Chapter 8

Implementing LID in Special Areas

For LID to be successful in as many places as possible, special areas need special considerations. This chapter summarizes some of these special areas and identifies how LID can be incorporated into the design and development process. By recognizing that LID may not be practical in all places, we help facilitate the local discussion and decision-making process that must occur to determine how these special issues will be addressed.

These special areas include:

- Transportation corridors,
- CSO and SSO issues,
- Brownfield sites,
- High risk areas such as wellhead protection areas, karst areas, and special water designations.

Bioswale and porous pavers in Ann Arbor, MI.

East Street reconstruction consisting of 26-foot asphalt section converted to 18 feet of asphalt with two 3.5-foot concrete porous paver strips (and ribbon curb) that infiltrates all road runoff and some rooftop and sidewalk runoff.

Source: JFNew

Transportation corridors. Highways and roads comprise a significant portion of total impervious surface, especially in more urban areas. Emphasis to date has been to remove stormwater from the roadway as swiftly as possible to ensure public safety and the integrity of the road system. This presents a challenge to incorporating LID practices.

CSO and SSO issues. The impact of stormwater on the local sewer system is extremely important in several Michigan communities where the excess flow produced by adding runoff to a sewer flow, directly or indirectly, results in a hydraulically overloaded system.

Brownfield sites. Redevelopment of Brownfields is a policy priority of Michigan and numerous communities. Typically these sites were highly disturbed or degraded during prior land development. To date, the goal is usually to minimize permeation of rainfall to the subsurface to minimize contact and movement of onsite pollutants.

High-risk areas. High-risk areas include sites such as wellhead protection areas, source water protection areas, sensitive streams, and areas of porous limestone bedrock known as karst. In certain communities, LID will need to be tailored to complement programs in place to address high risk areas.

These special areas are discussed in this chapter. To tailor these special issues to local situations, both LID techniques and policy issues are described below.

Transportation Corridors

Using LID in transportation corridors, especially heavily traveled highways, is somewhat constrained. By design, much of the right-of-way (ROW) is paved with impervious materials built over compacted subgrade. While normal highway design may allow some portion of the corridor to be landscaped, standard earthwork practices result in these corridors being constructed using a soil mantle that has been excavated, filled, and totally altered from its natural form and function.

Also, the linear dimensions of this land use further constrain the type and capacity of LID measures that might be applied within the ROW.

Roadway design, construction, and maintenance must all be considered when selecting measures that effectively manage the quality, rate, and volume of roadway runoff. (For communities that have a stormwater permit, certain practices and procedures are a matter of compliance.)

LID technologies, including both nonstructural and structural, can help meet these requirements and can also be applied in a variety of other settings. Nonetheless, roads must recognize and address these specific challenges in managing stormwater.

- The need to manage stormwater while maintaining safe road conditions.
- Uncompacted soils, trees, and tall vegetation present safety hazards.
- Limited available space and the need to locate BMPs within the right-of-way, if possible.
- Drainage area imperviousness greater than 50 percent, and sometimes near 100 percent.
- Areas of extensive disturbance and compaction of soils (cut and fill).
- Potential for spills of hazardous materials (runoff containment).
- Use of deicing chemicals and salts, and the need to dispose of removed snow.
- Higher concentration of pollutants as compared to many other land uses.
- Thermal impacts to receiving streams in both summer and winter.

Construction of Meadowlake Farms bioswale with infiltration, Bloomfield Township, MI.
Source: Hubbell, Roth, & Clark

Despite these limitations, there are numerous opportunities to incorporate LID practices in the transportation system. These opportunities include:

- Design of new construction,
- Reconstruction projects,
- Maintenance activities, and
- As part of a community redesign process.

Examples of these opportunities can be found in the case studies.

Transportation and stormwater pollution

Stormwater runoff from roads is a significant source of stormwater pollutants, as well as a significant source of thermal pollution to receiving waterways. The chemical constituents of roadway runoff are highly variable. The Federal Highway Administration identifies a number of roadway runoff pollutants and possible sources (Table 8.1).

Compared to other land uses and impervious surfaces, roadway runoff tends to have higher levels of sediment and suspended solids, which must be considered when selecting BMPs. In addition, roadway runoff may also contain salts, deicing materials, and metals that can affect both receiving waters and vegetation and must be considered in BMP selection.

In addition to the water quality issues associated with roadway runoff, temperature impacts can also affect water quality. Roadway systems can deliver large amounts of warm or cold water directly and rapidly to receiving streams and wetlands, resulting in significant temperature impacts for aquatic species. Studies have shown that the runoff from summer storm events may exceed 90 degrees F, and winter runoff may be 37 degrees F colder than the receiving stream ambient temperature (Galli, 1990, Pluhowski, 1970). These temperature impacts can have profound impacts on the aquatic systems of a receiving stream, and significantly alter and reduce the aquatic diversity.

Table 8.1
Pollutants and Sources in Highway Runoff

Pollutents	Source
Particulates	Pavement wear, vehicles, atmospheric deposition, maintenance activities
Nitrogen, Phosphorus	Atmospheric deposition and fertilizer application
Lead	Leaded gasoline from auto exhausts and tire wear
Zinc	Tire wear, motor oil and grease
Iron	Auto body rust, steel highway structures such as bridges and guardrails, and moving engine parts
Copper	Metal plating, bearing and bushing wear, moving engine parts, brake lining wear, fungicides and insecticides
Cadmium	Tire wear and insecticide application
Chromium	Metal plating, moving engine parts, and brake lining wear
Nickel	Diesel fuel and gasoline, lubricating oil, metal plating, bushing wear, brake lining wear, and asphalt paving
Manganese	Moving engine parts
Cyanide	Anti-caking compounds used to keep deicing salts granular
Sodium, Calcium Chloride	Deicing salts
Sulphates	Roadway beds, fuel, and deicing salts

Source: FHWA Stormwater Best Management Practices in an Ultra-Urban Setting

General considerations for implementing LID along transportation corridors

Not all transportation elements offer the same opportunities for LID. In general, the greater the traffic volume and mix of vehicles using the roadway, the fewer measures can be accommodated within the right-of-way (ROW). However, locations such as park-and-ride lots and recreational pathways can use numerous LID BMPs with few constraints.

While many of the LID measures discussed in this manual are appropriate for use in managing roadway runoff, these measures should be designed and implemented with consideration of the nature of runoff from road surfaces. Specifically:

High levels of total suspended solids. Roadway runoff has higher levels of suspended solids compared to many other urban land uses. Roadway runoff should not be discharged directly to many BMPs, specifically infiltration systems without measures to reduce sediment loads. The following pretreatment BMPs can be used to reduce sediment loads:

The City of Battle Creek Willard Beach Park Project showcases LID practices to the community by installing rain gardens and porous asphalt throughout the park roadway system. During a rainstorm, notice the amount of runoff from the traditional asphalt (top) versus the porous asphalt at the start of the park (bottom). These BMPs address both stormwater quantity and temperature concerns that are often associated with roadway runoff.
Source: City of Battle Creek

- Vegetated systems such as grassed swales and filter strips.
- Structural elements such as catch basin inserts, filters, and manufactured treatment units.
- Maintenance measures such as street sweeping and vacuuming.

