus, nitrogen, and metals in addition to sediment.[68] The addition of a forebay can therefore enhance pollutant removal and extend the life of the bioretention soil media.

New Structural Stormwater BMPs

New structural stormwater BMPs can be strategically located to manage stormwater runoff from directly connected impervious areas on existing developed sites. Such areas are considered disconnected when stormwater runoff is retained on-site using Infiltration BMPs or Stormwater Reuse BMPs that are selected, sized, and designed following the guidance contained in other sections of this Manual. However, it is important to note that not all structural BMPs will disconnect DCIA, treatment alone does not treatment alone does not retain the WQV and strategic planning is necessary to do so.

Stormwater retrofits involving installation of new structural stormwater BMPs generally fall into three major categories depending on where the BMPs are applied:

Close to the Source. This is the most common type of stormwater retrofit, which involves installation of small-scale structural stormwater BMPs close to the source of runoff generation and prior to runoff entering the storm drainage system. Because they are located close to the source, these retrofits provide greater flexibility for siting, manage smaller runoff volumes, and are more cost-effective than drainage system or outfall retrofits. Numerous examples exist of these types of retrofits. Common examples include off-line infiltration systems located within parking lot or roadway medians, and rain barrels or cisterns used for collection and reuse of rooftop runoff.

Within the Drainage System. Existing drainage systems can be modified to improve pollutant removal and provide retention/infiltration. The pollutant removal benefits provided by these types of retrofits are typically limited to removal of coarse solids and floatables. They also commonly involve new subsurface structures and modification of the storm drainage system, which can be less cost-effective than other types of retrofits. In some cases, conventional drainage systems can be retrofitted with infiltrating catch basins, perforated pipe, and other underground infiltration systems to meet retention requirements. Drainage system retrofits are most cost-effective when combined with retrofits installed close to the source to reduce the volume of runoff that reaches the drainage system. Common examples of drainage system retrofits include:

- Replacing older style catch basins with deep-sump, hooded catch basins.
- Installing hoods on existing catch basins.
- Installing new infiltrating catch basins upgradient of existing catch basins or replacing existing catch basins with infiltrating catch basins.

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[68] Johnson J. & Hunt W. 2016. Evaluating the spatial distribution of pollutants and associated maintenance requirements in an 11-year-old bioretention cell in urban Charlotte, NC. Journal of Environmental Management. 184 (Pt 2), 363–370.

- Use of manufactured or proprietary devices (such as smaller grates) that catch sediments, trash, organic matter, and other particulates.
- Replacing existing storm drains with perforated drainpipe.
- Installing new tree filters upgradient of existing catch basins or replacing existing catch basins with tree filters.
- Installing proprietary filtration devices in existing catch basins (i.e., catch basin inserts) or other manufactured treatment devices within the drainage system to capture sediment and other pollutants.
- Elimination of curbing.

At the Outfall. New stormwater BMPs can be constructed at or just upgradient of the outfalls of existing drainage systems. Due to the "end-of-pipe" nature of these retrofits, such BMPs are commonly designed as off-line systems, requiring the use of flow diversion structures to retain and/or treat runoff from the water quality storm and bypass larger flows. Most structural stormwater BMPs can be used for this type of retrofit, given sufficient space and maintenance access. However, BMPs designed for wet conditions such as stormwater ponds and wetlands tend to be most conducive to outfall retrofits given the frequent presence of shallow groundwater and poorly drained soils at outfall locations. For these reasons, the feasibility of infiltration BMPs at outfalls is often limited.

Structural stormwater BMPs should be selected to address the water quality objectives for the site (e.g., for specific target pollutants associated with a water quality impairment) and any secondary objectives or co-benefits such as flood reduction, habitat restoration, and community enhancement. Potential constraints may include site conditions, owner preferences and limitations, maintenance considerations, cost/budget considerations, and the overall approach (opportunistic versus planning approach). Refer to Chapter 8 - Selection Considerations for Stormwater BMPs for selection of appropriate BMPs for retrofit applications.

Once suitable structural stormwater BMPs are selected based on water quality objectives and site constraints, the BMPs should be sized to meet the retention and/or treatment requirements presented in Chapter 4 - Stormwater Management Standards and Performance Criteria. Retrofit BMPs are generally sized to maximize retention/treatment performance given the site and project constraints. Stormwater BMP Performance Curves can be used for optimizing sizing in terms of costs and benefits. Retrofit sizing and credits (i.e., quantifying the pollutant and DCIA reduction benefits), including the use of the BMP Performance Curves for retrofit sizing, are further described in the Retrofit Sizing and Crediting section of this chapter. Chapter 10 - General Design Guidance for Stormwater Infiltration Systems and the BMP-specific design guidance in Chapter 13 - Structural Stormwater BMP Design Guidance provide additional design considerations for retrofits involving new structural stormwater BMPs.