LID Meets Permaculture: Sustainable Stormwater Management in the Mountains of Western North Carolina

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ABSTRACT

Inhabitants of the Southern Appalachian Mountain Range of Western North Carolina have a long tradition of living sustainably from the land. More recently, however, there has been a rapid increase in population from outside the region and corresponding development pressures that have resulted in degradation of numerous pristine mountain water resources. Nonpoint source pollution from stormwater runoff is the primary cause of degradation of many of these waters. There are numerous obstacles to protecting water resources in the region including lack of stormwater and steep slope development regulations, perceived conflicts with private property rights, and a general lack of awareness of both the causes and solutions of nonpoint source pollution.

In an effort to advance stormwater management practices in the region, a group of stakeholders joined together in 2008 to implement a stormwater low impact development (LID) best management practice (BMP) demonstration project in Mars Hill, North Carolina. The goal of the project is to develop cost-effective, sustainable, stormwater practices, appropriate for the mountain region that will educate and inspire the regional community. A unique aspect of this project is the incorporation of permaculture design principles, which consider the often complex human interrelationships with landscapes and ecosystems. This paper provides an overview of the Mars Hill LID demonstration project and explores the benefits of incorporating permaculture design principles into LID projects.

INTRODUCTION

The Southern Appalachian Mountain range of western North Carolina is among the most biodiverse regions in the United States. Inhabitants of this remote region have a long tradition of living sustainably from the land – from the eleven thousand year history of the Cherokee Indians to the early European settlers of the 18th and 19th centuries. This connection to the environment is still thriving today in various forms – from native craftspeople to the local food movement to the growth of sustainable intentional communities.

During the past decade, there has been a rapid increase in population from outside the region and corresponding development pressures that have resulted in degradation of numerous pristine mountain water resources. Nonpoint source pollution from stormwater runoff is the primary cause of degradation of many of these waters. There have been multiple high profile examples of poor development and inadequate stormwater management practices in the region, and many residents are becoming increasingly concerned about protecting and conserving water resources. The recent drought of 2007 and 2008 – the most severe in 113 years of record keeping – further underscored the critical need to protect water resources in the region. Moreover, in this mostly rural region, protections of water resources in the form of stormwater and erosion control regulations, are often inadequate or lacking entirely, and sometimes perceived to be in conflict with private property rights.

In an effort to advance stormwater management practices in the region, a group of stakeholders joined together in 2008 to implement a stormwater low impact development (LID) best management practice (BMP) demonstration project at the newly renovated town hall facility in Mars Hill, North Carolina. The team of stakeholders included representatives from town, county, state, federal, university, non-profit and private sectors. The team presented the project concept to several granting agencies and was able to secure grant funding as well as donated technical services and materials to implement the project.

The goal of the project is to develop cost-effective, sustainable, stormwater practices, appropriate for the mountain region that will educate and inspire the local and regional community as well as designers, contractors, and government officials. In an effort to meet this goal, and to build upon the long tradition of sustainable resource use in the region, the project team incorporated permaculture design principles. These design principles emphasize the use of native vegetation and materials, multiple functionality of BMPs where possible, aesthetic elements, as well as human interrelationships with the landscape. The resulting integrated system design consists of over 20 BMPs featuring proven LID practices as well as innovative permaculture elements.

WHY PERMACULTURE?

The term "permaculture" may or may not be familiar to the reader, and even for those familiar with the term, permaculture may be difficult to define. The term permaculture was coined by Australian ethnobotanists Bill Mollison and David Holmgren in the 1970s as a contraction of the words "permanent" and "agriculture." Permaculture generally refers to a design approach that takes a holistic system view, observes the interrelationships of different parts and mimics sustainable natural systems. Whereas many sustainable design systems often emphasize the mitigation of human impacts, permaculture emphasizes *regenerative* design and seeks ways to positively integrate humans within ecosystems.