Proper design of vegetative BMPs. Vegetative BMPs such as grassed swales and filter strips can be highly effective in reducing pollutant loads from roadways, but must be properly designed in terms of slope, flow velocity, flow length, and vegetative cover. (Chapter 7 provides detailed design information on vegetative BMPs).

Vegetated BMPs are most effective for water quality treatment when the vegetation growth is lush and not frequently cut. Concerns with the increase of friction losses, through completely vegetated swales can be addressed with proper plant selection. Typically, there is a direct relationship between height and thickness of vegetation and friction losses in vegetated swales. The higher the friction losses in a watercourse the higher the water depth at a given flow. For appropriate herbaceous plant species with flexible stems (such as Fowl Manna Grass, Bottlebrush Sedge, Brown Fox Sedge, etc.), flows that result in water depths just above plant submergence will actually result in the plants laying down in the flow and significantly decreasing friction losses for high flows. Improperly designed or maintained systems may increase rather than reduce pollutant load.

Consider the issue of spills. It is cost prohibitive to design for spill containment on all sections of roadway, but the designer should consider the potential for spills and the necessary action should a spill occur. Subsurface systems, infiltration systems, or vegetative systems may have to be replaced should a spill occur. While this may seem to be a limiting factor in the use of such systems, many existing storm sewers from roadways discharge directly to receiving streams with no opportunity to contain or mitigate a spill before discharge to a receiving stream. Therefore, while BMP restoration may be required after a spill, a stream discharge of a spill may be prevented. Consider the materials that are carried in vehicles when selecting BMPs. For example, some highways restrict certain hazardous materials so those highways may be more apt to use infiltration BMPs vs. highways that allow all vehicles.

Deicing materials. Use of deicing materials and salts may affect vegetation, soil conditions, and water quality. Consider the types of vegetation used in vegetative BMPs, as chloride levels may adversely affect some vegetation as well as the soil microbial community. Proximity to water supply sources should also be considered when designing infiltration BMPs as well as the potential for groundwater chloride levels to be impacted by roadway runoff.

Disposing of snow removed from roadways must also be considered. This snow may ultimately be deposited in BMP areas and may contain higher concentrations of roadway salts and sediments. The potential impacts of this material on the BMP should be addressed in the design process (See Appendix C for a list of salt tolerant plants).

Temperature impacts. The temperature impacts of runoff from roadways can significantly affect receiving stream aquatic habitat. Roadways, especially asphalt roadways, tend to absorb heat and lack cooling vegetation in the ROW that can help cool runoff. Many existing storm sewers from roads discharge directly and immediately to receiving waters. New discharges should mitigate temperature impacts prior to discharge to the receiving water. This may involve:

- Vegetated systems and buffers to replace sections of concrete swales or pipes that impart heat to runoff. Multiple small drainage elements that use vegetated swales for conveyance will help reduce the temperature impacts from roadway runoff.
- If extended detention systems, wet ponds, or constructed wetlands are used for peak rate mitigation, the discharge from these systems could be further mitigated by using vegetated swales or buffers, as these impoundments may also create adverse temperature impacts. The discharge from an extended detention system could be conveyed via a vegetated swale, or dispersed through a level spreader. Discharges should not be piped directly into receiving streams or wetlands.
- Extended detention systems should include design elements to reduce temperature impacts. Recommended techniques include:
  - Design system with minimal permanent pool.
  - Preserve existing shade trees; plant trees

along shoreline (where feasible and still allowing for proper maintenance access).

- ◦ Avoid excessive riprap and concrete channels that impart heat to runoff.

LID BMPs: Small Steps to Full Integration

The following LID implementation guide provides simple, low effort LID application concepts up to full integration of LID into new road construction, road reconstruction, and maintenance activities.

Easy to implement strategies

The first and foremost strategy is to avoid or minimize impacts. This includes limiting clearing and grubbing, minimizing site compaction, reducing impervious areas, and using native vegetation wherever possible. These strategies are detailed below and described in more detail in Chapters 6 and 7.

- **Minimize clearing and grubbing and soil compaction as feasible**. Existing vegetation, including tree canopy, understory, prairies, pastures, etc., along with root structure and litter on the ground can capture and evapotranspire significant amounts of annual rainfall before it ever has a chance to become runoff. In these landscapes, even when rainfall does reach the ground, it has a much higher likelihood of infiltrating into the soil than in cleared and compacted areas.

  As the traffic volume and travel speeds decrease, this measure becomes more easily implementable. For instance, for low volume, low speed roads – residential streets, gravel roads, etc. — removal of existing vegetation should be limited only to the actual corridor of the pavement surface and subsurface materials. The rhizosphere (plant rooting zone) is the area of the landscape where the most significant water quality treatment benefits are achieved. Leaving as much of the existing rhizosphere in place as possible is the first, best and least cost BMP for road projects. (This may require working with local community to discuss vegetation height requirements in the ROW).

- **Reduce compaction on non-load bearing areas.** Compaction beyond 85 percent of maximum dry bulk density can inhibit root growth. Compaction requirements for non-load bearing areas should be limited to 80 to 85 percent. This lowered compaction requirement ensures that the basic soil pore structure is mostly left intact. For more information on compaction, plant needs and structural stability see www.forester.net/ecm_0209_optimizing.htm

- **Consider reducing impervious surfaces**. Where feasible and safe, consider impervious area reduction strategies for reducing road widths, particularly on residential streets. Changes in road widths will clearly reduce the cost of road construction and reconstruction. The rationale for existing road widths should be systematically re-examined for opportunities to reduce impervious surfaces, particularly for low-service roads.

- **Re-evaluate roadside ditch cleaning and or/ mowing practices**. Efforts should be made to retain existing vegetation during maintenance. For example, consider excavating or clean out of the up-gradient section of the ditch only (e.g., approximately top three quarters of ditches) and retaining vegetation in the down-gradient.

  Washington State DOT assessed routine highway ditch cleaning alternatives or service levels for water quality benefits, surveyed bioswales to evaluate conditions promoting water quality benefits, and assessed restabilization and revegetation options for use after ditch cleaning and for restoring bioswale vegetation.

Evaluate roadside ditching operations to retain existing vegetation where possible.

Source: Bloomfield Township

Of the options explored, the study found the greatest water quality benefits when the first three quarters of the ditch were excavated and vegetation was retained in the remainder. The ditch treated in this manner was capable of reducing TSS by approximately 40 percent, total phosphorus by about 50 percent, and total and dissolved copper and zinc each by roughly 20 to 25 percent. Analysis of survey data also showed that bioswales with broad side slopes, wide bases, and total storage volumes equivalent to three inches of runoff from the impervious drainage area consistently supported good vegetation cover and showed few signs of damage. Refer to henvironment.transportation.org/environmental_issues/construct_maint_prac/compendium/manual/10_11.aspx#tooltip. This approach may not be feasible for highways or other roadways with safety specifications for maximum depth of standing water in roadside ditches.

