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Montreat Aquifer Recharge: Implementing Low Impact Design Patterns in a Sustainable Community to Achieve Optimum Aquifer Recharge

James Adam Gobrecht
jgobrech@utk.edu

To the Graduate Council:

I am submitting herewith a thesis written by James Adam Gobrecht entitled "Montreat Aquifer Recharge: Implementing Low Impact Design Patterns in a Sustainable Community to Achieve Optimum Aquifer Recharge." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science in Landscape Architecture, with a major in Landscape Architecture.

Curtis E. Stewart, Major Professor

We have read this thesis and recommend its acceptance:

Brad Collett, Tracy Moir-McClean

Accepted for the Council:
Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

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A Thesis Prepared for the
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Degree
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The University of Tennessee Landscape Architecture Program, Assistant Professor Department of Plant Sciences; Matt Hall - Lecturer, College of Architecture and Design at the University of Tennessee at Knoxville.

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Abstract

This study was conducted over the period of several months in response to a problem presented to the author by Administrators of a town named Montreat located in the Blue Ridge Mountains in North Carolina. The problem this study attempts to address is decreasing aquifer recharge within Montreat, which in the past has led to strains on the local well system during times of drought. Anytime this happens it is a problem for the town of Montreat because the community has to then draw its potable water from nearby Asheville. This is an expense that a town with a limited budget like Montreat would like to avoid.

In order to address the issue of aquifer recharge in this area research of storm water management techniques known as low impact development (LID) was conducted. Research was focused specifically on those LID strategies that slow down or stop stormwater runoff and allow it to infiltrate the soil and replenish ground water supplies. An in-depth, site-specific analysis helped to locate where in the town these strategies should be implemented to be most effective.

Based on this research a site-specific plan involving several different LID design solutions was developed to better manage stormwater runoff in Montreat and help recharge the community's aquifer.

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Introduction

Montreat, North Carolina

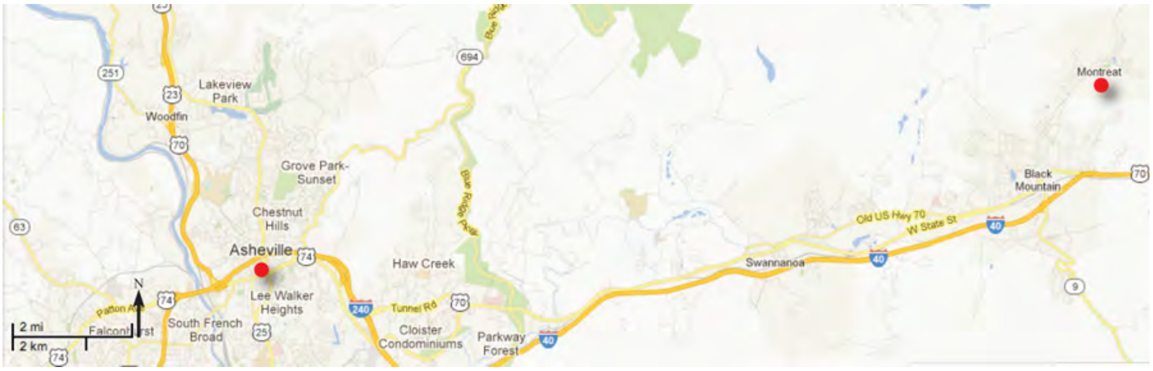

Figure 1 -Map illustrating the relationship in distance between Asheville and Montreat, maps.google.com

Resting at the foot of Graybeard Mountain in the Blue Ridge Mountain Range of Western North Carolina, Montreat is just a mile or so upstream from the town of Blackmountain. Both Blackmountain and Montreat sit immediately adjacent to Interstate 40 approximately 15 miles east of Asheville on the edge of the Pisgah National Forest. Montreat covers an area of 1,756 acres. Because sixty percent of the town is conservation easement, and these areas are owned by the MRA, Montreat College, and the Presbyterian Church, institutions which are 'tax exempt,' tax revenue can not be collected on this land. The income saved from this tax relief could be invested in private water conservation techniques, like cisterns or public water treatment techniques, like Low Impact Development (LID) Best Management Practices (BMPs).

