Stormwater Management Assessment and Opportunities for the Willow Brook Watershed, Rochester, New Hampshire

Prepared by
The University of New Hampshire Stormwater Center

Prepared with Support from NH Department of Environmental Services
March 2012

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ACKNOWLEDGEMENTS

Funding for this project was provided by a grant from the NH Department of Environmental Services with funding from the US Environmental Protection Agency under Section 319 of the Clean Water Act. The study was a collaboration of between the project partners Lorie Chase (Cocheco River Watershed Coalition), Melodie Esterberg (the City of Rochester), Nancy Booth (School Street School), Sally Soule (NH Department of Environmental Services), and the UNH Stormwater Center. The project success was the result of the strong community engagement and commitment to the watershed by Lorie Chase.

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Stormwater Management Assessment and Opportunities for the Willow Brook Watershed, Rochester, New Hampshire

Report by the University of New Hampshire Stormwater Center

EXECUTIVE SUMMARY

The purpose of the Assessment Report is to address the declining water quality of Willow Brook and central Rochester caused by runoff from urbanization and increases in impervious cover (IC). Increases in IC are unavoidable for urban areas with increasing populations. Many types of IC, such as rooftops, lawns, driveways, parking lots and roads, are well documented as major sources of nitrogen, phosphorus and sediment to surface waters. In the Willow Brook watershed IC accounts for 15.9 % of the land cover. Industrial and commercial land use combined represents 7% of the land cover and residential areas 29% of the land cover. Pollutant load analyses indicate that industrial and commercial land uses account for 25% of the annual total nitrogen (TN) load, 18% of the annual total phosphorous (TP) load, and 20% of the annual sediment load in the watershed. Residential land use accounts for 37% of the annual TN, 46% of the annual TP, and 43% of the annual sediment loads. A further examination by impervious cover type identifies pavements as a predominant source. In residential land uses, driveways constitute 6% of the area and 47% of the sediment load, 41% of the TP load, and 28% of the TN load. For industrial land uses, parking areas only account for 12% of the IC area but contributes 71% of the sediment, 36% of the TP, and 40% of the TN load. For commercial use, roadways account for 4% of the IC area, but contribute 76% of the sediment load, 45% of the TP load, and 53% of the TN load annually.

The impacts of IC can be substantial and directly affect the value, aesthetics, and usability of our surface waters. As populations grow so will the percentage of IC area within the watershed further impacting surface waters. However, a range of strategies exist to reduce IC and its impacts including the use of Low Impact Development (LID). The City of Rochester is fortunate to have widespread soils that have tremendous infiltration capacity. Numerous existing infiltration and filtration designs were identified in the field surveys that had been completed years before. Presumably the choice to use infiltration and filtration approaches would have been due to the ease of these style of approaches in this type of hydrologic soil group setting.

This Report presents recommendations for the City of Rochester and a review of locations identified to be primary areas of concern. Labor and equipment are not included in the planning estimates as they are anticipated to be installed by municipal staff and a component of existing operations and maintenance. Cost estimates do not represent detailed designs costs which are still required and are for planning purposes only. These estimates could be used for planning capital

budgets, seeking additional grant opportunities, and illustrating the relative ranking of each location.

The Green Infrastructure approaches and techniques recommended in the Report can all be implemented by existing city staff. Recommendations include additional equipment and labor demands, both available for purchase or hire. The equipment expenses range from minimal costs equivalent to that of a large service vehicle.

A generalized management approach for the Willow Brook Watershed is described below. At most sites, treatment strategies will be very similar and will consist of: 1) removal of existing catch basin, 2) installation an infiltration/filtration system (ie., bioretention, tree filter, porous pavement), and 3) connection of system bypass to existing storm drain or surface drainage as appropriate.

INTRODUCTION

This Report presents recommendations for controlling and managing the increased non-point source pollution associated with impervious cover. Non-point source pollution such as construction site erosion, leaking automotive fluids, nutrient loading associated with agricultural and residential fertilizers and pesticides, road salt and other pollutants are all present in stormwater runoff. The recommendations presented can be used to reduce degradation in the watershed by identifying and targeting problem areas for stormwater runoff improvements while preparing for future growth.

This Report presents strategies for minimizing the impacts of stormwater management using Low Impact Development (LID). A central element of LID is maintaining the natural hydrology of a watershed to the maximum extent possible. This is accomplished by limiting land disturbance as much as possible, slowing down the flow of stormwater to limit peak flows and increase infiltration, and manage stormwater on-site. Structural methods include the use of vegetated filtration and infiltration systems such as raingardens, bioretention systems, tree filters, dry wells, and porous pavements. LID systems are typically used to provide both treatment through some form of filtration media, and reduction of stormwater runoff volumes by infiltration and recharge. In an urban retrofit environment LID is commonly used to augment existing drainage infrastructure. Nonstructural methods, such as minimizing clearing and grading, maintaining natural flow paths, and disconnecting impervious surfaces, focus on prevention and reduction of stormwater volumes and pollutants at their source. These nonstructural approaches are typically preferred where possible and may reduce the need for more costly structural best management practices. Buffers of thick vegetation around surface water resources such as wetlands, lakes, ponds, or streams are considered among the most effective stormwater management practices.

BACKGROUND

Willow Brook is a tributary to the Cocheco River in the urban center of Rochester, NH. This small urban stream is impaired for Primary and Secondary Contact Recreation (E. coli). Its direct receiving waters, the Cocheco River, are impaired for Aquatic Life Use (benthic macroinvertebrates and habitat) as well as Primary Contact Recreation (E. coli). Likely sources

are nonpoint source pollutants from urban stormwater runoff. The Cocheco River Watershed Coalition (CRWC) in cooperation with the City of Rochester Public Works Department (DPW)

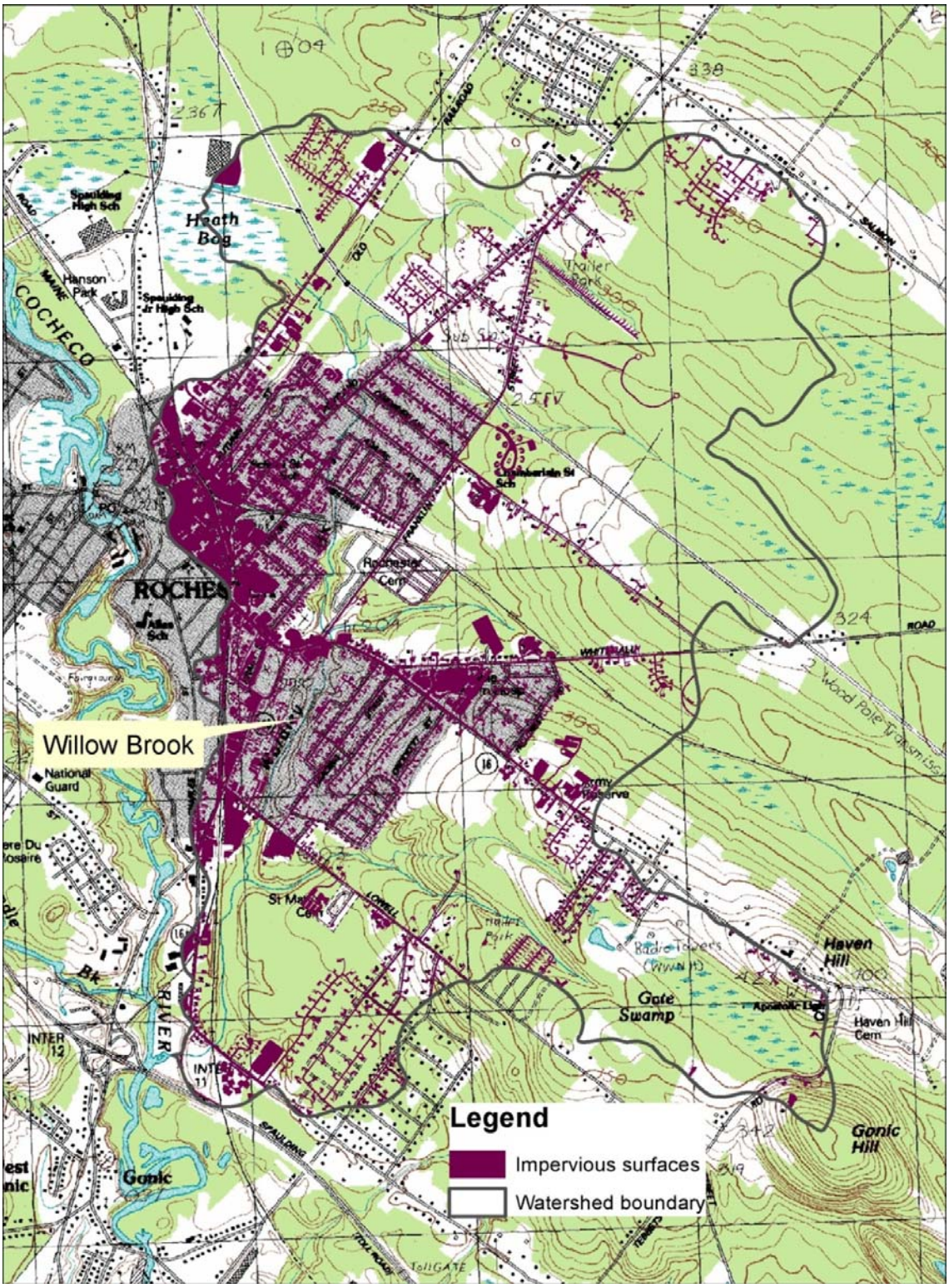


Figure 1: Impervious surfaces within the Willow Brook watershed

and the University of New Hampshire Stormwater Center (UNHSC) developed and implemented a plan for installation of LID practices, conducted outreach and educational activities, and effectively reduced IC percentages to address water quality impairments in the watershed. The project was funded through NHDES 319 Watershed Assistance Grants to addresses the nonpoint source pollution from urban runoff in two pilot locations.

Since the 1960's the City of Rochester has had a population increase of 87% growing from 16,000 people to 30,000 people in 50 years. This increase in population has had a corresponding increase in IC which has led to increased stormwater runoff and degradation of water quality in the watershed.

Much of the developed landscape that exists today was not designed with a consideration of the impacts from stormwater runoff. This was acceptable because of low population density. As populations increased and city centers transitioned from rural to urban, more sophisticated stormwater controls became necessary. Historically, in many towns the design and maintenance of drainage systems were simple. Repairs and improvements would be in response to complaints or damage to property during large storm events. As development and impervious cover have increased, so has the need to mitigate the impacts of existing IC in urban watersheds for both flooding and pollutant loads. The need to address urban runoff has also increased because of changing rainfall patterns and increasingly intense rainfall events.

Stormwater runoff is water from rain or melting snow that does not soak into the ground. It flows over land from rooftops, paved areas, compact soils, steep slopes, and saturated vegetated areas. As it flows, stormwater runoff collects and transports pollutants including sediment and organic matter; pet waste; automobile fluids (oil, grease, gasoline, antifreeze); deicing products (road salt); pesticides and fertilizers; grass clippings, leaves and other yard waste; and cigarette butts and other litter.

While traditional stormwater management practices are designed to collect, detain, and divert water to the nearest surface water, time and experience have shown that this approach does not adequately address the cumulative hydrologic or water quality impacts of urbanization. Development creates impervious surfaces that prevent water from infiltrating through the underlying soil. Impervious and disturbed surfaces from development can cause changes to both water quality and hydrology altering the movement of water through the landscape. Changes to water quality from increased IC include increased pollutant loads, higher bacterial contamination, and higher temperatures. These changes can degrade fisheries, inhibit certain uses, such as swimming, and increase treatment costs for public water supplies. Hydrologic changes resulting from increased impervious area include increased volume and velocity of stormwater runoff entering receiving waters, reduced groundwater levels, more frequent flooding and road over-topping, reduced stream flows during dry weather, and degradation of stream channels and banks that reduce habitat quality.

ASSESSMENT PROCESS

The general approach and methodology used in this study is outlined in this section

1. **Land-Use, Land-Cover Watershed Assessment:** The watershed was characterized by remote sensing and GIS analyses for land uses, land cover. In particular an impervious cover analysis was performed to determine types of IC in the watershed.
2. **Field Inventory:** An initial inventory was taken of the infrastructure and drainage controls associated with the Willow Brook watershed. This included man-made and naturally evident drainage paths, approximations of total sub-drainage areas and general site characteristics such as slope and distance to receiving water bodies.
3. **Treatment Strategies Selection:** Planning level treatment strategies were developed for the 10 identified locations. Strategies were selected based on their relative cost effectiveness, treatment effectiveness and long term manageability.
4. **Pollutant Loading Analyses:** Pollutant loads were calculated using the land use and impervious cover analyses. This was used to identify, target, and prioritize recommendations for best management practices (BMP).
5. **Impervious Cover Reduction Projections**: Effective impervious cover (EIC) reductions were calculated for a variety of retrofit implementation rates to achieve a goal of 10% IC. The rates and time period to implementation are: 50 year, 40 year, 30 year, 20 year and 10 years. EIC is impervious cover that is not disconnected. Disconnection refers to the practice of directing runoff from IC such that it does not contribute directly to stormwater runoff from a site, but directs stormwater runoff to on-site treatment practices or vegetated buffers to be filtered or infiltrated into the native soils.

IMPERVIOUS COVER, LAND USE, AND POLLUTANT LOADS

A land use and impervious cover assessment was performed for the Willow Brook watershed in March of 2011.

Figure 2 illustrates the land use and Figure 3 illustrates the impervious surface distribution for the watershed. The watershed contains 2,515 acres, 401 of which are considered IC (15.9% by land mass). Figure 5 details the percentages of IC and land use types. At 15.9% IC the Willow Brook watershed lies in the impacted zone according to the impervious cover model assessment method NHDES uses to determine attainment. In order to reach attainment it is estimated that approximately 6% of the impervious cover in the watershed will have to be disconnected or treated. Plans will need to be put in place to prevent the watershed from increasing the IC % as population increases and current land uses undergo development. Appendix D provides detailed breakdown of land use and impervious cover methods and results of these analyses.

The Impervious Cover Model (ICM) was first proposed in 1994 by Tom Schueler and the Center for Watershed Protection. It was first introduced as a management tool to diagnose the severity of future stream problems in urban and urbanizing watersheds. Since its introduction the ICM has been adapted as a surrogate for impaired water attainment. Numerous watershed studies throughout the country have correlated the percentage of IC to the overall health of a watershed and its ability to meet designated uses. National studies have also demonstrated that stream

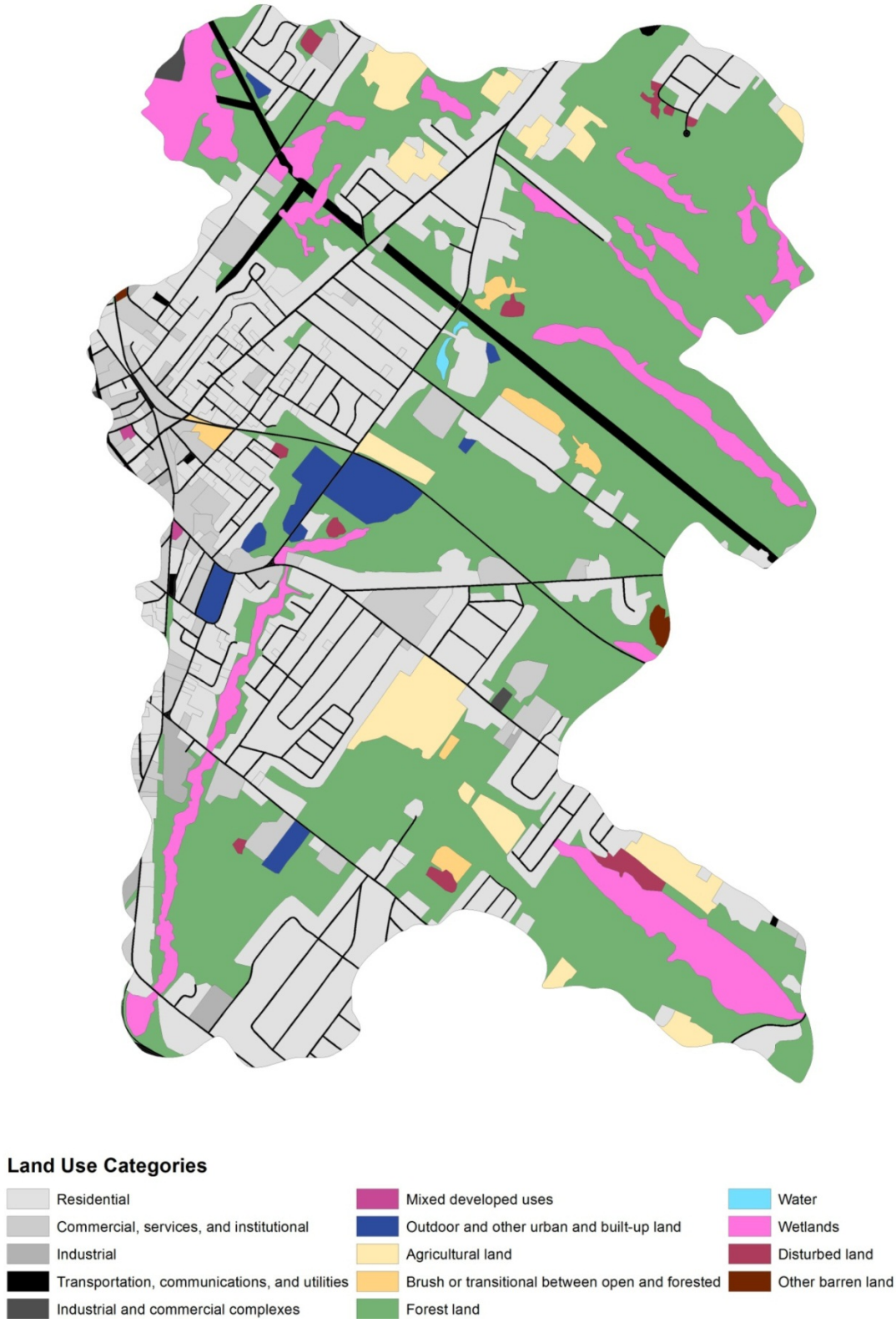


Figure 2: 2005 Land use for the Willow Brook watershed.

