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# Municipal Climate Adaptation Guidance Series: Stormwater Management

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## Introduction

Climate models predict, and recent experience shows, that storm events will become more severe and more frequent resulting in more extreme weather conditions. When stormwater is discussed by a community, flooding is often part of the conversation. Flood probabilities are typically expressed using terms like “10-year” or “100-year flood”. What this means is that <u>every</u> year there is a 10% chance of a 10-year flood, a 1% chance of a 100-year flood and a 0.02% chance of a 500- year flood. The fact that both a 100-year and a 500-year flood hit York County within one twelve- month period in 2006 and 2007 serves to emphasize the importance of robust stormwater management that takes changing climate conditions into account. It can be difficult to decide where to start when a community is faced with the inevitability of weather events that will produce significant stormwater; with local roads and areas that already have stormwater management problems; and with multiple high priority needs, many of which require significant funding, to address the problem.

This section will introduce low impact development, a method to manage stormwater on-site; green infrastructure, using natural features to help manage stormwater; the Stream Smart Crossings program, a program that helps design road crossings that increase resilience to stormwater and that also supports aquatic connections to improve stream habitat; along with Best Management Practices for handling stormwater.

## Natural or Green Infrastructure

Because Maine has both low density development (in many areas) and dense urban development, sometimes within the same community, the inadequacies and expense of centralized water systems and the need for strategies to remove pollutants from water before discharge into local waterways is forcing many towns and cities to realize that constructing conventional stormwater systems or repairing roads that are damaged repeatedly cannot be the entire solution. Instead stormwater can be managed through a careful combination of building and not building new infrastructure. When Maine communities consider stormwater management, use of natural infrastructure, like forests and wetlands, should be among the strategies considered.

Natural infrastructure can be described in terms of ecosystems like forests, meadows and wetlands. Putting these natural systems to work in tandem with built systems can be both cost-effective and highly efficient. For example, a community could decide to evaluate land to determine where it may be best to avoid development rather than to have to build infrastructure to control stormwater. As Colgan, Yakovleff, and Merrill’s *Economics of Natural & Built Infrastructure Report*, 2013, states, cost-benefit analysis of this scenario shows that benefits fall into two categories: 1) avoided costs (not having to build costly infrastructure, no degradation to water quality) and 2) non-market benefits (such as value of wildlife habitat, scenic lands and healthy ecosystems). The costs would be those involved with not developing particular lands utilizing one or both of these methods: 1) Protection of riparian (waterway and lake) and wetland buffers through zoning and/or purchase of the land or development rights of the land and 2) Conservation easement (purchase of land or development rights of the land) of forested areas and meadows.

So how do natural systems actually work to control floodwater?

Forests slow runoff through friction and interception especially when trees are in leaf. Water that reaches the forest floor flows in different ways; some of it infiltrates directly into the ground, some evaporates, some is taken up by the plants in the forest, and some runs off to nearby wetlands, waterways or waterbodies. A mature forest can absorb up to 14 times more water than the equivalent area of grass.

Wetlands and vegetated riparian floodplains moderate flooding by buffering water flows and probably most importantly, by storing the runoff and releasing it slowly, which also aids in purification of the water. The case of Rutland and Middlebury, Vermont, as presented in the Colgan, Yakovleff, and Merrill 2013 report, is an interesting example of where wetlands worked to protect a community. During Tropical Storm Irene in 2011, a large wetland between the two towns protected Middlebury from flooding even though it was further downstream and could have seen even higher flows than Rutland which did experience much damage due to flooding. Wetlands and riparian areas also provide critical wildlife habitat which while not directly related to stormwater management are nonetheless assets and beneficial to Maine communities throughout the state.

Meadows, for the purposes of this document, are areas not dominated by trees that contain mostly grasses and herbaceous plants. Meadows are not a natural evolutionary state in Maine since they will be succeeded by forest if not maintained. However, meadows that are maintained (by annual mowing or other means) can provide stormwater storage and infiltration far beyond the ubiquitous mown turf grass which is nearly as impervious as pavement. Meadows provide settling of sediments through frictional resistance as water moves through the grasses, biofiltration (storage of materials containing pollutants within the plants' structure) and infiltration (improving water quality through absorption of water into groundwater which also decreases the volume of water exiting the site). Like wetlands, meadows also provide critical wildlife habitat.

