dcr
Massachusetts

IPSWICH RIVER
WATERSHED
ASSOCIATION

Ipswich River Targeted Watershed Grant Fact Sheet:

Three Low-Impact Development Case Studies

Prepared by:

Massachusetts Department of Conservation and Recreation and
The Ipswich River Watershed Association

Low Impact Development (LID) overview

Low impact development (LID) describes an array of land planning and development practices that manage stormwater and reduce pollution to streams, lakes, wetlands, and coastal areas. A key objective in LID is designing a landscape so that the movement, treatment, and storage of stormwater are similar to what occurs on a natural landscape. To meet this objective, engineers and developers design and install stormwater treatment practices that allow rain water to soak into the ground ("infiltrate") close to where it falls, and make use of soil and plants to filter and absorb stormwater. Sound LID design involves the preservation of natural areas, especially those in low-lying places that naturally collect stormwater, and the grading of the landscape to disperse runoff from roofs, roads, and parking areas into existing natural areas or specially planted areas (called "rain gardens" or "bioretention" areas). In areas where pavement is required, strategies are used to minimize the area of pavement, and, in some cases, to use permeable paving materials that allow stormwater to infiltrate into the ground.

Stormwater-related problems LID can help address:

By promoting infiltration of stormwater, reducing overland runoff, and protecting vegetated areas, LID practices can help reduce each of the problems below, typically associated with conventional development:

Groundwater Depletion: Groundwater enables streams to continue to flow between rain storms and keeps wetlands saturated. When extensive paved surfaces and rooftops prevent rain from replenishing groundwater, stream and wetland levels can drop, endangering fish and wildlife.

Flooding: When rain water is unable to soak into the ground, the large volumes of runoff can exceed the ability of storm drains, culverts, and streams to transport it during large storms, potentially causing these structures to fail and inundating roads and other developed areas.

Erosion: When stormwater cannot soak into the ground, it runs over surfaces in large quantities at high velocity, removing topsoil, scouring stream banks, and destabilizing slopes.

Nonpoint Source Pollution: When stormwater flows directly over land, it picks up sediment and other pollutants from sources such as pet waste, fertilizers, and automobile by-products that can contaminate streams, lakes, wetlands, and coastal areas.

LID considerations for new development

Architects, builders and planners have many options when incorporating LID into new construction projects. One of the most effective strategies is to leave as much of the land as possible undeveloped, by clustering buildings together on only a portion of the available land and establishing legal protections that ensure the undeveloped parts of the parcel remain in their natural condition. Also, during site excavation, underground drywell systems can be installed to store rooftop runoff until it can slowly absorb into the ground. Roads and driveways can be designed to be shorter or narrower than found in typical construction to reduce the area of paved surfaces. Also, by eliminating curbs or adapting their design, planted road edges and parking lot islands can be used to collect and infiltrate stormwater, which reduces or eliminates the need for catch basins and underground storm drain systems.

Some LID design strategies require waivers from local zoning, land use, or building regulations which were often put in place before the benefits of LID were well understood. As a result, incorporating LID into new development may require spending longer periods of time, and sometimes more money, during the permitting phase of a project. These costs are often recuperated during the construction phase, because dispersed, natural stormwater treatment systems are generally less costly to build than centralized, conventional stormwater infrastructure. Also, as the benefits of LID become increasingly recognized, local, state, and federal regulations are being revised to provide incentives for LID design choices and make it easier and less costly to obtain approvals for these designs. Like all stormwater treatment practices, LID practices need to be maintained in order for them to perform optimally. The expected lifespan of the practices and the cost and time associated with maintenance should be clearly understood and planned for, during design.

New developments can save open space by clustering homes and minimizing paved surfaces.