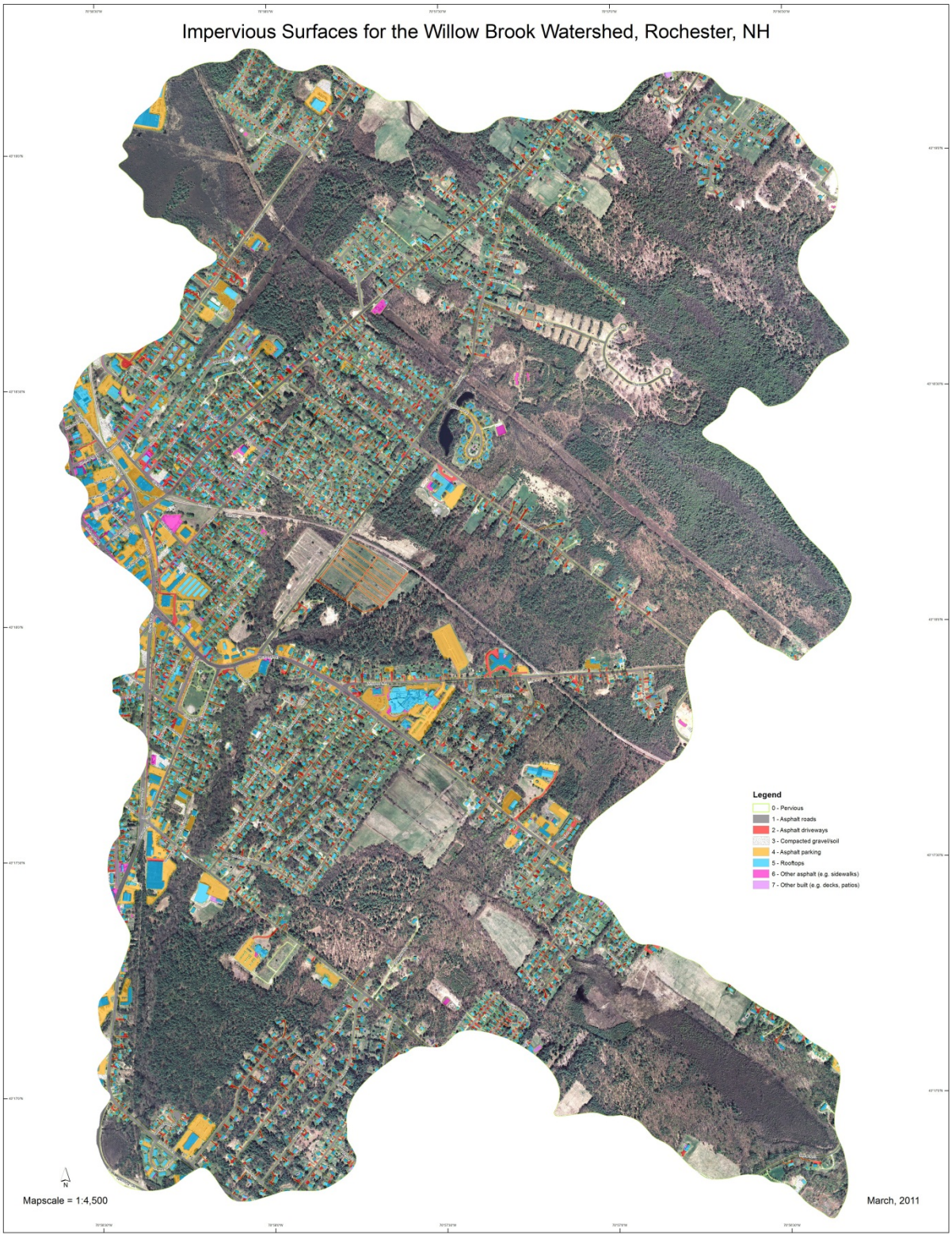


Figure 3: Mapped impervious surfaces in the Willow Brook Watershed

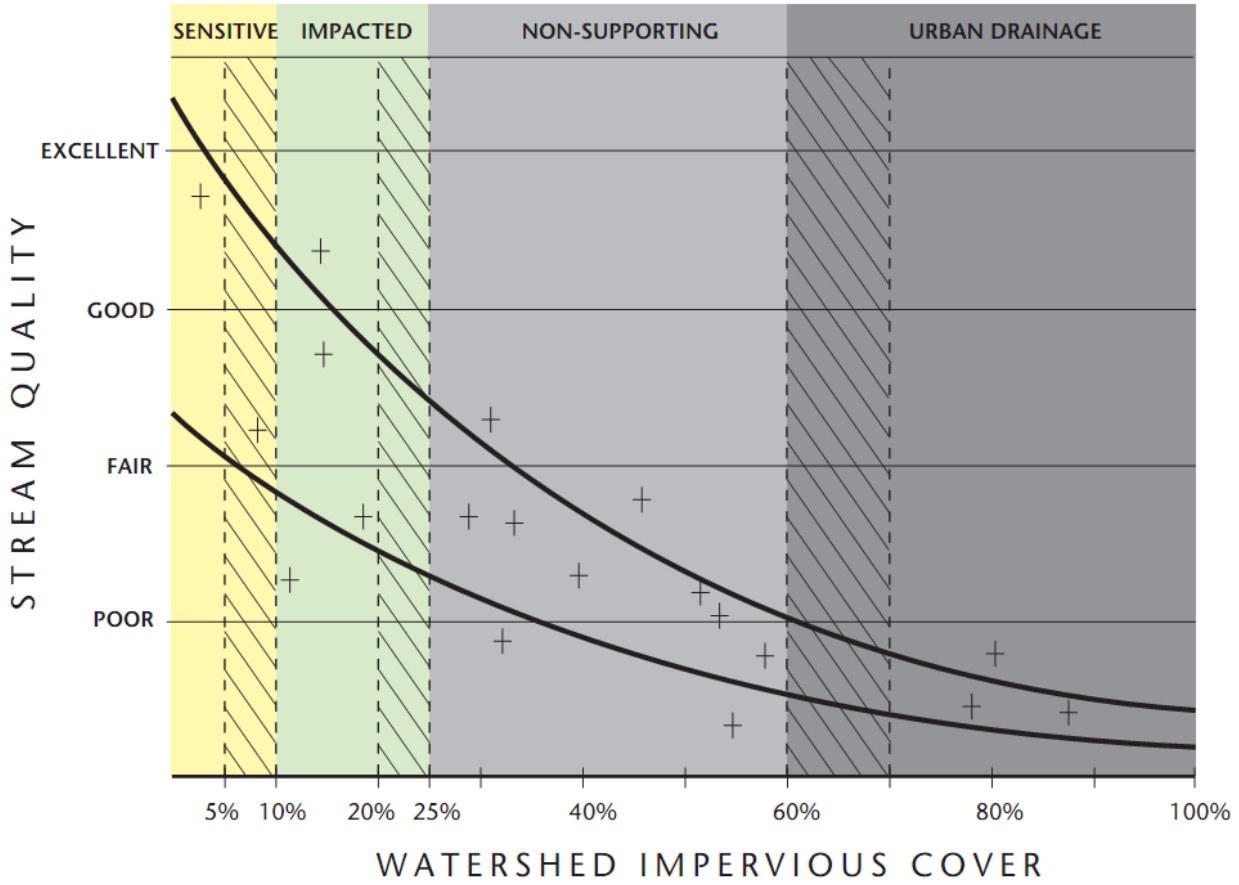


Figure 4: Watershed Impervious Cover vs. Stream Quality (Schueler, 2010)

quality indicators will decrease as the percent of IC increases. More local studies have verified this threshold as well.

Stream studies performed by the Center for Watershed Protection support the use of IC as a surrogate measure of the impacts on hydrology, chemistry, and biology of a stream, including impacts to aquatic life. There is also a strong correlation between pollutant loads and stormwater flows from impervious areas. According to studies, it is reasonable to rely on the surrogate measure of percent IC to represent the combination of pollutants that can contribute to aquatic life impacts. The ICM concept has engendered much debate and some confusion among planners, engineers and regulators. Most communities continue to struggle with how to influence or optimize watershed IC limits and/or how to apply techniques to mitigate its impact.

Central to some of the confusion around IC disconnection is the classification of IC. IC has some very beneficial properties as a watershed metric in that it is very measurable and is somewhat universal or at least easily categorized in an urban setting. In many watershed management plans IC is discussed in general and no differentiation is given as to class of IC. From a pollutant loading perspective it is necessary to examine the IC type. Not all IC is equal with respect to pollutant load. For example rooftops will generally have substantially less load than roadways which will accumulate transportation related polluntants. Figure 5 charts the IC

categories in the watershed. Rooftops are the largest individual category however, as a class, pavements (roads, driveways, parking lots, and other asphalt) is the largest class of IC at 65%.

IC is strongly correlated with land use and municipal zoning categories and these analyses can offer reliable forecasts of current and future (buildout) pollutant loads. This can be useful for engineers, planners, municipal officials, and economists to use. The range of IC mitigation strategies are quite broad and vary depending on the intervention point. Many of the strategies outlined in this document are engineered BMPs treating and reducing the amount of runoff generated. Other non-structural strategies including planning strategies are discussed in greater detail later.

For reference, changes in population, land conversion are presented for the Lamprey River watershed and changes in impervious cover for the entire coastal watershed. The LR watershed is similar to the Cocheco River watershed and similar changes can be expected.

The coastal watershed has increased IC at a rate of approximately 2% for every 10 years as measured from 1990 through 2005. The Lamprey River watershed experienced a population increase of 3.4 times over a 50 year period (from 28,915 in 1960 to 98,990 in 2010), while urban and developed land has increased 4.9 times over a 43 year period (from 3,192 acres in 1962 to 15,673 in 2005).

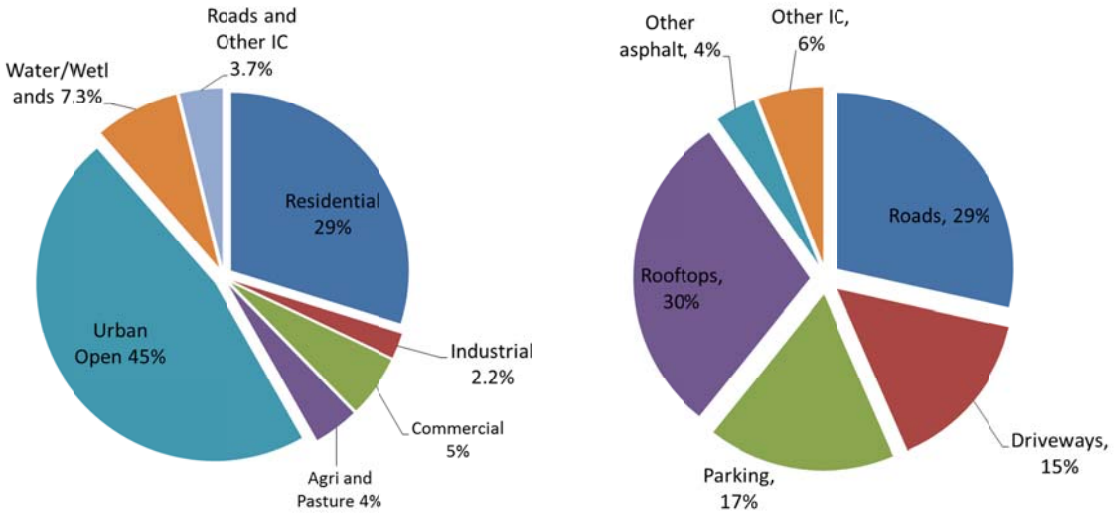


Figure 5: 2005 Distribution of Land Cover and 2010 Impervious Surface Type in Willow Brook.

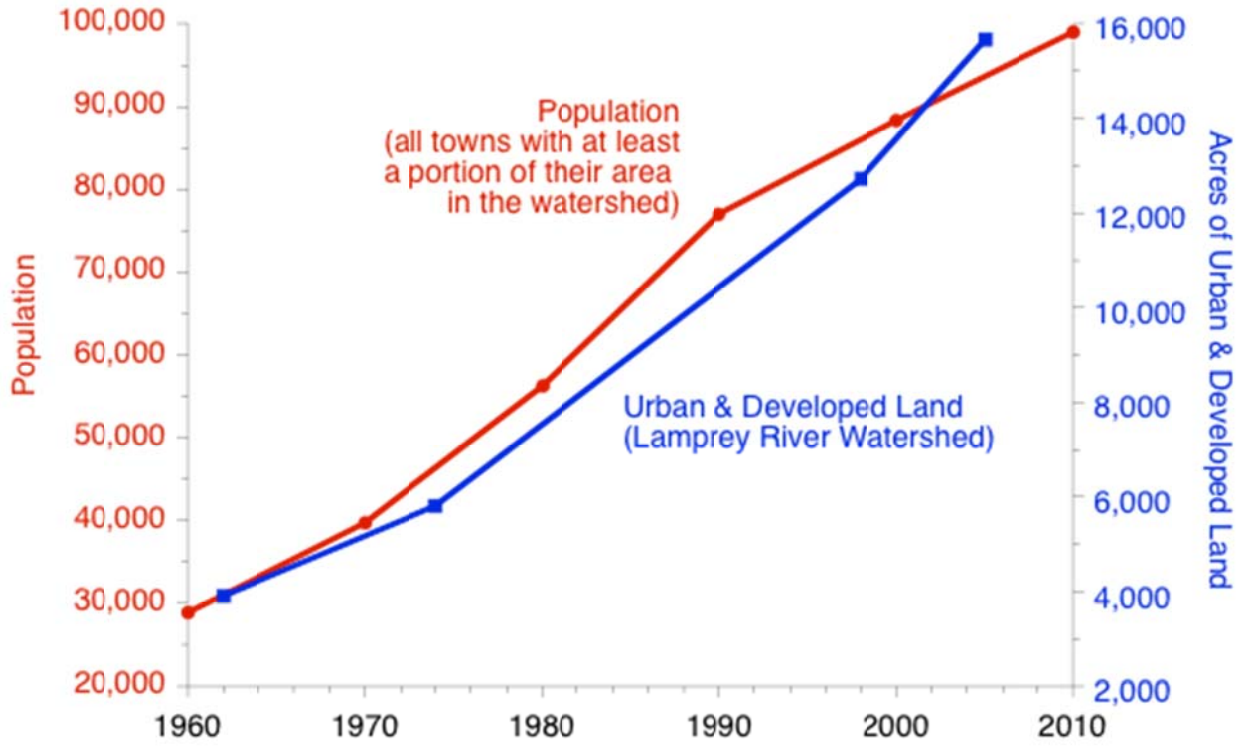


Figure 6: Trends in population and land use in the Lamprey River watershed. Population data from the US Census; land use data from NH GRANIT.

Table 1: Percent of total impervious area for communities in Lamprey River Watershed

Watershed Community	% increase since 1990	% Impervious		
		1990	2000	2005
Barrington	80.8%	2.6	4	4.7
Brentwood	90.0%	5	7.7	9.5
Candia	77.8%	2.7	4.1	4.8
Deerfield	100.0%	1.5	2.4	3
Durham	63.8%	4.7	7.2	7.7
Epping	95.0%	4	6.5	7.8
Exeter	65.3%	7.5	11	12.4
Fremont	96.7%	3	4.9	5.9
Lee	78.4%	3.7	5.8	6.6
Newfields	119.4%	3.1	5.5	6.8
Newmarket	71.2%	5.9	8.8	10.1
Northwood	66.7%	2.4	3.4	4
Nottingham	86.7%	1.5	2.3	2.8
Raymond	75.5%	5.3	8	9.3
Strafford	64.3%	1.4	2	2.3

Table 2: Percent of total impervious area for New Hampshire Coastal watershed (1,086 sq.mi.)

Year	Impervious Area Cover (%)	Impervious Area Cover (Acres)
1990	4.30	28,710
2000	6.30	42,618
2005	7.50	50,351

Source: http://www.granit.und.edu/

Table 3: 2010 Acres of pervious and impervious area by land use in the Willow Brook Watershed.[1]

Land Use	% of Watershed	Pervious	Asphalt Roads	Asphalt Driveways	Compacted gravel/soil	Asphalt Parking	Rooftops	Other Asphalt	Other built (e.g. decks, patios)	Total
Multi-Family	3.5%	47.8	5.2	6.3	2.1	7.3	16.4	2.3	0.7	88.0
Residential	29%	569.1	15.3	44.4	7.1	5.6	72.2	3.9	5.8	723.3
Industrial	2.2%	44.2	0.7	0.2	0.2	6.5	3.4	0.1	0.2	55.6
Commercial	5%	44.2	5.6	3.8	4.3	46.7	25.3	6.1	0.4	136.4
Agri and Pasture	4%	97.9	0.3	0.1	0.3	0.0	0.2	0.0	0.0	98.7
Urban Open	45%	1120.2	5.8	3.8	1.5	1.6	1.9	1.7	0.2	1136.7
Water/Wetland	7.3%	183.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	183.3
Roads and Other IC	3.7%	7.2	81.4	1.5	1.0	1.1	0.0	0.5	0.0	92.6
Total	100%	2113.7	114.3	60.0	16.6	68.8	119.3	14.6	7.2	2514.5

[1] Recent project undertaken by UNHSC researchers (UNHSC, unpublished data 2011a)

Table 4: 2010 Type and percent of impervious cover in the Willow Brook watershed.

Impervious Cover Type	% of Watershed	% of Impervious Cover
Roads	4.5%	29%
Driveways	2.4%	15%
Parking	2.7%	17%
Rooftops	4.7%	30%
Other asphalt	0.6%	4%
Other IC	0.9%	6%
Total	15.9%	100%

POLLUTANT LOAD BY LAND USE

Pollutant concentrations vary between land use types. Figure 5 illustrates the breakdown of current land use and IC coverage in the Willow Brook watershed. Pollutant load estimates are to be used for planning purposes only. Load calculations are valuable as a comparison tool for relative significance of land uses and BMP treatment approaches. Pollutant concentrations are applied according to the area of land use in the watershed to generate a mass load in lbs per year. The pollutant load calculations for a watershed are based on the USEPA Simple Method. The Simple Method is recommended by NHDES in the *New Hampshire Stormwater Manual*[2] (1). The methods for pollutant calculation are detailed in Appendix I: Pollutant Analyses Methodology.

[2] New Hampshire Stormwater Manual, Volume 1 Stormwater and Antidegradation, Chapter 8 Pollutant Loading Calculations, Rev 1.0, December 2008

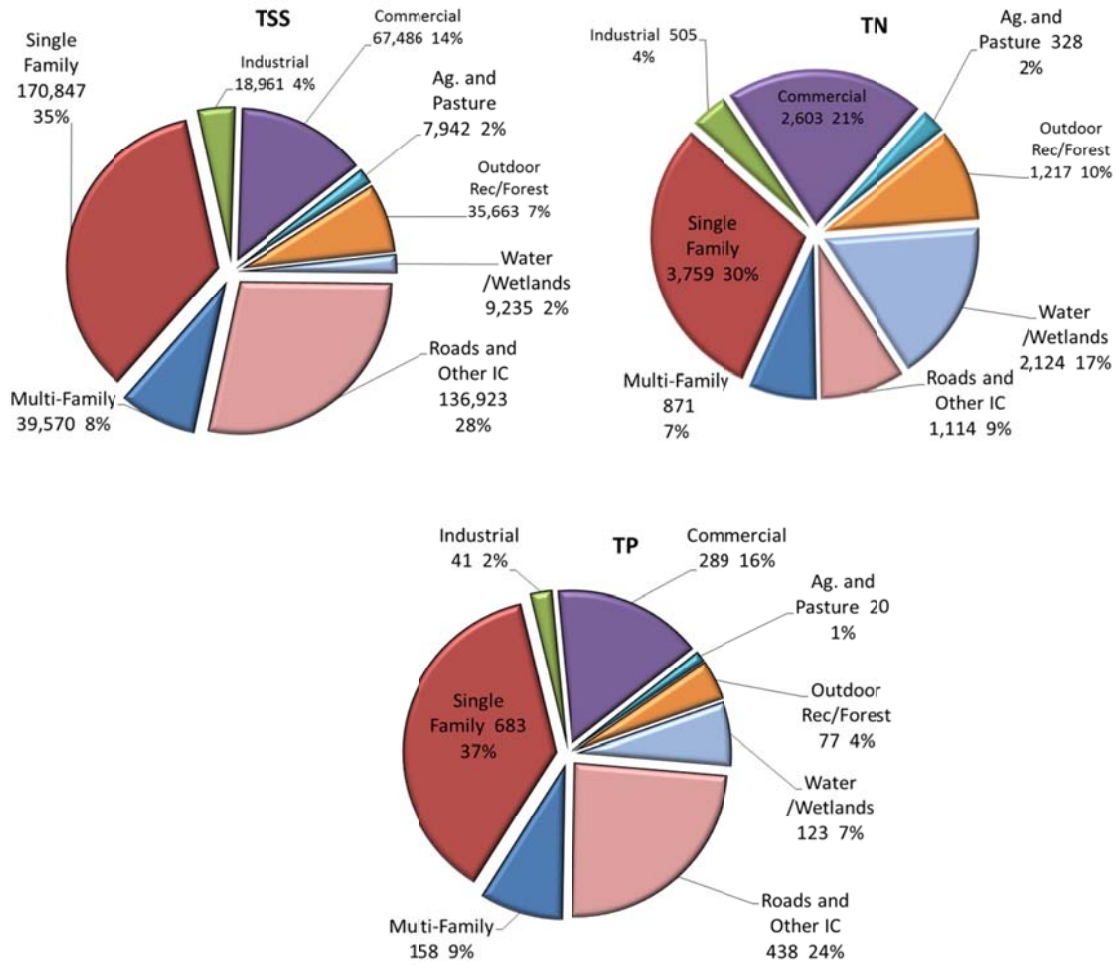


Figure 7: Estimated Distribution of TSS, TN, and TP Load by Land Use (lbs/yr)

An examination of general sediment loads (as measured by TSS) in a residential land use yields concentrations estimated to be relatively low at100 mg/L. Residential land use is 29% of the total land area (723 acres). Sediment loading in an industrial land use yields higher concentrations 149 mg/L and constitute 2% (56 acres) of the land area. It is important to note that substantial reductions in pollutant loading could be achieved by addressing some of the areas with relatively low land cover but high loading and high % IC, in particular commercial and industrial areas.

Table 3 illustrates the breakdown of current impervious areas by land use in the watershed. Pollutant load estimates between general land use categories are illustrated in Figure 7.

A more detailed examination of pollutant load by land use subcategories was performed to differentiate between IC types such as parking, driveway, roadway, and rooftops.

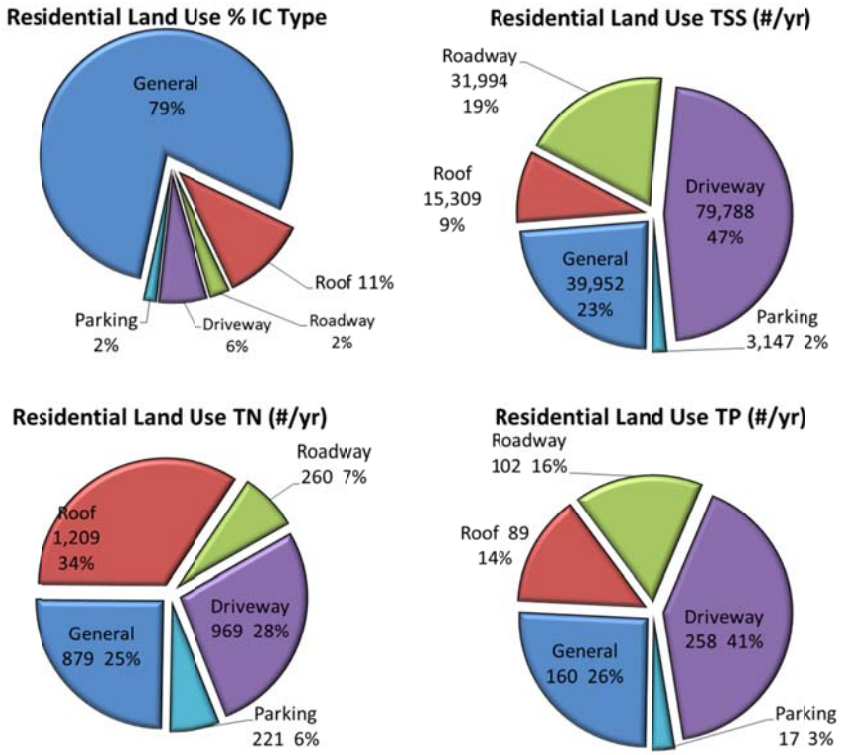


Figure 8: Residential pollutant load by land use and IC type

In residential land uses (

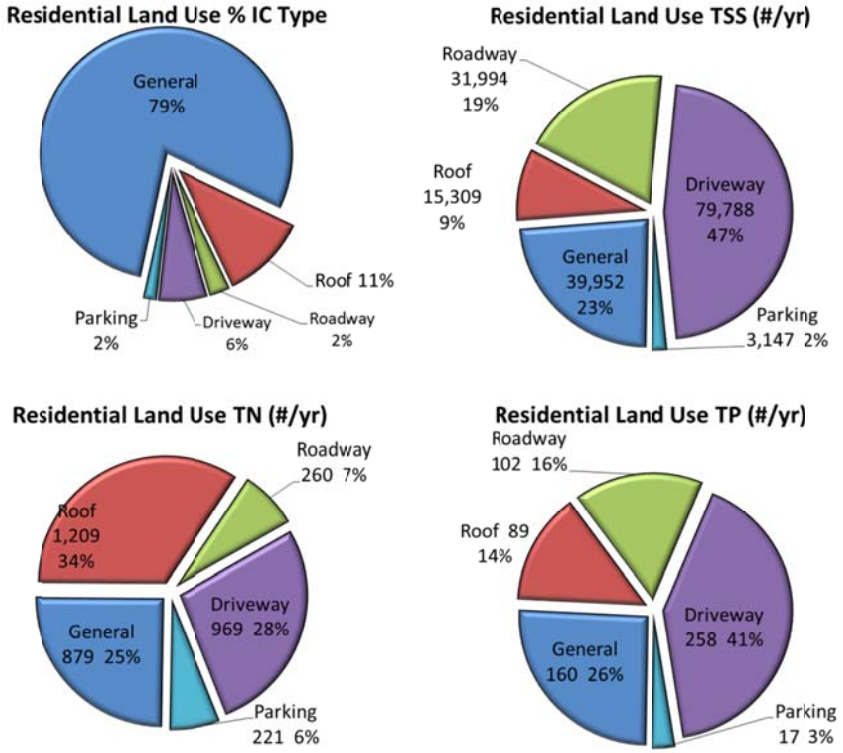


Figure 8), driveways constitute 6% of the area but make up 47% of the sediment load, 41% of the TP load, and 28% of the TN load.