Permaculture differs from many other design systems in that it arises from a system of three core ethics: 1) Care of people, 2) Care of planet, and 3) Equitable sharing. Design principles, strategies, and techniques all stem from these ethics. Figure 1 illustrates the basic hierarchy of the permaculture design system (Mollison, Holmgren).

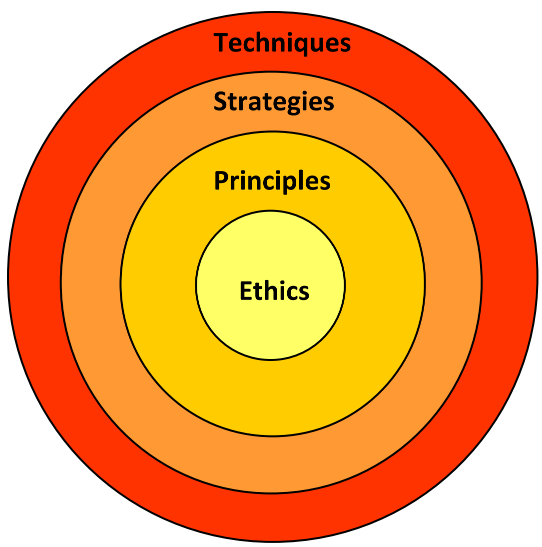

Figure 1. Order of Permaculture Design System.

At its best, permaculture design solves multiple interrelated problems systemically by mimicking biological patterns. For instance, water quality degradation, topsoil loss, an over-specialized economy, and vulnerable food supply may all be addressed with a single permaculture strategy for land management.

When seeking an effective method for spreading and storing water in soil, permaculture designers look for the methods used in nature to diffuse or concentrate water. Trees use a hierarchical branching pattern to distribute water and minerals from the roots out towards the new-growth wood. In the 1950s, Australian farmer, P.A. Yeomans imitated this branching structure to create the "Keyline System," a low-technology method of water management that relies on carefully placed branching sub-soil swales to distribute water out from the valleys to the ridges of a watershed, thereby retaining water and nutrients in the soil. This simple act sets the stage for dramatic accumulation of topsoil and reforestation.

A distinct assumption of permaculture design is that, over evolutionary spans of time, some natural organism or system has at one time encountered the essence of any problem likely to be encountered in human affairs. Usually the solutions that emerge through evolution are so elegant and effective that permaculture design seeks to imitate them instead of attempting to engineer new ones. The principles in permaculture emerge from attempts to replicate the natural patterns of ecosystems, that are intrinsically more efficient than engineered systems. Permaculture principles provide a structured approach allowing humans to act as beneficial rather than intrinsically destructive participants within ecosystems.

In contrast to the ethics and principles of permaculture which are generally universal, strategies and techniques may vary by region and situation. They are endless in number, limited only by the creativity and resources of the designer. For example one permaculture system comprises a mixed-use forest agriculture plot producing maple syrup, oyster mushrooms, high-value sugar maple lumber and ginseng thereby restoring the ecosystem, capturing stormwater runoff and building topsoil, while providing economically valuable food, medicine, sustainably produced timber, and long-term employment opportunities.

In terms of stormwater management, a permaculture design may look very similar to an LID design with an integrated, decentralized system of rainwater catchment, vegetated roofs, bioretention, and permeable pavement. However, the permaculture designer may ask the additional question, “How can we sustainably manage stormwater and benefit water quality while also providing additional benefits to the humans in the local community and improving the effectiveness of LID?” In response to this question, the permaculture designer may also consider how to integrate food-producing community gardens into the design and develop relationships with the local community in terms of education, recreation, and employment. Table 1 shows a general comparison of LID and Permaculture design system elements.

There are numerous similarities between LID and permaculture design principles. However, the permaculture design philosophy asks additional questions which are likely to become increasingly important in this world of global climate change, declining ecosystems, and finite natural resources – not only how can we better manage stormwater runoff and save our water resources, but how can humans function beneficially as integral parts of these ecosystems. To answer these questions, permaculture seeks to draw inspiration from natural ecosystems, evolutionary biology, and indigenous wisdom as well as advancements in modern science and technology.