LID considerations for retrofitting existing development

Opportunities to use LID in areas where development and critical infrastructure already exist can be challenging. In these cases, catch basins and storm drains have usually been installed to flush stormwater directly into nearby streams and wetlands. A primary LID retrofit strategy is to redirect stormwater away from existing storm drains and toward natural or constructed planted areas, where it can infiltrate into the ground or be taken up by plants. Subtle changes to site grading or small alterations of road edges may be all that is required to change stormwater flow paths. LID strategies can also be incorporated into existing development by replacing traditional pavement with "pervious" paving materials, designed to allow stormwater to soak through, into the ground. (However, if the underlying soils are severely compacted, that will limit the infiltration of stormwater.) In areas where groundwater replenishment isn't a critical concern, another LID option is installing vegetated roof tops, called "green roofs," on buildings that are structurally capable of handling the load. This not only reduces stormwater runoff, but can insulate the building, provide pockets of habitat for birds or insects, and improve views from neighboring buildings. However, by intercepting rainfall, green roofs can also reduce the amount of rainfall that replenishes groundwater. For more information on green roofs, see Ipswich River Targeted Watershed Grant Fact Sheet: Green Roof Case Study.

Installing rain gardens along streets to collect run-off is a common retrofit.

Retrofits may be more expensive than incorporating LID into new construction because builders must work around or upgrade existing drainage systems. LID retrofits may be most cost-effective to install if major reconstruction is already planned for a site. In many cases, LID retrofits in highly developed areas will not be able to treat and infiltrate all the runoff from larger storms. As a result, LID retrofit features are often designed to direct stormwater that exceeds their capacity back into the traditional storm drain system. As with LID in new development areas, LID practices in retrofit areas need to be maintained in order to perform optimally, and the expected lifespan of the practices and the cost and time associated with maintenance should be understood and provided for before construction begins.

Ipswich River Targeted Watershed Grant Case Studies

A watershed is an area of land in which all surface and most ground water flows downhill to a common point, such as a river or stream outlet, lake, or estuary.

As part of a demonstration project designed to showcase practices that can help improve low-flow and water quality conditions in the Ipswich River and its tributaries, the Massachusetts Department of Conservation and Recreation (DCR), with funding from the United States Environmental Protection Agency (EPA) under a cooperative agreement, implemented four LID case study projects. The purpose of the projects was to assess, quantify, and demonstrate the benefits of LID. Three of the LID projects are described in this fact sheet. The fourth, a green roof, is the subject of a separate fact sheet: Ipswich River Targeted Watershed Grant Fact Sheet: Green Roof Case Study. For more information about the cooperative agreement, funded under the EPA Targeted Watersheds Grant Program, please see the last page of this publication.

The Ipswich River Watershed, in northeastern Massachusetts, has suffered from extreme low-flow condtions in recent decades.

Partridgeberry Place LID Subdivision

Project Lead: Massachusetts Department of Conservation and Recreation
Project Funding: U.S. Environmental Protection Agency
Project Partner/Developer: The Martins Companies
Project Design/Engineering: Meridian Associates
Data Collection and Analysis: Geosyntec Consultants

Partridgeberry Place is a new residential development in Ipswich, Massachusetts, which showcases many important LID design principles, providing an opportunity to study the impact of these design features on stormwater runoff. Using a design by Meridian Associates, the Martins Companies built Partridgeberry Place as a "cluster development" on a 38-acre parcel.

Clustering refers to setting aside a portion of a buildable parcel – using deed restrictions or other legal measures – to ensure that it remains undeveloped, in exchange for increasing the density of the layout of the buildings and roads on the rest of the parcel. This often saves money by reducing the total cost of land clearing, site grading, and road infrastructure and provides aesthetic and environmental benefits associated with protecting natural areas.

At Partridgeberry Place, twenty houses are clustered on 0.2-acre lots around a small wooded hill, and 28 acres of woods behind the houses were left undeveloped and protected as conservation land. In addition to the cluster design, these LID features were included in the original design:

- Front, side, and rear setbacks to property lines are 10 ft., 10 ft., and 5 ft., respectively – much less than in the original one-acre zoning.
- All 20 homes share a common septic system, eliminating the need for septic fields on each lot.
- Pavement is minimized by the cluster design and by using narrow roads (18 ft.) and very short driveways (approximately 20 ft.).
- All rooftop stormwater drains to drywells, and from there infiltrates directly into the ground, rather than becoming surface runoff.