For industrial land uses (Figure 9), parking only accounts for 12% of the IC type but contributes 71% of the TSS, 36% of the TP, and 40% of the TN load.

Roadways account for 4% of the IC for commercial land use (Figure 10) yet contribute 76% of the TSS pollutant load, 45% of the TP pollutant load, and 53% of the TN pollutant load.

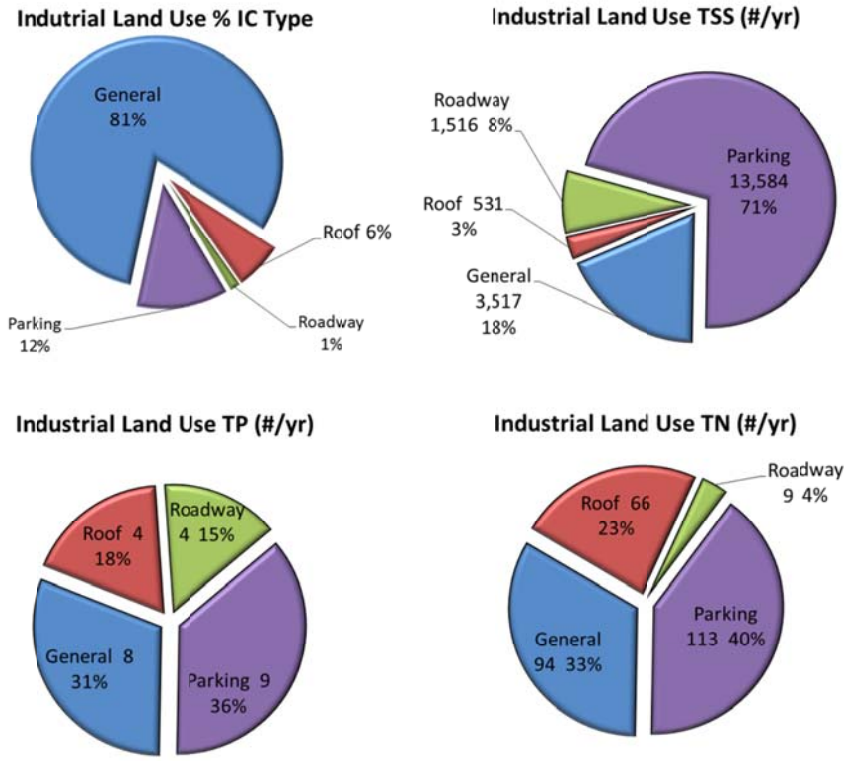


Figure 9: Industrial pollutant load by land use and IC type

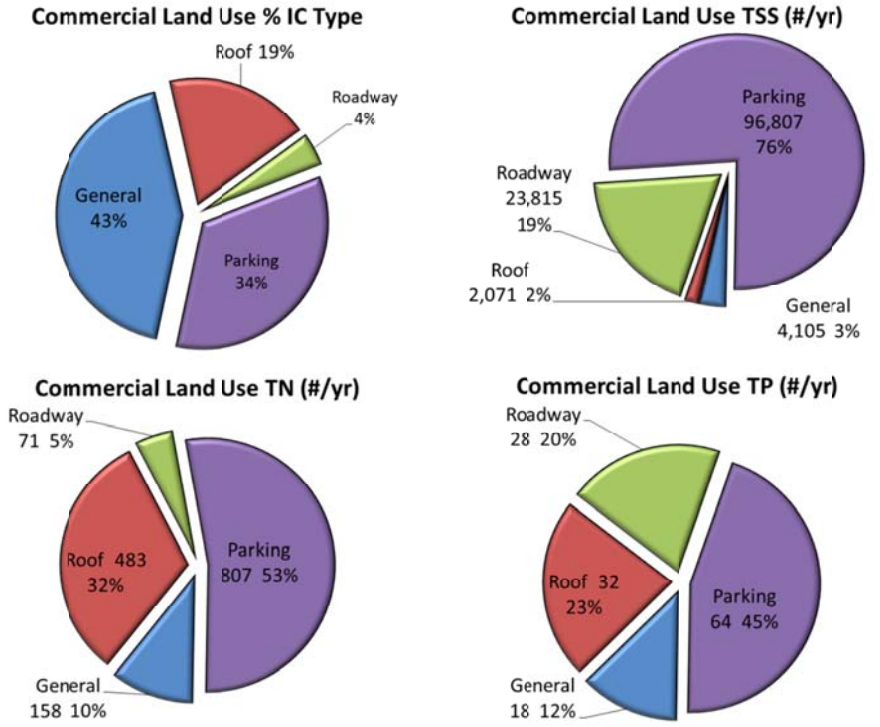


Figure 10: Commercial pollutant load by land use and IC type

Loads will change with different pollutants of concern and through refinement of modeling methods. These can be used to inform management decisions, targeting and prioritizing of BMPs for different land uses, especially in areas of high environmental sensitivity.

WATERSHED SURVEY SUMMARY

A windshield-level watershed survey was performed for the major land use (LU) categories to identify typical LID strategies that can be employed watershed wide. The LU characterization is listed below. Table 5 details locations surveyed for the following land uses including:

1. Parking Lots, Rooftops, Driveways
2. Streets & Roads
3. Commercial
4. Industrial
5. Institutional
6. Residential

The survey included 10 sites which include a BMP recommendation, an approximate drainage area, difficulty ranking for installation, and brief notes. To further understand the sources and magnitudes of pollutants a brief description of the major land uses is provided below along with predominant pollutant sources and estimated pollutant loads from each land use category. A complete listing of loading pollutant loading sources is provided in the Appendix H: BMP, Load, and Impervious Cover Tracking Spreadsheet.

Table 5: Overview of Windshield Survey of Major Land Use Classes

Number	Class	Example	Size	Potential Retrofit	Difficulty	Notes
1	Parking Lots, Rooftops, Driveways	Congress St.	1/2 acre	Rain Garden, Tree Filter	1	Potential for tree filters with many catch basins in the area. Potential raingarden in the parking lot across from Congress St. if the pavement is removed.
2	Streets & Roads	Richardson, Harding, Coleman	1 acre	Tree Filter	1	
3	Commercial	YMCA	1 acre	Rain Garden, weir wall	2	Bioretention and snow dump at the end of the driveway. Can capture roof runoff with the bioretention. Potential for a weir wall in the trench outback, ice from the rink gets piled up here.
4		Public Service	1/2 acre	Rain Garden, Tree Filter	1	Corner of Meadow and Hemlock, many catch basins around the site. Can capture sheet flow from Old Dover Rd.
5	Industrial	Factory Ct	1/2 acre	Drywell, ADS	3	Potential for drywells coming down the hill next to catch basins. Large outfall pipe going directly into the river, Potential for ADS
6	Institutional	School St. School	1 acre	Rain Garden, Porous Pavement, Drywell	2	Porous pavement replaced the basketball court. A drywell and three raingardens installed on site.
7	Residential	Weeping Willow Dr.	1/3 acre	Rain Garden, Tree Filter	1	Cul-de-sac neighborhood with trenches on the each side of the road to carry water to the end of the road. 2, maybe 3 raingardens or bioswales and a tree filter at the corner of Weeping Willow Dr. and Old Dover Rd.
8		Lupine Ln.	1 acre	Rain Garden, Tree Filter	1	Raingarden and two tree filters installed

Difficulty range from 1 – 3, 1 being the easiest and 3 difficult

Residential

Predominant Land Cover: Rooftops, driveways, roads, and lawns

Residential land uses range from high density, represented by the multiple unit structures of urban cores, to low density, where houses are on lots of more than an acre, on the periphery of urban expansion. Linear residential developments along transportation routes extending outward from urban areas should be included as residential appendages to urban centers.[3]

Table 6: Predominant Pollutant Sources for residential

Pollutant	Pollutant Sources
Gross Solids, Sediment, and Floatables	Streets, lawns, driveways, roads
Pesticides and Herbicides	Residential lawns and gardens, roadsides, utility right-of-ways, soil wash-off
Organic Materials/Oxygen Demanding Substances	Residential lawns and gardens, animal wastes
Metals	Automobiles, soil erosion
Oil and Grease/ Organics Associated with Petroleum	Roads, driveways, illicit dumping to storm drains
Bacteria and Viruses	Lawns, roads, soil erosion, leaky sanitary sewer lines, animal waste, septic systems
Nitrogen, Phosphorus, and Other Nutrients	Lawn fertilizers, animal waste

Source: U.S. EPA 1999 (Preliminary Data Summary of Urban Storm Water BMPs).

Table 7: Predominant Pollutant Concentrations for residential

Source Area Unit	TSS mg/L	TP mg/L	TN mg/L
Residential (General) [4]	100	.40	2.2
Med. Density Residential [5]	85	.52	5.15
Residential Roof	19	.11	1.5
Residential Street	172	.55	1.4
Driveway	173	.56	2.1

[2] Caraco (2001), default values averaged from several individual assessments

[3] Camp, Dresser, and McKee, Merrimack River Watershed Assessment Study, Draft Screening Level Model, January 2004

[3] James R. Anderson, Ernest E. Hardy, John T. Roach, And Richard E. Witmer, "A Land Use And Land Cover Classification System For Use With Remote Sensor Data," Geological Survey Professional Paper 964 (1976)

Commercial/Institutional

Predominant land cover: Rooftops, parking lots, commercial landscape

Commercial areas are those used predominantly for the sale of products and services. They are often abutted by residential, agricultural, or other contrasting uses which help define them. Components of the Commercial and Services category are urban central business districts; shopping centers, usually in suburban and outlying areas; commercial strip developments along major highways and access routes to cities; junkyards; resorts; and so forth. The main buildings, secondary structures, and areas supporting the basic use are all included—office buildings, warehouses, driveways, sheds, parking lots, landscaped areas, and waste disposal areas.[1]

Table 8: Predominant pollutant sources for commercial sites

Pollutant	Pollutant Sources
Gross Solids, Sediment, and Floatables	lawns, roads,
Pesticides and Herbicides	commercial landscaped areas, soil wash-off
Organic Materials/Oxygen Demanding Substances	commercial landscaping
Metals	Automobiles
Oil and Grease/ Organics Associated with Petroleum	parking lots, automobile emissions
Bacteria and Viruses	Lawns, leaky sanitary sewer lines
Nitrogen, Phosphorus, and Other Nutrients	Lawn fertilizers, automobile exhaust, soil erosion, animal waste, detergents

Source: U.S. EPA 1999 (Preliminary Data Summary of Urban Storm Water BMPs).

Table 9: Predominant Pollutant Concentrations for commercial sites

Source Area Unit	TSS mg/L	TP mg/L	TN mg/L
Commercial (General) [3]	77	.33	2.97
Commercial Roof	9	.14	2.1
Commercial Street	468	NA	NA
Commercial Parking	27	.15	1.9

[3] Camp, Dresser, and McKee, Merrimack River Watershed Assessment Study, Draft Screening Level Model, January 2004

Industrial

Predominant Land Cover: Roof, parking lots, industrial landscape

Industrial areas include a wide array of land uses from light manufacturing to heavy manufacturing plants. Identification of light industries—those focused on design, assembly, finishing, processing, and packaging of products—can often be based on the type of building, parking, and shipping arrangements. Light industrial areas may be, but are not necessarily, directly in contact with urban areas; many are now found at airports or in relatively open country. Heavy industries use raw materials such as iron ore, timber, or coal. Included are steel mills, pulp and lumber mills, electric power generating stations, oil refineries and tank farms, chemical plants, and brick making plants. Stockpiles of raw materials and waste product disposal areas are usually visible, along with transportation facilities capable of handling heavy materials.[1]

Table 10: Predominant pollutant sources for industrial sites

Pollutant	Pollutant Sources
Gross Solids, Sediment, and Floatables	construction activities, atmospheric deposition, drainage channel erosion
Pesticides and Herbicides	utility right-of-ways, industrial landscaped areas, soil wash-off
Metals	Automobiles, bridges, atmospheric deposition, industrial areas, soil erosion, corroding metal surfaces, combustion processes
Oil and Grease/ Organics Associated with Petroleum	parking lots, vehicle maintenance areas, gas stations, illicit dumping to storm drains, automobile emissions
Bacteria and Viruses	leaky sanitary sewer lines, septic systems
Nitrogen, Phosphorus, and Other Nutrients	atmospheric deposition, automobile exhaust, detergents

Source: U.S. EPA 1999 (Preliminary Data Summary of Urban Storm Water BMPs).

Table 11: Predominant Pollutant Concentrations for industrial sites

Source Area Unit	TSS mg/L	TP mg/L	TN mg/L
Industrial (General) [3]	149	.32	3.97
Industrial Roof	17	NA	NA
Industrial Parking	228	NA	NA
Heavy Industrial	124	NA	NA

[3] Camp, Dresser, and McKee, Merrimack River Watershed Assessment Study, Draft Screening Level Model, January 2004

Undeveloped Areas

Predominant Land Cover: Forest, grassland, others.

Undisturbed areas generally contribute little to overall pollutant loads measured at a river, stream, lake, pond, or other receiving water types. While there may be pollutant loads, the overall runoff from these areas during storm events is often small and result only disturbed areas (ie. construction) and from extreme precipitation events.

Examples of Infiltration in the WB Watershed

School Street School: This demonstration location is a small K-4 neighborhood school that had no existing stormwater management that directly impacted the usability of the surrounding areas. This location was representative of an ultra-urban retrofit with no drainage infrastructure. Many of the challenges faced with this location would be typical. The project resulted in the implementation of eight different LID retrofit strategies virtually eliminating most of the direct runoff from the sites impervious areas. These strategies included raingardens (3), a dry well, rainbarrels, roof drains, pervious concrete sidewalks, and a porous asphalt basketball court by a donation from Pike Industries.

Lupine Lane Residential Subdivision: This demonstration location was a recently built residential subdivision with conventional curb, catch basin and gutter stormwater conveyance. This project was representative of more recent residential development with common drainage infrastructure. Retrofits included a rain garden and two tree filters to effectively disconnect roughly 78 percent of the impervious cover.

Educational programming for the neighborhood residents and students was also included in the project.

IMPERVIOUS COVER REDUCTION AND LONG TERM IMPLEMENTATION

IC reduction targets were calculated for the current IC reduction rate and 10, 20, 30, 40, and 50-Yr rates of implementation with the goal of achieving 10% for the watershed. The rates and time period to attainment (10%) are summarized in Figure 11 and Table 12. Based on the current implementation within Willow Brook for 2011 a rate of 0.03% was achieved for 0.821 Ac of disconnection and treatment. At this rate of implementation, and barring any other IC increase in the watershed, an EIC target of 10% will be achieved by the year 2193.

Scenarios are presented for 50-year, 40-year, 30-year, 20-year and 10-year implementation calendars. Implementation rates range from 0.12% to 0.59% per year. These implementation rates yield IC disconnection of 3.0-14.9 acres per year respectively.

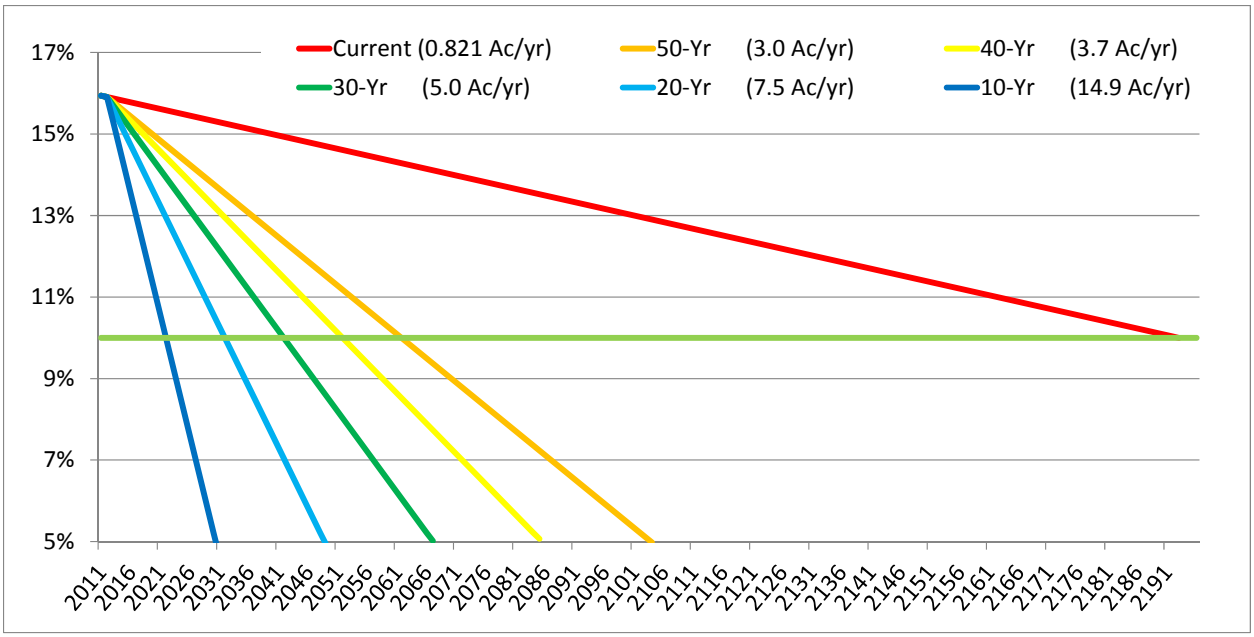


Figure 11: IC reductions for 10-, 20-, 30-, 40-, 50-Yr implementation rates for Willow Brook, Rochester, NH

Table 12: Summary of IC reduction target estimates over 6 implementation scenarios

Implementation Rates	Current (0.821 Ac/yr)	50-Yr (3.0 Ac/yr)	40-Yr (3.7 Ac/yr)	30-Yr (5.0 Ac/yr)	20-Yr (7.5 Ac/yr)	10-Yr (14.9 Ac/yr)
2012 Impervious Cover Beginning	15.94%	15.94%	15.94%	15.94%	15.94%	15.94%
Yrs to Implementation	181	50	40	30	20	10
Total % IC Disconnected Per Year	0.03%	0.12%	0.15%	0.20%	0.30%	0.59%
Total Acres Treated Per Year	0.8	3.0	3.7	5.0	7.5	14.9

Three important points emerge when considering implementation:

1. Improved LID regulations are critical in slowing future additions of IC in the watershed. Without such requirements, standard rates of development could quickly outpace any IC disconnection progress. The degree of importance will vary depending on the degree of build-out in the watershed. The Willow Brook Watershed contains a large amount of forested area (45%). Efforts to conserve resource rich portions of this land type will help centralize development where improvements are more easily and cost effectively targeted.

2. Harnessing growth and redevelopment can be a powerful tool for reducing impervious cover. Commercial and private sector redevelopment disconnection and treatment requirements will help meet municipal permit requirements by leveraging capital improvements to properties in the watershed. Nationally, municipalities are recognizing the multiple benefits of Low Impact Development and incorporating it into their long-term capital programs. See the 2011 report entitled *Forging the Link: Linking the Economic Benefits of Low Impact Development and Community Decisions* for details (UNHSC, 2011).

3. Implementation rates can yield aggressive disconnection of the easiest IC targets at first. Over time as implementation progresses, targeted disconnection of acreage may become more difficult and costly to achieve. Conversely, the cost of LID implementation will be reduced with increasing degree of familiarity by the City staff and the design and construction community. Improved zoning ordinances and development regulations will balance IC disconnection between the municipality, private, and commercial economic improvement projects.

Figure 12: Estimated Population Growth for Rochester and Associated Increase in Impervious Cover

LOW IMPACT DEVELOPMENT BEST MANAGEMENT PRACTICES

Structural Low Impact Development Best Management Practices

Rain Garden

Bioretention systems are among the most common low impact development (LID) stormwater approaches. Runoff flows into landscaped depressions, where it ponds and infiltrates the soil. The engineered soil mix and vegetation provide water quality treatment and infiltration similar to undeveloped areas. UNHSC has evaluated a number of such systems. Of key importance is engineering an appropriate soil with just the right proportion of sands and silts. Too many fine materials like silts may clog the system, too few and there may be issues with vegetation establishment and nutrient removal. There are many designs, both good and bad, available for bioretention systems. It is important that any design be refined for targeted pollutants, regional climate and general aesthetic qualities.

