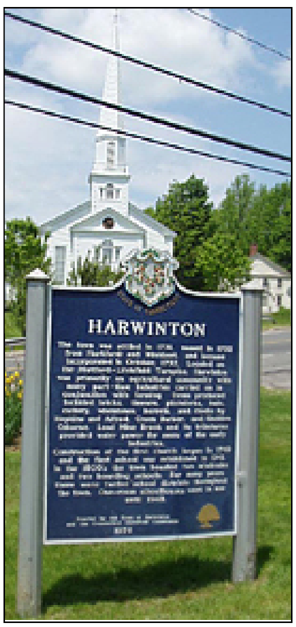
Date: March 1, 2011

HARWINTON

Public Educational Materials on Stormwater Management & Low Impact Development



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Date: March 1, 2011

This document contains information from authentic and highly regarded Low Impact Development sources, including results of independent observations of LID systems in the field by the author, Steven D. Trinkaus, PE. Sources are identified where this material has been used.

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This project was made possible by a grant from the Connecticut Department of Environmental Protection through the Farmington River Enhancement Grant Program.

The grant is intended to support the formation of a local committee to:

- review existing municipal regulations and ordinances, and
- draft recommended changes to remove barriers to low impact development (LID) and create opportunity for low impact development practices to be employed in Harwinton.

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1.0 Overview of Water Resources in the Town of Harwinton

The Town of Harwinton is located eastern portion of Northwestern Connecticut.   The western portion of the town is located in the Naugatuck River Watershed, while the eastern portion of the town is located in the Farmington River Watershed.   It is a rural community with mostly residential development, along with some commercial development located along the Route 118 corridor.

The surface water quality for the majority of the town is rated Class A (known or presumed to meet water quality criteria which support designated uses such as potential drinking water supply, fish and wildlife habitat, recreational use, agricultural and industrial supply, and other legitimate uses including navigation) as stated on map entitled "Water Quality Classifications Map of Connecticut, compiled by James Murphy; 1987" prepared for the Connecticut Department of Environmental Protection.

The majority of the town has a GAA groundwater classification which means that the groundwater is suitable for direct human consumption without the need for treatment. This information was also taken from the above referenced map.

There are three main watercourses in Harwinton, Leadmine Brook and Rock Brook which are tributary to the Naugatuck River and Poland River which is tributary to the Farmington River. The Naugatuck River forms most of Harwinton's western boundary.

The Town of Harwinton has a strong desire to maintain the high quality of the surface and groundwater in their community.

2.0 Introduction

2.1. Purpose of the Document

The purpose of this document is to provide an understanding of the direct and indirect adverse impacts of development and stormwater on the natural environment. It is generally understood that stormwater, when not properly controlled can cause pollution and adverse impacts on our environment. These impacts range from increased flows, which cause erosion of natural stream channels; to closures of water recreational areas due to high bacteria counts in the water. This document also discusses the benefits of Low Impact Development (LID) strategies and how these strategies could help the Town of Harwinton minimize the adverse impacts from stormwater.

2.2 What is Stormwater Runoff

Before we can learn about LID concepts, we need to have an understanding of the natural hydrologic cycle and how development affects the hydrologic cycle and causes adverse impacts to our environment.

The natural hydrologic cycle shows how water travels through our environment in the many forms that provide a myriad of environmental benefits. It is a continuous cycle of the movement of water in our environment.

There are five key elements to the hydrologic cycle: condensation, precipitation, infiltration, runoff, and evapotranspiration/rainfall abstraction. These occur simultaneously and, except for precipitation, continuously. The NASA's Observatorium website provides the following definitions for each element of the Hydrologic Cycle:

A. Condensation is the process of water changing from a vapor to a liquid. Water vapor in the air rises mostly by convection. This means that warm, humid air will rise, while cooler air will flow downward. As the warmer air rises, the water vapor will lose energy, causing its temperature to drop. The water vapor then has a change of state into liquid or ice.
B. Precipitation is water being released from clouds as rain, sleet, snow, or hail. Precipitation begins after water vapor, which has condensed in the atmosphere, becomes too heavy to remain in atmospheric air currents and falls. In many cases, precipitation evaporates as it falls through the atmosphere and returns as water vapor.
C. Infiltration is that portion of the precipitation that reaches the Earth's surface and seeps into the ground. The amount of water that infiltrates the soil varies with the degree of land slope, the amount and type of vegetation, soil type and rock type, and whether the soil is already saturated by water. The more openings in the surface (cracks, pores, joints), the more infiltration occurs. Water that doesn't infiltrate the soil flows on the surface as runoff.
D. Runoff is the amount of rainfall which is left after evapotranspiration and infiltration occur. Under natural conditions, 10-30% of the annual rainfall becomes runoff. As impervious areas increase, both evapotranspiration and infiltration are reduced, thus increasing runoff.
E. Evapotranspiration is water evaporating from the ground and transpiration by plants. Evapotranspiration is also the way water re-enters the atmosphere. Evaporation occurs when radiant energy from the sun heats water, causing the water molecules to become so active that some of them rise into the atmosphere as vapor. Transpiration occurs when plants take in water through the roots and release it through the leaves, a process that can clean water by removing contaminants and pollution. Rainfall Abstraction is the physical process of interception of rainfall by vegetation, evaporation from land surfaces & upper soil layers, evapotranspiration from plants, infiltration of rainfall into the soil surface and surface storage within natural depressions. Rainfall abstraction can be estimated as a depth of water on a site. (http://physics.ship.edu/~mrc/astro/NASA_Space_Science/observe.arc.nasa.gov/nasa/earth/hydrocycle/hydro1.html)

When development occurs on a site, many changes to the hydrologic cycle will result from the disturbance of the natural land form, the creation of impervious surfaces and the application of chemical compounds which can adversely affect our environment. All of these changes affect the stormwater which is generated on the site.

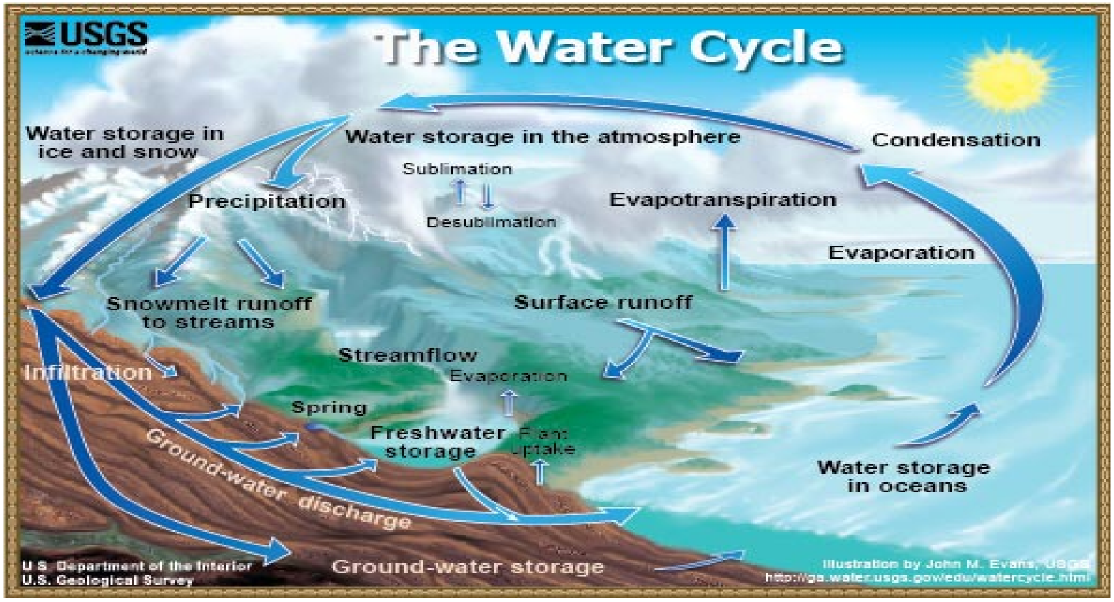

Figure 2.2.a – The Hydrologic Cycle

The 2004 Connecticut Stormwater Quality Document prepared by the CT DEP defines stormwater as follows:

"Storm water runoff is a natural part of the hydrologic cycle, which is the distribution and movement of water between the earth's atmosphere, land and water bodies. Rainfall, snowfall, and other frozen precipitation send water to the earth's surfaces. Storm water runoff is surface flow from precipitation that accumulates in and flows through natural or man-made conveyance systems during and immediately after a storm event or upon snowmelt. Storm water eventually travels to surface water bodies as diffuse overland flow, a point discharge, or as groundwater flow. Water that seeps into the ground eventually replenishes groundwater aquifers and surface waters such as lakes, streams and oceans. Groundwater recharge also helps maintain water flow in streams and wetland moisture levels during dry weather. Water returned to the atmosphere through evaporation and transpiration to complete the cycle."