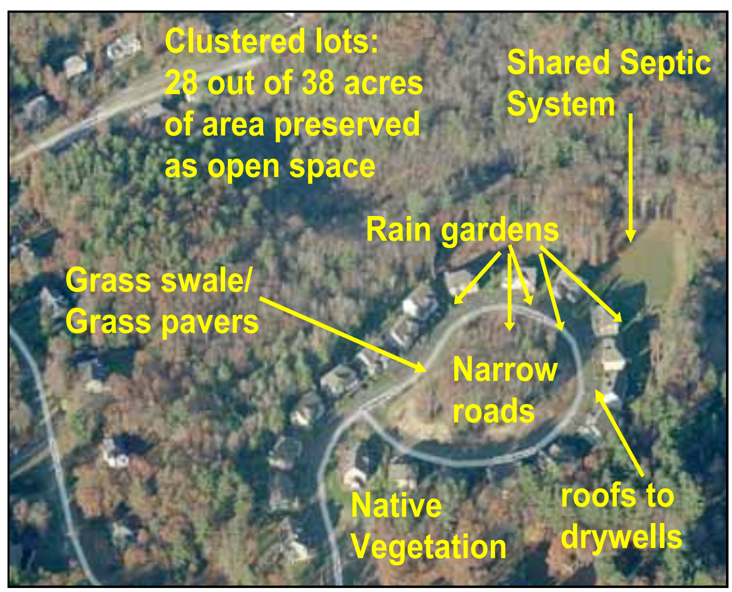
Lots in Partridgeberry Place are clustered to maximize open space.

During construction, DCR contracted with the Martins Companies to include these additional LID strategies:

A "grass paver" swale was installed along one side of the street. Grass pavers are a plastic matrix imbedded in the soil that prevents it from becoming compacted and impermeable to stormwater by heavy foot traffic or vehicles. (Note: Since the completion of the monitoring study, this practice has been replaced with a cobble road edge.)

A large raingarden was installed to capture any runoff from the grass swale that does not infiltrate through the grass pavers, providing another opportunity for this stormwater to infiltrate, before overflowing into a detention pond.

Three lots in Partridgeberry Place include rain gardens to collect and absorb rain falling on the driveway.



LID Features at Partridgeberry Place. (Note: Since the completion of the monitoring study, the grass pavers have been replaced with a cobble road edge.)

Monitoring and Modeling

DCR contracted with Geosyntec Consultants to study surface runoff at the site, a process that involved taking physical measurements and using a computer model to evaluate runoff patterns. To measure the volume and rate of stormwater runoff, flow gauges were placed at the inflow and outflow points in all the major stormwater management features around the property. Additionally, a flow gauge was installed in a forested part of the property to measure stormwater flow in the undisturbed or "predevelopment watershed" condition. Lastly, a rain gauge was installed on site to track all rainfall during the study period. Data were collected for 44 storms of various sizes during the summer of 2008.

Using the data collected from the site, Geosyntec Consultants developed a computer model that could simulate and compare how much runoff would be produced from the following four conditions:

- **The Pre-developed Condition:** The whole 38-acres is fully-forested.
- **The LID Subdivision:** Partridgeberry Place as it was built, with cluster design and LID features.
- **A Cluster-Only Subdivision:** A 20-house subdivision with clustering identical to Partridgeberry Place, but with conventional stormwater management features, such as curbs and catch basins, instead of LID features (i.e., no roof drywells, swales, or rain gardens).
- **A Conventional Subdivision:** A 20-house subdivision with 1-acre lots for every house and conventional stormwater management features (e.g. curbs and catch basins). No clustering or LID.

For these four conditions, the total volume and peak rate of stormwater runoff were compared for a range of increasingly large storm sizes: 2-year, 10-year, 25-year, 50-year, and 100-year storms (these are storms that occur, on average, every 2 years, 10 years, 25 years, 50 years, and 100 years). By predicting the runoff patterns that each site design would produce, the study characterized how effective the LID features and clustering designs were at reducing runoff compared to conventional development and how well they served to mimic the undeveloped condition.

Water was measured as it passed through V-notched weirs (pictured) and other structures.

Partridgeberry Place Key Findings

How do the runoff volumes and peak runoff rates for the four development alternatives differ?