Figure 13: Rain Garden at Horne St. School in Dover, NH

Tree Filter and Tree Wells

Tree box filters are mini bioretention systems that combine the versatility of manufactured devices with the water quality treatment of vegetated systems. They serve as attractive landscaping and drainage catch basins. Unlike many other forms of urban landscaping, they are not isolated behind curbs and can therefore take advantage of the water and nutrients in runoff. Their water quality treatment performance is high, often equivalent to other bioretention systems, particularly when well distributed throughout a site. Because of their small size, they are commonly treating relatively small areas (<10,000 sf) typical of a catch basin drainage.

Figure 14: Tree Box Filter at West Edge Parking Lot in Durham, NH

Dry Well

A dry well, sometimes called a seepage pit, is a subsurface storage facility that temporarily stores and infiltrates stormwater runoff from the roofs of residential structures. Roof leaders connect directly into the Dry Well, which may be either an excavated pit filled with uniformly graded stone, wrapped in geotextile or a prefabricated storage chamber or pipe segment. Dry Wells discharge the stored runoff via infiltration into the surrounding soils. In the event that the Dry Well is overwhelmed in an intense storm event, an overflow mechanism (surcharge pipe, connection to larger infiltration area or rain garden, etc.) will ensure that additional runoff is safely conveyed downstream.

A dry well is a cylindrical underground pre-cast system with perforated sides that allows captured stormwater to infiltrate in the ground white retaining the debris and sediment carried by

the stormwater. The debris and sediment will remain in the well and will require periodic maintenance to be removed (LGA 2011).

Figure 15: Dry Well (LGA)

Figure 16: Dry Well (Waterkeeper 2008)

Gravel Wetland

The subsurface gravel wetland is a recent innovation in Low Impact Development (LID) stormwater design. It approximates the look and function of a natural wetland, effectively removing sediments and other pollutants commonly found in runoff, while enhancing the visual appeal of the landscape and adding buffers or greenscape to urban areas. The subsurface gravel wetland evaluated at UNHSC is a horizontal-flow filtration system that should not be confused with stormwater wetlands that function more like ponds. Instead, it relies on a dense root mat, crushed stone, and an anaerobic, microbe rich environment to improve water quality. Like other filtration systems, it demonstrates a tremendous capacity to reduce peak flow and improve water quality.

Porous Pavements

Porous asphalt (PA) is an extremely effective approach to stormwater management. Unlike retention ponds, porous asphalt systems do not require large amounts of additional space. Rainfall drains through pavement and directly infiltrates the subsurface. This significantly reduces runoff volume and peak flows, decreases its temperature, improves water quality, and essentially eliminates the impervious surface. It also speeds snow and ice melt, reducing thesalt required for winter maintenance. The porous asphalt design tested at UNHSC is distinctive in its use of coarse sand as a sub base filter course-a refinement that enhances its effectiveness in improving water quality.

BMP Type	BMP Cost	Water Quality Treatment	Water Quantity Management	Maintenance Sensitivity
Bioretention/ Raingarden[6]	$18,000 cost per acre	Excellent	Excellent; however, it is suitable for water quality volume sizing only. May be most effectively used as a source control strategy reducing the overall percentages of effective impervious cover (EIC) and minimizing size of end of pipe structures.	Medium, requires periodic pruning of vegetation to prevent nutrient cycling and maintain aesthetic appearance. Periodic inspections for clogged surface areas, water routing and rodent burrowing are also important.
Tree Filter/ Tree Well[1]	$25,000 cost per acre 2,500 per unit	Excellent	This system is suitable for effective impervious cover (EIC) reduction only. Reduction of EIC will result in significantly lower water quantity management efforts (N.H. Des 2008).	Low, requires periodic replacement of vegetation (every five to ten years) and periodic inspection for trash accumulation and infiltration capacity.
Drywell[7]	$4 - $9 per cubic foot of storage volume provided (SWRPC, 1991; Brown and Schueler, 1997)	Excellent	. This structure is suitable to enhance water quality by reducing the amount of stormwater quality design storm runoff volume to be treated by the other, downstream stormwater management facilities.	Medium, requires inspection at least four times annually as well as after every storm exceeding 1 inch of rainfall.
Gravel Wetland[1]	$22,500 cost per acre	Excellent	Excellent; however, it is suitable for water quality volume sizing only.	Medium, requires periodic cutting of vegetation to prevent nutrient cycling. Pretreatment should be free draining, open structures stabilized with grass.
Porous Pavements[1]	Porous asphalt avg. $2.80/sq ft (UNHSC) Pervious concrete avg. $4.60/sq ft (NNCPA) Includes materials and installation	Excellent, except for nitrogen	Excellent. Is sufficient for quantity and quality control.	Medium, requires minimum two to four cleanings per year with a vacuum truck.

[6] UNHSC 2009 biannual report
[7] New Jersey Stormwater Best Management Practices Manual • Chapter 9.3: Standard for Dry Wells • February 2004

Non-Structural Strategies

Improved Regulations and Ordinances

The power of zoning and future growth for meeting IC reduction goals is a tremendous opportunity. Harnessing the improvements and upgrades associated with redevelopment can be an important element of IC reduction for existing areas. From a municipal perspective, the least cost effective approach is to rely solely upon municipal improvements. Commercial and private sector redevelopment disconnection and treatment requirements will help meet municipal permit requirements by leveraging capital improvements to properties in the watershed. A standardization of code and zoning updates for stormwater management is analogous to fire code, energy efficiency requirements, and other improvements for which commercial redevelopments are accustomed to.

Planning for better stormwater management is challenging because water resources are not confined to municipal boundaries and watershed plans are not always integrated into master plans. In addition, the visions supported by master plans are not always implemented through regulations or zoning. Sound planning should help communities (and their neighbors within the watershed) set the groundwork for sound policies and ultimately better protection of valuable water resources. While most communities have a master plan or comprehensive plans outlining a vision for the community, many land use decisions are made on a parcel-by-parcel basis. These parcel-by-parcel decisions can have cumulative impacts on water resources, stormwater infrastructure, and municipal budgets. A growing trend is emerging where municipalities are updating local regulations and developing guidelines to reflect the higher treatment standards of today. One of the most applicable methods is updating stormwater management standards in the planning board's site plan review regulations. Updated stormwater regulations or the development of a separate stormwater ordinance typically reflect s a BMP toolbox which now includes many systems capable of advanced stormwater management. These systems often incorporate some form of filtration and/or infiltration. Development of improved regulations will mean that new developers will be part of the solution in building the necessary infrastructure that protects water resources and ultimately decreases municipal expenses saving taxpayers money.

Historically, our wetlands, rivers, lakes, and estuaries have provided the work of cleaning and protecting our water resources, referred to as ecosystem services. Intense development can significantly impair water quality and change how surface and groundwater interact. With increases in impervious surfaces, the landscape's ability to absorb rainwater runoff decreases, reducing the amount of groundwater recharge. A variety of strategies exist for protecting water resources including non-structural approaches such as buffer conservation and stormwater ordinance adoption; decentralized structural controls such as rain gardens and porous pavements; and centralized strategies like subsurface infiltration chambers.

Protection of Critical Resource Areas

The most permanent and assured protection of sensitive resource areas is achieved through the use of conservation easements and conservation land acquisitions. Sensitive areas can also be effectively protected or buffered from development impacts by establishing overlay districts that prohibit or restrict development in drinking water or wellhead source areas, wetlands, shoreland buffers, wildlife corridors, cold water streams, and other critical natural resource areas.

Advanced Stormwater Management

Updated stormwater ordinances typically reflect a BMP toolbox which now includes many systems capable of advanced stormwater management. These systems typically incorporate some form of filtration and/or infiltration. Unfortunately, many toolboxes include ineffective practices as part of the accepted list. Rather, the trend is to add BMPs and leave the selection to the designer. Cost is a primary reason simple conventional practices are still widely used despite the availability of more effective practices. Until these ineffective practices are removed from consideration, their widespread usage will remain.

Stormwater Utilities

When reviewing development proposals, long-term and cumulative costs for municipal stormwater infrastructure should be considered. Communities pay for maintaining, replacing, and upgrading aging infrastructure. Many municipalities, while already burdened with aging and inadequate infrastructure, are facing new federal requirements for managing stormwater to higher levels and are unsure as to how to finance these necessary upgrades. Some communities are addressing costs by implementing stormwater utility fees. The stormwater utility fee is similar to those paid for electricity or drinking water that is based on usage and supports stormwater infrastructure and management. The funds are dedicated exclusively to stormwater needs. Fees are typically based on lot characteristics such as impervious area, and reductions in the fee are often offered for practices that reduce discharges and treat for water quality. These fee reductions can serve as an incentive to encourage more innovative and effective stormwater management practices. Stormwater utility fees are commonly based on an equivalent residential unit (ERU) that represents the average impervious area of a single family lot, usually several thousand square feet. Land uses with higher impervious areas, such as commercial developments, would pay an ERU multiple as higher levels of impervious area require more maintenance and management. In areas of the US, fees in the range of $2-$6 per ERU per month have been documented for residential properties and range from $25-$75 per month per acre of impervious area for commercial properties. Stormwater utilities are an essential element to successful municipal compliance with federal stormwater regulations.

Adoption of Innovative Land Use Ordinances

Land use ordinances can be used to help protect water resources by incorporating environmental characteristics in zoning, or requirements, or by providing incentives for conservation developments, as well as establishing environmental protection performance standards that development proposals must meet.

Watershed-based zoning is a land use management technique that identifies specific permitted uses within a defined watershed boundary as opposed to political boundaries. Typically, watershed-based zoning is conducted as part of a larger land use or watershed planning effort that protects specific resources by setting limits on the level of impervious surfaces and density within a zone. To achieve the success of watershed-based zoning necessary to reach water quality protection, land planning zoning standards are often required. Successful watershed-based zoning may typically require an initial assessment of existing conditions, that may include a natural resources inventory; an analysis of existing impervious surfaces and future conditions/ build out; and the development of Master Plan language consistent with the zone recommendations, with specific prescriptive actions to mitigate the impacts of land use changes in the zone and long term monitoring.

Updating Site Plan and Subdivision Review Regulations

More effective stormwater management strategies and performance requirements need to be outlined in town regulations and considered by developers and municipal staff early in the development planning process. Promoting the latest state and federal standards such as water quality treatment and infiltration is the best way to prevent problems before they happen. If not already detailed in a land use ordinance, these regulations should specify the standards developers need to meet. Developers should submit designs that meet performance standards, have requirements for inspections, and incorporate financial sureties that stormwater, erosion, and sediment control measures will be built and maintained as proposed.

Sample site plan review regulations are included in Appendix: I.

THE ECONOMICS OF LOW IMPACT DEVELOPMENT

The environmental and water quality benefits of LID are commonly known. However, considerable economic, infrastructure, and adaptation planning benefits are also being realized through the incorporation of LID-based strategies. Less widely known are the potential economic benefits of using a combination of Green Infrastructure (or LID) and Gray Infrastructure (conventional) for stormwater management. LID is commonly misperceived as only adding expense to a project; however, this perspective fails to acknowledge the broader benefits that can be observed in terms of whole project costs for new construction, and in some instances, increased life-cycle benefits as well.

The misperception generally focuses on budget line item increases, such as the added expense associated with incorporating bioretention instead of standard landscaping, or the additional costs of utilizing porous pavements over traditional pavement.

While individually, Green Infrastructure elements will add expense to a project, at the same time, costs savings are often realized on an overall project basis as the need for conventional stormwater infrastructure such as curbing, catch-basins, piping, ponds, and other hydraulic controls are reduced. Of course, cost savings are not observed when compared with a complete lack of stormwater management, but rather for projects consistent with new state and federal permitting requirements addressing volume and pollutant reduction. Basic stormwater

management strategies such as ponds and swales are generally cheaper to design and install, but may not meet regulatory guidelines with respect to water quality treatment.

The Case Studies presented in Appendices D,E, and F, focus on project costs that are typically the basis for most municipal budgeting decisions. LID structural controls will rarely be less expensive than minimal stormwater management and cost benefits may not be possible for retrofitting of existing stormwater management facilities. The greatest potential economic benefit exists for management of combined sewer overflow and wastewater treatment upgrades, which is often the single greatest municipal expense for communities that are required to separate stormwater and wastewater sewers. In addition, there are ecological services and benefits that provide cost savings by protecting adjacent and downstream abutters from property loss by storing and treating the water before it leaves the site.

Economic benefits associated with the use of LID:

- Whole project cost savings for new development by reduction of drainage infrastructure ranging from 6-26%
- Land development savings from a reduced amount of disturbance
- Higher property values of 12 to 16 percent
- Reduction in home cooling by 33 to 50 percent from the use of natural vegetation and reduced pavement area.

APPENDIX A: TERMINOLOGY

Best Management Practices (BMP's): Methods and means that have been determined to be the most effective, practical approaches of preventing or reducing pollution and detrimental impacts from stormwater runoff (Durham).

Buffer: A vegetated area or zone separating a development from a sensitive resource or neighboring property in which proposed development is restricted or prohibited (Durham).

Impervious Surfaces: A material with low permeability that impedes the natural infiltration of moisture into the ground so that the majority of the precipitation that falls on the surface runs off or is not absorbed into the ground. Common impervious surfaces include, but are not limited to, roofs, concrete or bituminous paving such as sidewalks, patios, driveways, roads, parking spaces or lots, and storage areas, compacted gravel including drives and parking areas, oiled or compacted earthen materials, stone, concrete or composite pavers, wood, and swimming pools (Durham).

Polycyclic Aromatic Hydrocarbons (PAHss): PAH's are "a group of organic chemicals that includes several petroleum products and their derivatives" (EPA 2009b).

Pollutant: A pollutant is a substance that adversely affects the usefulness of a resource and is in a form that can be incorporated into, or be ingested by organisms within, the environment (EPA 2009b).

Chlorides: Chloride is a salt compound resulting from the combination of the gas chlorine and a metal. Common chlorides include sodium chloride (NaCl) and magnesium chloride (MgCl2) (EPA 2009a).

Unimproved Road: An unimproved road is a gravel or low use road that does not contain drainage features (Wyoming_Technology_Transfer_Center 2010).

Runoff: Stormwater runoff is the generated when precipitation from rain and snowmelt events flows over impervious surfaces (NPDES 2011).

Sediment: Sediment is a collection of loose particles that settle at the bottom of a body of water. Sediment is generated from the erosion of soil or from the decomposition of plants and animals(EPA 2009b).

Sheet Flow: Sheet flow is a shallow lateral flow traveling across an impervious surface.

Total Suspended Solids (TSS): TSS is a "measure of the filterable solids present in a sample, as determined by the method specified in 40 CFR Part 136" (NPDES 2004).

Gravel Roads Management Systems (GRMS): When referring to management systems, historically such systems have been referred to as 'gravel roads management systems' or 'gravel roads maintenance systems.' In keeping with this precedent, the term 'gravel roads management or maintenance system' (GRMS) is used to refer to systems designed to plan and program

unsealed roads maintenance and improvement processes (Wyoming_Technology_Transfer_Center 2010).

Drainage Terms: When a road is more than simply tracks in the surrounding countryside made by four (or more) wheeled vehicles one should describe it as 'formed' or 'improved.' To some, an 'improved' road merely has ditches and other drainage features, while to others, an 'improved' road also has imported surfacing aggregate (Wyoming_Technology_Transfer_Center 2010).

Dirt Roads: Use of this term by roads professionals is discouraged, though it is popular with the general public. Though sometimes synonymous with the term 'earth roads' below, the term 'dirt roads' should not be used due to its multiple meanings (Wyoming_Technology_Transfer_Center 2010).

Earth or Native Soil Roads: This term should be used to describe roads surfaced with soil from the immediate vicinity. To some, even a road that has material pulled up from the borrow pit to form the road is no longer an 'earth' road. When using these terms, care should be taken to indicate whether or not the native soil has been moved from its original location to the road (Wyoming_Technology_Transfer_Center 2010).

Gravel Roads: This term is problematic due to its widespread use with multiple meanings. To some, a 'gravel' road implies crushed alluvial rock while to others it simply implies that surfacing material has been imported. Roads made with a crushed shale surface may be called a 'shale road' or they may be simply known as a 'gravel road;' the situation is similar for other roads surfaced with a particular type of crushed or processed aggregate. Given these ambiguities, this term should be used with caution, and when it is used, it should be concisely defined. Chemically Treated Roads: A chemically treated unsealed road has had dust suppressant (other than water) or soil stabilizer added to it recently enough to bind together or significantly alter the road's surfacing material from its original, untreated state (Wyoming_Technology_Transfer_Center 2010).

Surface Treated Roads: Roads comprised of aggregate topped with a sealant, typically asphalt, cutback asphalt or emulsified asphalt, are referred to as 'surface treated roads.' They may also be referred to as 'bituminous surface treated' or 'BST' roads. When a layer of aggregate chips is placed on top of the asphalt, the road may be referred to as a 'blotter road' or a 'chip seal road.' When no chips are added, the road may be referred to as an 'inverted penetration' ('invert pen') road. Other terms referring to various surface treatments include 'armoring,' 'armouring,' 'metalling' and 'running course.' These terms are not in widespread use and their use is discouraged. If they are used, they should be concisely defined (Wyoming_Technology_Transfer_Center 2010).

Paved Roads: The use of the terms 'paved' and 'unpaved' is discouraged because they have such widely disparate meanings to different people and in different parts of the world. To some, any road with constructed layer(s) to carry traffic is considered a pavement, while in other places any road with a semi-permanent surface is 'paved,' while to still others, the term 'pavement' implies

that the road is constructed with hydraulic or asphaltic concrete and is placed with a screed (Wyoming_Technology_Transfer_Center 2010).

Sealed Roads: When a road's surface is semi-permanent and water-resistant, the road is said to be 'sealed.' 'Unsealed' roads are those with a granular surface that are or may be maintained on a routine basis with a motor grader, and are the road types whose repair and maintenance is the topic of this paper (Wyoming_Technology_Transfer_Center 2010).

Porous Media: Material with open connected pore spaces that allows water to percolate through it such as granular soils, gravel, crushed stone, pervious pavements, and woven and non-woven geosynthetics (Durham).

Redevelopment: Any man-made change to previously improved real estate, including but not limited to buildings or other structures, mining, dredging, filling, grading, paving, excavation, and drilling operations (Durham).

Riparian: Referring to anything connected or immediately adjacent to the shoreline or bank of a stream, river, pond, lake, bay, estuary or other similar body of water (Durham).

Riparian buffer: The naturally vegetated shoreline, floodplain or upland forest adjacent to a surface water body. Riparian buffers provide stormwater control flood storage and habitat values. Wherever possible, riparian buffers should be sized to include the 100-year floodplain as well as steep banks and freshwater wetlands (Durham).

APPENDIX B: OPERATIONS AND MAINTENANCE MANUAL FOR SCHOOL STREET SCHOOL

City of Rochester
Department of Public Works
Willow Brook Watershed Project
Best Management Practices
Operations & Maintenance Plan

City of Rochester, NH
January, 2012
University of New Hampshire Stormwater Center
Durham, NH 03824

Abstract:
This Operations and Maintenance Plan has been written for the City to guide maintenance activities of BMPs installed for the City through funds acquired from NHDES to restore and improve stormwater runoff conditions in the Willow Brook Watershed. Willow Brook, a tributary to the Cocheco River in the urban center of Rochester is impaired for Primary and Secondary Contact Recreation (e. coli). Its direct receiving waters, the Cocheco River, are impaired for Aquatic Life Use (benthic macroinvertebrates and habitat) as well as Primary Contact Recreation (E. coli). Sources are listed as unknown, but are likely nonpoint source pollutants from urban stormwater runoff. The CRWC with the City of Rochester Public Works Dept.(DPW), and the UNH Stormwater Center(UNHSC) staff developed a plan for installation of LID demonstration practices, conducted outreach and educational activities, and performed pilot projects using Low Impact Development to reduce effective impervious cover (EIC).

BMPs utilized in the Willow Brook Watershed Project Include:

- Dry Wells
- Rain Gardens
- Tree Filters
- Porous Pavements

BMP Owner:
City of Rochester (all Lupine Lane locations)
City of Rochester and the Rochester School Department (all School Street School locations)
O&M Responsible Party: The City of Rochester
The City of Rochester will use the Department of Public Works (DPW) and the School Department (SD) for routine inspection and monitoring of all BMPs

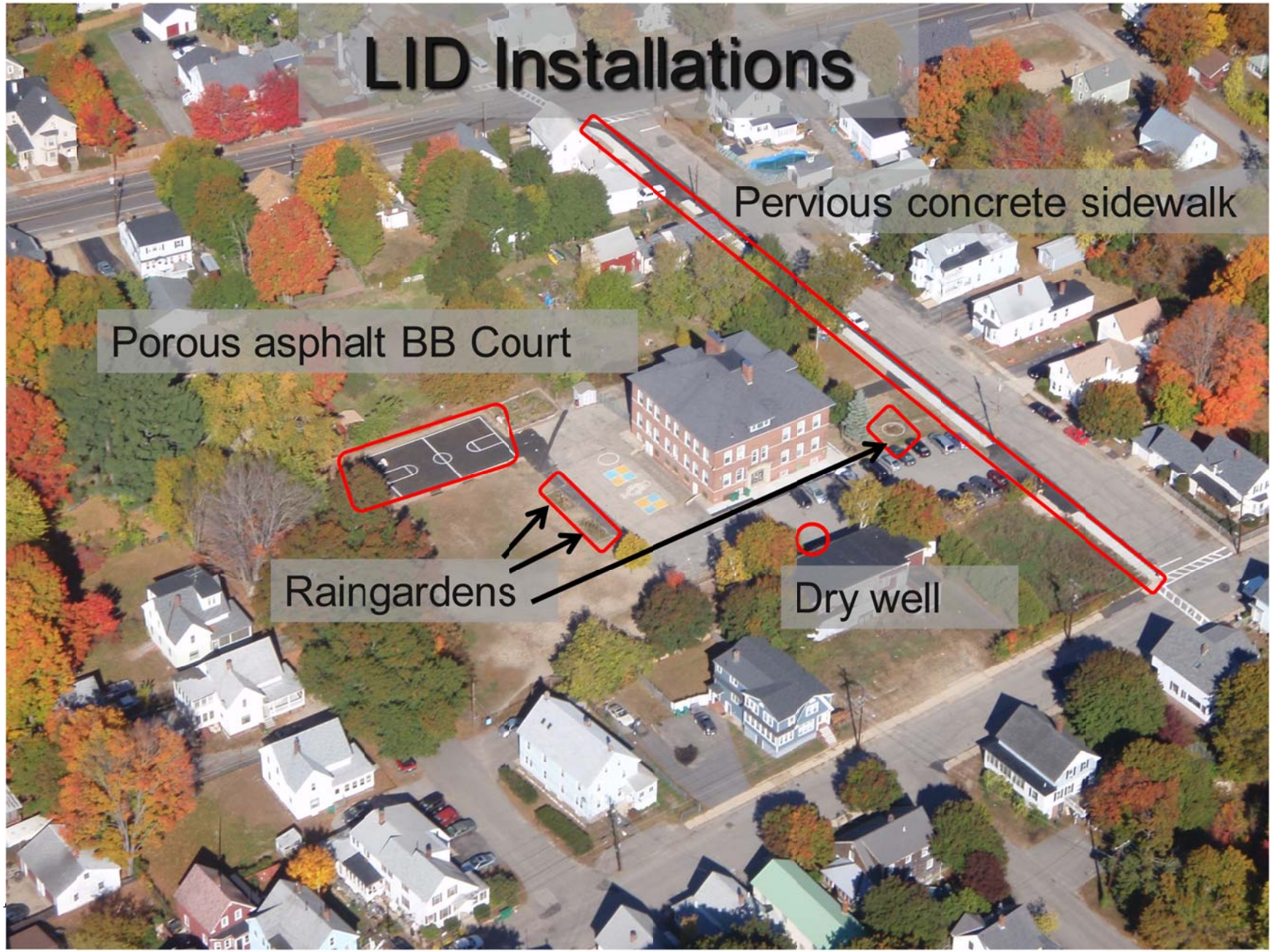
Schedule for Inspection & Maintenance:
See attached O&M procedures for each specific BMP.