Table 1. Comparison of Permaculture and LID Design Systems

System Element	LID	Permaculture
Ethics-based	Optional	Essential
Mimics natural systems	Yes	Yes
Integrated systems	Yes	Yes
Decentralized systems	Yes	Yes
Sustainable design principles	Yes	Yes
Primary function	Mitigative	Regenerative
Primary objectives	Stormwater management	Productive human/ecosystem interrelationships
Human/ecosystem relationship	Secondary	Primary
Ongoing economic benefit	Uncommon	Essential
Level of engineering	Varies	Low
Energy conservation	Optional	Essential
Use of native materials	Optional	Essential
Food production	Uncommon	Essential
Maintenance	Varies	Multi-purpose
Aesthetics	Landscaped or natural	Natural
Cost	Medium (labor and materials)	Low (mostly labor/ human capital)

PROJECT SITE

The site selected for the project is the newly-renovated town hall facility for the Town of Mars Hill, North Carolina, approximately 20 miles north of the City of Asheville – the largest city in Western North Carolina. The Town of Mars Hill has a population of approximately 2,200 and is home to Mars Hill College, which has a student population of approximately 1,500.

The site was selected because of its high visibility, accessibility, hydrologic conditions, and natural features including steep slopes representative of the surrounding mountain region, and relatively high percentage of impervious cover. Annual rainfall in Mars Hill averages approximately 42 inches per year, which is among the lowest rainfall totals in North Carolina and is especially low for the mountain region for which average annual rainfall exceeds 80 inches in some areas. The Town of Mars Hill is situated within the Ivy River watershed, a Class II water supply watershed, in Madison County, North Carolina within the French Broad River Basin. Despite ongoing efforts by various agencies to improve water quality in the Ivy River watershed, fecal coliform, sediment, and nutrients have led to continued impairment of water quality throughout the watershed.

The Mars Hill Town Hall property encompasses approximately 1.3 acres and is approximately 70% impervious. The average elevation is approximately 2,360 feet and slopes on the site range from approximately 6% to 24%. The total contributing drainage area to the downstream project limit is approximately 4.4 acres. The hydrologic soil group in the project area is primarily Type B and runoff curve numbers for the project area range from 70 for pervious areas to 92 for impervious areas. Approximately 80% of all storm events in the area have a depth of 0.85 inch or less and approximately 90% of all storm events have a rainfall depth of 1.3 inches or less.

The property adjacent to the Town Hall facility is occupied by the Mars Hill Housing Authority and is primarily used as housing for elderly and disabled residents. The proposed project site includes two levels of paved parking and open grassy areas downslope from the parking lots. Stormwater runoff from the roof of the Town Hall building and the parking lots flow into grassy areas down slope of parking lots and eventually into a tributary of the Ivy River. Because of the high percentage of impervious cover and the steep slopes at the site, high stormwater volumes and velocities are contributing to streambank erosion in the downstream tributary of the Ivy River. Expected pollutants include petroleum hydrocarbons and metals from the parking lot runoff as well as metals and nutrients from the roof runoff and sediment from adjacent open areas. Figure 2 presents an aerial view of the site and drainage area and Figure 3 shows a photograph of the project site.

Figure 2. Aerial view and drainage boundaries of Mars Hill LID project site.

Figure 3. Photograph of Mars Hill Town Hall, site of the LID demonstration project.

DESIGN APPROACH

A multi-disciplinary design approach was followed for the project, including the disciplines of hydrology, engineering, landscape architecture, and permaculture design as well as the contributions from a diverse stakeholder group. The primary design goals are listed below.