Not surprisingly, the pre-developed condition generated the least amount of total runoff and the lowest peak rate of runoff for all storm sizes. This means that a fully forested site would allow the most rainwater to either be taken up by plants or infiltrate into the ground, instead of running off after a storm. In fact, researchers observed that the forest was so effective at capturing and infiltrating stormwater, that for storms less than ¼-inch (which represented 2/3 of the 44 storms during the study period), all the rainfall either infiltrated or evaporated. In other words, no runoff was generated by the forest during most storms.

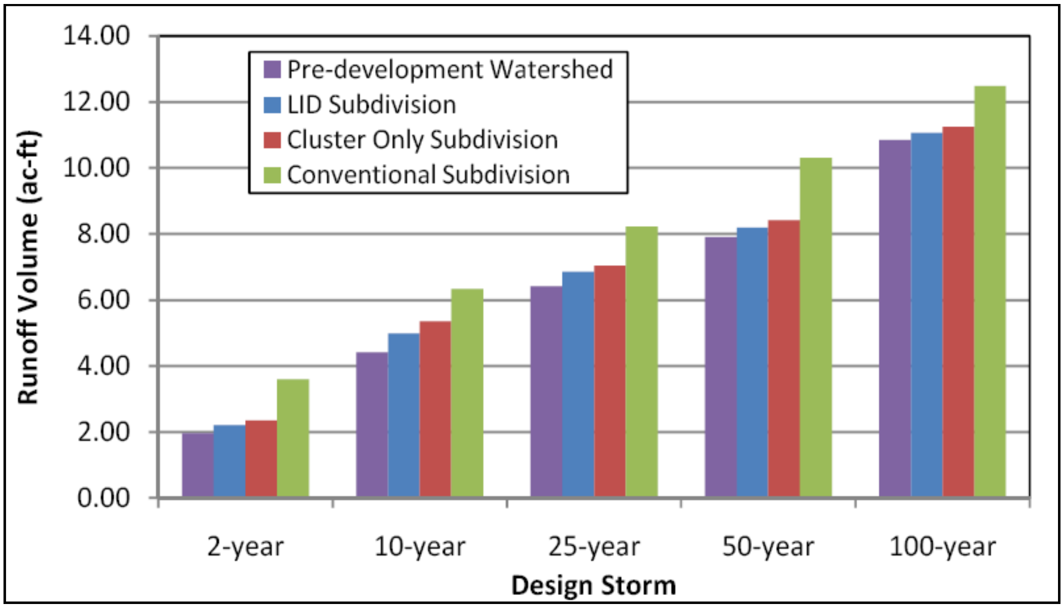
Central rain garden after a storm

The LID Subdivision and Cluster-Only Subdivision behaved similarly to each other, producing slightly more total runoff volume and slightly higher peak rates (measured in cubic feet per second) of stormwater flow than the undeveloped condition. The LID Subdivision produced slightly less runoff and slightly lower peak rates than the Cluster-Only Subdivision for all storms, because additional LID practices, such as rain gardens, roof drywells, and a grass paver swale, were used to manage stormwater.