List of O&M Tasks:
See attached O&M procedures and checklist for each specific BMP.

Source of Long-Term O&M Funding:
City of Rochester annual department budgets (DPW or SD).

BMP Locations:
See attached Site Overview Maps

Attachments
School Street School Overview Map.
Lupine Lane Overview Map.
Maintaining Raingardens at School Street School
UNHSC Biofilter Maintenance Guide and Checklist
UNHSC Leaching Catchbasin and Sediment Trap Maintenance Guide and Checklist.
UNHSC Porous Pavement Maintenance Guide and Checklist.


LID Installations
Pervious concrete sidewalk
Porous asphalt BB Court
Raingardens
Dry well

Lupine Lane Installations
Tree Filter
Tree Filter
Raingarden

Maintaining the Rain Gardens at School Street School, Rochester, NH

Year 1

Watering

1. For the first three weeks after planting, water the rain gardens once per week. It is not necessary to water during a given week if one-inch of rain accumulates.
2. Water the garden during droughty periods in mid-summer if needed.

Weeding

1. First identify what is a weed and what is a rain garden plant. Look closely at the weed to become familiar with its leaf shape and arrangement, current height and other noteworthy features. Once the weeds are identified, assign a specific weed for each student or group of students to hand pull. This way ensures only the weeds are removed.
2. Remove plants carefully in order not to disrupt the rain garden species. Pull from the base of the plant. It is easier to pull weeds when the weeds are young and small.
3. Take the weeds to a compost pile.
4. Check the status of weeds and pull them, if necessary, once every three weeks in the summer.

Year 2 and Beyond

General maintenance

In spring when new growth begins, cut off the dead plant material. (Keep stems and seedheads on during winter for visual interest, winter lessons, wildlife cover, and food for birds.)

Watering

Water the garden only in drought.

Weeding

Continue weeding as needed. Rain garden plants will fill in the spaces and form dense root mass, which will significantly reduce weeding over time. It is still worthwhile to monitor the garden for weeds every three to four weeks during the summer.

Litter, Sand and Leaves Removal

Periodically remove litter that may blow into the garden. Clean up leaves at the end of the growing season to prevent the dead leaves from forming an impervious mat in winter. Remove deposits of sand that may wash in with stormwater.

Funding for this project was provided in part by a Watershed Assistance Grant from the NH Department of Environmental Services with Clean Water Act Section 319 funds from the U.S. Environmental Protection Agency.

Background

A rain garden planting is not maintenance free and will regularly need some maintenance to remove weeds and dead plant material. Fortunately, time spent caring for the garden decreases over time. The plants have been chosen for this rain garden because they are adapted to the climate and soils and can tolerate excessive heat, bitter cold, drought and flooding. The do not need fertilizer, winter protection or irrigation.

The first two years require the most care while the plants are establishing themselves in the garden. As they are maturing during the first year, they need regular watering to encourage root development. Irrigate the plants so that the water soaks deeply into the ground, which is equivalent to a one-inch rainfall. Short sprinkles of water encourage the roots to grow along the surface. When roots grow along the surface, plants are less hardy during droughts and freezing temperatures.

Pull weeds to reduce competition for space, light, and water. Most weeds are pioneer species, which means they can grow very quickly, They fill in the spaces and often can crowd out new rain garden plants. Additionally they give the garden a messy, unkempt appearance. The use of mulch to prevent weeds is questionable as the mulch may block infiltration of stormwater though the garden soil.

Much of the maintenance during the establishment years occurs through the summer months. Therefore, before summer vacation, enlist volunteers to monitor, water, and weed the garden during summer vacation. Local garden clubs, summer school students, scout troops, families, and Master Gardeners may be willing to volunteer during the summer. Most potential volunteers will say "yes" when asked.

Extensions

This maintenance plan has been derived from a project developed at the University of Wisconsin Arboretum called *Earth Partnership for Schools* <uwarboretum.org>. Their curriculum includes extensions of the maintenance plan in which students learn about plant and garden care while managing a new rain garden. Objectives are that students will 1) Understand plant needs for survival, 2) Learn basic land care principles, and 3) Participate in a service learning project. In addition to the activities listed in our maintenance guide on the reverse, Extension Activities include:

1. Keep track of how many weeds are pulled and how many of each kind.
2. Return to the classroom and make a chart of the weeds pulled. Save the chart to compare with future weeding sessions. Take note how numbers and types of weeds change over time.
3. Create a field guide to the rain garden plants and weeds.
4. Identify and research the rain garden and weed species. Find out if the weeds are native or non-native. Learn about their history and life cycles.

Project Partners: Cocheco River Watershed Coalition, City of Rochester, UNH Stormwater Center, 2011

Regular Inspection and Maintenance Guidance for Bioretention Systems / Tree Filters

Maintenance of bioretention systems and tree filters can typically be performed as part of standard landscaping. Regular inspection and maintenance is critical to the effective operation of bioretention systems and tree filters to insure they remain clear of leaves and debris and free draining. This page provides guidance on maintenance activities that are typically required for these systems, along with the suggested frequency for each activity. Individual systems may have more, or less, frequent maintenance needs, depending on a variety of factors including the occurrence of large storm events, overly wet or dry (I.E., drought), regional hydrologic conditions, and the upstream land use.

ACTIVITIES

The most common maintenance activity is the removal of leaves from the system and bypass structure. Visual inspections are routine for system maintenance. This includes looking for standing water, accumulated leaves, holes in the soil media, signs of plant distress, and debris and sediment accumulation in the system. Mulch and/or vegetation coverage is integral to the performance of the system, including infiltration rate and nutrient uptake. Vegetation care is important to system productivity and health.

ACTIVITY	FREQUENCY
A record should be kept of the time to drain for the system completely after a storm event. The system should drain completely within 72 hours.	After every major storm in the first few months, then biannually.
Check to insure the filter surface remains well draining after storm events. **Remedy**: If filter bed is clogged, draining poorly, or standing water covers more than 15% of the surface 48 hours after a precipitation event, then remove top few inches of discolored material. Till or rake remaining material as needed.	
Check inlets and outlets for leaves and debris. **Remedy**: Rake in and around the system to clear it of debris. Also, clear the inlet and overflow if obstructed.	Quarterly initially, biannually, frequency adjusted as needed after 3 inspections
Check for animal burrows and short circuiting in the system. **Remedy:** Soil erosion from short circuiting or animal boroughs should be repaired when they occur. The holes should be filled and lightly compacted	
Check to insure the filter bed does not contain more than 2 inches accumulated material **Remedy:** Remove sediment as necessary. If 2 inches or more of filter bed has been removed, replace media with either mulch or a (50% sand, 20% woodchips, 20% compost, 10% soil) mixture.	
During extended periods without rainfall, inspect plants for signs of distress. **Remedy:** Plants should be watered until established (typical only for first few months) or as needed thereafter.	
Inspect inlets and outlets to ensure good condition and no evidence of deterioration. Check to see if high-flow bypass is functioning. **Remedy:** Repair or replace any damaged structural parts, inlets, outlets, sidewalls.	Annually
Check for robust vegetation coverage throughout the system. **Remedy:** If at least 50 % vegetation coverage is not established after 2 years, reinforcement planting should be performed.	
Check for dead or dying plants, and general long term plant health. **Remedy:** This vegetation should be cut and removed from the system. If woody vegetation is present, care should be taken to remove dead or decaying plant Material. Separation of Herbaceous vegetation rootstock should occur when over-crowding is observed.	As needed

1/15/2011, University of New Hampshire Stormwater Center

CHECKLIST FOR INSPECTION OF BIORETENTION SYSTEM / TREE FILTERS

Location: Inspector:
Date: Time: Site Conditions:
Date Since Last Rain Event:

Inspection Items	Satisfactory (S) or Unsatisfactory (U)		Comments/Corrective Action
1. Initial Inspection After Planting and Mulching			
Plants are stable, roots not exposed	S	U	
Surface is at design level, typically 4" below overpass	S	U	
Overflow bypass / inlet (if available) is functional	S	U	
2. Debris Cleanup (2 times a year minimum, Spring & Fall)			
Litter, leaves, and dead vegetation removed from the system	S	U	
Prune perennial vegetation	S	U	
3. Standing Water (1 time a year, After large storm events)			
No evidence of standing water after 72 hours	S	U	
4. Short Circuiting & Erosion (1 times a year, After large storm events)			
No evidence of animal burrows or other holes	S	U	
No evidence of erosion	S	U	
5. Drought Conditions (As needed)			
Water plants as needed	S	U	
Dead or dying plants	S	U	
6. Overflow Bypass / Inlet Inspection (1 times a year, After large storm events)			
No evidence of blockage or accumulated leaves	S	U	
Good condition, no need for repair	S	U	
7. Vegetation Coverage (once a year)			
50 % coverage established throughout system by first year	S	U	
Robust coverage by year 2 or later	S	U	
8. Mulch Depth (if applicable)(once every 2 years)			
Mulch at original design depth after tilling or replacement	S	U	
9. Vegetation Health (once every 3 years)			
Dead or decaying plants removed from the system	S	U	
10. Tree Pruning (once every 3 years)			
Prune dead, diseased, or crossing branches	S	U	

Corrective Action Needed	Due Date
1.	
2.	
3.	

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Regular Inspection and Maintenance Guidance for Leaching Catchbasins and Sedimentation Traps

Regular inspection and maintenance is critical to the effective operation of Leaching Catchbasin systems.
It is the responsibility of the owner to maintain the Leaching Catchbasin in accordance with the minimum design standards.
This page provides guidance on maintenance activities that are typically required for these systems, along with the suggested frequency for each activity.
Individual systems may have more, or less, frequent maintenance needs, depending on a variety of factors including the occurrence of large storm events, overly wet or dry (I.E., drought), regional hydrologic conditions, and any changes or redevelopment in the upstream land use.

ACTIVITIES

Visual inspections and vacuuming are routine for system maintenance. This includes inspection for standing water, and removal by vacuum of leaves, trash, debris and sediment accumulation in the system.

1ST YEAR POST-CONSTRUCTION ACTIVITY	FREQUENCY
Check that surface inlet is free and able to convey water. **Remedy:** Remove debris and unclog grated inlet.	After every major storm in the first few months, then biannually.

POST-CONSTRUCTION ACTIVITY	FREQUENCY
Check system for accumulated sediment, leaves and debris. **Remedy**: If there is significant accumulation of sediment, leaves and debris such that ½ of the original sump volume has been filled vacuum the sediment with a vactor truck.	Annually
Check for standing water in the catchbasin **Remedy:** If there is significant standing water 72 hrs after a storm event, remove accumulated materials by vacuuming thoroughly. A vactor truck is recommended.	

1/25/2012, University of New Hampshire Stormwater Center

CHECKLIST FOR INSPECTION OF LEACHING CATCHBASINS AND SEDIMENTATION TRAPS

Location: Inspector:
Date: Time: Site Conditions:
Date Since Last Rain Event:

Inspection Items	Satisfactory (S) or Unsatisfactory (U)	Comments/Corrective Action
1st Year Post-Construction Monitoring (After every major storm for the first three months)		
Surface inlet is free and able to convey water	S U	
Post-Construction Routine Monitoring (at least every 12 months thereafter).		
1. Accumulation of Sediment and Trash		
Evidence of sediment accumulation, trash, and debris.	S U	
Standing water evident in the system.	S U	
Sediment, trash, or debris filling more than ½ of the system	S U	

Corrective Action Needed	Due Date
1.	
2.	
3.	

NOTES:

1/25/2012, University of New Hampshire Stormwater Center

Regular Inspection and Maintenance Guidance for Porous Pavements

Regular inspection and maintenance is critical to the effective operation of porous pavement. It is the responsibility of the owner to maintain the pavement in accordance with the minimum design standards. This page provides guidance on maintenance activities that are typically required for these systems, along with the suggested frequency for each activity. Individual systems may have more, or less, frequent maintenance needs, depending on a variety of factors including the occurrence of large storm events, seasonal changes, and traffic conditions.

Inspection Activities

Visual inspections are an integral part of system maintenance. This includes monitoring pavement to ensure water drainage, debris accumulation, and surface deterioration.

ACTIVITY	FREQUENCY
Check for standing water on the surface of the pavement after a precipitation event. If standing water remains within 30 minutes after rainfall had ended, cleaning of porous pavement is recommended.	2 to 4 times per year, more frequently for high use sites or sites with higher potential for run-on
Vacuum sweeper shall be used regularly to remove sediment and organic debris on the pavement surface. The sweeper may be fitted with water jets.	
Pavement vacuuming should occur during spring cleanup following the last snow event to remove accumulated debris, at minimum.	
Pavement vacuuming should occur during fall cleanup to remove dead leaves, at minimum.	
Power washing can be an effective tool for cleaning clogged areas. This should occur at mid pressure typically less than 500 psi and at an angle of 30 degrees or less.	
Check for debris accumulating on pavement, especially debris buildup in winter. For loose debris, a power/leaf blower or gutter broom can be used to remove leaves and trash.	
Check for damage to porous pavements from non-design loads. Damaged areas may be repaired by use of infrared heating and rerolling of pavement. Typical costs may be 2,000/ day for approximately 500 ft of trench.	

Maintenance Activities

Routine preventative cleaning is more effective than corrective cleaning.

Activity	Frequency
Controlling run-on and debris tracking is key to extending the life of porous surfaces. Erosion and sedimentation control of adjacent areas is crucial. Vacuuming adjacent non porous asphalt can be effective at minimizing run-on.	Whenever vacuuming adjacent porous pavements
Repairs may be needed from cuts of utilities. Repairs can be made using standard (non-porous) asphalt for most damages. Repairs using standard asphalt should not exceed 15% of total area.	As needed
Do not store materials such as sand/salt, mulch, soil, yard waste, and other stock piles on porous surfaces.	
Stockpiled snow areas on porous pavements will require additional maintenance and vacuuming. Stockpiling on snow on porous pavements is not recommended and will lead to premature clogging.	
Damage can occur to porous pavement from non-design loads. Precautions such as clearance bars, signage, tight turning radius, high curbs, and video surveillance may be required where there is a risk off non-design loads.	
Posting of signage is recommended indicating presence of porous pavement. Signage should display limitation of design load (i.e. passenger vehicles only, light truck traffic, etc. as per pavement durability rating.)	

2/2011, University of New Hampshire Stormwater Center

CHECKLIST FOR INSPECTION OF POROUS PAVEMENTS

Location: Inspector:
Date: Time: Site Conditions:
Date Since Last Rain Event:

Inspection Items	Satisfactory (S) or Unsatisfactory (U)	Comments/Corrective Action
1. Salt / Deicing *Note complete winter maintenance guidance is available at UNHSC		
Use salt only for ice management	S U	
Piles of accumulated salt removed in spring	S U	
2. Debris Cleanup (2-4 times a year minimum, Spring & Fall)		
Clean porous pavement to remove sediment and organic debris on the pavement surface via vacuum street sweeper.	S U	
Adjacent non porous pavement vacuumed	S U	
Clean catch basins (if available)	S U	
3. **Controlling Run-On (2-4 times a year)**		
Adjacent vegetated areas show no signs of erosion and run-on to porous pavement	S U	
4. Outlet / Catch Basin Inspection (if available) (2 times a year, After large storm events)		
No evidence of blockage	S U	
Good condition, no need for cleaning/repair	S U	
5. Poorly Drained Pavement (2-4 times a year)		
Pavement has been pressure washed and vacuumed	S U	
6. Pavement Condition (2-4 times a year minimum, Spring & Fall)		
No evidence of deterioration	S U	
No cuts from utilities visible	S U	
No evidence of improper design load applied	S U	
7. Signage / Stockpiling (As Needed)		
Proper signage posted indicating usage for traffic load	S U	
No stockpiling of materials and no seal coating	S U	

Corrective Action Needed	Due Date
1.	
2.	
3.	

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APPENDIX C: LAND USE, IMPERVIOUS COVER, AND POLLUTANT LOAD METHODS

Land use and impervious surface mapping was conducted in March 2011 by the Complex Systems Research Center at UNH. The GRANIT staff mapped land uses, land cover, and impervious surfaces for the Willow Brook watershed (2,515 acres) in Rochester, NH. This document provides a brief overview of the methodology used, and summarizes the results of the mapping effort.

The land use and land cover classification process was as follows. This data set contains 56 categories of land use data (polygons) for 58 towns in southeast, New Hampshire. The primary source used to derive the data were digital color ortho-photographs (1-foot resolution) collected in the spring of 2005. Sanborn Inc. of Colorado Springs, CO produced the photography. Other sources used to develop the classification included road centerline data from the New Hampshire Department of Transportation (NHDOT), surface water data from the New Hampshire Hydrography Dataset (NHHD), and wetlands data from the National Wetlands Inventory(NWI) of the United States Fish and Wildlife Service (FWS). A set of mapping standards and protocols were developed to govern key technical components of the project, including definitions of the land use classes and identification of feature automation protocols. The land use classification codes were based on a hybrid of the USGS Anderson land-use and land-cover classification system (Levels I and II),(http://landcover.usgs.gov/classes.html), as modified to satisfy the Land use component of the I-93 Corridor Widening-funded project referenced in the project description. These mapping standards and protocols were developed jointly and/or reviewed by staff from various regional planning agencies and the Office of Energy and Planning along with Complex Systems Research Center

The impervious cover classification process was as follows. The first step was to delineate the Willow Brook watershed. This was done using standard ArcGIS (v10) watershed tools applied to a digital elevation model derived from the National Elevation Dataset (NED) as of the summer of 2010. Generally described, the watershed boundary was delineated by creating a pour point near the confluence of Willow Brook and the Cocheco River (-70.9758 longitude, 43.2824 latitude), and selecting all upstream pixels that flow into that location. The derived raster was then converted to a vector feature class representing the boundary of the watershed.

Impervious surfaces were then delineated for the watershed based on 1-foot resolution aerial photography collected in April of 2010. Impervious surfaces were mapped into the following categories:

Code	Description
1	Asphalt roads
2	Asphalt driveways
3	Compacted gravel/soil
4	Asphalt parking
5	Rooftops
6	Other asphalt (e.g. sidewalks and other asphalt areas that do not fit the above categories)
7	Other built (e.g. patios and decks around buildings and swimming pools, probably somewhat pervious)

The processing involved identifying and mapping impervious surfaces within the newly created watershed boundary. This step progressed by interpreting visible features in the aerial photography and automating each by screen-digitizing the extent into individual polygons and coding its type (as described above) into the appropriate impervious surface category.

Table 1 lists the acreages for the various impervious surface categories cross-tabulated by land use category. (The land use data was derived from 1-foot resolution aerial photography acquired in 2005, and is available from the GRANIT data archive.) Figure 1 shows an overview of the Willow Brook watershed along with a generalized representation of the mapped impervious surfaces. Figure 2 shows a large scale view of an area within the watershed with the individual impervious categories discretely symbolized. Figure 3 displays the 2005 land use delineation and distribution for the Willow Brook watershed.

Table 1. Impervious surfaces by type and land use category for the Willow Brook watershed. (All figures reported in acres.)