Stream characteristics are also significant natural infrastructure factors when considering storm water management. Streams in their natural state meander and contain debris, both of which slow and buffer flood events. Natural streambeds also enhance biodiversity. Unfortunately, in order to control streams near developed areas, many waterways have been artificially straightened and lined with impervious materials like concrete to limit their natural tendency to migrate laterally over time. Straight channels allow water to move more quickly and to peak at a higher level than a natural channel would permit. As development of a waterway's watershed increases, natural infrastructure is lost and more area is covered with impervious surface, thus decreasing infiltration and increasing runoff into streams and rivers. This decreases the water quality of the river or stream and increases its 'flashiness' or response to flood events.

Numerous studies have shown the relationship between open space conservation and mitigation of downstream flooding. As noted in the Colgan, Yakovleff, and Merrill 2013 report, FEMA data used by Brody & Highfield's 2013 report for Land Use Policy show that communities that used open space conservation as a flood mitigation tool saved $200,000 in annual avoided flood damage. In addition, the types of costs associated with conserving land from development are typically less than building infrastructure to perform the same stormwater management and protection functions.

### Low Impact Development (LID)

When building new infrastructure, communities can invest in Low Impact Development (LID) which mimics natural systems using smaller decentralized built systems. LID is now an important part of EPA stormwater regulations and can achieve comparable or better results than conventional stormwater systems. LID is the most cost effective when done during new construction but it can be retrofitted into older development with good results as well.

According to the United States Environmental Protection Agency, LID is "an approach to land development (or re-development) that works with nature to manage stormwater as close to its source as possible. LID employs principles such as preserving and recreating natural landscape features, minimizing effective imperviousness to create functional and appealing site drainage that treats stormwater as a resource rather than a waste product." While LID (or IMP, Integrated Management Practice, which employs similar strategies) will not entirely replace the need for centralized treatment and disposal of stormwater, it can reduce the amount of water moving through the system in any given timeframe. In addition, it can provide solutions to site-specific needs. LID methods include:

- Innovations in roof designs such as green (vegetated) and blue (retains water and releases it slowly) roofs.
- Porous paving materials, such as permeable pavement or permeable pavers that allow water to infiltrate
- Biological water retention areas including rain gardens and artificial wetlands
- Vegetated buffer strips, dry or wet swales
- Level spreaders which are designed to disperse stormwater over a level shallow area to prevent erosion and capture sediment, often dispensing it evenly into a vegetated area for further treatment
- Stormwater planters or tree box filters
- Rain barrels or dry wells

Besides providing stormwater management, biological water retention areas also provide benefits like small-scale urban wildlife refuges and aesthetically pleasing landscapes. Street trees and vegetated buffer strips placed beside roads and within parking lots allow water infiltration, cool the air in summer and reduce air pollution. Permeable pavement and pavers allow infiltration and reduces formation of ice. LID can be simple like rain barrels that collect water off a roof for later use or rain gardens sized for a single site. Rain gardens collect runoff, detain it, and allow it to infiltrate with only high volume events experiencing runoff. They also serve as snow melt holders and are aesthetically pleasing.

In Maine, winter nearly always brings snow, which when climate change is factored in, can mean more extreme snowfall in shorter periods of time. The ability of communities to remove snow efficiently from roads, sidewalks and parking lots is always a concern of municipal officials. Adopting LID strategies can assist by providing places to store snow (vegetated buffer strips, rain gardens, swales) which will also infiltrate once the snow begins to melt.

Communities should follow these guidelines when considering LID:

- Minimize impervious areas (lower minimum street widths in residential areas, reduce parking requirements)
- Ensure adequate on-site snow storage is planned for and clearly designated on development plans prior to approvals
- Limit areas of clearing and grading when developing land (follow natural topology, restrict tree cutting to immediate building envelope and protect desirable trees)
- Minimize directly connected impervious areas (drain impervious areas as sheet flow to natural systems such as vegetated buffers, break up flow directions from large paved surfaces such as parking lots by utilizing breaks in curbing that empty into vegetated buffers or swales, collect roof runoff in dry wells or rain gardens)
- Manage stormwater at its source (break up drainage with numerous small systems to fit in with natural topology and drainage conditions)