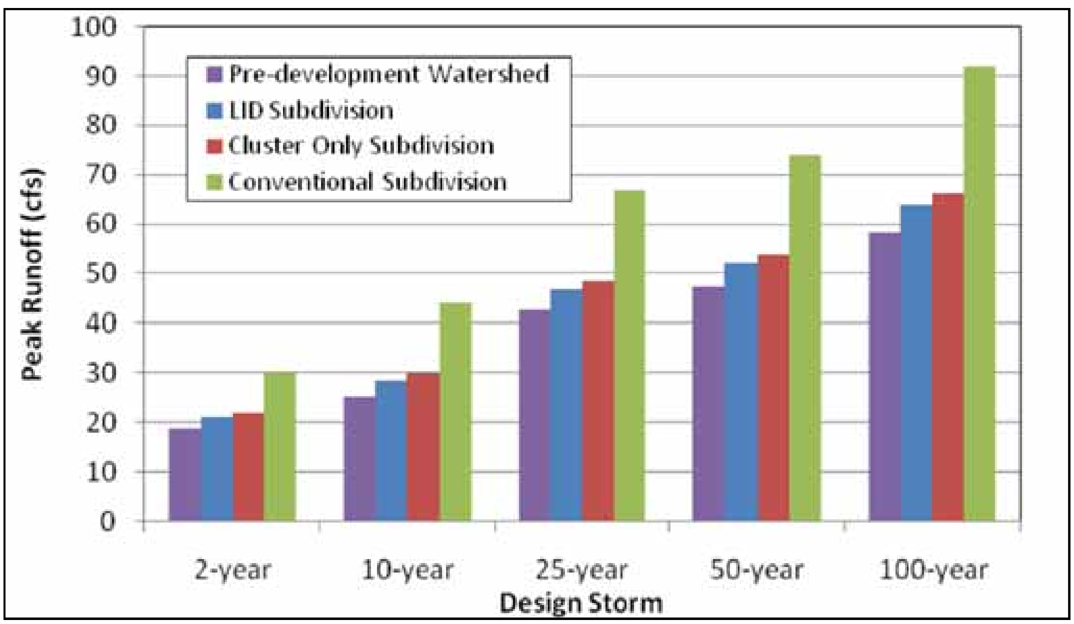
In contrast, the Conventional Subdivision produced significantly more runoff and significantly higher peak rates than all the other scenarios. The greater runoff and peak flows can be explained by the use of more pavement, more site clearing, and conventional stormwater management technologies that direct runoff from roofs, driveways, and roads directly into piped stormwater systems.

These findings suggest that clustering – preserving large areas in their natural condition and reducing areas of pavement – can go a long way toward minimizing the harmful changes to runoff patterns that can result from conventional development. Incorporating LID stormwater features into a cluster design to filter and infiltrate runoff can help even further approximate, though not replicate, the hydrology of the pre-developed site.

Total volume of runoff from modeled storms, in acre-feet



Peak rate of runoff from modeled storms, in cubic feet per second



Silver Lake Beach LID Retrofit

Project Lead: Massachusetts Department of Conservation and Recreation
Project Funding: U.S. Environmental Protection Agency
Project Partner: Town of Wilmington, MA, Department of Public Works
Project Design/Engineering: Geosyntec Consultants
Project Construction: Cali Corporation
Data Collection and Analysis: U.S. Geological Survey

The town beach at Silver Lake, a 28-acre pond in Wilmington, MA, was frequently closed due to high levels of *Escherichia coli* (*E.coli*) bacteria believed to be from polluted stormwater runoff. *E. coli* are associated with human or animal feces and can be harmful to humans upon contact. The major sources of these bacteria were thought to be from stormwater runoff, which carried feces from geese and other water fowl that browsed near the swimming area, and pet and wildlife waste from the surrounding neighborhoods. In each of the eight summers leading up to the LID renovations described here, high bacteria counts had required the town to close the beach for a week or more. In 2005, the Town of Wilmington entered into a partnership with DCR to redevelop the beach parking lot, which was badly in need of repair, incorporating the numerous LID practices described below to reduce the amount of polluted runoff entering the lake.

In 2005, the Town of Wilmington incorporated a number of LID practices to reduce the volume of polluted runoff entering the lake from the Silver Lake beach parking lot and surrounding area.

LID practices installed at Silver Lake Beach

"Daylighted" stormwater drainage pipes

Parts of two drainage pipes that carried stormwater from the parking lot and surrounding neighborhood directly into the lake were "daylighted." Daylighting refers to replacing an underground pipe or culvert with an above-ground feature. In this case, the last section of each pipe was replaced with a planted swale that filters the collected stormwater through vegetation and exposes it to sunlight. This helps break down bacteria and allows some stormwater to infiltrate into the soil before reaching the lake. One of the swales also replaced a grassy area that had served as a feeding area for geese. The steep sides of the swale and the higher vegetation discouraged geese from gathering, thereby removing a large source of fecal matter.

Swale under construction

Permeable pavement and bioretention cells

The town also replaced the conventionally paved beach parking lot, which was in need of resurfacing, with a combination of permeable pavers, porous asphalt, conventional asphalt, and bioretention cells.

Half of the original asphalt lot was replaced with a combination of permeable paving stones in the parking spaces and porous asphalt in the driving lane, all over a 12" base of crushed stone. The other half of the parking lot was repaved with conventional (impermeable) asphalt and graded so that runoff drains to the porous half of the parking lot or to bioretention areas, which were installed as traffic islands throughout the parking lot and around its periphery to collect and absorb overflow runoff.