Land Use	Pervious	Asphalt roads	Asphalt driveways	Compacted gravel/soil	Asphalt parking	Rooftops	Other asphalt (e.g. sidewalks)	Other built (e.g. decks, patios)	Impervious Total	Total
	Acres									
1110 - Multi-family, medium to high rise apartments and condominiums (4 or more stories)	0.1	0.0	0.0	0.4	1.3	1.1	0.0	0.0	2.9	**3.1**
1120 - Multi-family, low rise apartments and townhouses, but not duplexes (1 - 3 stories)	47.7	5.1	6.3	1.8	5.9	15.3	2.2	0.7	37.2	**84.9**
1130 - Single family/duplex	542.3	13.9	42.3	7.0	5.0	67.4	3.6	5.6	144.8	**687.1**
1140 - Mobile home parks	25.0	1.4	2.2	0.1	0.0	4.4	0.2	0.2	8.3	**33.3**
1150 - Group and transient quarters	1.8	0.0	0.0	0.0	0.6	0.4	0.1	0.0	1.1	**2.9**
1210 - Commercial retail	5.1	2.7	1.1	1.4	11.8	6.1	1.5	0.1	24.8	**29.9**
1220 - Commercial wholesale	1.2	0.1	0.1	0.0	2.0	1.5	0.1	0.0	3.8	**5.0**
1230 - Services	4.7	0.7	0.6	1.1	7.4	3.1	2.1	0.0	15.1	**19.8**
1240 - Lodging	0.6	0.1	0.0	0.0	0.0	0.1	0.0	0.0	0.2	**0.8**
1250 - Government	5.8	0.4	0.0	0.3	5.0	1.8	0.6	0.0	8.1	**13.9**
1260 - Institutional	18.4	0.7	1.6	0.3	11.2	7.4	1.0	0.1	22.2	**40.6**
1270 - Educational	5.6	0.0	0.3	0.0	1.9	1.5	0.5	0.0	4.2	**9.8**
1280 - Indoor cultural/public assembly	2.3	0.6	0.1	1.1	4.7	2.0	0.2	0.2	8.8	**11.1**
1300 - Industrial	5.0	0.4	0.2	0.1	6.5	3.4	0.0	0.0	10.6	**15.7**
1420 - Rail transportation	5.0	0.2	0.0	0.1	0.0	0.0	0.0	0.0	0.3	**5.3**
1441 - Limited & controlled highway right-of-way	0.2	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.5	**0.7**
1442 - Road right-of-way	6.3	80.6	1.4	1.0	0.8	0.0	0.5	0.0	84.3	**90.6**
1446 - Parking structure/lot	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.3	**0.3**
1447 - Auxiliary transportation	0.6	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.4	**1.0**
1460 - Electric, gas and other utilities	33.9	0.2	0.0	0.0	0.0	0.0	0.1	0.2	0.4	**34.3**
1470 - Water and wastewater utilities	0.2	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.1	**0.3**
1520 - Office park	0.2	0.0	0.0	0.0	0.8	0.2	0.0	0.0	1.1	**1.3**
1530 - Shopping mall	0.2	0.0	0.0	0.0	1.5	1.2	0.0	0.0	2.7	**2.9**
1610 - Multiple stories, residential in upper stories only	0.1	0.3	0.0	0.0	0.1	0.1	0.1	0.0	0.5	**0.6**
1690 - Other mixed uses	0.0	0.0	0.0	0.1	0.2	0.2	0.0	0.0	0.6	**0.6**
1730 - Outdoor recreation	5.7	0.3	0.0	0.6	0.3	0.0	0.5	0.0	1.7	**7.4**
1740 - Cemeteries	31.1	0.2	2.2	0.4	0.0	0.0	0.0	0.0	2.8	**33.9**
1780 - Maintained open area	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**1.6**
2000 - Agricultural Land	97.9	0.3	0.1	0.3	0.0	0.2	0.0	0.0	0.8	**98.7**
3000 - Brush or Transitional Between Open and Forested	17.8	0.1	0.0	0.0	0.0	0.0	0.1	0.0	0.1	**17.9**
4000 - Forest Land	1047.1	4.7	1.5	0.2	1.4	1.6	0.5	0.1	10.1	**1,057.2**
5000 - Water	1.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**1.8**
6000 - Wetlands	181.3	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.2	**181.5**
7600 - Disturbed Land	14.5	0.1	0.1	0.0	0.0	0.2	0.5	0.0	0.9	**15.4**
7900 - Other Barren Lands	2.5	0.4	0.0	0.2	0.0	0.0	0.1	0.0	0.7	**3.2**
Total	**2,113.7**	**114.3**	**60.0**	**16.6**	**68.8**	**119.3**	**14.6**	**7.2**	**400.8**	**2,514.5**

Figure 1. Impervious surfaces within the Willow Brook watershed.

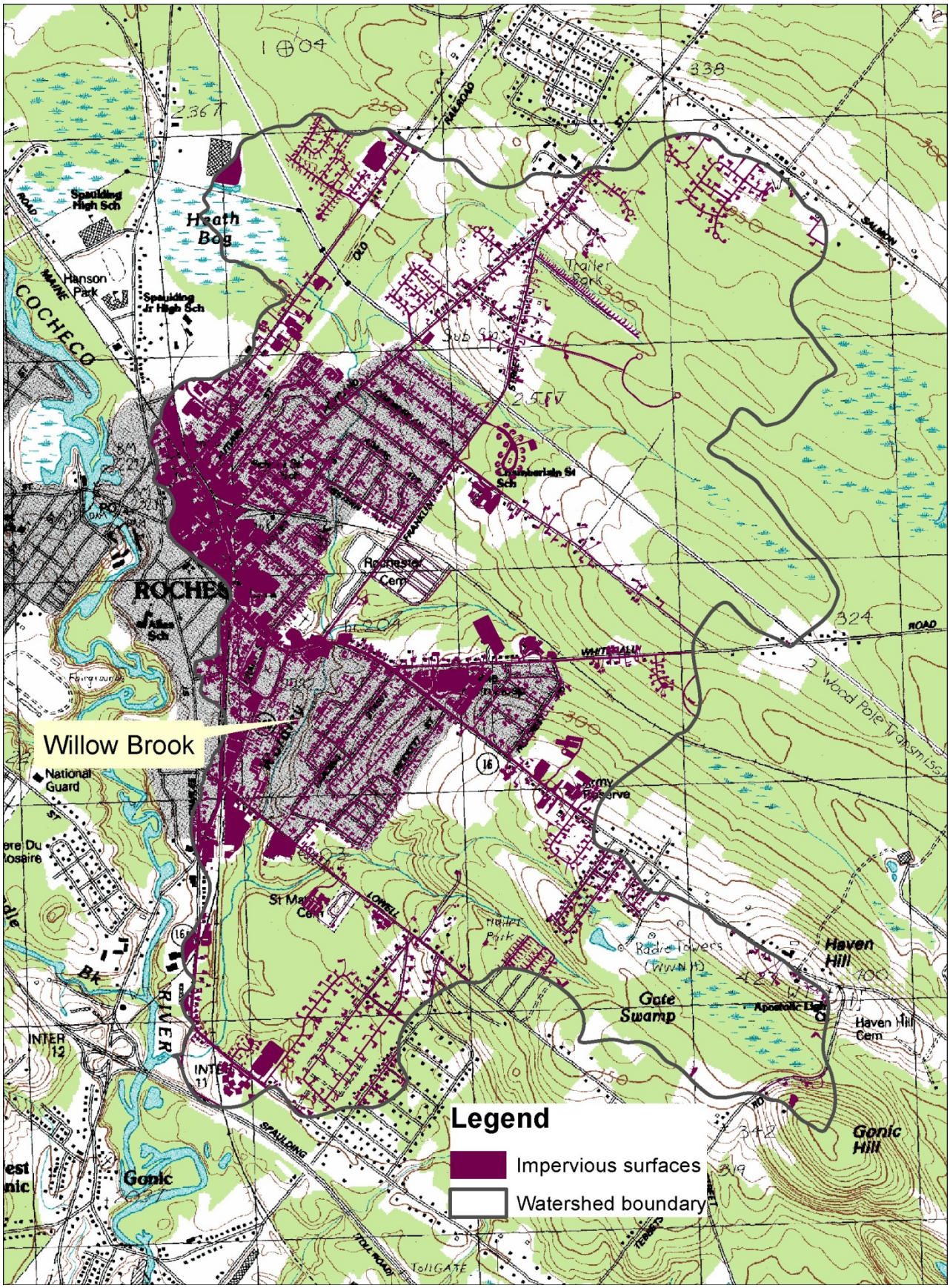
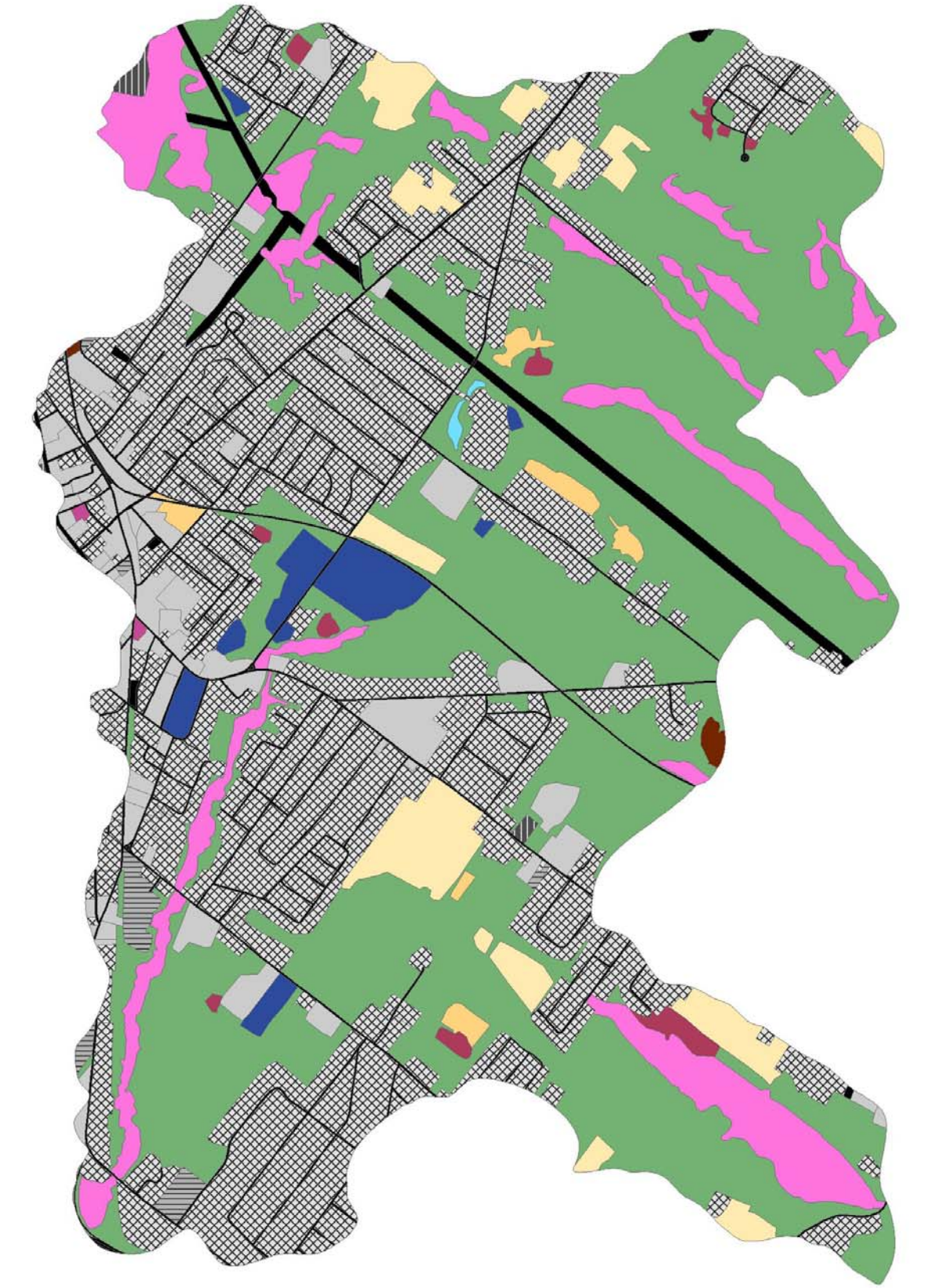


Figure 2. Large scale view of impervious surfaces in the Willow Brook watershed

Figure 3. 2005 Land use for the Willow Brook watershed.



APPENDIX D: LOW IMPACT DEVELOPMENT ECONOMIC CASE STUDY: GREENLAND MEADOWS

The following case studies are from the 2011 report entitled *Forging the Link: Linking the Economic Benefits of Low Impact Development and Community Decisions.*

The complete report and resources can be found at http://www.unh.edu/unhsc/forgingthelink.

UNIVERSITY OF NEW HAMPSHIRE STORMWATER CENTER

Greenland Meadows LID Case Study: Economics

Utilizing an LID approach that featured porous asphalt and a gravel wetland, a cost-competitive drainage system was designed for a large retail development.

Greenland Meadows is a retail shopping center built in 2008 by Newton, Mass.-based New England Development in Greenland, N.H.

The development at Greenland Meadows features the largest porous asphalt and gravel wetland installation in the Northeast.

The development is located on a 56-acre parcel and includes three, one-story retail buildings, paved parking areas consisting of porous asphalt and non-porous pavements, landscaping areas, a large gravel wetland, and advanced stormwater management facilities. The total impervious area of the development – mainly from rooftops and non-porous parking areas – is approximately 25.6 acres.

Framingham, Mass.-based Tetra Tech Rizzo provided all site engineering services and design work for the stormwater management system, which included two porous asphalt installations covering a total of 4.5 acres along with catch basins, a sub-surface reservoir for rooftop runoff, and a large gravel wetland for the treatment of nitrogen. The UNH Stormwater Center provided guidance and oversight with the porous asphalt installations and supporting designs.

This case study shows how a combination of porous asphalt and standard pavement design with a sub-surface gravel wetland was more economically feasible than a standard pavement design with a conventional sub-surface stormwater management detention system. This analysis covers some of the site-specific challenges of this development and the environmental issues that mandated the installation of its advanced LID-based stormwater management design.

FORGING THE LINK : Linking the Economic Benefits of Low Impact Development and Community Decisions can be found at http://www.unh.edu/unhsc/ftl/

According to Austin Turner, a senior project civil engineer with Tetra Tech Rizzo, the Conservation Law Foundation feared that a conventional stormwater treatment system would not be sufficient for protecting water quality. "Since there was interest in this project from many environmental groups, especially CLF, permitting the project proved to be very challenging," Turner said. "We were held to very high standards in terms of stormwater quality because Pickering Brook and the Great Bay are such valuable natural resources."

ADDRESSING ENVIRONMENTAL ISSUES

During the initial planning stage, concerns arose about potential adverse water quality impacts from the project. The development would increase the amount of impervious surface on the site resulting in a higher amount of stormwater runoff compared to existing conditions. The development is located immediately adjacent to Pickering Brook, an EPA-listed impaired waterway that connects the Great Bog to the Great Bay.

Tetra Tech Rizzo worked closely with New England Development, the UNH Stormwater Center, the New Hampshire Department of Environmental Services, and the Conservation Law Foundation (CLF) on the design of this innovative stormwater management system with LID designs.

HYDROLOGIC CONSTRAINTS

Brian Potvin, P.E., director of land development with Tetra Tech Rizzo, said one of the main challenges in designing a stormwater management plan for the site was the very limited permeability of the soils. "The natural underlying soils are mainly clay in composition, which is very prohibitive towards infiltration," Potvin said. "Water did not infiltrate well during site testing and the soils were determined to not be adequate for receiving runoff." As such, Tetra Tech Rizzo focused on a stormwater management design that revolved around stormwater quantity attenuation, storage, conveyance, and treatment.

ECONOMIC COMPARISONS

Tetra Tech Rizzo prepared two site work and stormwater management design options for the Greenland Meadows development:

Conventional: This option included standard asphalt and concrete pavement along with a traditional sub-surface stormwater detention system consisting of a gravel sub-base and stone backfill, stormwater wetland, and supporting infrastructure.

LID: This option included the use of porous asphalt and standard paving, a subsurface stone reservior for rooftop runoff, a subsurface gravel wetland, and supporting infrastructure.

The western portion of the property would receive a majority of the site's stormwater prior to discharge into Pickering Brook.

TABLE 1: Comparison of Unit Costs for Materials for Greenland Meadows Commercial Development

ITEM	CONVENTIONAL OPTION	LID OPTION	COST DIFFERENCE
Mobilization / Demolition	$555,500	$555,500	$0
Site Preparation	$167,000	$167,000	$0
Sediment / Erosion Control	$378,000	$378,000	$0
Earthwork	$2,174,500	$2,103,500	–$71,000
Paving	$1,843,500	$2,727,500	$884,000
Stormwater Management	$2,751,800	$1,008,800	–$1,743,000
Addtl Work-Related Activity (Utilities, Lighting, Water & Sanitary Sewer Service, Fencing, Landscaping, etc.)	$2,720,000	$2,720,000	$0
Project Total	**$10,590,300**	**$9,660,300**	**–$930,000**

*Costs are engineering estimates and do not represent actual contractor bids.

TABLE 2: Conventional Option Piping

	TYPE	QUANTITY	COST
Distribution	6 to 30-inch piping	9,680 linear feet	$298,340
Detention	36 and 48-inch piping	20,800 linear feet	$1,357,800

TABLE 3: LID Option Piping

	TYPE	QUANTITY	COST
Distribution	4 to 36-inch piping	19,970 linear feet	$457,780
Detention*	—	0	$0

*Costs associated with detention in the LID option were accounted for under "earthwork" in Table 1.

Table 1 compares the total construction cost estimates for the conventional and the LID option. As shown, paving costs were estimated to be considerably more expensive (by $884,000) for the LID option because of the inclusion of the porous asphalt, subbase, and subsurface reservoir. However, the LID option was also estimated to save $71,000 in earthwork costs as well as $1,743,000 in total stormwater management costs, primarily due to piping for storage. Overall, comparing the total site work and stormwater management cost estimates for each option, the LID alternative was estimated to save the developers a total of $930,000 compared to a conventional design, or about 26 percent of the overall total cost for stormwater management. **Tables 2 and 3** further break down the differences in stormwater management costs between the conventional and LID designs by comparing the total amount of piping required under each option.

Although distribution costs for the LID option were higher by $159,440, the LID option also completely removed the need to use large diameter piping for subsurface stormwater detention. The elimination of this piping amounted to a savings of $1,357,800. "The piping was replaced by the subsurface gravel reservoir beneath the porous asphalt in the LID alternative," Potvin said. "Utilizing void spaces in the porous asphalt subsurface reservoir to detain stormwater allowed us to design a system using significantly less large diameter pipe. This represented the most significant area of savings between each option."

CONSERVATIVE LID DESIGN

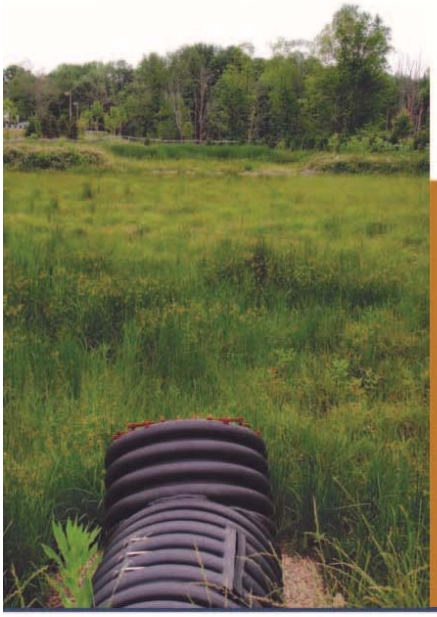
Although the developers were familiar with the benefits of porous asphalt, Potvin said they were still concerned about the possibility of the systems clogging or failing. "The developers didn't have similar projects they could reference," he said. "For this reason, they were tentative on relying on porous asphalt alone."

To resolve this uncertainty, the Tetra Tech Rizzo team equipped the porous pavement systems with relief valve designs: additional stormwater infrastructure including leaching catch basins. "This was a conservative 'belt and suspenders' approach to the porous asphalt design," Potvin said. "Although the porous pavement system is not anticipated to fail, this design and strategy provided the developers with a safety factor and insurance in the event of limited surface infiltration."

To further alleviate concerns, a combination paving approach was utilized. Porous asphalt was limited to passenger vehicle areas and installed at the far end of the front main parking area as well as in the side parking area, while standard pavement was put in near the front and more visible sections of the retail center and for the loop roads, delivery areas expected to receive truck traffic. "This way, in case there was clogging or a failure, it would be away from the front entrances and would not impair access or traffic into the stores," Potvin said.

LID SYSTEM FUNCTIONALITY

The two porous asphalt drainage systems – one in the main parking lot and one in the side parking area – serve to attenuate peak flows, while the aggregate reservoirs, installed directly below the two porous asphalt placements, serve as storage. The subbase includes the use of a filter course of medium-grained sand, which provides an additional means of stormwater treatment. Peak flow attenuation is insured by controlling the rate at which runoff exits with an outlet control structure. Nearly the entire site is routed to the gravel wetland on the west side of the site. The gravel wetland is designed as a series of flow-through treatment cells providing an anaerobic system of crushed stone with wetland soils and plants. This innovative LID design works to remove nitrogen and other pollutants as well as mitigate the thermal impacts of stormwater.



CURRENT CONDITIONS

As of 2011, and 3 years of operation, LID in a commercial setting is functioning well both from a durability and water quality perspective. Water quality monitoring indicates a very high level of treatment (see accompanying water quality fact sheet). The porous pavements continue to function well for both permeability and durability. They retain a high level of permeability in part due to a routine maintenance schedule. Pavement durability for passenger vehicles has been strong. Durability has been an issue for non-design loads. In parking areas designed for passenger vehicles only, on occasion, tractor trailers have used the paved areas for turning resulting in damaged pavement. Damage and repairs to porous pavements were managed similarly to standard pavements. The durability is consistent with the standard asphalt and concrete areas where damage is also observed from the demands of high use. The inadvertent use of porous pavements for non-design loads can be prevented by careful design including the use of tight turning radius, obstructions for large vehicles, and the posting of signs.