## Stream Crossing Structures and Culverts

Culverts are of particular concern in Maine; The New England Environmental Finance Center's 2011 report, *A Financial Impact Assessment of LD 1725 Stream Crossings*, indicates a very large number of culverts throughout the state are undersized and unable to accommodate peak water flows during flood events and therefore are prone to failure. When culverts fail, roadways are washed away. Tropical Storm Irene caused the failure of 960 culverts in Vermont; damage to Vermont roads and bridges was estimated to exceed $700 million. Field surveys of road crossings in Maine also show that many Maine's culverts currently act as barriers to fish passage and other natural stream processes. Increasing the resilience of these structures to flood events not only protects important infrastructure it also helps to improve and maintain the habitat values of Maine's aquatic network.

Vermont's experience during Hurricane Irene provides a cautionary tale showing why Maine communities should carefully assess culverts in light of changing climate conditions when planning for stormwater control. Increasing levels of precipitation and increasing numbers of extreme precipitation events will overwhelm structures designed for historic climate conditions. Increasing amounts of impervious surface will also magnify the effects of stormwater. An inventory of the size, condition and location of culvert provides important baseline information for determining which culverts are the most important to repair, upgrade, and replace. Even without a systematic inventory of culverts and road crossings, local knowledge can probably offer up some chronic problem areas where culverts fail to handle current levels of precipitation and either overtop during storm events or fail completely and wash out. Either of these situations will cause disruptions to community life, economic conditions and emergency management services. Much of the state is covered by an inventory of road crossings on public roads done for the main purpose of assessing the crossings' impacts on fish passage. The inventory is available on-line and includes details such as size and condition along with pictures for each crossing. Inventory work is ongoing so if your town is not currently included, it may be soon; more information and the available data can be found here .

> Tools to Help with Culvert Sizing
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> 1. StreamStats in Maine:
> StreamStats is a Web application that incorporates a Geographic Information System (GIS) to provide users with access to an assortment of tools that are useful for a variety of water-resources planning and management purposes, and for engineering and design purposes.
>
> 2. Extreme Precipitation in New York and New England Tool: provides precipitation data for a given location including estimates for extreme precipitation. This tool can be used to find out how many inches of precipitation will fall during different storm events.
>
> 3. MaineDOT Culvert Sizing Guidance

There are many different ways to sort and prioritize culverts. You can prioritize based on the design perspective to determine which culverts should have diameters updgraded or from the management perspective to determine which crossings should be inspected or repaired first or a combination of approaches. Culvert and crossing prioritization should also include impacts to vulnerable populations from a disruption in service should a road become impassable because of a crossing failure. Some kind of inventory and prioritization will help with planning and funding for the needed work to create more resilience in the stormwater management infrastructure.

## **STREAM SMART CROSSINGS** (see Stream Smart Section for more detail on this approach)

Maine Audubon, in partnership with the Maine Department of Inland Fisheries and Wildlife and many other organizations including the Maine Department of Environmental Protection, has developed a program of workshops and materials for Maine's Stream-Smart program. Much of the material is available on-line and gives extensive direction and guidance on replacing aging or failed stream crossing structures or placing new correctly-sized and sited structures (please the References section of this document). Maine's Stream-Smart Program recommends the following rules for stream crossing structures (known as the Four S's):

- Span the stream
- Set the elevation correctly
- Slope should match the natural stream
- Substrate in the crossing

There are partnership opportunities for funding and technical assistance when using Stream Smart design for a crossing. For more information contact the Maine Coastal Program or the Habitat Restoration coordinator at The Nature Conservancy.

While mapping, assessing existing culverts and prioritizing culvert replacement methodology can vary, depending on a community's needs, following the Stream Smart principles helps to insure the overall health of Maine's stream systems along with creating more resilience in the transportation infrastructure to changing climate conditions.