In an overflow parking area to the side of the main parking lot, two patches of additional permeable paving materials were installed: Gravelpave™ – gravel reinforced by a plastic matrix to prevent compaction and retain permeability; and Flexi-Pave™ – a flexible porous paving material made from crushed recycled tires and stone.

The many permeable surfaces and bioretention cells allow stormwater to infiltrate into the ground, where pollutants can be broken down by natural processes.

Monitoring Study and Research Questions

DCR contracted with the U.S. Geological Survey (USGS) to monitor groundwater beneath the parking lot to make sure it would not become contaminated by the runoff infiltrating through the porous pavement. USGS installed a series of observation and sampling wells in the parking lot to assess the concentrations of chemicals commonly found in stormwater runoff from residential areas or vehicles, including phosphorus, nitrogen, dissolved metals, and petroleum hydrocarbons. Samples were collected for five months prior to the start of construction and for one year after construction was complete. During the study period, the parking lot was used heavily during the summer and sparingly in the winter. The permeable pavers and porous asphalt sections of the parking lot were cleared of snow but were neither sanded nor salted during the winter.

DCR also consulted with the Wilmington Board of Health to track its sampling for *E. coli* in the water at Silver Lake beach. The Board of Health tests water quality samples at the beach once a week during the summer and closes the beach for swimming if bacteria levels considered dangerous for human contact are detected. Lastly, Geosyntec performed infiltration tests on all the permeable paving surfaces to assess the rate at which stormwater flows through the porous materials.

Silver Lake Beach Key Findings

Do the combined effects of the LID retrofits help reduce beach closures at the swimming area?

Yes. In the five years between project completion and the time of this publication, there were no beach closures at Silver Lake due to *E. coli*, suggesting the retrofit work substantially reduced the amounts of bacteria entering the lake from the combined sources of stormwater and Canada geese. [It should be noted that the beach was closed one time following a bloom of blue-green algae, which can be toxic and is usually associated with an influx of phosphorus or nitrogen, found in fertilizers, wastewater, and in nature.]

Are the four types of permeable paving materials infiltrating as designed?

Yes. Infiltration tests were performed on all four surfaces, soon after installation and again during the following two summers, to determine the rate at which water could pass through each surface. All four permeable surfaces infiltrated as well as, or better than, designed, depending on the paving material, with infiltration rates ranging from 49 inches per hour to almost 10,000 inches per hour – all well above the rate that stormwater would build up over these surfaces.

Did installing permeable paving materials increase the risk of groundwater contamination?

No: The monitoring showed no evidence of groundwater contamination resulting from the installation of the permeable materials in the parking lot. While these results are encouraging, further study on this topic is recommended, as the present study was limited by small sample sizes and a short study period.

Silver Lake Neighborhood LID Retrofit

Project Lead: Massachusetts Department of Conservation and Recreation
Project Funding: U.S. Environmental Protection Agency
Project Partner: Town of Wilmington, MA, Department of Public Works
Project Design/Engineering: Geosyntec Consultants
Project Construction: Cali Corporation
Data Collection and Analysis: U.S. Geological Survey

Another LID retrofit project was undertaken near Silver Lake in Wilmington, across the water from the town beach, in a 3-acre residential neighborhood that borders the lake. The Town of Wilmington partnered with DCR to demonstrate practices that could help reduce the amount of stormwater entering the lake from the rooftops, driveways, and streets in this neighborhood.

Twelve rain gardens and two strips of permeable pavers were installed in front of homes, in the public right-of-way, along the two streets of the neighborhood. Stormwater from rooftops, driveways, and roads, which would otherwise flow into catch basins and discharge directly to the lake, was redirected into the rain gardens and pavers and allowed to infiltrate. Under-drains below the permeable pavers and overflow drains from the rain gardens directed excess stormwater back into the original storm drain system. In addition to reducing pollution entering Silver Lake, the rain gardens and permeable pavers were also designed to help reduce frequent street flooding that occurred in the neighborhood.

Permeable pavers along Silver Lake Ave. sit on top of stone beds that capture and filter runoff and allow it to soak into the ground.