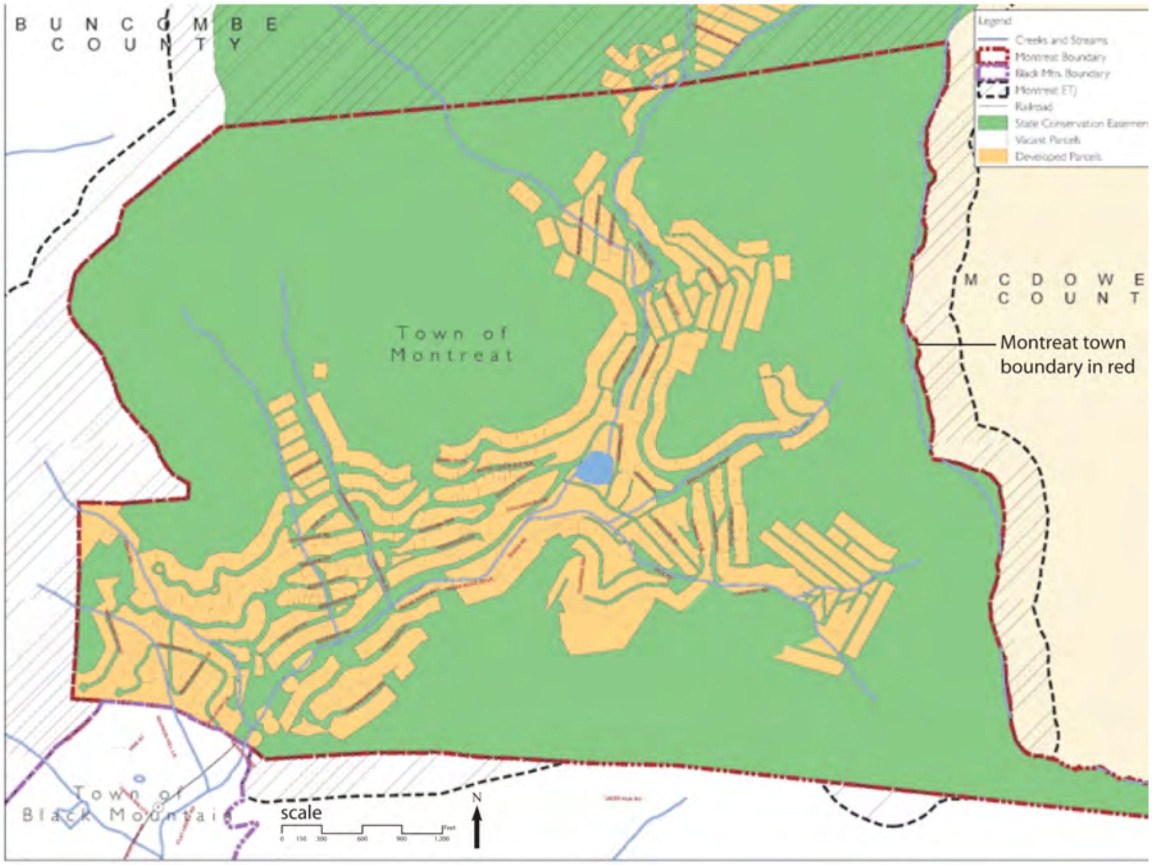

Figure 2 - Montreat Town Limits, Development Parcels, and Conservation Easement-townofmontreat.com

Montreat was established in1897 by a Presbyterian Minister named John Collins, as a mountain spiritual retreat. Originally, those who planned and built Montreat wanted the town to be constructed as what we know today as "a sustainable community." That is, they wanted to make a place for themselves nestled in the heart of Southern Appalachia 2that would have little to no effect on the surrounding environment and would conserve and preserve local resources for future generations. (1)

Montreat's Fresh Water Challenges:

Montreat's primary source of potable water comes from a network of eight wellheads located throughout the community. Though the community has access to a fresh water grid connected to the nearby Asheville, it collects its fresh drinking water from an aquifer which feeds these wells and helps to prevent the town from having to draw potable water from Asheville, except during times of drought.

The Town of Montreat is part of the Upper French Broad Watershed covering approximately 2958 miles. According to The Environmental Protection Agency (EPA) and its Enforcement and Compliance History Online (ECHO), Montreat has no sources of water contamination that are large enough to be of concern. However, Montreat College's Morgan Science Building has been listed by ECHO as a "hazardous waste handler" and a "hot-spot" for possible water contamination violations. Though there have been no toxic releases reported or fines levied to this point, there remains a possibility for local surface water bodies to be contaminated by hazardous waste, by accident, improper disposal, etc.