SUMMARY

Although the use of porous asphalt and gravel wetlands in large-scale commercial development is still a relatively new application, this case study showed how LID systems, if designed correctly and despite significant site constraints, can bring significant water quality and economic benefits. With Greenland Meadows, an advanced LID-based stormwater design was implemented given the proximity of the development to the impaired Pickering Brook waterway. In addition to helping alleviate water quality concerns, the LID option eliminated the need to install large diameter drainage infrastructure. This was estimated to result in significant cost savings in the site and stormwater management design.

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APPENDIX E: LOW IMPACT DEVELOPMENT WATER QUALITY CASE STUDY: GREENLAND MEADOWS

The following case studies are from the 2011 report entitled *Forging the Link: Linking the Economic Benefits of Low Impact Development and Community Decisions***.**

The complete report and resources can be found at http://www.unh.edu/unhsc/forgingthelink.

Greenland Meadows
LID Case Study: Water Quality

Greenland Meadows is a retail shopping center built in 2008 by Newton, Mass.-based New England Development in Greenland, N.H.

The development is located on a 56-acre parcel and includes three one-story retail buildings (Lowe's Home Improvement, Target, and a supermarket), paved parking areas consisting of porous asphalt and non-porous pavements, landscaping areas, a large gravel wetland, as well as advanced stormwater management facilities.

Greenland Meadows features the largest porous asphalt and gravel wetland installation in the Northeast.

The total impervious area of the development – mainly from rooftops and non-porous parking areas – is approximately 25.6 acres, considerably more as compared to pre-development conditions. Prior to this development, the project site contained an abandoned Sylvania light bulb factory with the majority of the property vegetated with grass and trees.

Framingham, Mass.-based Tetra Tech Rizzo provided site drainage engineering, which included the design of two porous asphalt installations covering a total of 4.5 acres along with a sub-surface gravel wetland. The University of New Hampshire (UNH) Stormwater Center provided design guidance, LID project review, and oversight with the LID installations.

ADDRESSING ENVIRONMENTAL ISSUES

During the project permitting stage, concerns arose about potential adverse water quality impacts from the project. The development would increase the amount of impervious surface on the site resulting in a higher amount of stormwater runoff compared to existing conditions. The development is located immediately adjacent to Pickering Brook, an impaired waterway that connects to the Great Bay. One group that was particularly interested in the project's approach to managing stormwater was the Conservation Law Foundation (CLF), an environmental advocacy organization.

LID SYSTEM FUNCTIONALITY

The two porous asphalt drainage systems – one in the main parking lot and one in the eastern parking area – serve to attenuate peak flows, while the aggregate reservoirs, installed directly below the two porous asphalt placements, serve as storage for the underlying sand filter.

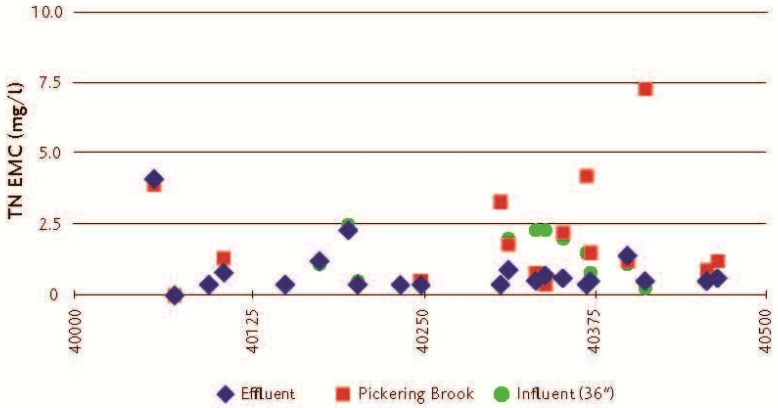
Runoff from the sand filter, which itself provides extended detention and filtration, flows through perforated underdrain pipes that converge to a large gravel wetland on the west side of the site. The gravel wetland is designed as a series of flow-through treatment cells providing an anaerobic system of crushed stone with wetland soils and plants. This innovative LID design works to remove pollutants as well as mitigate the thermal impacts of stormwater.

WATER QUALITY MONITORING

A four-phase wet weather flow monitoring program involving the use of automated samplers was implemented at the Greenland Meadows site in order to assess background conditions for Pickering Brook, evaluate stormwater quality runoff from the project site, and determine the resultant water quality of Pickering Brook downstream from Greenland Meadows. This effort is also being done to assess treatment system performance with respect to effluent concentrations (pre- and post-construction) and upstream receiving water conditions.

The first three phases of montoring were completed between July of 2007 and October 2010 and included:

- pre-construction monitoring (phase one),
- construction activity monitoring (phase two), and
- one year of post-construction monitoring (phase three).



The fourth phase is currently underway and will include four years of monitoring to determine the long-term performance of the system. Runoff constituent analyses routinely include total suspended solids (TSS), total petroleum hydrocarbons-diesel (TPH-D), total nitrogen (NO_3, NO_2, NH_4, TKN), and total metals (Zn). Additional analytes such as total phosphorus and ortho-phosphate have been added due to their relative importance in stormwater effluent characteristics.

	POST-CONSTRUCTION	PRE-CONSTRUCTION	PICKERING BROOK
Total Suspended Solids	3 mg/L	5 mg/L	53 mg/L
Total Nitrogen	0.50 mg/L	0.55 mg/L	1.35 mg/L
Total Phosphorus	0.005 mg/L	0.05 mg/L	.145 mg/L

WATER QUALITY PERFORMANCE

To date, the median TSS, TN, and TP concentrations for the post-construction treated runoff are below pre-construction monitoring concentrations and significantly below concentrations found in the receiving waters of Pickering Brook. The results are depicted above.

Monitoring results indicate that the stormwater management systems are operating well and are providing a high level of treatment for runoff originating from a high contaminant load commercial site, offering significant protection to the impaired receiving waters of Pickering Brook.

Water quality results show that effluent pollutant levels leaving the site at the gravel wetland are typically at or below ambient stream concentrations across a wide range of contaminants. In addition, baseflow benefits, while not yet quantified, are observed discharging in a manner similar to shallow groundwater discharge, providing a nearly continuous source of cool, clean baseflow from the site.

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APPENDIX F: LOW IMPACT DEVELOPMENT ECONOMIC CASE STUDY: BOULDER HILLS

The following case studies are from the 2011 report entitled *Forging the Link: Linking the Economic Benefits of Low Impact Development and Community Decisions***.**

The complete report and resources can be found at http://www.unh.edu/unhsc/forgingthelink.

Boulder Hills, New Hampshire LID Case Study: Economics

This case study shows how utilizing an LID approach to site drainage engineering, specifically with porous asphalt installation, led to more cost-effective site and stormwater management designs.

Utilizing an LID approach that featured porous asphalt resulted in economic benefits in addition to more effective stormwater management for this residential development project.

Boulder Hills, paved in 2009, is a 24-unit active adult condominium community in Pelham, New Hampshire that features the state's first porous asphalt road. The development was built by Stickville LLC on 14 acres of previously undeveloped land and includes a total of 5 buildings, a community well, and a private septic system. In addition to the roadway, all driveways and sidewalks in the development are also composed of porous asphalt. Located along the sides and the backs of the buildings are fire lanes consisting of crushed stone that also serve as infiltration systems for rooftop runoff.

The benefits of implementing an LID design as compared to a conventional development and stormwater management plan included cost savings and positive exposure for the developers, improved water quality and runoff volume reduction, as well as less overall site disturbance and the ability to stay out of wetland and flood zone areas. Over time, the porous asphalt placements are also anticipated to require less salt application for winter de-icing, resulting in additional economic and environmental benefits.

FORGING THE LINK : Linking the Economic Benefits of Low Impact Development and Community Decisions can be found at http://www.unh.edu/unhsc/ftl/

SFC Engineering Partnership Inc. designed the project site and development plan including all drainage. The University of New Hampshire (UNH) Stormwater Center advised the project team and worked with Pelham town officials, providing guidance and oversight with the installation and the monitoring of the porous asphalt placements.

Prior to development, the project site was an undeveloped woodland area sitting atop a large sand deposit. Soils on the parcel were characterized with a moderate infiltration rate and consisted of deep, moderately well to well drained soils. Wetland areas were located in the south and east sections of the parcel, with a portion of the site existing in a 100-year flood zone.

DESIGN PROCESS

Initially, SFC Engineering Partnership began designing a conventional development and stormwater management plan for the project. However, according to David Jordan, P.E., L.L.S., manager of SFC's Civil Engineering Department, difficulty was encountered because of the site's layout and existing conditions. "The parcel was burdened by lowland areas while the upland areas were fragmented and limited," Jordan said. "Given these conditions, it was challenging to make a conventional drainage design work that would meet town regulations.

Comparison of Two Designs, LID Design (top) and Conventional (bottom) for Boulder Hills, Pelham, NH (SFC, 2009).

We found ourselves squeezing stormwater mitigation measures into the site design in order to meet criteria. The parcel also did not have a large enough area that could serve as the site's single collection and treatment basin. Instead, we were forced to design two separate stormwater detention basins, which was more expensive. This approach was also cost prohibitive because of the necessity of installing lengthy underground drainage lines."

When LID and specifically, porous asphalt, emerged as a possible stormwater management option for the site, the developer, Stickville LLC, was receptive. Stickville was aware of the advantages of LID and porous pavement and was interested in utilizing these measures as a possible marketing tool which could help differentiate them as green-oriented developers. SFC advised Stickville LLC to pursue this option. Jordan had attended a seminar on porous pavement presented by The UNH Stormwater Center which covered the multiple benefits of utilizing this material, including its effectiveness for being able to meet stormwater quantity and quality requirements.

"Per regulations, the amount of stormwater runoff from the site after development could not be any greater than what it was as an undeveloped parcel," Jordan said. "In addition to controlling runoff, stormwater mitigation measures also had to be adequate in terms of treatment. Porous pavement allows us to do both. For a difficult site such as Boulder Hills, that represents a huge advantage."

According to Jordan, the Town of Pelham responded very favorably to the idea of incorporating LID with the project. "The planning board was on board from the very beginning," he said. "They were very supportive of utilizing porous asphalt and recognized the many benefits of this option."

The project was paved by Pike Industries, a leader in the production of porous asphalt in the Northeast.

ECONOMIC COMPARISONS

SFC Engineering Partnership designed two development options for the project. One option was a conventional development and drainage plan that included the construction of a traditional asphalt roadway and driveways. The other option, an LID approach, involved replacing the traditional asphalt in the roadway and driveways with porous asphalt and using subsurface infiltration for rooftop runoff, essentially eliminating a traditional pipe and pond approach.

Although porous asphalt was more costly than traditional asphalt, the engineers found that utilizing this material would result in cost savings in other areas:

- Installing porous asphalt significantly lowered the amount of drainage piping and infrastructure required.
- Using porous asphalt reduced the quantity of temporary and permanent erosion control measures needed
- Using porous asphalt cut in half the amount of rip-rap, and lowering the number of catch basins from eleven to three.
- The LID design completely eliminated the need to install curbing, outlet control structures, as well as two large stormwater detention ponds.
- There was a 1.3 acre reduction in the amount of land that would need to be disturbed, resulting in lower site preparation costs.

ITEM	CONVENTIONAL	LOW IMPACT	DIFFERENCE
Site Preparation	$23,200.00	$18,000.00	–$5,200.00
Temp. Erosion Control	$5,800.00	$3,800.00	–$2,000.00
Drainage	$92,400.00	$20,100.00	–$72,300.00
Roadway	$82,000.00	$128,000.00	$46,000.00
Driveways	$19,700.00	$30,100.00	$10,400.00
Curbing	$6,500.00	$0.00	–$6,500.00
Perm. Erosion Control	$70,000.00	$50,600.00	–$19,400.00
Additional Items	$489,700.00	$489,700.00	$0.00
Buildings	$3,600,000.00	$3,600,000.00	$0.00
PROJECT TOTAL	**$4,389,300.00**	**$4,340,300.00**	**–$49,000.00**

This table shows the construction estimate cost comparisons between the conventional and the low impact development options. As shown, the LID option resulted in higher costs for roadway and driveway construction. However, considerable savings were realized for site preparation, temporary and permanent erosion control, curbing, and most noticeably, drainage.

Overall, the LID option was calculated to save the developers $49,000 ($789,500 vs. LID cost of $740,300) or nearly 6 percent of the stormwater management costs as compared to the conventional option.

CONCLUSIONS

Beyond its effectiveness at reducing stormwater runoff, facilitating more groundwater infiltration, and promoting water quality benefits, porous asphalt was shown in this case study to be capable of bringing positive economic results. Primarily, cost savings were achieved in the Boulder Hills site development design through a significant reduction in the amount of drainage infrastructure and catch basins required, in addition to completely eliminating the need for curbing and stormwater detention ponds. Moreover, with considerably less site clearing needed, more economic and environmental benefits were realized. Compared to a conventional development plan, an option utilizing LID featuring porous asphalt was shown in this example to be more economically feasible.

Overall, the LID option was calculated to save the developers $49,000, or nearly 6 percent of the stormwater management costs, as compared to the conventional option.

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APPENDIX G: BMP, LOAD, AND IMPERVIOUS COVER TRACKING SPREADSHEET

APPENDIX H: POLLUTANT ANALYSES METHODOLOGY

Pollutant concentrations are generally applied according to the area of land use in the watershed to generate an actual mass load in lbs per year. The pollutant load calculations for a watershed are based on a Simple Method. The Simple Method is recommended by NHDES in the *New Hampshire Stormwater Manual*[8] (1).

The Simple Method estimates pollutant loads with the following equation:

$$L = 0.226 \times R \times C \times A$$

Where: L = Annual Loads (lbs)
R = Annual Runoff (inches)
C = Pollutant concentration (mg/l)
A = Area (acres)
0.226 = unit conversion
Annual runoff is determined by:

$$R = P \times P_j \times Rv$$

Where: P = Annual rainfall (inches)
$P_j = 0.9$
Rv = Runoff coefficient
Runoff coefficient is determined by:

$$Rv = 0.05 + 0.9I_a$$

Where: I_a = % (decimal) impervious area draining to BMP

[8] New Hampshire Stormwater Manual, Volume 1 Stormwater and Antidegradation, Chapter 8 Pollutant Loading Calculations, Rev 1.0, December 2008

APPENDIX I: TOWN OF DURHAM SITE PLAN REVIEW REGULATIONS

Excerpt from

SUBDIVISION REGULATIONS OF DURHAM, NEW HAMPSHIRE

7.01 Phase 1 - Preliminary Conceptual Consultation Submission

The Preliminary Conceptual Consultation phase is intended to provide the applicant, the Planning Board, and the staff with a better understanding of the site and the opportunities and constraints imposed on its use by both the natural and built environment. It is anticipated that this analysis will result in a subdivision plan that reflects the conditions of the site; those areas most suitable for conservation and open space will be preserved, those areas most suitable for the proposed use will be utilized, while those that are not suitable for development or that present significant constraints will be avoided to the maximum extent possible. Therefore, the submission requirements provide that the applicant submit basic information about the site, an analysis of that information, and a sketch plan in the form of an overlay sheet.

The submission must contain, at a minimum, the following information unless a waiver has been granted pursuant to Section 5.02 A. 3):

A. A completed request form (Attachment 2) including the following:

1. The names, addresses, and phone numbers of the record owner(s) and the applicant,
2. The names and addresses of all consultants working on the project,
3. A list of the names and addresses of all the abutters, as shown in town records not more than five (5) days before the day of filing; and a list of all holders of conservation, preservation, or agricultural preservation restrictions on the subject property and abutting parcels, and
4. Evidence of right, title, or interest in the property.

B. A Site Context or Locus Map drawn at a size adequate to show the relationship of the proposed subdivision to the adjacent properties, and to allow the Board to locate the subdivision within the municipality. The location map shall show:

1. Existing subdivisions in the proximity of the proposed subdivision.
2. Locations and names of existing streets.
3. Boundaries and designations of zoning districts.
4. An outline of the proposed subdivision and any remaining portion of the owner's property if the formal application will cover only a portion of the owner's entire contiguous holding.

C. An accurate scale Site Inventory Plan of the parcel at a scale of not more than fifty (50) feet to the inch showing as a minimum:

1. The proposed name of the development, north arrow (True Meridian), date, and scale.
2. The boundaries of the parcel based upon a standard boundary survey prepared by a registered land surveyor and giving the bearings and distances of all property lines.
3. Existing restrictions or easements on the site (if none, so state).
4. The topography of the site at an appropriate contour interval depending on the nature of the use and character of the site as determined by the Director of Planning and Community Development.
5. The ***major*** natural features of the site and within five hundred (500) feet of the site, including wetlands, vernal pools, streams, ponds, floodplains, groundwater aquifers, significant wildlife habitats, scenic views or areas, significant geological features, prime agricultural soils, unfragmented forest blocks, resources identified by the New Hampshire Natural Heritage Bureau or other important natural features. Wetlands on the site shall be identified and delineated by a New Hampshire Certified Wetlands Scientist and shall be certified by the person performing the delineation. Information on adjacent properties may be from published sources.
6. The soils on the site through a high intensity soil survey (HISS). The Planning Board may allow the submission of a medium intensity soils survey if it determines that a HISS is not required to determine that the proposed density of development conforms to the zoning requirements or to evaluate the appropriate use of the property.
7. Vegetative cover conditions on the property according to general cover type.
8. Watershed and sub-watershed boundaries.
9. Existing buildings, structures, or other improvements on the site including streets, driveways, stone walls, fences, trails, graveyards, and cemeteries (if none, so state).
10. Locations of all culturally, historically or archaeologically significant buildings, features, or sites .
11. The location and size of existing utilities or improvements servicing the site (if none, so state).
12. Any potential sources of fire protection water supply within one half mile of the site including public water mains, existing fire ponds, or possible sources of water supply.

D. A Site Analysis Map at the same scale as the inventory plans (see C. above) highlighting the opportunities and constraints of the site in a bubble diagram or

annotated format. This plan should enable the Planning Board to determine: which portions of the site are unsuitable for development or use (Primary Conservation Areas); which areas of the site have potential conservation or open space value (Secondary Conservation Areas) that should be addressed in the subdivision plan; which portions of the site are unsuitable for on-site sewage disposal if public sewerage is not available; which areas of the site may be subject to off-site conflicts or concerns (noise, lighting, traffic, etc.); and which areas are well suited for the proposed use.

E. A Site Analysis Narrative describing the existing conditions of the site, the constraints and opportunities created by the site, the open space conservation potential of the site, and the proposed development. The narrative must include a calculation of the "Usable Area" of the site based upon a High Intensity Soil Survey in accordance with Section 175- 55 of the Zoning Ordinance and the maximum number of units that can be included in the subdivision based upon this calculation and the dimensional requirements of the zone. This submission should include a narrative description of the existing road system that will provide access to the project and any issues related to traffic capacity, safety, sight distances, or other traffic considerations together with any preliminary studies done relative to the site including wetland delineations, traffic studies, market studies, or other information that will help the Board understand the project.

F. A Sketch Plan, drawn at the same scale as the site analysis plan, and in a form that allows it to be overlain on the site analysis plan, showing the general concept for land conservation and development, the location of identified Primary and Secondary Conservation Areas, and the conceptual layout of lots and roads in accordance with the four step design process set forth in Section 9.08.

7.02 Phase 2 - Preliminary Design Review Submission

The Preliminary Design Review phase is designed to allow the applicant, Board, and staff the opportunity to review the proposed layout of the subdivision and to identify any issues or concerns with the layout before final engineering design is completed and the formal application is submitted. The submission requirements therefore focus on the overall utilization of the site and the layout of the subdivision rather than engineering details.

The submission must contain, at a minimum, the following information unless a waiver has been granted pursuant to Section 5.02 B. 3):

A. A completed request form (Attachment 2) including the following:

1. The names, addresses, and phone numbers of the record owner(s) and the applicant,
2. The names and addresses of all consultants working on the project,
3. A list of the names and addresses of all the abutters, as shown in town records not more than five (5) days before the day of filing; and a list of all holders of conservation, preservation, or agricultural preservation restrictions on the subject property and abutting parcels,
4. Evidence of right, title, or interest in the property, and
5. Copies of the most recently recorded deed for the parcel and of all deed restrictions, easements, rights-of-way, or other encumbrances currently affecting the property.

B. The Site Context or Locus Map submitted in Phase 1 or a Site Context or Locus Map meeting the requirements of Section 7.01 B**.**

C. An updated Site Analysis Map meeting the requirements of Section 7.01 D**.** reflecting any new or updated information developed since the inventory and analysis phase together with an updated calculation of the Usable Area and maximum number of units that may be developed on the site.

D. A Conceptual Subdivision Plan, based upon the updated calculation of the Usable Area and related maximum density, and supporting documentation showing:

1. The proposed name of the subdivision and the assessor's map and lot numbers.
2. The names and addresses of the record owner(s), applicant, all consultants who prepared the plan, and adjoining property owners.
3. The date the plan was prepared, north point, and graphic map scale.
4. The zoning district in which the proposed subdivision is located and the location of any zoning boundaries affecting the subdivision.
5. The boundaries of the parcel based upon a standard boundary survey prepared by a registered land surveyor and giving the bearings and distances of all property lines.
6. The location of all soil tests pits as may be required under these regulations or the provisions of the zoning ordinance including all failed test sites or pits as well as those approved. All approved sites shall be clearly distinguished from unapproved sites.
7. The a*pproximate* location and dimensions of proposed common open space, playgrounds, public areas, and parcels of land proposed to be dedicated or reserved for public use.
8. The *approximate* location of existing and proposed lot lines, easements, and rights-of-way.
9. The a*pproximate* location, alignment, width, and tentative names of all

existing and proposed streets and street rights-of-way, including all street extensions or spurs that are reasonably necessary to provide adequate street connections and facilities to adjoining development or undeveloped areas.