- **Incorporate native Michigan plants more comprehensively into roadside and median planting plans**. MDOT has experimented with native plantings with mixed success (See www.forester.net/ec_0004_integrated.html). Some of the issues cited in the past – problems with seed availability and invasives control -- can be better addressed now because of increased expertise of local native plant nurseries and companies devoted to landscape restoration.
- **Limit the use of curb and gutter and storm sewer wherever possible**. Where practical, particularly in areas with either well-draining soils or where there is sufficient fall to move water into swales and channels, runoff can be directed via sheet flow or to appropriately protected drainage features for storage and enhanced evapotranspiration and infiltration. Unprotected road edges are notoriously prone to cracking and crumbling. Where sheet flow moves over pavement edges, ribbon/flush curbing can be used to protect the pavement and help control drainage off the road surface.
- **Avoid discharging directly into a waterbody**. Traditional approaches to stream channel and water quality protection include ending the pipe well uphill of the stream bank and lining the area between the end of the pipe and the stream bank with well-graded stone and/or a high velocity mulch blanket. LID approaches can accomplish better water quality and even some volume reduction by discharging storm sewer and underdrains into vegetated areas, including constructed wetlands, bioretention/detention basins, and vegetated swales. These controls may sometimes be accomplished by acquiring land outside of the standard right of way.

> California Department of Transportation (CalTrans) developed a roadside management toolbox, which is a Web-based decision making tool for improving the safety and maintenance requirements of roadsides. CalTrans formally adopted an integrated vegetative management strategy to reduce the need for ongoing vegetation management. The most inexpensive "tool" for minimizing long-term roadside vegetative maintenance is native landscaping at $2 to $10 per square yard.

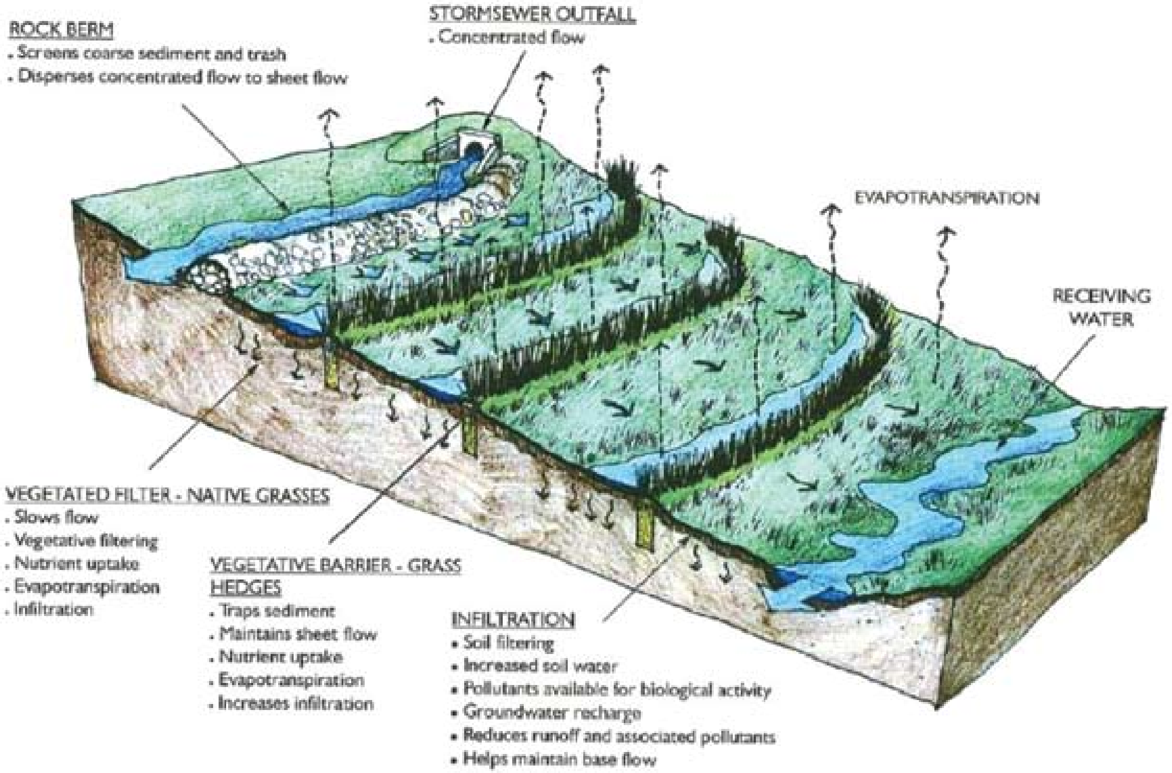
- **Consider alternative methods of energy dissipation where existing land allows** (in lieu of concrete or supplement rock pads). This can include tall, thick native plantings that act as a porous, "green" weir. (Figure 8.1)
- **Consider the use of infiltration berms** and retentive grading in areas that slope down from the roadway (Figure 8.1 and Figure 8.2).

Moderate-to high-level LID implementation

- **Incorporate street trees**. Wherever possible, integrate street trees, particularly in urban and suburban areas. The use of structural soils in these areas allows for street side tree plantings that can thrive and also provide significant structural stability. These areas can accept sidewalk/rooftop and road drainage and provide an overstory for shading and rainfall capture.

  Structural soil is a designed planting medium which can meet pavement design and installation requirements, while remaining root penetrable. The Cornell Urban Horticultural Institute has developed the structural soil system. This system includes gap-graded gravels made of crushed stone, clay loam, and a hydrogel stabilizing agent. This system creates a rigid stone lattice with the voids partially filled by soil (Figure 8.3).
- **Use pervious pavement**. Reducing impervious surfaces can also be accomplished by mixing impervious and pervious pavement types, textures, and colors. This juxtaposition of paving surfaces, textures, and colors can provide other benefits such as traffic calming or easy access to utilities.