When the stormwater is being generated by the natural environment, there are very little adverse impacts associated with stormwater. However, when development occurs on the land, there are profound impacts that occur which can significantly modify the natural hydrologic cycle. The adverse impacts can be summarized as reduced rates of infiltration, reduced evapotranspiration, increased rates and volumes of runoff, and increased pollutant loads in the runoff. These changes can be seen in Figure 2.2.b.

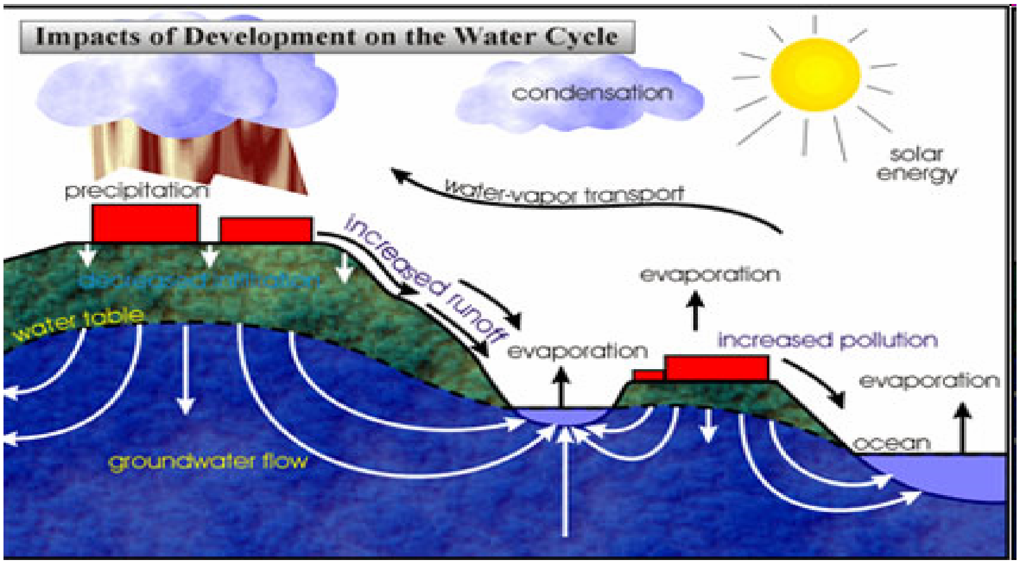

Figure 2.2.b – Changes to the Hydrologic Cycle as a result of development

It can be seen from Figure 2.2.c that as impervious cover increases, there is less base flow into the ground, less evapotranspiration from the vegetation and increased runoff from the impervious areas.