- Develop an integrated low impact stormwater management system.
- Provide a wide variety of demonstration BMP types.
- Provide treatment for the 90% water quality storm (~1.3”).
- Provide design which accommodates extreme storm events.
- Incorporate BMPs with proven treatment effectiveness.
- Incorporate current research, particularly from North Carolina State University.
- Incorporate permaculture design principles and techniques.
- Integrate human/ecosystem interrelationships for the community including neighbors, town employees, college and public school students, and visitors.
- Develop simple, reproducible, cost-effective designs likely to be considered by local community.
- Provide educational elements, including signage.
- Make site accessible and enjoyable, including circulation, seating, and shade.

- Use native vegetation including edible plants where possible.
- Use locally available materials, where possible.
- Demonstrate flow and relationships between different ecosystems.
- Develop aesthetically pleasing design, consistent with the town hall aesthetics.
- Develop low maintenance designs.
- Provide opportunities for collaboration with local college and other students.
- Provide BMP monitoring capabilities.
- Minimize costs within limited grant-funded budget.

The multi-disciplinary design team worked to achieve these goals in conjunction with a diverse stakeholder group. The stakeholder group and primary roles are summarized in Table 2 below.

Table 2. List of Primary Stakeholders and Primary Roles

Stakeholder	**Primary Roles**
Madison County Soil and Water Conservation District	• Primary project sponsor • Water quality objectives • Rural and agricultural perspective
Mountain Valleys RC&D	• Regional value in 7-county area
Town of Mars Hill	• Local community value • Aesthetics compatible with site • Maintenance needs
Mars Hill College	• Undergraduate research opportunities • Site monitoring
Madison County Public Schools	• Educational opportunities
Mars Hill Housing Authority	• Use of site by adjacent residents
North Carolina State University	• Current research in stormwater LID
Design Team (Project Management, Engineering, Hydrology, Landscape Architecture, Permaculture Design)	• Site hydrology • Engineering feasibility • Aesthetic elements • Permaculture design principles • Human interaction with landscape • Monitoring and maintenance

Design review meetings were held with the local stakeholders and presentations were made to the local community in order to provide opportunities for community involvement in the project.

RESULTING DESIGN

The resulting design integrates more than 20 different BMPs and is shown in Figure 4. Beginning with the oversized parking lot, some excess asphalt was removed and replaced with rain gardens, shade trees, and several different types of permeable pavements. This helped to clarify the parking lot circulation pattern, demonstrate different pervious paving options to designers and contractors, store and treat stormwater runoff and provide shade for the parking lot. A *mycelium filter strip* was designed to intercept sheet flow from the parking lot prior to overflowing into one of several different bioretention or treatment wetland devices.

Figure 4. Design layout of Mars Hill project site.

From the permeable parking area, an arbor with a vegetated roof leads visitors over a bridge and into a demonstration *infiltration garden*. A pervious pathway then takes the visitor along a biofiltration strip, planted with a variety of native grasses, several bioretention devices, a submerged gravel wetland, and a stormwater wetland with signage and seating located at appropriate places. A low seat wall was designed to allow groups to gather and listen to information about the project.

The area will be lushly planted with a variety of wetland and upland plants. The wetland plants include deep-water aquatic species and species for shallow water.

Shade trees were provided along the road and throughout the garden to cool the site and improve the aesthetics of the site. Care was taken to choose plants that are low maintenance, native, and have four-season interest. Many of the plants are edible for neighbors and visitors to enjoy. A path connects the site to the adjacent public housing so that the garden is an amenity for the community and serves multiple purposes.

The system was designed to demonstrate flow and the interrelationship of various ecosystems with drier biofiltration strip areas upstream followed by progressively wetter BMPs as the system moves downstream. Vegetated bioswales with turf reinforcement matting connect the bioretention cells and wetlands while both wooden and rock check dams were designed to dissipate velocities. A 2,500-gallon underground cistern captures runoff from the Town Hall roof and will be used for watering landscape.