After performing what is known in the landscape architecture industry as a "surface triage," an textural analysis of the different kinds of surfaces found in Montreat, both natural and manmade, it was determined that there are existing concerns. These include a large amount of paved parking area and roads found in the downtown area, and the lack of stormwater control techniques to protect natural areas. This could lead to the local stream system, which helps to recharge ground water supplies, being contaminated by runoff containing vehicle fluids. Despite this, Montreat's stream system and well-water supply reportedly remain unharmed and clean according to the EPA, ECHO, and Montreat College tests.

Montreat's Well System and Underlying Aquifer:

*Figure 3 - Well Pump House and Water Filtration Facility #1-A in Montreat**

Montreat rests on top of what is classified as a Regolith-Fractured Crystalline Rock Aquifer System. The geology of this system consists of mostly fractured gneiss and schist bedrock mixed with soils that are conducive to water infiltration; mostly very stony, Ashe-Cleveland-rock outcrop complex, the majority of which sit on 15-30 percent slopes, except for in the flatter valley area, which is mostly developed urban land. (2)

Though the natural water supply created by the region's precipitation rates (45-50 inches annually) in the Upper French Broad Watershed has for the most part been adequate to meet the needs of this small community. However, there have been times when drought has caused the water supply in the aquifer to dwindle to the point where the town has had to supplement its supply by drawing water from Asheville's water-grid. Montreat is located in a severe drought zone and depends on its system of wells for potable water.

When local aquifers are stressed and the community has to draw potable water from Asheville it is costly. Montreat would like to avoid this scenario whenever possible.

This creates a challenge to recharge Montreat's aquifer sufficiently enough each year to reduce the need to draw water from Asheville's grid. Today, Montreat's ground water supply is being cyclically recharged by the town's wealth of creeks and streams. This means that the surface water bodies found in the area, Flat Creek and its tributaries soak the soil around them to a degree that water infiltrates the bedrock (parent material) under Montreat's soil profiles and adds water to underground systems. Unfortunately, these surface water bodies do not supply enough fresh water to keep Montreat's aquifer charged in times of severe drought.

Basically the problem is this; the physiology surrounding the town consists of extremely steep mountain slopes down which stormwater runoff moves at high speed to meet with the surface water body systems. This web of creeks and streams carry this runoff away from the area before it has an opportunity to infiltrate the soil and recharge the aquifer. Though this is a natural process, the natural balance that existed predevelopment had been offset by the installation of large areas of impermeable pavement, large buildings, roads, etc. The goal of Low Impact Development is to restore the natural balance of the amount stormwater runoff compared to the amount of water that infiltrates local soils to adequately recharge the aquifer.

Hypothesis:

It is believed that if LID design techniques are implemented where effective in and around the town of Montreat, sufficient volumes of stormwater can be slowed and captured to positively effect this community's ground water supply by improving aquifer recharge in this area and reducing the town's need to draw on outside sources of fresh water during a drought.

Chapter 1

Analyzing Fresh Water Conditions Globally, Nationally, Regionally and in the Montreat Area

Part I: Freshwater - A Threatened Global Resource

Figure 1.1 - photo by http://www.pulsarmedia.eu/data/media/27/EarthFromSpace_2560x1024.jpg

Whether we consciously realize it or not, water is essential to virtually every human endeavor, from growing food to making clothes and computers, to the simplest things like quenching our thirst. The growing number of water shortages around the world and the likelihood of these shortages leading to economic distress, food crises, social tensions, and even projected wars fought over water resources suggest that these challenges will, in the near future, rival if not surpass those posed by declining fossil fuel supplies.

The world's water problem is emerging as much more worrisome than its dwindling fossil fuels situation for three reasons. First, unlike oil and coal, water is much more than a commodity: it is the basis for all life on earth. Our species' decisions about water; how to use it, allocate it, and manage it, are deeply ethical ones not only in the sense of survival, but in the sense that Sustainable Communities promise social equity, that is, an equal opportunity for everyone to have access to the same resources. They determine the survival of every species on our planet, including our own. Second, unlike fossil fuels, water has no substitute, while the global economy fanes to be moving away from fossil fuels toward solar, wind, and other noncarbon energy sources, there is no transitioning away from water. Third, it is through water that we will experience the impacts of climate change and overpopulation most directly.