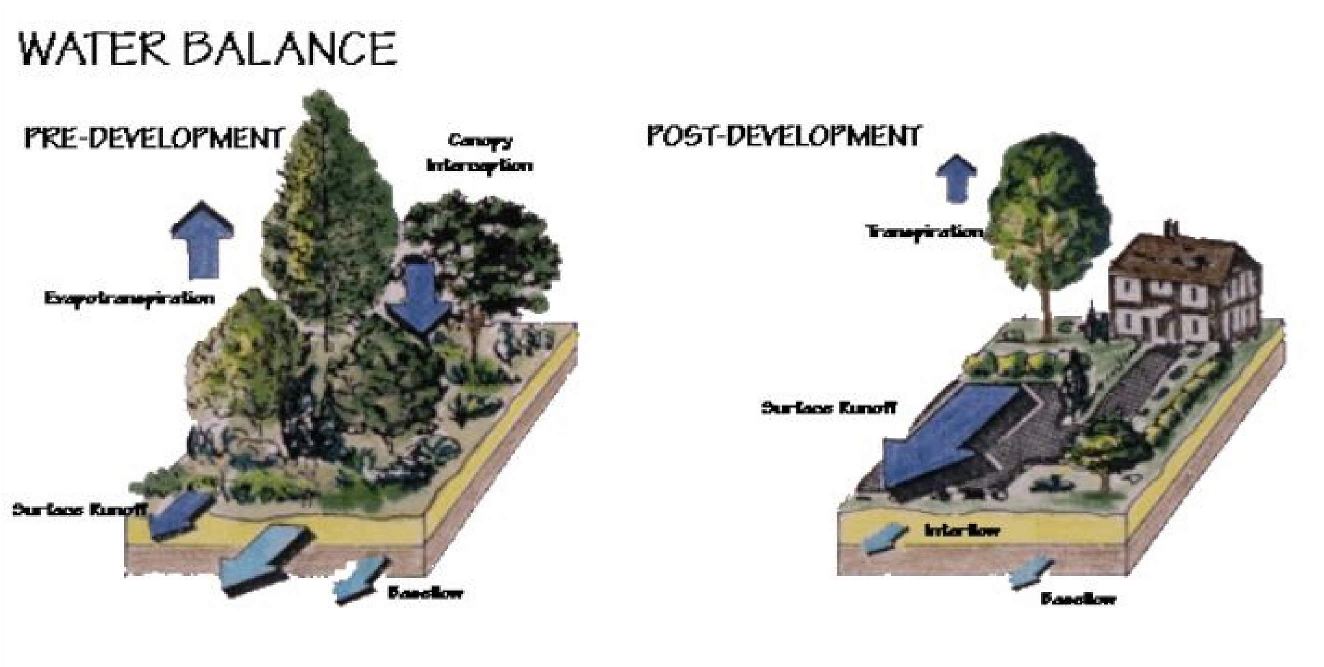

Figure 2.2.c – Effects of Impervious Cover on Water Balance

2.3 What are the Impacts of Development and Stormwater

Land development has the potential to create many adverse impacts on the environment both during the construction period and after construction has been completed. When land is cleared, and stripped of the natural organic layer on top of the soil, the soil loses its ability to infiltrate runoff, thus more runoff is created, which in turn increases the likelihood of erosion of the soil and subsequent sedimentation. After construction has been completed, the large, interconnected impervious area prevents rainfall from infiltrating into the ground. Because of this, more of the rainfall is converted to runoff, which is demonstrated in Figure 2.2.c.

While the addition of a small amount of impervious area on a single lot may not appear to create an issue, the cumulative impact of many small increases of impervious area can quickly become significant. It has been well documented that when the total impervious cover in a watershed is between 10% and 25% that the natural aquatic environment can be adversely affected. Once the impervious coverage exceeds 25% in a watershed, the adverse impacts to the aquatic ecological systems are often irreversible. There have been some studies which have shown that adverse water quality impacts can occur with impervious cover being between 5 – 7% (RI DEM Stormwater Document).

The following table highlights the typical percentages of impervious cover for various land uses.

Table 2.3.a – Typical Amounts of Impervious Cover Associated with Different Land Uses

Land Use	**Percent Impervious Cover**
Commercial & Business Districts	85%
Industrial	72%
High Density Residential (1/8 acre zoning)	65%
Medium-High Density Residential (1/4 acre zoning)	38%
Medium-Low Density Residential (1/2 acre zoning)	25%
Low Density Residential	
1 acre zoning	20%
2 acre zoning	12-16%
3 acre zoning	8%
5 acre zoning	5-8%
10 acre zoning	2.4%

(Source: RI DEM Stormwater Document, April 2010)

The 2004 CT DEP Stormwater Quality Document states the following adverse impacts which can occur in our environment due to changes in the Hydrologic Cycle:

Hydrologic:

- Increased runoff volume
- Increased peak discharges
- Decreased runoff travel time
- Reduced groundwater recharge
- Reduced stream baseflow
- Increased frequency of bankfull and overbank floods
- Increase flow velocity during storms
- Increase frequency and duration of high stream flows

Figure 2.3.a – Stream Channel Impact from increased runoff volumes (S. Hayden photo)

Stream Channel and Floodplain Impacts:

- Channel scour, widening and downcutting
- Streambank erosion and increased sediment loads
- Shifting bars of coarse sediment
- Burying of stream substrate
- Smothering of aquatic insects and fish eggs
- Loss of pool/riffle structure and sequence
- Man-made stream enclosures or channelization
- Floodplain expansion

Figure 2.3.b – Stream Channel Impacts (R.Claytor file photo)


Figure 2.3.c – Deposition of sediment in a wetland (S. Hayden photo)

Water Quality Impacts:

- Excess Nutrients (Nitrogen and soluble phosphorous)
- Sediments
- Pathogens
- Organic Materials
- Hydrocarbons
- Metals
- Synthetic Organic Compounds
- De-icing Constituents
- Trash and Debris
- Thermal Impacts
- Freshwater discharge to estuarine systems