The list of BMPs for the Mars Hill LID demonstration project includes:

- Vegetated biofiltration strip with native grasses
- Bioretention cells of varying depths and filter media (3)
- Submerged gravel wetland
- Stormwater wetland
- Vegetated bioswales and checkdams (4)
- Infiltration trench
- Raingardens (2)
- Permeable Interlocking Concrete Pavers (PICP)
- Grasspavers
- Pervious concrete
- Arbor with vegetated roof
- Cistern
- Permaculture infiltration garden
- Mycelium filter strip
- Permeable walking trail

The plant list for the project includes 21 different tree species, 18 shrub species, 19 wetland plant species, and 29 perennial and grass species which are native to the area. Edible species include pawpaw, persimmon, serviceberry, blueberry, elderberry, strawberry and oyster mushrooms. Additionally, 31 of these 87 species in the planting list have secondary benefits as food, medicine, spice, and as material for furniture and tool making.

Permaculture Design Elements

Two particular BMPs, inspired by permaculture design, are worth noting: 1) the mycelium filter strip and 2) the on-contour infiltration garden. The mycelium filter strip, also known as a mycofiltration strip, uses living mushroom mycelial nets to filter pollutants from stormwater runoff (Figure 5). The genus of mushrooms selected for the project is oyster mushrooms (Pleurotus spp.) which have been shown to transform petroleum hydrocarbons into harmless fungal carbohydrates (Stamets). This low-cost BMP consists of using native tulip poplar wood chips inoculated with the oyster mushroom mycelium and placed in burlap sacks within a 12-inch deep trench. The parking lot runoff will be intercepted by this mycelium filter strip, absorbing and metabolizing petroleum hydrocarbons into non-toxic plant fertilizer. A downstream monitoring location was incorporated into the design in order to evaluate treatment effectiveness. After two to three years of use, the myceliated woodchips can then be removed and added to the swales in the infiltration garden as nutritive mulch for trees and shrubs. Older woodchips can also be used to inoculate the next cycle of woodchips. Tulip poplar is the most common tree species in this bioregion and is also a fast-growing multi-use species. In a future phase of the project, stands of coppiced tulip poplar could be grown onsite to continuously regenerate substrate material for the mycelium filter strip.

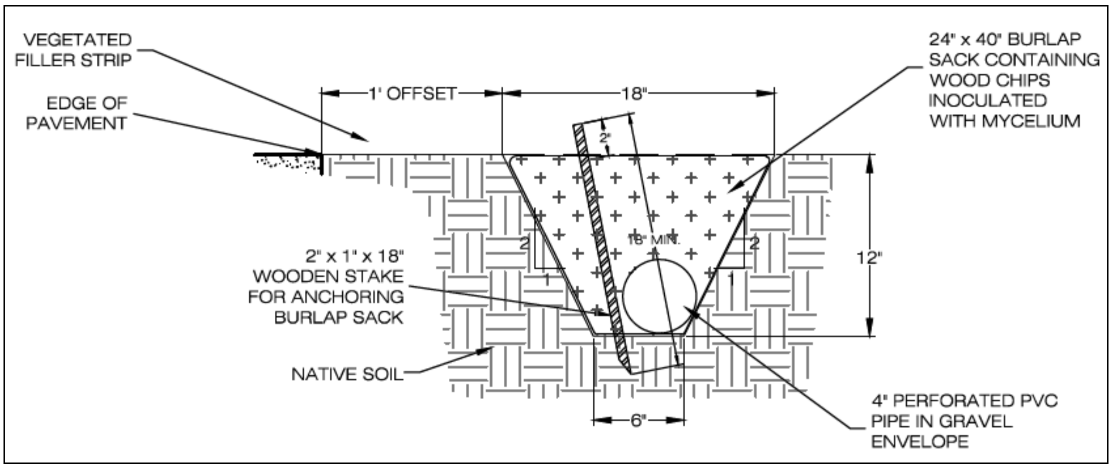

Figure 5. Cross-section of mycelium filtration strip.