Figure 8.1
Alternative outfall BMP using rock berm and alternating strips of native vegetation

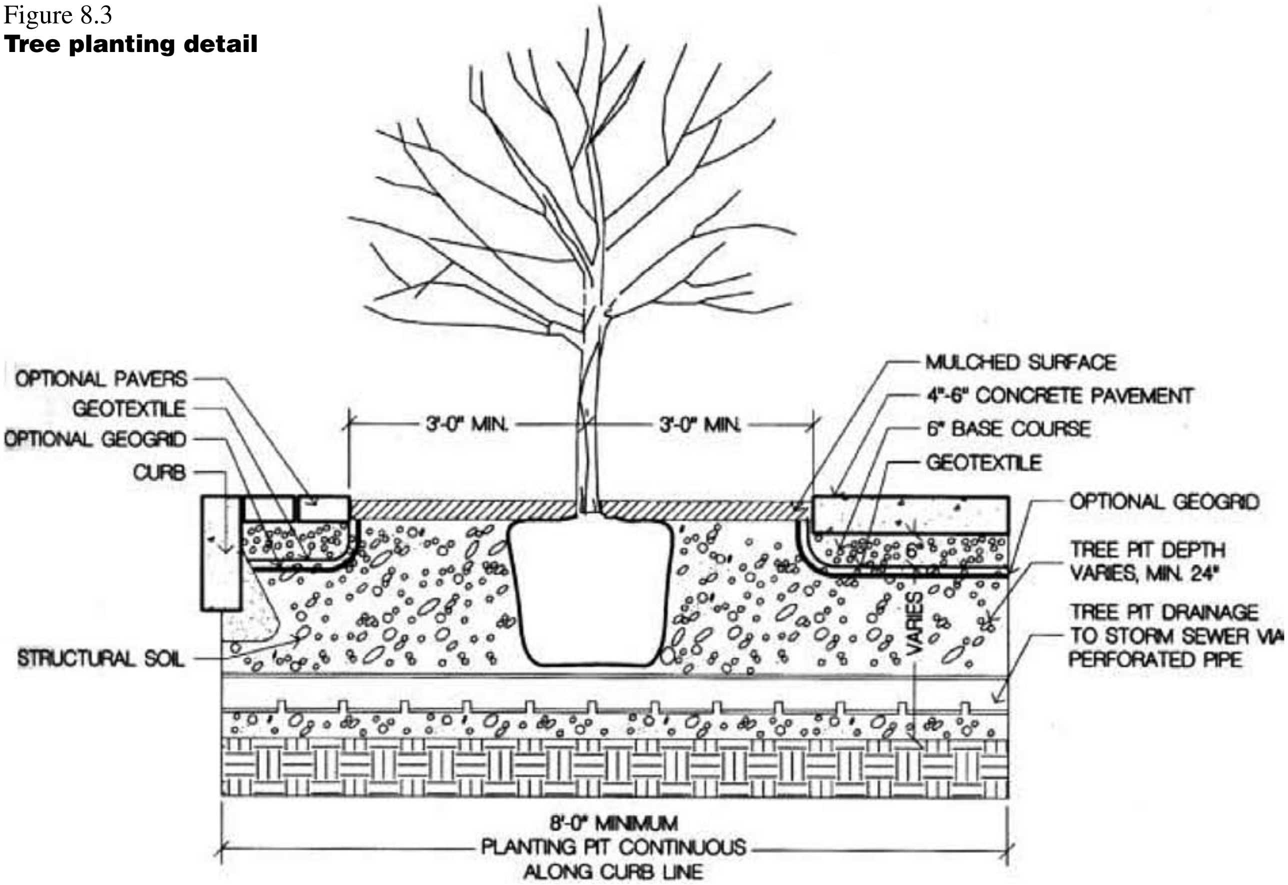


Source: Scaief, J. and Murphee, G., 2004

Figure 8.2
Mature rock berm and native vegetation filter berms

Source: Scaief, J. and Murphee, G., 2004

Figure 8.3
Tree planting detail



Source: Cornell Urban Horticultural Institute

The Easy Street case study shows 3.5-foot porous concrete paver block strips on either side of an 18-foot conventionally paved surface. The paver blocks can easily be lifted off their subbase in order to reach water pipes beneath the street. In addition, in the driver's eye these strips make the street look narrower, even though the pavers can handle the same loads as the asphalt. This perception of a narrower street has resulted in significantly slower speeds through what once was a "cut-through" street.

- **Take advantage of planted areas surrounded by impervious surfaces**. For instance, cul-de-sac interior circles and boulevard medians are typically planted areas. These areas are usually mounded at or above the road surface (convex topography). These areas could just as easily be depressions (concave topography) that capture drainage from the road, either over ribbon curb or through curb cuts in mountable or standard curb around the island or boulevard.

The Pokagonek Edawat Housing Development located in Dowagiac, MI includes the use of 25,000 square feet of interlocking pavers for the primary driving surface.
Source: Pokagon Band of Ptawatomi Indians

- **Require bioretention capability in the design of dry detention basins**. This can include replacing existing soils with engineered soil. Replacing existing soils with well-drained, organic soils can provide valuable water quality benefits, some storage, enhanced evapotranspiration opportunities, and an excellent growth medium for plantings even in areas with poor, fine-grained soils. These basins can be fitted with underdrains and overflows to facilitate drying out and eliminate flooding.
- **Incorporate LID into park-and-ride and other parking lots**. Consider using porous pavement, underground storage, and other subsurface infiltration practices on park- and- ride sites and parking lots.

Complete integration of LID design

Complete integration of LID is more likely possible on suburban or urban street settings, where other considerations, such as pedestrian access, commercial establishment visibility, aesthetics, recreation opportunities, and traffic calming can also impact design elements. This can be best accomplished by including various stakeholders in the process (e.g., transportation agencies, local planners and elected officials, and the public).

Complete integration of LID design would include such elements as conserved or planted trees, vegetated swales with amended soils, and subsurface aggregate storage:

- Incorporate swales into curb extensions mid-block and/or at intersections.
- Use permeable pavement materials for on- or off-street parking areas and sidewalk or bike lanes.
- Create underground storage under parking areas that can also receive rooftop runoff.

The City of Portland, Oregon is in the midst of re-defining how urban streets look and perform hydrologically. The figure below, taken from the Gateway Green Streets Master Plan for Portland, vividly demonstrates the look and suggests the effectiveness of this design on mitigating street runoff impacts.

Opportunities for moving LID forward

Local leadership is needed to move LID implementation forward in Michigan. This leadership needs to occur within transportation agencies as well. Numerous opportunities exist for agencies with transportation responsibility to encourage LID implementation.

Portland Gateway Green Streets Master Plan

Source: City of Portland, OR, Bureau of Environmental Services

Wayne County Miller Road Revitalization Project

The Miller Road Revitalization Project, located near the Ford Rouge Complex, implemented LID techniques to make the busy transportation corridor safer, more attractive, and more environmentally effective.

A 1.5-mile greenbelt promenade was developed on both sides of Miller Road with hundreds of trees and 20,000 shrubs. In addition, over 22 acres of sustainable landscaping was planted along the road. Irrigation is provided by mill water from the Detroit River, using pipes originally installed by Henry Ford. Swales are used along the road to filter stormwater before flowing to the Rouge River.

Swale along Miller Road in Dearborn, MI

Source: Atwell Hicks

Opportunities for MPOs

Metropolitan Planning Organizations (MPOs) designated under the Safe, Accountable, Flexible, Efficient, Transportation Equity Act: A Legacy for Users (SAFETEA-LU), have mandated responsibilities for developing long-range transportation plans and transportation improvement programs. Typically, MPOs work closely with road implementing agencies in their jurisdiction. And often, the MPO is also the council of governments representing a variety of local governments. Such is the case for SEMCOG. Thus, MPOs can play a major role in advocating for implementation of LID techniques.