Figure 2.3.d – Nutrient impacts in freshwater river

The water quality impacts associated with storm water runoff is called non-point source pollution. The United States Environmental Protection Agency defines non-point source pollution as follows:

Non-point source (NPS) pollution, unlike pollution from industrial and sewage treatment plants, comes from many diffuse sources. NPS pollution is caused by rainfall or snowmelt moving over and through the ground. As the runoff moves, it picks up and carries away natural and human-made pollutants, finally depositing them into lakes, rivers, wetlands, coastal waters, and even our underground sources of drinking water. These pollutants include:

A. Excess fertilizers, herbicides, and insecticides from agricultural lands and residential areas;
B. Oil, grease, and toxic chemicals from urban runoff and energy production;
C. Sediment from improperly managed construction sites, crop and forest lands, and eroding stream banks;
D. Salt from irrigation practices and acid drainage from abandoned mines;
E. Bacteria and nutrients from livestock, pet wastes, and faulty septic systems;
F. Atmospheric deposition and hydromodification are also sources of non-point source pollution.

The most common pollutants which are found in non-point source runoff are Litter, Sediment and Total Suspended Solids (TSS), Total Nitrogen (TN), Total Phosphorous (TP), Metals, such as Zinc (Zn) and Copper (Cu), Hydrocarbons, Thermal Impacts, Oxygen demanding substances and Pathogens. Each pollutant and its impact on the natural environment are stated below.

Litter

Litter while not causing toxic impacts on the environment, the presence of litter is an aesthetic issue that is not well received by the public.

Total Suspended Solids (TSS) and Sediment

Total Suspended Solids are particles dissolved in water. In excessive amounts it causes turbidity in water. The turbidity blocks light in the water column which causes reduced photosynthesis, which in turn reduces the oxygen levels in the water. Coarse and fine sediments can clog the gravel substrate in breeding streams thus affecting the biological community ability to reproduce. Common sources of TSS and sediment are runoff from construction sites, winter sanding operations, atmospheric deposition and decomposition of organic matter, such as leaves.

Nutrients

Excessive levels of Phosphorous in fresh water are a concern as these nutrients encourage excessive growth of plants and algae. When these plants die, the decomposition of the organic matter reduces oxygen levels in the water, thus adversely affecting the biological community in the water body. Nitrogen, in the form of nitrate, is a direct human health hazard and an indirect hazard in some areas where it leads to a release of arsenic from sediments. While not a major concern for freshwater systems, nitrate can cause environmental impacts in tidal regions, even though the source of nitrate can be far away from coastal regions. When the algae dies and sinks to the bottom, its decomposition consumes oxygen, depriving fish and shellfish in those deep waters of oxygen, a condition known as hypoxia. Sources of nutrients are organic and inorganic fertilizers, animal manure, biosolids and failing sewage disposal systems.

Metals

Metals in non-point source runoff are very toxic to aquatic life. The adverse effects of metals are far reaching for both aquatic and human health. Many metals can bioaccumulate in the environment, which can affect higher living organisms. While the concentration of zinc or copper in stormwater generally is not high enough to bother humans, these same concentrations can be deadly for aquatic organisms. Many microorganisms in soil are especially sensitive to low concentrations of cadmium. Cadmium is also very harmful to humans. Chromium is very toxic to fish and can cause birth defects in animals.

Of the above discussed metals, zinc and copper are the two metals which are found dominantly in non-point source runoff. Metals commonly bind themselves to sediment and organic matter in stormwater and thus are transported to the receiving waters. Since natural rainfall is slightly acidic, metal roofs or components on the roof can be a significant source of the metal concentrations in stormwater.

Hydrocarbons

Total Petroleum Hydrocarbons are highly toxic in the aquatic environment, especially to aquatic invertebrates. The primary sources of petroleum hydrocarbons are oil, grease and gas spills, along with vehicle exhaust. Polycyclic Aromatic Hydrocarbons are also toxic to aquatic life. The primary source of these hydrocarbons is the incomplete burning of fossil fuels. PAH’s generally deposited by atmospheric deposition on an impervious surface, especially large flat roof areas. When it rains, the accumulations of pollutants due to atmospheric deposition are carried off in the stormwater.

Thermal Impacts

Impervious surfaces, such as roofs and paved areas can heat up during sunny days and hold onto this heat. When rainfall occurs on these heated surfaces, the resulting runoff has its temperature raised. As this heated runoff is discharged into receiving waters, the temperature of the receiving water is raised to a level which can exceed the tolerance limits for fish and invertebrates, thus lowering their survival rates. Elevated water temperatures will also contribute to reduced oxygen levels in the water.