The second permaculture design inspired BMP was named the *on-contour infiltration garden* which is a series of on-contour swales and berms on a slope designed to slow runoff velocities, provide stormwater retention, and promote infiltration and groundwater recharge as well as topsoil accumulation and retention (Figure 6). This low-cost, low-technology BMP creates terraced garden areas planted with native edible species which will be accessible to residents in the neighboring housing complex and visitors.

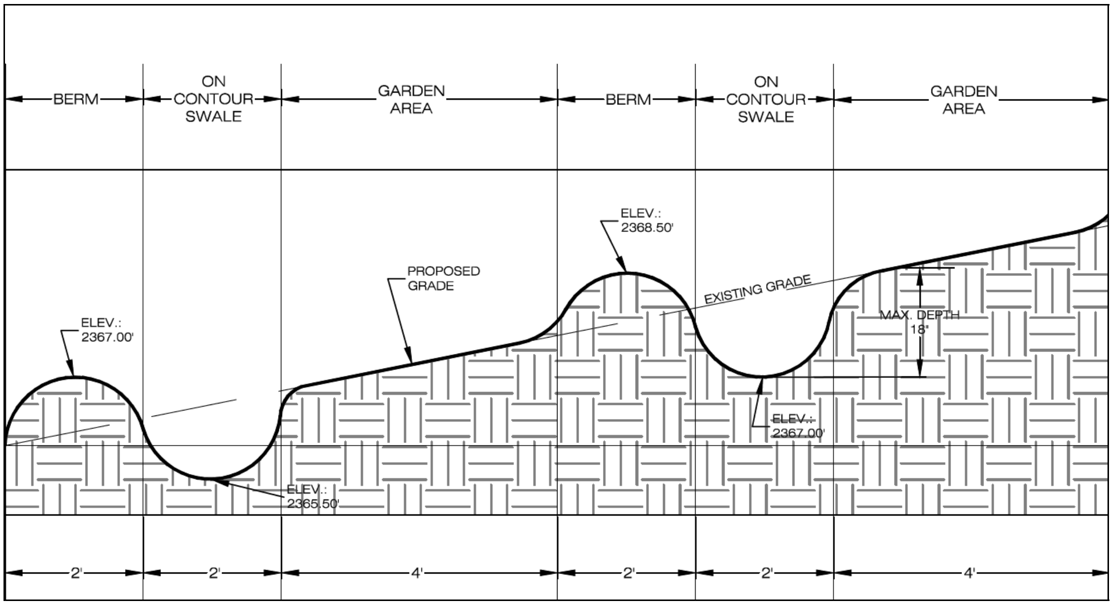

Figure 6. Profile of on-contour infiltration garden.

CONCLUSIONS

Construction of the Mars Hill Stormwater LID Demonstration Project began in November 2009 and is expected to be completed in early 2010 (Figures 7 and 8). Over 20 low impact and permaculture-inspired BMPs are being integrated on the site behind the Mars Hill Town Hall building at a construction cost of less than $100,000.


Figure 7. Mars Hill LID demonstration project site under construction.

Figure 8. Mars Hill LID demonstration project site under construction.

During the past three decades, low impact development (LID) has gradually and increasingly informed and transformed the way in which nonpoint source pollution from stormwater runoff is addressed. The proponents of LID have been pioneers and champions of watershed and ecosystem restoration.

Permaculture is a highly promising design philosophy, with many similarities to LID design, but which also asks some deep and pointed questions that could inform and even transform the way LID is approached. The LID demonstration project in Mars Hill, North Carolina is considered a first step within this bioregion in asking some of these questions about the potential beneficial human role within ecosystems and in restoring water quality. The conversation between LID proponents and designers and the permaculture community should be further explored, especially in light of current global environmental challenges. The authors would like to encourage LID designers to seek out experienced permaculture designers and invite their input on stormwater LID projects. As the Mars Hill LID demonstration project is soon completed and community involvement is increased, additional findings and lessons learned will be shared with the greater LID community.

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