Vegetation within right-of-way on Miller Road in Dearborn, MI
Source: Atwell Hicks

Furthermore, an emerging trend in federal transportation legislation and regulations is to integrate environmental protection issues early in the transportation planning process. This transportation planning institutional structure and policy trend presents an opportunity to promote LID in the process of implementing roadway plans and projects. SEMCOG, for example, has developed a procedure for ensuring that transportation agencies in Southeast Michigan consider a variety of potential environmental concerns when proposing a project for the transportation plan and transportation improvement program.

Several suggested action steps are proposed for consideration by MPOs:

- MPOs should become familiar with the content of this manual and the Best Management Practices that can apply to road projects.
- MPOs should incorporate policies into the transportation plan that advance LID implementation. Coordinating with watershed management plans or Total Maximum Daily Loads (where they exist) will result in policies that are unique for the needs of the waterway.
- MPOs should help educate road implementing agencies on LID techniques, including operational and maintenance practices.
- MPOs should convene representatives of road agencies in the area to discuss policy options and to identify opportunities and impediments in supporting LID. For areas under a stormwater permit program, the benefits of achieving compliance through use of LID should be considered.
- MPOs should use this manual to develop a checklist of actions for road agencies to use in project design and as part of operation and maintenance. Also, MPOs should develop prototype language for contractor specifications that include LID.
- Finally, MPOs should consider giving priority to projects that incorporate LID techniques.

LID policies incorporated into transportation plan

SEMCOG includes LID policies in their long-range transportation plan, specifically through a document, *Integrating Environmental Issues in the Transportation Planning Process: Guidelines for Road and Transit Agencies.*

One policy specifically stated in the SEMCOG process is to "Integrate stormwater management into the design of the site. If appropriate, utilize low impact development practices that infiltrate stormwater into the ground (e.g., swales, rain gardens, native plantings)."

Opportunities for implementers

Incorporating LID into roadway projects is not a minor undertaking. It involves a shift in perspective where the value of water quality and stream channel protection is reflected during different phases of a project — conception, design, construction, and maintenance. In areas where the MPO chooses to take many of the actions suggested above, the process will be more seamless.

Regardless of the MPO's level of activity, there are a number of actions that road agencies should do to be a proactive part of state and local government efforts to restore and protect water resources.

- Land use planning is a primary function of local government. Local plans and policies reflect community desires. Road agencies should be familiar with local water issues and the community's efforts to address them, including whether the community is covered by a stormwater permit, as well as the extent to which LID is applied in site development.
- More county drain commissioners and/or offices of public works have developed or are developing programs to protect water quality. Many of these programs have implications for roadway design or maintenance, including limitations on stormwater runoff.
- It is critical to consider the potential for applying LID techniques as early in the process as possible. Once designers are committed to the project design, it is hard to change course for what would likely be perceived as a secondary consideration, i.e., using LID techniques. Early meetings, at the project conception phase, with the local unit of government are encouraged.
- Many road agencies have written guidelines, procedures, and manuals. Consider revisions to existing manuals and procedures that incorporate LID supportive practices and policies.
- Include language in contractor specifications that spell out expectations during design and construction.

Michigan Avenue Streetscape Bioretention Facilities

City of Lansing

In 2004, the City of Lansing formed the Mayoral Task Force to address future infrastructure needs and improvements along four blocks of Michigan Avenue. The committee recommended the following elements be addressed in redeveloping the streetscape:

- Create more welcoming gathering places,
- Highlight pedestrian crosswalks,
- Make the corridor more environmentally friendly, and
- Add streetscape improvements such as kiosks, benches, and signage.

Michigan Avenue rain gardens in planter boxes in Lansing, MI.
Source: Tetra Tech

Street view of rain gardens in planter boxes in Lansing, MI.
Source: Tetra Tech

Construction on the project began in spring 2006 and incorporated landscape planters and sidewalk paving improvements, including new concrete sidewalk and accenting clay pavers, ornamental fencing, and site furnishings. In addition, a series of concrete, under-drained bioretention facilities (i.e., rain gardens) were designed as part of the enhancement project. The rain gardens were developed in conjunction with the city's controlled sewer overflow work as a means to control, clean, and dispense stormwater in an urban environment.

The rain gardens are designed to remove sediment, nutrients, heavy metals, and other pollutants, as well as reduce water temperature, and promote evaporation and transpiration of stormwater runoff, thereby reducing the overall impact to the Grand River. The project budget was $1.8 million.

Soil testing was required to address the numerous plant challenges such as impacts of road salt, drought, shade, height, and beauty, as well as soil challenges such as permeability, compaction, longevity, and available nutrients. The engineered soil specification was a mix of 30 percent sand, 30 percent topsoil, 10 percent coir fiber, and 30 percent municipal compost. The plants include Southern Blue Flag, Tall Tickseed, Nodding Wild Orchid, Rough Blazing Star, Switch Grass, Sweet Flag, Marsh Blazing Star, Swamp Milkweed, St. John's Wort, Rose Mallow, Boneset, Joe-Pye Weed, Beard-tongue, and Ironweed.

Maintenance and monitoring is provided by the City of Lansing Public Services Department and through an Adopt a Rain Garden program. Estimated maintenance costs are $30,000 per year for weeding, cleanup, plant replacement, mulching, and underdrain cleaning. In the future, interpretive educational signage will be posted in the gardens, providing information about stormwater pollution to pedestrians.

Easy Street in Ann Arbor, MI before LID implementation
Source: JFNew

Easy Street in Ann Arbor, MI after LID implementation
Source: JFNew

Easy Street

City of Ann Arbor

The Easy Street pavement rehabilitation project evolved into a re-envisioning of an overall street design. Easy Street drains via storm sewers to Mallets Creek, which is one of six creeks that drain to the Huron River through the city. Easy Street is a major asphalt thoroughfare through the City of Ann Arbor that had been resurfaced in over 10 years.

Over several years, residents of Easy Street initiated various design efforts to achieve a more integrated street design. The goal was a road design that would assist in stormwater management, along with addressing traffic calming, pedestrian access, and landscaping.

The project plan resulted in the installation of three-foot wide porous pavers on both sides of the street. Infiltration rates in the pavers can be maintained between four and eight inches per hour. In one hour, the pavers can infiltrate almost two times the depth of a 100-year rain event. Because the pavers' infiltration rate is approximately 16 to 32 times higher than the surrounding soil, it can take the runoff from an area at least 16 times its own size and still exceed the soil's infiltration capacity. The City of Ann Arbor has an annual maintenance program in place to take care of porous pavement.

The project includes an evaluation plan with pre- and post-construction flow and water quality monitoring, along with hydrologic and hydraulic modeling of conditions before and after construction.