Oxygen Demanding Substances

Oxygen demanding substances are plant debris and soil organic matter which when they decompose in an aquatic environment require a significant amount of oxygen for the chemical reaction. This results in less available oxygen in the water for other aquatic organisms. Less than 5 mg O/l becomes harmful to fish.

Pathogens

Pathogens are bacteria and viruses, which can cause disease in humans. Most pathogens are found in discharges from overflowing sanitary sewers or in combined sanitary/stormwater systems. Both fecal coliform and enterococci are used as indicators for the presence of pathogenic organisms, yet their presence does not mean a pathogen is present, just that there is a higher risk of being present.

3.0 Overview of Low Impact Development

3.1 What is LID?

Low Impact Development (LID) is an ecologically friendly approach to site development and stormwater management that aims to mitigate development impacts to land, water and air. This approach emphasizes the integration of site design and planning techniques that conserve natural systems and hydrologic functions on a site.

The concept of Low Impact Development (LID) utilizes five major tools to reduce the impact of development on the environment. These primary tools are:

i. Encourage Conservation Measures,
ii. Reduce Impervious Areas,
iii. Slow runoff by using landscape features,
iv. Use multiple measures to reduce and cleanse runoff,
v. Pollution prevention

Each LID tool is enumerated below:

i. Encourage Conservation Measures

- Implement Open Space or Cluster Development Regulations to preserve large tracts of the site,
- Implement "Site Fingerprinting" to minimize land clearing & soil disturbance,
- Minimize soil compaction,
- Provide low maintenance landscaping & plant native species which will minimize the use of fertilizers and pesticides,
- Use Source Erosion Control measures

ii. Reduce Impervious Areas

- Disconnect impervious coverage to the maximum extent practical to encourage overland flow conditions across vegetated surfaces,
- Reduce pavement widths for local roads,
- Use Permeable Pavement, Porous Concrete, and Open Course Pavers for parking areas and other low traffic areas,
- Use Porous Concrete for sidewalks.

iii. Slow runoff by using landscape features

- Maintain Pre-Development Time of Concentration by long flow paths on vegetated surfaces;
- Minimize the extent of flow on impervious surfaces,
- Maintain and encourage overland flow conditions across vegetated areas for at least 75', where feasible.

iv. Use multiple measures to reduce and cleanse runoff

- Maintain pre-development infiltration rates by preserving those soils with moderate to high infiltrative capacities,
- Maintain existing vegetation to Maximum Extent Practical,
- Remove pollutants from runoff by flow thru vegetated systems, allow natural infiltration to occur,
- Encourage the use of rain gardens for roof runoff,
- Encourage the use of rain barrels or cisterns to collect & reuse runoff.

v. Pollution prevention

- Minimize applications of sand and salt on roads & parking areas,
- Use "Source Controls" such as weekly sweeping of large impervious areas,
- Minimize application of fertilizers on turf areas.

3.2 Measures to Evaluate the Effectiveness of LID

A primary objective of Low Impact Development is to mimic the pre-development hydrologic conditions on a site. At the current time, this objective is measured by two metrics. The first is the reduction of the post-development runoff volume to the pre-development runoff volume for the 90% rainfall event. The second metric is to match the Runoff Curve Numbers (RCN) for post-development conditions to pre-development conditions. Along with the matching of the RCN, it is also important to have the post-development time of concentration (Tc) match or closely approximate the pre-development Tc. By achieving this metric, there should be no or little change in the post-development runoff rate, which minimizes the need for detention facilities. In either case, the overall goal is to have a developed site mimic or come as close as possible to the pre-development hydrologic conditions. This condition is known as "Hydrologic Transparency".

3.3 Goals and Benefits of LID

The overriding goal of LID is to create developments which are in harmony with the natural environment while ensuring that the vision of the developer can also be achieved. The general goals for LID are listed below:

- Preservation of environmentally sensitive areas, and naturally vegetated systems to reduce changes to the hydrology of the watershed,
- Focus on maintaining natural drainage patterns as a key goal in the design of the site,
- Prevent direct adverse impacts to wetlands, watercourses (both perennial & intermittent), to the maximum extent practical,
- Minimize the extent of impervious cover and thus reduce the increases in runoff volume,

- Implement source controls for water quantity and water quality, while minimizing the extent of structural drainage systems,
- Create a landscape environment that is multi-functional for all users.