The Stream Smart principles are intended to help communities and land owners avoid common problems with stream crossing structures such as:

- Pinching the stream (inadequate structure span) which can cause the structure to become perched and lead to scour or to fail completely during high-volume precipitation events
- Incorrect elevation which can impede the flow downstream
- Slope that doesn't follow the stream's natural slope which can cause sedimentation problems
- Structure bottom too high which impedes adequate flow and functionality as a natural stream

In addition, inadequate or improperly sited stream crossing structures can pose the following problems to fish and wildlife:

- Flows too fast or too steeply (fish or wildlife cannot pass through to go upstream)
- Flow can be too shallow (impediment to passage)

- Poses a physical barrier to wildlife (perched outlet, inlet blocked by debris, blockages can cause water to warm too much for coldwater fish species like trout)

Using Stream Smart principles not only helps to support conditions for Maine's abundant wildlife and fish through improved fish and wildlife passage it also adds resilience to stream crossing structures through capacity to handle increased flows.

### Best Management Practice (BMP)

No discussion of stormwater management would be complete without inclusion of BMPs – built infrastructure to control runoff. However, rather than focus on BMP designs, this section will discuss methods for communities to get the most out of BMP systems.

BMPs are often a large detention (meant to detain water temporarily before it is gradually drained into a storm sewer or waterway) or retention feature (meant to hold water indefinitely) constructed to control the rate of stormwater discharge from a site. These BMPs differ from the approach that LID takes since BMP considers runoff a waste product to be contained or disposed of whereas smaller LID systems mimic pre-development hydrological conditions and infiltrate water on-site. Other types of BMPs like sand traps and infiltration trenches or basins do perform infiltration on-site so in practice the line between BMPs and LID is blurred in functionality if not in aesthetics.

In Maine, all sites prior to new development should be assumed to have good condition groundcover, whether wooded or meadow and all sites post-development should be assumed to have poor since there is no guarantee that property owners will maintain the site in its best possible condition and because construction equipment compacts the soils on any developed site to some extent. Any site that was wooded within the last 5 years should be considered undisturbed forest for pre-construction run-off conditions and calculations regardless of any cutting that may have occurred prior to the development permit issuance.

Pretreatment devices installed on BMPs will remove unwanted materials from stormwater runoff prior to its entrance into the BMP and thus prevent failures due to sedimentation and blockage. Pretreatment solutions include upfront settling basins, a deep sump catch basin not in the series, or a maintainable filter. The pretreatment device should be set up so that when it requires maintenance, it will begin to fail. For best results, failure means the pretreatment device should not only stop collecting sediment but also will stop passing water through. The failure must be obvious so that the pretreatment device will be serviced.

The cold weather climate of Maine should be a factor when considering BMPs, for example, the design of infiltration systems should assume storage only and no exfiltration during winter months, where possible, the use of traditional overflows to a municipal system as backup in case of freezing, separation of infiltration BMPS from the road by more than 10 feet and use of small volume BMPs only where infiltration might seep under the roadway. When infiltration units are used with vegetation, fencing to protect the vegetation from salt and plowing is important.

All stormwater controls should be sized assuming annual maintenance only, as it rarely happens more frequently. Sizing should also take into account higher rainfall events such as the 50 and 100-year storm. Failure of BMPs is often due to lack of maintenance or poor design of the BMP such that the unit must essentially be replaced each time it requires cleaning. Another frequent contributor to BMP failure is lack of access to the BMP because it is on private land.

Maine communities can apply this checklist when considering a BMP:

- Is the BMP difficult to access by equipment?
- Is the BMP difficult to clean without complete renovation?
- Is there a maintenance easement to access the BMP?
- Is there an ability to see when the unit is full or clogged with sediment?
- Does the owner of the BMP understand the maintenance needs?
- Is there the ability to back charge the owner if the municipality must do the maintenance work?
- Is maintenance required too frequently due to under-sizing of BMP?
- Is the proposed maintenance burden on the owner too great (set up for failure)?

Important Considerations for Stormwater BMP Design

- Sized to treat all stormwater on-site, preferably for a 100-year storm event
- Formal equipment access
- Ease and minimal cost of cleaning
- Permanent maintenance easement
- Method and easy access for evaluation of maintenance
- Pretreatment devices strongly recommended to prevent clogging or sedimentation problems
- Provisions for groundwater monitoring and assessment of quantities of water removed along with estimates in the design of expected sediment quantities
- A detailed and reasonable Operations & Maintenance (O & M) plan should be developed

## FUNDING

An excellent way for a community to plan for funding stormwater management solutions is through Capital Improvement Planning (CIP). CIP is a budgeting process that any community regardless of its size can undertake on a yearly basis. While CIP is done on a yearly basis, it also provides a community with a budgetary vision for a 5–10 year horizon range and gives the community a big picture product.