Communication with Residents

The town-owned right-of-way where the rain gardens were located extended into the front yard of many of the homes. As a result, most of the rain gardens appeared to be part of the residents' landscaping. DCR and the Wilmington Department of Public Works sent fliers and held neighborhood meetings to inform the residents of the purpose and nature of the project, solicit their feedback during the planning stages, and request their participation as stewards of the gardens after the first three years (the project contractor, Cali Corporation, maintained the LID features for three years after installation).

Rain gardens on Silver Lake Ave. and Dexter St. collect rain water that flows off the street and allow it to slowly soak into the ground.

Letters updating the residents on the status of the project were mailed at several points during the project. Residents were also invited to participate in a "Rain Garden Maintenance Party," where they were invited to pick out additional plantings to enhance the rain gardens and learn about the yearly maintenance requirements. Residents from about half the homes on the two streets participated in the day, and the gardens appeared to be well-maintained during the project's fourth summer, under the care of the neighborhood residents.

Monitoring Study and Research Questions

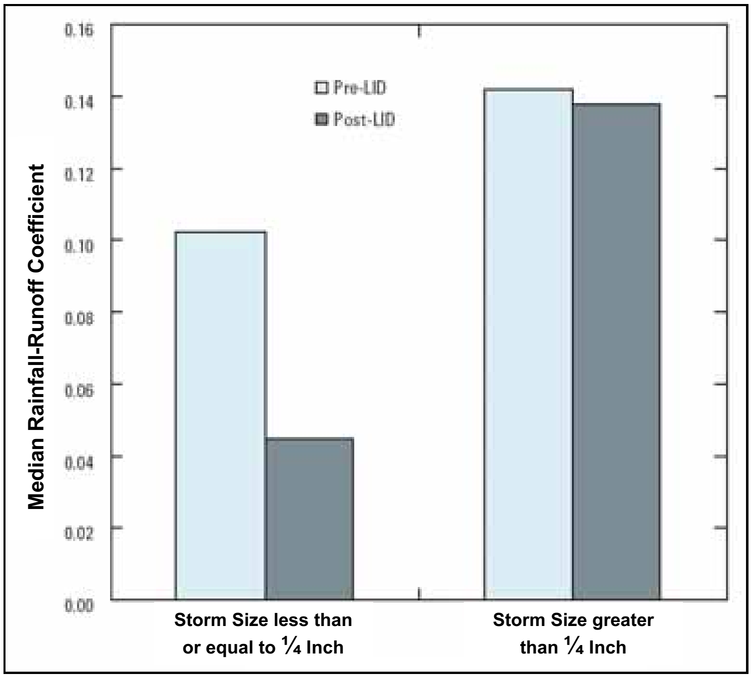
DCR contracted with the U.S. Geological Survey (USGS) to monitor the volume and quality of stormwater that was discharged from the neighborhood to the lake through a storm drain. USGS researchers installed a rain gauge to measure the volume of rainfall, along with equipment in the storm drain to continuously monitor runoff volumes from the neighborhood. Additional equipment in the storm drain was used to capture water quality samples during the larger storms, to measure concentrations of phosphorus, nitrogen, dissolved metals, petroleum hydrocarbons, and bacteria. Monitoring was conducted for four months prior to the LID retrofit work and fourteen months after the work was completed. Similarly sized storms from before and after the retrofit work were compared to see if there were differences in runoff volume and pollutant concentrations. Researchers also calculated the percent of total rainfall during each storm that entered Silver Lake through the storm drain (the "runoff coefficient").

Location of LID features and the monitoring site in the Silver Lake neighborhood

Silver Lake Neighborhood Key Findings

Do the rain gardens and permeable pavement help reduce runoff?