Addressing CSO and SSO Issues

A significant source of water quality impairment comes from stormwater runoff that has been mixed with untreated sewage or wastewater. Some Sanitary Sewer Overflows (SSOs) and all Combined Sewer Overflows (CSOs) are discharges of mixed stormwater and untreated wastewater directly to lakes and streams, and even into basements. CSOs result from excessive stormwater entering a sewer system. SSOs can be caused by precipitation or failure of the sewer system (blockage, breakage, etc.). In the case of an SSO, the sanitary sewer system is designed to collect and transport sanitary wastes only and stormwater is transported by a storm sewer system, whereas CSOs come from sewer systems designed to transport both stormwater and sanitary wastes in one pipe. Correction of CSOs and precipitation-related SSOs can be difficult and costly because of the size of the systems involved and the large areas they serve, resulting in huge volumes of stormwater to the systems.

Protecting Michigan's vast surface waters is important to the state's citizens. Therefore, Michigan implemented its current CSO control program around 1988. Appropriate controls for each community were chosen, and most are in place or under construction. Michigan's CSO program requires either separation of the combined sewer system or retention of all flows from storms up to the one-year, one-hour storm and treatment of the discharges above that size storm (including skimming, settling, and disinfection).

In Michigan, LID controls are not expected to be a benefit in terms of replacing or allowing a downsizing of end-of-pipe treatment. However, managing stormwater runoff by implementing LID through techniques such as infiltration, green roofs, and capture reuse reduces the volume of stormwater entering the sewer system. For combined sewers, volume reduction reduces the size or frequency of overflow events from the treatment basins. The cost of implementing LID for CSO control needs to be weighed against the needs of the receiving stream and the expected benefit. Where water quality concerns exist such as Total Maximum Daily Loads for nutrients, reduction of loadings from treated CSOs may be important.

CSO Retention Treatment Basin in the City of Birmingham

Source: Rouge River National Wet Weather Demonstration Project.

LID BMPs in CSO and SSO areas

CSO communities are generally older and heavily urbanized. Redeveloping and reclaiming older inner-city properties presents an opportunity to plant trees, increase open space, and decrease impervious surfaces. In addition, stormwater from roads and other impervious surfaces can be directed to these expanded open areas using methods like curb cuts in place of traditional catch basins and pipes.

For newly developing areas that discharge stormwater into combined sewers, LID methods prevent volume increases to these systems and avoid additional overflows. Traditional stormwater control methods can make problems worse if the volume of stormwater discharges increase.

For SSOs, Michigan law does not allow for the discharge of raw sewage. If the sewer system's excessive stormwater inputs can be partially addressed through LID, it may provide some benefit and should be considered in determining a final solution. SSOs can result when excessive stormwater enters the sanitary sewer either through direct inflow from manholes and improper connections or from infiltration of groundwater into pipes. Where excessive inflow is the concern, LID provides numerous opportunities for capturing stormwater and transporting it away from the sanitary sewer. If infiltration into the system is also of concern, LID infiltration techniques may need to be limited in the proximity of the sanitary system.

The following are examples of implementing LID techniques in an urban area as part of a CSO/SSO reduction strategy.

- Use rain gardens on residential property.
- Integrate cisterns into redevelopment projects.
- Use subsurface infiltration when renovating public parking lots.
- Create community-wide tree planting initiatives, especially where canopy extends over impervious surfaces.
- Integrate porous pavement in appropriate street and parking lots during renovation.
- Create community gardens and open space for areas cleared of unused structures that are not planned for new buildings.
- Plant vegetated roofs on redeveloped commercial and institutional buildings.
- Restore the riparian corridor during redevelopment and on public property.

Tollgate Drain Wetlands

City of Lansing

Source: Fishbeck, Thompson, Carr & Huber

The Tollgate Drain Drainage District is served by a county drain established in the late 1800s, but which no longer provided an adequate outlet for the densely developed residential neighborhoods served by a combined sewer system built in the 1950s. Frequent flooding was problematic. A CSO separation project was completed for the 210-acre Groesbeck neighborhood. The new Tollgate Drain was then designed to divert stormwater through a state-of-the-art stormwater treatment wetland located in Fairview Park with overflows to the Groesbeck Golf Course where the stormwater could be used for irrigation.

An entire Michigan ecosystem was conceived and designed into the Tollgate Wetlands, which is the focal piece of Fairview Park. This stormwater treatment system uses limestone cascades to aerate and neutralize the pH of the urban stormwater runoff, a peat filter for ion-exchange and removal of pollutants associated with urban runoff, level spreaders to disperse concentrated flows and allow for a wide-variety of native Michigan plants for water uptake and pollutant breakdown. A wet pond is also incorporated into the design to settle particulates before excess stormwater is recharged into the ground through irrigation at the Groesbeck Municipal Golf Course. The design results in a “zero discharge” stormwater system with a proven track record of water quality improvements and flood prevention.

The estimated cost to construct a traditional drain outlet to the Red Cedar River was about $20 million. This approach was rejected in favor of the innovative Tollgate Wetlands “zero discharge” approach. The final cost of the Tollgate Wetland project cost $6.2 million.

Implementing LID on Brownfield Sites

Every community in Michigan is in some stage of redevelopment. In many locations where redevelopment is underway, the previous use of the parcel has left behind a residue of pollution, which may constrain the types and extent of LID solutions for stormwater management. The general term used to describe such sites is “brownfields,” to distinguish them from the undeveloped fields of suburban development (or “greenfields) where only cultivation has taken place. Brownfields and the residual contaminants they contain are from a host of different uses including commercial, industrial, municipal waste handling, demolition, and even military.

Unlike many conventional developments, impervious footprints on brownfields cannot always be minimized through site designs that incorporate more porous surfaces to allow for infiltration. Direct infiltration on a brownfield site may introduce additional pollutant loads to groundwater and nearby surface waters. However, green infrastructure practices exist that can retain, treat, and then reuse or release stormwater without it ever coming in contact with contaminated soils.

Bioswale at Macomb County Administration Building, Mt. Clemens, MI.

Understand the contamination on the site

Well-planned stormwater management associated with brownfield redevelopment requires a thorough knowledge of the site's contamination. The extent of the location(s) of contamination, the maximum concentrations of the contaminants, and the risks associated with the contamination remaining in place are critical pieces of information in determining whether LID BMPs are appropriate.

Stormwater management associated with redevelopment of a brownfield site, when done without sufficient knowledge of site conditions, frequently results in increased loadings of contaminants to the stormwater system. Actions that cause contamination to migrate beyond the source property boundaries at levels above cleanup criteria are considered "exacerbation." Consequences associated with exacerbation of existing conditions exist under Michigan's cleanup programs. Increased infiltration that results in loadings to the local storm sewer systems may be exacerbation. The cleanup programs allow contamination to remain in place when the current and reasonably foreseeable site conditions would not result in any unacceptable risk. If the redevelopment of the site changes site conditions so that stormwater drainage patterns are changed, the risks must be further evaluated to ensure the conditions at the site remain protective and that the proposed stormwater management design will prevent exacerbation of the existing contamination.