10. Typical street cross-section drawing(s) for all proposed streets including details relating to thickness, crowning, and construction materials.
11. The a*pproximate* location of proposed swales, retention ponds, drainage easements, and other stormwater management facilities.
12. Where public sewer service is to be provided, the conceptual layout of proposed sewage systems, including but not limited to, the tentative locations of sewer mains and pump stations.
13. Where public water service is to be provided, the conceptual layout of proposed water distribution facilities including water mains, fire hydrants, storage tanks, and, where appropriate, wells or other water sources.
14. The exact locations of existing utility easements and *approximate* locations of proposed utility easements.
15. Where installation of the improvements is proposed to be done in phases, a delineation of the proposed sections within the Conceptual Subdivision Plan and a schedule of deadlines within which applications for formal approval of each section are intended to be filed.
16. An estimate of the amount and type of vehicular traffic that will be generated by the project.

E. Documentation of the four-step design process for determining the layout of proposed conservation lands, house sites, streets, and lot lines, as described in Section 9.08.

F. A Resource Impact and Conservation Plan meeting the following requirements:

1. The Resource Impact and Conservation Plan shall categorize the impacts of the proposed activities and physical alterations on those resources shown on the Site Analysis Map. All proposed improvements, including, but not necessarily limited to grading, filling, streets, buildings, utilities, and stormwater detention facilities, as proposed in the Conceptual Subdivision Plan and related documents, shall be taken into account in preparing the Resource Impact and Conservation Plan. This plan shall clearly demonstrate that the Conceptual Subdivision Plan will minimize site disturbance and the impacts on identified resources to the greatest extent practicable.

2. The Plan shall identify the potential impacts of the proposed development on identified resources, how the subdivision is being designed to minimize the impacts, and the activities that will be

undertaken to mitigate any potential adverse impacts. The plan shall address the potential impacts on the following:

(a) primary impact areas (i.e., areas directly impacted by the proposed subdivision),
(b) secondary impact areas (i.e., areas in proximity to primary areas that may be impacted), and
(c) designated protected areas including proposed common open space.

G. A Preliminary Common Open Space Ownership and Stewardship Plan that includes, but shall not necessarily be limited to, the following if the subdivision contains any proposed common open space:

1. A description of all common open space and any other lands and facilities proposed to be owned by the Town, or a conservation organization, or a home owners association, or that will be permanently protected by conservation easements. This description shall include a map indicating the approximate location of these lands and facilities.
2. A description of proposed ownership arrangements for the parcels identified in 1.
3. A description of the proposed conservation restrictions that will permanently protect these parcels.
4. A description of proposed arrangements for the long-term stewardship of the common open space including management objectives and techniques for each parcel or area together with an indication of who will have the primary and secondary responsibilities for this.

H. The Board may request additional information be submitted as part of the Phase 2 review or as part of the formal application where it finds it necessary in order to determine whether the Conceptual Subdivision Plan is likely to result in a final plan that meets the requirements of these regulations. This may include, but is not limited to, the following:

1. An hydrogeologic assessment prepared by a Certified Geologist or Registered Professional Engineer, experienced in hydrogeology.
2. A projection of the amount and type of vehicular traffic to be generated on an average annual daily basis and during peak hours. The trip generation rates used shall be taken from the most recent edition of *Trip Generation Manual,* published by the Institute of Transportation Engineers. Trip generation rates from other sources may be used if the applicant demonstrates to the Planning Board that these sources better reflect local conditions.
3. A traffic impact analysis prepared by a Registered Professional Engineer with experience in traffic engineering. The analysis shall evaluate traffic

impacts based upon typically daily peak hour traffic and any special traffic conditions identified by the Planning Board. The analysis shall indicate the expected average daily vehicular trips, peak-hour volumes, access conditions to the site, distribution of traffic, types of vehicles expected, effect upon the level of service of the street giving access to the site and neighboring streets which may be affected, and recommended improvements to maintain the desired level of service on the affected streets.

7.03 Phase 3 - Formal Application Submission

A Formal Application shall be filed with the Planning Board or its designated agent at least twenty-one (21) calendar days prior to a regularly scheduled meeting of the Board. A Formal Application shall be submitted using the form available from the Planning Office (Attachment 1), and shall be accompanied by:

A. A letter of intent detailing the proposal;

B. A list of the names and addresses of all the abutters, as shown in town records not more than five (5) days before the day of filing; and a list of all holders of conservation, preservation, or agricultural preservation restrictions on the subject property and abutting parcels;

C. Any additional documents, as requested by the Planning Office;

D. A plat which shall be prepared by a land surveyor, using a scale of 1 inch equals 100 feet or larger (i.e., 1 inch equals 50 feet, 1 inch equals 20 feet, etc.) and shall include:

1) proposed subdivision name or identifying title;

2) name and address of the applicant and the owner (if different from the applicant);

3) names of owners of abutting properties;

4) North Arrow (True Meridian);

5) locus plan showing general location of the total tract within the Town;

6) name, address, license number, telephone and seal of the surveyor;

7) boundary survey including bearings, distances, and the location of permanent markers;

8) location of property lines, including entire undivided lot, lot areas, and frontage on public right-of-way; each lot shall be numbered according to the tax map numbering system;

9) deed restrictions;

10) open space to be preserved;

11) existing and proposed streets with class, names, and right-of-way widths;

12) evidence that an application has been submitted for State subdivision approval, if applicable; and

13) an approval block meeting the specifications of the Town.

E. The current deed, purchase and sale agreement, and copies of all easements, deed restrictions, rights-of-ways, or other encumbrances currently affecting the property together with explicit authorization by the owner(s) for the applicant to submit the application if the owner(s) is (are) not the applicant.

F. A Final Common Open Space Ownership and Stewardship Plan that includes but is not limited to the following if the subdivision contains any proposed common open space:

1) The boundaries, acreage, and proposed ownership of all proposed common open space and any other land that is proposed to be owned by the Town or other entity.
2) Provisions for the management of the common open space detailing the entities responsible for maintaining various elements of the property and describing management objectives and techniques for each parcel or part of the property.
3) Copies of proposed deeds, conservation easements, and other legal documents relating to the ownership and stewardship of the common open space.
4) Evidence that a municipal organization or an independent party will be designated to assure compliance with all conservation restrictions and that the designated party is willing to assume this responsibility including provisions for the creation and funding of a Stewardship Account to defray the cost of such oversight.
5) If ownership of any of the common open space will rest with a homeowners association, community association, or similar group, the following documents and evidence shall be provided:

    a. A description of all lands and facilities to be owned by the homeowners or community association. This description shall include a map of the proposal indicating the precise location of those lands and facilities.
    b. Provisions setting forth the powers, duties, and responsibilities of the association, including the services to be provided.
    c. A Declaration of Covenants, Conditions, and Restrictions, giving perpetual easement to the lands and facilities owned by the association. The Declaration shall be a legal document that also provides for automatic association membership for all owners in the subdivision or land development and shall describe the

mechanism by which owners participate in the association, including voting, elections, and meetings. Furthermore, it shall give power to the association to own and maintain the common property and to make and enforce rules.

d. Provisions prescribing the process by which association decisions are reached and setting forth the authority to act.

e. Provisions requiring each owner within the subdivision or land development to become a member of the association including statements establishing cross covenants or contractual terms binding each owner to all other owners for mutual benefit and enforcement.

f. Requirements for all owners to provide a pro rata share of the cost of the operations of the association.

g. A process of collection and enforcement to obtain funds from owners who fail to comply.

h. A process for transition of control of the association from the developer to the unit owners.

i. Provisions describing how the lands and facilities of the Community Association will be insured, including limit of liability.

j. Provisions for the dissolution of the association, in the event the association should become non-viable, including provisions for the disposition of any common open space or other land and facilities owned by the association.

G. The Board may request additional information be submitted as part of the formal application where it finds it necessary in order to determine whether the Subdivision Plan meets the requirements of these regulations. This may include, but is not limited to, the following:

1. An hydrogeologic assessment prepared by a Certified Geologist or Registered Professional Engineer, experienced in hydrogeology.
2. A projection of the amount and type of vehicular traffic to be generated on an average annual daily basis and during peak hours. The trip generation rates used shall be taken from most recent edition of *Trip Generation Manual,* published by the Institute of Transportation Engineers. Trip generation rates from other sources may be used if the applicant demonstrates that these sources better reflect local conditions.
3. A traffic impact analysis prepared by a Registered Professional Engineer with experience in traffic engineering. The analysis shall evaluate traffic impacts based upon typically daily peak hour traffic and any special traffic conditions identified by the Planning Board. The analysis shall indicate the expected average daily vehicular trips, peak-hour volumes, access conditions to the site, distribution of traffic, types of vehicles

expected, effect upon the level of service of the street giving access to the site and neighboring streets which may be affected, and recommended improvements to maintain the desired level of service on the affected streets.

SECTION 9: Design Standards

9.06 Stormwater Drainage

A. General Requirements - All developments shall provide adequate management of stormwater runoff and prevent the discharge of stormwater runoff from creating or contributing to a water quality impairment. All applications shall be accompanied by a completed Site Plan Review Checklist (provided in Attachment 6 of these regulations) to the Planning Board prior to consideration for review. Developments that disturb 10,000 or more square feet must submit to the Planning Board for review and approval, a Stormwater Management Plan (Plan) describing all proposed stormwater management system elements, practices, and associated designs, including all calculations and analyses of said designs. However, if the applicant submits an approved Alteration of Terrain (AOT) permit, there would be no need for the town requiring a Stormwater Management Plan. The applicant must still provide an operation and maintenance plan as provided for in (C) (5) below. The Planning Board reserves the right to require any development that disturbs less than 10,000 square feet to submit and then implement an approved Stormwater Management Plan (complete as described below or abbreviated) to prevent degradation of local water resources. All elements of the Plan must be designed/prepared by a New Hampshire Registered Professional Engineer in accordance with the Design Standards below. The Plan must contain the following parts and presented in the order listed below:

B. Stormwater Management Plan - Part I

1) An Existing Conditions Site Plan showing all pre-development surface water bodies and wetlands, drainage patterns, and watershed boundaries, buffer zones, topographic contours with minimum 2-foot intervals, scale bar, north arrow, title block with project name, applicant's name, and map and parcel number, designer's stamp and wetland scientist's stamp (if applicable), legend, locus plan, benchmarks, and appropriate notes with datum and other plan references, instructions, and detail descriptions. The Existing Conditions Site Plan shall be provided in hard copy (minimum 22-inch by 34-inch) at an appropriate scale in tens of feet per inch (maximum of 100 feet per inch) such that all important site and hydrologic features are easily recognized. Existing buildings, structures, pavement, utilities, and soils information with coding as HSG-A, B, C, or D shall be included on the Existing Conditions Site Plan. High Intensity Soil Survey (HISS) mapping may be required per request by the Planning Board.

2) A Proposed Conditions Site Plan showing all proposed post-development temporary and permanent stormwater management system elements and erosion and sediment control BMPs and all important hydrologic features. The Proposed Conditions Site Plan must be at the same scale as the Existing Conditions Site Plan with consistent title block, plan features, and descriptors including but not limited to the following:

a. Existing and proposed topographic contours (2-foot minimum contour interval; 1-foot contour intervals may be required for sites with limited relief and/or where proposed stormwater outfalls are located adjacent to buffer zones)
b. Proposed areas of disturbance with total area of disturbance clearly labeled in square feet
c. Existing and proposed buildings and structures
d. Stormwater discharge locations keyed to drainage analyses
e. Wells and sanitary protective radii
f. Septic systems
g. Plan references and notes (including sequence of soil disturbance)
h. Proposed and existing public and private utilities
i. Proposed project components to become property of or the responsibility of the Town shall be labeled as such
j. Existing and proposed impervious surfaces and pavements with areas used to calculate EIA clearly identified and the square footage of each type identified and labeled.

3) Details of individual design elements shown on separate plan sheets following the Proposed Conditions Site Plan.

C. Stormwater Management Plan - Part II.

1) Drainage Analysis that includes calculations comparing Pre- and Post-Development stormwater runoff rates (cubic feet per minute) and volumes (cubic feet) based on a 1-inch rainstorm, and the 2-year, 10-year, and 25-year 24-hour frequency storms. Calculations shall include, but not be limited to, the sizing of all structures and BMPs including of sizing of emergency overflow structures based on assessment of the 100-year 24-hour frequency storm discharge rate. Phased applications for the original parcel apply as though the development of the entire parcel were proposed in one application at one time.

2) Drainage Analysis Results Summary tabulated for each proposed outfall or catchment outlet point including runoff rates and volumes for each storm event analyzed above.

3) An Erosion and Sediment Control Plan for all proposed construction activities in accordance with the most current New Hampshire Stormwater Manual.

4) Copies of any additional permits or plans required for compliance with Environmental Protection Agency (EPA) and/or New Hampshire Department of Environmental Services (NHDES).

5) A comprehensive Operation and Maintenance Plan for long-term maintenance of all proposed stormwater management elements and BMPs including the proposed schedule of inspections and anticipated maintenance.

9.06.1 Design Standards

A. The Stormwater Management Plans submitted to the Planning Board shall meet the following minimum requirements:

1) Where applicable, the Plan must comply with the EPA Phase II Stormwater Rules and the Town's MS4 Stormwater Discharge Permit, as amended.

2) All proposed measures shall be in accordance with the NH Stormwater Management Manual volume (December 2008 or current revision) a copy of which is available from NHDES: des.nh.gov/organization/divisions/water/stormwater/manual.htm

3) Water Quality Protection: All aspects of the application shall be designed to protect the water quality of the Town of Durham's water bodies as follows:

a. No person shall locate, store, discharge, or permit the discharge of any treated, untreated, or inadequately treated liquid, gaseous, or solid materials of such nature, quantity, noxiousness, toxicity, or temperature that may run off, seep, percolate, or wash into surface or groundwaters so as to contaminate, pollute, harm, impair or contribute to an impairment of such waters.

b. All storage facilities for fuel, chemicals, chemical or industrial wastes, and biodegradable raw materials shall meet the standards of the New Hampshire Department of Environmental Services (NHDES).

c. All projects under review by the Planning Board of such magnitude as to require a stormwater permit from EPA or NHDES shall comply with the standards of EPA and/or NHDES AOT program, with respect to the export of total suspended solids and other pollutants.

4) Stormwater Management For New Development: All proposed stormwater management and treatment systems shall meet the following performance standards:

a. Existing surface waters, including lakes, ponds, rivers, perennial and intermittent streams (natural or channelized), and wetlands (including vernal pools) shall be protected by the minimum buffer setback distances specified in the Zoning Ordinance. Stormwater and erosion and sediment control BMPs shall be located

outside the specified buffer zone unless otherwise approved by the Planning Board. Alternatives to stream and wetland crossings that eliminate or minimize environmental impacts shall be considered whenever possible. When necessary, as determined by the Planning Board or their representative, stream and wetland crossings shall comply with state recommended design standards to minimize impacts to flow and enhance animal passage (see University of New Hampshire Stream Crossing Guidelines May 2009, as amended http://www.unh.edu/erg/stream_restoration/nh_stream_crossing_guidelines_unh_web_rev_2.pdf).

b. LID site planning and design strategies must be used to the MEP in order to reduce the generation of the stormwater runoff volume for both new and redevelopment projects. An applicant must document why LID strategies are not appropriate if not used to manage stormwater.

c. All stormwater treatment areas shall be planted with native plantings appropriate for the site conditions: grasses, shrubs and/or other native plants in sufficient numbers and density to prevent soil erosion and to promote proper treatment of the proposed runoff.

d. All areas that receive rainfall runoff must be designed to drain within a maximum of 72 hours for vector control.

e. Salt storage areas shall be covered or located such that no direct untreated discharges to receiving waters are possible from the storage site. Snow storage areas shall be located such that no direct untreated discharges to receiving waters are possible from the storage site. Runoff from snow and salt storage areas shall enter treatment areas as specified above before being discharged to receiving waters or allowed to infiltrate into the groundwater.

f. Runoff shall be directed into recessed vegetated and landscape areas designed for treatment and/or filtration to the MEP to minimize Effective Impervious Cover (EIC) and reduce the need for irrigation systems.

g. The Plan shall make provisions to retain stormwater on the site by using the natural flow patterns of the site. Effort shall be made to utilize natural filtration and/or infiltration BMPs (i.e., bioretention areas, subsurface filtration/infiltration systems, ponds, swales, etc). Proof of such effort shall be provided to the Planning Board.

h. Measures shall be taken to control the post-development peak rate runoff so that it does not exceed pre-development runoff for the 2-year, 10-year and 25-year, 24-hour storm events. Similar measure shall be taken to control the post-development runoff volume to filtrate the WQv according to the following ratios

of Hydrologic Soil Group (HSG) type versus infiltration rate multiplier: HSG-A: 1.0; HSG-B: 0.75; HSG-C: 0.4; HSG-D: 0.15. For sites where infiltration is limited or not practicable, the applicant must demonstrate that the project will not create or contribute to water quality impairment. Infiltration structures shall be in locations with the highest permeability on the site. Measures shall be taken to protect against on and off-site peak flow to prevent overloading of existing downstream facilities.

i. The biological and chemical properties of the receiving waters shall not be degraded by the stormwater runoff from the development site.

j. The design of the stormwater drainage system shall provide for the disposal of stormwater without flooding or functional impairment to streets, adjacent properties, downstream properties, soils, or vegetation.

k. The design of the stormwater management systems shall take into account upstream and upgradient runoff that flows onto, over, or through the site to be developed or re-developed and provide for this contribution of runoff.

l. Appropriate erosion and sediment control measures shall be installed prior to any soil disturbance such that the area of disturbance shall be kept to a minimum. Disturbed areas shall be stabilized within thirty (30) days.

m. Measures shall be taken to control erosion within the project area. Sediment in runoff water shall be trapped and retained within the project area using approved measures. Wetland areas and surface waters shall be protected from sediment.

n. All temporary control measures shall be removed after final site stabilization. Trapped sediment and other disturbed soil areas resulting from the removal of temporary measures shall be permanently stabilized prior to removal of temporary control measures.

o. Every effort shall be made to use pervious parking surfaces as an alternative to impervious asphalt or concrete for general and overflow parking areas. Pervious pavement shall be appropriately sited and designed for traffic and vehicle loading conditions.

p. Whenever practicable, native site vegetation shall be retained, protected, or supplemented. Any stripping of vegetation shall be done in a manner that minimizes soil erosion.

q. Whenever practicable, all subsurface filtration BMPs shall include perforated underdrains positioned a minimum of 8-inches above the bottom of the filter bed to prevent extended periods of saturated conditions.

5) Redevelopment Project Requirements: Because redevelopment may present a wide range of constraints and limitations, an evaluation of options may be proposed to work in conjunction with broader state watershed goals and local initiatives. Stormwater requirements for redevelopment vary based upon the surface area of the site that is covered by existing impervious surfaces. In order to determine the stormwater requirements for redevelopment projects, the percentage of the site covered by existing impervious areas must be calculated.

For sites meeting the definition of a redevelopment project and having less than 40% existing impervious surface coverage, the stormwater management requirements will be the same as other new development projects with the important distinction that the applicant can meet those requirements either on-site or at an approved off-site location, within the same watershed within the Town of Durham, provided the applicant satisfactorily demonstrates that impervious area reduction and LID strategies and BMPs have been implemented on-site to the MEP.

For redevelopment sites with more than 40% existing impervious surface coverage, stormwater shall be managed for water quality in accordance with one or more of the following techniques, listed in order of preference:

a. Implement measures onsite that result in an EIA of at least 30% of the existing impervious surfaces and pavement areas, and 50% of the additional proposed impervious surfaces and pavement areas through the application of porous media; or

b. Implement other LID techniques onsite to the MEP to provide treatment for at least 50% of the redevelopment area; or

c. Implement off-site BMPs to provide adequate water quality treatment for an area equal to or greater than 50% of redevelopment areas may be used to meet these requirements provided that the applicant satisfactorily demonstrates that impervious area reduction, LID strategies, and/or onsite BMPs have been implemented to the MEP. An approved off-site location must be identified, the specific management measures identified, and an implementation schedule developed in accordance with local review. The applicant must also demonstrate that there is no downstream drainage or flooding impacts as a result of not providing on-site management for large storm events. To comply with local watershed objectives the mitigation site should be situated in the same subwatershed as the development and impact the same receiving water.

6) Responsibility for Installation and Construction: The applicant shall bear final responsibility for the installation, construction, inspection, and disposition of all stormwater management and erosion control measures required by the provisions of these regulations. Site development shall not begin before the Stormwater Management Plan receives written approval by the Planning Board. Best Management Practices shall be installed as designed and scheduled as a condition of final approval of the plan.

7) Plan Approval and Review: The Planning Board shall approve the Stormwater Management Plan if it complies with the requirements of these regulations and other requirements as provided by law. At the discretion of the Planning Board, a technical review by a third party may be required of any stormwater management and erosion control plan prepared under these regulations. The technical review shall be performed by a qualified professional consultant, as determined by the Planning Board, and the expense of which shall be the full responsibility of the applicant.

8) Maintenance and Inspection:

a. After final Planning Board approval and as a condition precedent thereto, the owner of record of the property shall cause notice of the requirements for maintenance pursuant to the stormwater management and erosion and sediment control plans, as approved by the Planning Board, to be recorded at the Registry of Deeds sufficient to provide notice to all persons that may acquire any property subject to the stormwater management and sediment control plans. See RSA 477:3-a. The notice shall comply with the applicable requirements for recording contained in RSA 477 and 478. The notice need not set forth the requirements at length, so long as it is sufficient to provide notice to prospective purchasers of the requirements for maintenance pursuant to the stormwater management and erosion and sediment control plans as approved by the Planning Board. The Planning Board may require routine inspections to insure compliance with the Stormwater Management, Groundwater Protection, Impervious Surfaces, and Erosion and Sedimentation Control sections of these regulations. Such inspections shall be performed by a designated agent with appropriate certifications at reasonable times to the landowner.

b. If permission to inspect is denied by the landowner, the designated agent shall secure an administrative inspection warrant from the district or superior court under RSA 595-B.