The answer depends on the size of the storm. The findings suggest that the rain gardens and permeable pavers were able to measurably reduce the volume of runoff from small storms (rainfall less than or equal to 0.25 inches). Prior to the LID retrofits, all storms – even small ones – produced some runoff from the neighborhood. After the retrofits, 33% of small storms produced no runoff at all. In addition, runoff coefficients calculated for small storms were found to decrease from a median of 10% prior to the LID retrofit work to a median of 4.5% after the retrofit. Lower runoff coefficients mean less water is flushing directly into the lake and more water is soaking into the soil, where it is either taken up by plants or recharged to the groundwater. In contrast, in the larger storm categories there were no observable differences in runoff coefficients before and after the LID retrofit work. This suggests that during larger storms, much of the runoff either bypassed the LID features or overflowed from them. This could have been the result of debris blocking the inlets, sediment build-up that reduced infiltration rates, or perhaps insufficient total rain garden area. This finding underscores the importance of proper design and maintenance of LID features.



The above graph shows the percent of total rainfall during each storm that entered Silver Lake through the storm drain (the "runoff coefficient") before and after the LID features were installed.

Do the rain gardens and permeable pavement help reduce pollutants that eventually go into Silver Lake?

The answer is not clear cut. While the data show that the rain gardens and permeable pavement did not significantly reduce pollutant concentrations or loads of nutrients, metals, petroleum hydrocarbons, or fecal bacteria, this conclusion is based on a limited data set. The storms that were sampled for pollutant concentrations were generally the larger storms, because these were much more likely to produce enough runoff for sampling purposes. As a result, the study may underestimate the water quality benefits associated with reducing the runoff volume from storms up to 0.25 inches – which represented about 60% of all the storms that were monitored.

The Ipswich River Targeted Watershed Grant

In 2004, through its Targeted Watersheds Grant Program, the United States Environmental Protection Agency (EPA) provided $1 million through a cooperative agreement to the Massachusetts Department of Conservation and Recreation (DCR) to demonstrate and study practices to help conserve water, reduce storm water pollution, and increase groundwater recharge throughout the Ipswich River watershed, in northeastern Massachusetts. Under this cooperative agreement, four low impact development (LID) and five water conservation projects were undertaken by DCR in cooperation with EPA, the United States Geological Survey (USGS), eight municipalities, the Ipswich River Watershed Association, and other cooperating partners. The projects were designed to (1) implement and quantify the benefits of LID and water-conservation techniques and (2) evaluate the impact of wide-spread application of these techniques throughout the watershed, using computer modeling simulations. Additional funding for this work was provided by DCR; USGS; the Ipswich River Watershed Association; and the towns of North Reading, Reading, Topsfield, and Wilmington. In-kind support was provided by DCR; the towns of Hamilton, Ipswich, Middleton, North Reading, Reading, Topsfield, Wilmington, and the city of Peabody; AquaSave LLC; the Martins Companies; the North Shore Housing Trust (since merged with Harborlight Community Partners); and Rainwater Recovery.

This is one in a series of three fact sheets that describes the work conducted under the cooperative agreement. The complete series includes:

- **Ipswich River Targeted Watershed Grant Fact Sheet: Green Roof Case Study**
- **Ipswich River Targeted Watershed Grant Fact Sheet: Water Conservation Case Studies**
- **Ipswich River Targeted Watershed Grant Fact Sheet: Three Low-Impact Development Case Studies**

For more information on the Ipswich River Targeted Watershed Grant, including links to study results and other publications, please visit:

http://www.mass.gov/dcr/watersupply/ipswichriver/index.htm.

The Massachusetts Department of Conservation and Recreation (DCR), an agency of the Executive Office of Energy and Environmental Affairs, oversees 450,000 acres of parks and forests, beaches, bike trails, watersheds, and dams, whose mission is to protect, promote, and enhance our common wealth of natural, cultural, and recreational resources. To learn more about DCR, our facilities, and our programs, please visit www.mass.gov/dcr. Contact us at mass.parks@state.ma.us.

Commonwealth of Massachusetts
Deval L. Patrick, Governor
Timothy P. Murray, Lt. Governor
Executive Office of Energy and Environmental Affairs
Ian A. Bowles, Secretary
Department of Conservation and Recreation
Richard K. Sullivan, Jr., Commissioner

This publication was developed, and the work described in this publication was funded, under Cooperative Agreement No. WS – 97117501 awarded by the United States Environmental Protection Agency to the Massachusetts Department of Conservation and Recreation. EPA made comments and suggestions on this publication intended to improve its technical accuracy. EPA does not endorse any commercial product or service mentioned in this publication.