A primary benefit of LID is a better balance between Conservation of Natural Resources, Growth, Ecosystem Protection and the Public Health. There are many benefits associated with the adoption of Low Impact Development strategies for all of the stakeholders in the development field. The three primary stakeholders in the development field are the environment, the public, and the developer. The benefits of LID for each stakeholder group are stated below.

a. Environmental Benefits:
    i. Preserve the biological and ecological integrity of natural systems through the preservation of large extents of contiguous land,
    ii. Protect the water quality by reducing sediment, nutrient and toxic loads to the wetland/watercourse aquatic environments and also terrestrial plants and animals,
    iii. Reduce runoff volumes in receiving streams

b. Public Benefits:
    i. Increase collaborative public/private partnerships on environmental protection by the protection of regional flora and fauna and their environments,
    ii. Balance growth needs with environmental protections,
    iii. Reduce municipal infrastructure and utility maintenance costs (roads and storm water conveyance systems)

c. Developer Benefits:
    i. Reduce land clearing and earth disturbance costs, reduce infrastructure costs (roads, storm water conveyance and treatment systems),
    ii. Reduce storm water management costs by the reduction of structural components of a drainage system,
    iii. Increase quality of building lots and community marketability

4.0 Types of Low Impact Development Treatment Systems

4.1 List of BMPS for Groundwater Recharge and Water Quality Treatment

FILTERING SYSTEMS

Bioretention: A shallow depression with vegetation that treats stormwater as it filters through a specific soil mixture. In order to be utilized for groundwater recharge, the bottom of the system must be unlined to infiltrate stormwater into the underlying soils.

Figure 4.1.a – Bioretention System

Tree Filter: A Bioretention system contained within a precast unit for use in retrofit situations in a commercial environment.

Figure 4.1.b – Filterra Tree Filter (www.filterra.com)

Surface Sand Filter: This system treats stormwater by the removal of coarse sediments in a sediment chamber or forebay, which is easily maintained prior to the stormwater filtering through a surface sand matrix. In order to be utilized for groundwater recharge, the bottom of the system must be unlined to infiltrate stormwater into the underlying soils.

Figure 4.1.c – Surface Sand Filter (UNHSC)

Organic Filter: This filtering practice uses an organic soil component such as compost or a sand/peat moss mixture to filter the stormwater. In order to be utilized for groundwater recharge, the bottom of the system must be unlined to infiltrate stormwater into the underlying soils.

Figure 4.1.d – Organic Filter

Dry Swale: These are vegetated open swales or depressions which are specifically designed to detail and infiltrate stormwater into the underlying soils. They use a modified soil mixture to enhance the infiltrative capacity of the system. In order to be utilized for groundwater recharge, the bottom of the system must be unlined to infiltrate stormwater into the underlying soils.

Figure 4.1.e – Dry Swale (UCONN NEMO)

INFILTRATION SYSTEMS

Infiltration Trenches: These are infiltration practices that store water volume in open spaces in a chamber or within the void spaces of crushed stone or clean gravel prior to the water being infiltrated into the underlying soils. These practices are permissible for runoff from residential roofs or small commercial roofs (<3,000 sq.ft.). For larger commercial roofs, pre-treatment via one of the filtering systems list above must be provided prior to discharge into this type of infiltration system.

4.1.f – Infiltration Trench (www.washco-md.net)

Infiltration Chambers: These are infiltration practices that store water volume in open spaces both within the chamber and the void spaces in the crushed stone.

Figure 4.1.g – Infiltration Chamber (www.tritonsws.com/Images/case-studies)

Infiltration Basin: This is an infiltration practice that stores stormwater in a flat, vegetated surface depression prior to infiltrating into the underlying soils.

Figure 4.1.h – Infiltration Basin – (www.wash-md.net)

Alternative Paving Surfaces: These are practices that will store and filter stormwater in the void spaces of a clean gravel base prior to infiltrating into the underlying soils.
Figure 4.1.i – Porous Pavements (www.stormwaterenvironments.com)

4.2 List of BMPs for Water Quality Treatment

WET VEGETATED TREATMENT SYSTEMS

Extended Detention Shallow Marsh: A stormwater basin that provides treatment by the utilization of a series of shallow, vegetated permanent pools within the basin in addition to shallow marsh areas.
Figure 4.2.a – Extended Detention Shallow Wetlands (www.wetlands.com.au)

Subsurface Gravel Wetlands: A stormwater system where water quality is provided by the movement of stormwater through a subsurface, saturated bed of gravel with the soil surface being planted with emergent vegetation.
Figure 4.2.b – Subsurface Gravel Wetlands (UNHSC)

Pond / Wetland System: A treatment system which combines the shallow, vegetated aspects of a marsh with at least one pond component.