When the contaminants on a site pose a threat to human health and the environment, the development proposal must first go through a due care review process mandated by the Michigan Department of Environmental Quality. Developers can take advantage of that process to discuss with the state methods for handling stormwater runoff, identifying areas and methods to avoid; and setting the groundwork for proper approaches.

General design considerations for brownfield sites

Once sufficient knowledge is available about the contamination on the site, brownfield redevelopment and LID techniques can be discussed. Brownfield redevelopment and LID both produce economic and environmental benefits by improving urban areas, protecting open space, and preventing further pollution of our water. However, in order to prevent further environmental damage by infiltrating precipitation through contaminated soil, onsite stormwater management must be done carefully, using particular design guidelines. Projects have been implemented across the country incorporating effective solutions to the challenge of developing a brownfield site with residual contamination, by incorporating appropriate natural systems for stormwater management.

The University of Michigan's School of Natural Resources and Environment developed the following design guidelines as part of a planning project that use low impact development techniques on contaminated sites. The following guidelines have been reviewed and adapted by the Michigan Department of Environmental Quality for this manual.

- **Avoid infiltration practices in contaminated area**. If infiltration is proposed and contaminated areas cannot be avoided, additional testing could demonstrate that residual contamination will not leach from the percolation of rainfall through the contaminated soils to groundwater in concentrations that present an unacceptable risk. If leach testing demonstrates infiltration would result

Horizontal grates can be added to a site as one way to separate stormwater from contaminated and non-contaminated areas. This was a measure employed at the Macomb County Public Administration Building to ensure that runoff from the site did not enter the storm drainage system in the older section of the parking lot, which directly drains to the Clinton River.

in additional unacceptable concentrations reaching the groundwater, design considerations to separate contaminated soils from contact with stormwater must be included.

LID practices on brownfield sites may include treatment and storage with reuse of stormwater rather than complete infiltration. Most brownfields that have residual contamination need caps, so vegetated areas need to be located above caps and fitted with underdrain systems to remove stormwater or reservoirs to capture it for later use.

Detention, retention, and biofiltration are suitable for contaminated sites when designed to prevent exfiltration to underlying soils and allow adequate time for water to be in contact with plants and trees for bioremediation. Infiltration trenches and basins collect stormwater and infiltrate or attenuate runoff. If fitted with filter devices for pre-treatment of contaminated water, these become wastewater treatment systems subject to requirements of National Pollutant Discharge Elimination System (NPDES) permits.

Permeable pavement and rain gardens are not usually suitable for sites with residual contamination that could be mobilized to groundwater, or to the storm sewer system in cases where these BMPs are underdrained. Additional features including impermeable liners and underdrains to storm sewers can be coupled with modified LID practices to safely filter stormwater without exposing the water to contaminated soils .

- **Retain/revegetate trees and vegetation**. Retaining and revegetating helps evapotranspirate stormwater runoff while intercepting large amounts of rainfall that would otherwise enter waterways as runoff.
- **Use impervious surfaces as additional caps**. When siting the development, consider locating buildings and other impervious surfaces over contaminated areas as long as escaping vapors or other contaminants are not present or are controlled to prevent health risks. The Macomb County case study strategically located the parking area over the small, contaminated area.
- **Implement practices that encourage evapotranspiration and capture/reuse**. Green roofs are an ideal way to reduce runoff from building roofs by encouraging evapotranspiration of rainwater. The redevelopment project at East Hills Center in Grand Rapids used a green roof for this purpose.

  Another option for brownfield sites is to capture and reuse stormwater for non-potable uses. This can include runoff storage in rain barrels for irrigation of green roofs or landscaped areas, or in cisterns that store rainwater for toilet flushing and other uses.
- **Include LID techniques in sites around brownfield areas**. New and redeveloped sites near brownfields should use green infrastructure practices to prevent additional runoff from flowing onto potentially contaminated areas.

The principle of separation

Keep clean stormwater separate from contaminated soils and water to prevent leaching and/or spread of contaminants.

LID uses soil and plants to clean and detain stormwater. This is an effective strategy on a wide range of sites, but it becomes more complicated when contaminants from historical uses are present. On brownfield sites, encouraging interaction between relatively clean stormwater and contaminated soil of contaminated groundwater can cause leaching of contaminants to groundwater, erosion of contaminated sediments, and lateral movement of contamination onto neighboring properties. In planners' and designers' enthusiasm to use LID, it is crucial that they avoid situations that could spread contamination from brownfield sites.

Redevelopment of a landfill: Fairlane Green

City of Allen Park

Fairlane Green, developed by Ford Land, is a one million-square-foot retail/recreational center with parks and trails on the 243-acre closed Allen Park Clay Mine Landfill. It is the largest landfill redevelopment project in Michigan and the largest in the country for retail use. The project incorporates environmentally friendly features including a 43-acre park, 3.5 miles of trails, and a three-phase retail development. In all, nearly two-thirds of the site is reestablished as natural green space.

Retail center that incorporated a cistern and rain garden.

Due to the potential for contamination, infiltration was not allowed on the site. The rain garden and detention basin BMPs did use liners to ensure infiltration did not occur.

In addition, redeveloping the industrial site required innovative methods to protect the landfill's integrity. Stress on the underlying landfill was reduced through a preloading soil fill program and lightweight geofoam fill. Geofoam was used in place of additional fill under buildings to eliminate additional weight on the landfill. These features allowed developers to reduce settlement levels and create shallow foundations.

Retail center with cistern for greywater needs

Developers maintained side slope stability with a soil buttress. The soil buttress helped stabilize one million cubic yards of fill on a 40-foot high slope. It was monitored to ensure safety during the construction process.

Utilities and foundations were placed in a landfill cap within an engineered fill layer. Nearly 17,000 feet of utilities were installed with utility corridor trenches lined with a combination geosynthetic clay liner and high density polyethylene (HDPE) liner. This liner prevented exfiltration and leakage from site utilities.

The Fairlane Green retail center includes prairie landscape and retention ponds which create natural habitat for wildlife that can flourish in an area that was previously unable to support them. A surprise bonus; the habitat attracted a snowy owl, the first in this area.

East Hills Center

City of Grand Rapids

The East Hills Center (EHC) project is a direct result of a 10-year organizing effort by the East Hills Association. The goal for the neighborhood was to revitalize a vacant, contaminated brownfield located within a mixed-use central corridor. The project redeveloped a former contaminated gas station into a net-zero stormwater discharge.

Vegetated roof on East Hills Center

Source: Fishbeck, Thompson, Carr, and Huber

The EHC effort began in 1994 when a neighborhood business was denied a building rehabilitation loan due to the contamination of the EHC site. For the next seven years, the neighborhood association campaigned for remediation of the site. The redeveloped East Hills Retail Center has become a LID example for urban infill projects.