## Other Options

There are other ways that a community can work to protect itself from the adverse effects of higher precipitation generating events. Working at the local level, communities can examine their ordinances and strengthen them with an eye towards stormwater protection that is balanced by natural infrastructure and LID. Starting with planning boards and municipal officials, educate the community about LID, natural infrastructure, BMPs and Stream-Smart crossings.

Using existing ordinances:

- Revise existing development controls through subdivision and site plan review ordinance changes to require retaining total runoff on each site. Please see the Model Site Plan Ordinance Addressing Stormwater Runoff included in this toolkit.
- If site plan review has not been adopted by the community, add it to the local ordinances. Please see the Model Site Plan Ordinance Addressing Stormwater Runoff included in this toolkit.
- Minimize site disturbance through ordinances that require clustering or conservation subdivisions and retention of open spaces
- Revise shoreland zoning ordinances to protect more than the minimum riparian buffer required by Maine State regulations
- Require that clearing limits and stockpiles be staked out on individual sites and ensure enforcement
- Review engineering calculations on site plans for overly optimistic pre and post runoff assumptions and/or require the developer to pay for engineering peer review of drainage calculations and site design.

Additional opportunities:

- Adopt guidance and design criteria using natural infrastructure for commercial and residential development
- Adopt LID requirements for development
- Set a good example on municipally owned properties
- Create a public education program and demonstration project using LID
- Hold a workshop for code enforcement officers, planning board members and the board of appeals members on Stream-Smart stream crossings and invite the general public
- Partner with land trusts and other land preservation organizations to permanently protect significant lands that have value for multiple reasons: wildlife habitat, water quality and stormwater control.

## References


**Economics of Natural & Built Infrastructure Report** (Colgan, Yakovleff, Merrill, May 2013, USM)
http://www.maine.gov/dacf/municipalplanning/docs/Economics_of_Natural_&_Built_Infrastructure.pdf

**Open Space Protection and Flood Mitigation: A National Study** (Brody, S. Highfield, W. 2013 as published in Land Use Policy, Volume 32, pages 89-95)

**Conservation Design for Stormwater Management (**Delaware Department of Natural Resources and Environmental Control, 1997)
http://water.epa.gov/polwaste/nps/upload/Delaware_CD_Manual.pdf

**A Financial Impact Assessment of LD 1725: Stream Crossings (**The New England Environmental Finance Center)
http://efc.muskie.usm.maine.edu/docs/ld1725_finanancial_impact_assessment.pdf

**Maine Stormwater Best Practices Manual**:
http://www.maine.gov/dep/land/stormwater/stormwaterbmps/

**U.S. Department of Environmental Protection, Low Impact Development**
http://water.epa.gov/polwaste/green/

**EPA's national stormwater calculator:**
http://www2.epa.gov/water-research/national-stormwater-calculator

**National Climate Assessment – Regional Projections 2012:**
http://nca2014.globalchange.gov/highlights#section-5682

**Assessing Vulnerability of Water Conveyance Infrastructure from a Changing Climate in the Context of a Changing Landscape Webinar:**
Download the slides.

**Maine's Sustainability Solutions Initiative at the University of Maine**:
Climate news: http://umaine.edu/maineclimatenews/

**Maine Stream Crossings:**
http://www.fws.gov/northeast/ecologicalservices/pdf/MaineStreamCrossings.pdf

**Maine Stream-Smart Program:**
https://sites.google.com/a/maineaudubon.org/stream-smart-road-crossing-workshops/
http://maineaudubon.org/wp-content/uploads/2012/04/StreamSmart-How-To-TechnicalGuidance.pdf

**Cornell University Extreme Precipitation in New York and New England:**
http://precip.eas.cornell.edu/

## References, continued

**UNH Stormwater Center, Virginia Commonwealth, and Antioch University New England – Forging the Link (Linking the Economic Benefits of Low Impact Development and Community Decisions):** http://www.antiochne.edu/wp-content/uploads/2014/11/LID-Economic-Benefits-Resource-Manual-2011.pdf