Figure 4.2.c – Pond/Wetland System (www.starenvironmentalinc.com)

Wet Swale: This is a vegetated depression or open channel designed to retain stormwater or intercept groundwater to provide water quality treatment in a saturated condition.

Figure 4.2.d – Wet Swale (Dr. Bill Hunt, NCSU)

4.3 List of BMPs for Pretreatment for Water Quality Systems

Filter Strips: These vegetated systems that are designed to treat stormwater from adjacent impervious area which occurs as overland flow.   These systems function by slowing flow velocities, which allows the removal of sediments and other pollutants.

4.3.a – Filter Strip (www.trinkausengineering.com)

Sediment Forebay: This is a depressed vegetated area prior to a larger stormwater treatment facility which will trap coarse sediments and reduce maintenance requirements of the larger treatment facility.
Figure 4.3.b – Sediment Forebay (www.vwrrc.vt.edu)

Deep Sump Catch Basin: These systems are modified structures that are installed as part of a conventional stormwater conveyance system. They are designed to trap trash, debris and coarse sediments. While the hooded outlet provides the potential to trap oil and grease, frequent maintenance is required to remove the oils from the water surface.

Proprietary Treatment Devices: These are manufactured systems which were engineered to provide a cost-effective approach to stormwater quality in a contained space. These systems include oil/grit separators, hydrodynamic separators, and a wide range of filter systems with specialized media. Research by the Center for Watershed Protection, University of New Hampshire Stormwater Center in the past few years have shown that many of these systems are not able to achieve the water quality goals as specified in Section 4.3.3. They may be appropriate for pretreatment in some situations. In order to use a proprietary treatment device, independent research documentation must be provided to justify the pollutant removal efficiency.

4.4 List of BMPs for Water Quantity Control

Wet Extended Detention Pond: This practice is primarily designed to address stormwater quantity increases. They have a deep permanent pool, but do not effectively remove stormwater pollutants. These systems may be located in areas of seasonally high groundwater.
Figure 4.4.a – Wet Extended Detention Pond (NCSU)

Dry Detention Pond: This practice has a dry bottom and is also designed to address changes in stormwater quantity only.
Figure 4.4.b – Dry Detention Pond (www.dhn.iihr.uiova.edu)

4.5 List of BMPs for Commercial Water Quality Retrofits

LID Urban Planter: These systems provide a "greening" of the urban streetscape while providing pollutant attenuation and potential reductions of runoff volume
Figure 4.5.a – LID Urban Planter (City of Portland, OR)

LID Curb Extension: These systems are used to reduce runoff volumes by infiltration as well as pollutants from runoff. They provide a "greening" benefit to any green in addition to a traffic calming device
Figure 4.5.b – LID Curb Extensions (City of Portland, OR)

Modular Wetland System: This system provides treatment of urban runoff in a small footprint. It utilizes the benefits of a Gravel Wetlands along with proprietary filters to remove pollutants.

Figure 4.5.c – Modular Wetland (modularwetland.com)

Filterra Bioretention System: This system is a bioretention facility for urban applications. By the flow through a proprietary media, the amount of pollutants in urban runoff is reduced.

Figure 4.5.d – Filtera Bioretention (Filterra.com)

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Low Impact Development Resources

A. Low Impact Development Center http://www.lowimpactdevelopment.org/

B. University of New Hampshire Stormwater Center http://www.unh.edu/erg/cstev/

C. Wisconsin Department of Natural Resources http://dnr.wi.gov/

D. Low Impact Development (LID) Urban Design Tools http://www.lid-stormwater.net/index.html

E. The Sustainable Site Initiative http://www.sustainablesites.org/

F. Environmental Protection Agency http://www.epa.gov/nps/lid/

G. Puget Sound Action Team http://www.psp.wa.gov/

H. Center for Watershed Protection http://www.cwp.org/

I. North Carolina State University Stormwater Engineering Group

http://www.bae.ncsu.edu/stormwater/

J. Chesapeake Stormwater Network http://www.chesapeakestormwater.net