Other green features

This project was selected by the U.S. Green Building Council (USGBC) as a pilot project for the LEED-CS rating system and received a gold level certification. The building was designed to have a highly insulated shell for maximum energy efficiency. The exterior walls were constructed with insulated concrete forms. Interior slabs are isolated from exterior surfaces to act as a heat sink for the sun's warming energy in the winter. An exterior and interior lightshelf was designed to control direct sunlight in the summer, while allowing the sun's warmth in the winter. The lightshelf bounces natural daylight into the spaces without direct sun glare.

Title: Rain garden at East Hills Center

Source: Fishbeck, Thompson, Carr, and Huber

Redevelopment using bioswales and rain gardens

Macomb County, City of Mt. Clemens

The Macomb County Department of Planning and Economic Development led an effort to transform an old gas station and automobile dealership, located in the City of Mt. Clemens, into a parking lot with numerous LID features. The contaminated section of the parking lot was capped and the parking lot and LID practices were designed to allow for infiltration BMPs only in areas not directly impacting the contaminated area.

Rain garden at Macomb County building in Mt. Clemens, MI

Source: Macomb County Planning and Economic Development

Four rain gardens and approximately 400 linear feet of bioswales were constructed on the site, which uses native plant materials that are very effective at holding stormwater in deep root systems and filtering out negative pathogens and pollutants.

The development also contains horizontal grates so runoff from the parking lot is completely captured and conveyed to the rain gardens and swales. This measure ensured that runoff from the site did not enter the storm drainage system in the older section of the parking lot, which directly drains to the Clinton River.

The price of the project was very similar in cost to a conventional development ($507,000), but less maintenance over the lifetime of this site will realize a more significant savings. The estimated maintenance costs for weeding, mowing, edging, and removing debris is $4,000 to $5,000 per year for the first two years and $2,000 to $4,000 after that.

From Model A to a model of redevelopment in Dearborn, MI

Ford Rouge Plant

Built by Henry Ford in the 1920s, the Rouge Truck Manufacturing Complex was a marvel of industrial efficiency. Raw materials went into one end of the plant and completed vehicles came out the other.

Native vegetation for stormwater infiltration at the Ford Rouge Center

Source: Atwell Hicks

Over time, the area devolved into a brownfield. In 2000, Ford Motor Company began a project to redevelop the plant as a model of sustainable manufacturing.

The centerpiece of stormwater management at this industrial area is a 10-acre green roof that can retain approximately 50 percent of the precipitation falling onto it. Additionally, it decreases the building's heating and cooling costs and will likely double the roof's lifespan.

World's largest green roof covering 454,000 square feet atop Ford's truck assembly plant in Dearborn, MI.

Other stormwater features include collecting excess runoff and reusing it throughout the plant. Porous pavement is used where new vehicles are parked; this allows water to drain through to a filter system that improves quality before it is used elsewhere. Due to the potential for contamination, infiltration was not allowed on the site. The BMPs (e.g., porous pavers) did use liners to ensure infiltration did not occur.

Landscaped swales and wetlands containing native plants, bushes, and trees remediate the soils surrounding the building by taking up, sequestering, and even treating pollutants that accumulated during more than 80 years of manufacturing. This vegetation also provides valuable habitat for wildlife and helps to clean water before it enters the nearby Rouge River. Water quality monitoring data show increased levels of dissolved oxygen necessary for fish and other species to thrive. Harmful bacteria levels are declining, which is beneficial not only to fish, but to the increasing numbers of people who enjoy spending time on the river.

Implementing LID in High Risk Areas

LID implementation can be an essential component of protecting high risk areas, such as sensitive streams and lakes. In addition, LID can be an important component in areas with public waters supply (e.g., wellhead protection areas) and karst areas; however, specific considerations to prevent pollution should be implemented.

LID BMPs for high risk areas

Use nonstructural BMPs as much as possible. High risk areas are areas where preventive nonstructural BMPs should be emphasized. These nonstructural BMPs work to prevent stormwater generation from the outset. In addition, certain structural BMPs (e.g., riparian corridor restoration and native revegetation) can also be used to prevent stormwater generation.

Consider additional requirements for "hotspot" land uses. A useful first step toward protecting high risk areas and implementing LID is to require special requirements for any and all land uses known to be especially pollutant-producing (either to surface water or to groundwater), the so-called "hot spots." In the Model Ordinance (Appendix H), specific provisions are included which target these "hot spot" land uses, requiring that specific pretreatment measures designed to manage the specific types of pollutants being generated are implemented at each development site. Tables 8.2 and 8.3 summarize the land uses and pretreatment options for these "hot spot" land uses.

Table 8.2
Pre-Treatment Options for Stormwater Hot Spots

Stormwater Hot Spots	Minimum Pre-Treatment Options
Vehicle Maintenance and Repair Facilities	A, E, F, G
Vehicle Fueling Stations	A, D, G
"Fast Food" Restaurants	B, C, D, I, K
Convenience Stores	B, C, D, I, K
Storage Areas for Public Works	A, B, D, E, F, G, H
Outdoor Storage of Liquids	G
Commercial Nursery Operations	I, J, L
Salvage Yards and Recycling Facilities*	M
Fleet Storage Yards and Vehicle Cleaning Facilities*	M
Facilities that Store or Generate Regulated Substances*	M
Marinas*	M
Certain Industrial Uses (listed under NPDES)*	M
Other Uses or Activities Designated by Appropriate Authority	As Required

**Regulated under the NPDES Stormwater Program*

Note: As used in this list, the term "Regulated Substances" shall mean any substances regulated under federal, state, or county environmental, pollution control, hazardous substance, and drinking water laws and regulations.

Table 8.3
Minimum Pre-Treatment Options

Minimum Pre-Treatment Options	
A	Oil/Water Separators/Hydrodynamic Devices
B	Sediment Traps/Catch Basin Sumps
C	Trash/Debris Collectors in Catch Basins
D	Water Quality Inserts for Inlets
E	Use of Drip Pans and/or Dry Sweep Material under Vehicles/Equipment
F	Use of Absorbent Devices to Reduce Liquid Releases
G	Spill Prevention and Response Program
H	Diversion of Stormwater away from Potential Contamination Areas
I	Vegetated Swales/Filter Strips
J	Constructed Wetlands
K	Stormwater Filters (Sand, Peat, Compost, etc.)
L	Stormwater Collection and Reuse (especially for irrigation)
M	BMPs that are a part of a Stormwater Pollution Prevention Plan (SWPPP) under a NPDES Permit

Use BMPs that protect water temperature. Sensitive streams and lakes, such as trout stream and trout lake designations, should consider the issue of temperature when selecting BMPs. In selecting a BMP, the goal is ensuring that runoff discharged from land development in warm weather months does not increase stream and lake temperatures which can result in harmful impacts to fish and other aquatic life. Michigan's trout species can't survive for more than brief periods in water temperatures above 70 degrees F (and lower temperatures for some species).

The following BMPs should be considered to manage temperatures:

- Protect or restore the riparian corridor.
- Protect or revegetate sensitive areas.
- Stormwater disconnection.
- Implement structural BMPs that control volume through infiltration.

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