The rise in global temperatures driven mainly by the atmospheric carbon overload produced by the last 150 years (since the beginning of the Industrial Revolution) of humanity's greenhouse gas emissions due to the burning of fossil fuels for energy. This is fundamentally altering the cycling of water between the sea, the earth's atmosphere, and the land. While climate change is a naturally occurring phenomenon going back beyond time limits that man is capable of measuring, it is a scientifically proven fact that our industrial endeavors which require the burning of fossil fuels are affecting the previously naturally balanced carbon cycle by adding more carbon to the cycle than was or would have been present with the lack of human activities. Due to this, climatologists warn of the now infamous "green house effect" in which heat and radiation from the sun enters earth's atmosphere and are prevented from escaping by the massive amounts of carbon dioxide now present in the atmosphere, causing the temperature to rise all over the planet. Because of this, climatologists are concerned about even more extreme floods and droughts and of changing precipitation patterns that will make dry areas drier and wet areas wetter and vice versa. These changes in the earth's atmosphere could have tragic consequences. For instance, climatologists predict that if the average annual temperature of the earth rises 1 degree, the mid-west region of America (which provides produce to 40% of the world) could turn into another dust bowl like it did in the early 20th century, potentially leading to mass starvation in areas all over the world. Climatologists are trying to warn the world of melting glaciers and ice caps that within a few decades could severely diminish the river flow capacities upon which almost a third of the world's population depend. Nature seems to be highlighting these warnings on cue, at every turn. (1.A)

Doing More - and Living Better - With Less Water:

Of all the water humans withdraw worldwide from rivers, lakes, and aquifers, 70% is used in agriculture, 20% is used in industry, and 10% in human consumption in cities and towns. With access to fresh water supplies tightening, the human population of the earth will need at least a doubling of fresh-water resources by 2025 to satisfy human needs while continuing to sustain the world's water dependant eco-systems. Fortunately, the opportunities to get more potable water per drop abound through recent investments in conservation, efficient use, recycling, and reuse. Also, desalinization is an option for "creating" more fresh water, although current techniques are inefficient and very expensive. (1.A)

Fresh Water, A Finite Resource:

We'd all like to believe there's an infinite supply of fresh water on the planet, and many of us, myself included, have used water as if it would never run out. But this assumption is tragically false. Fresh water amounts to approximately 2.6% of all the water on earth. The rest is seawater, frozen in ice, or water stored in the ground that is, for the most part, inaccessible to us. The hard fact is this; humanity is wasting, diverting, and polluting the earth's fresh water resources so quickly and relentlessly that the future of every species on the planet is being threatened. There is the same amount of water on the earth as there was at the time of the planet's creation and it is all the same water.

While some hydrologists concede that climate change is having an effect on the planet's hydrologic cycle and affecting the amount of fresh water that is available to us, it is not climate change that is the biggest threat to earth's fresh water supply. In certain parts of the world it is overpopulation that is driving fresh water resources to the brink. (1.G)

The following is the simplest scientific explanation that I have come across so far as to explain exactly what is happening as far as our fresh water supply worldwide.

The amount of fresh water on earth is approximately 36 million cubic kilometers (about 8.6 million cubic miles), a mere 2.6 % of the all the water on earth. Of this, only 11 million cubic kilometers (about 2.6 million cubic miles), or 0.77 %, counts as part of the hydrologic cycle in that it circulates relatively quickly. However, fresh water drawn from aquifers is renewable only by stormwater runoff. So, when it's all said and done, we can only rely on the 34,000 cubic kilometers (about 8,000 cubic miles) of stormwater that annually creates the runoff that cycles back to the oceans via creeks, streams, rivers (surface water) and groundwater. This is the only water considered available for human consumption (potable) because it can be harvested without depleting finite water resources. (1.B)

The Hydrologic Cycle:

Precipitation patterns are a crucial part of the hydrologic cycle, the process through which water circulates from the atmosphere to the earth and back, from a height of 15 kilometers (about 9 miles) above the ground to a depth of 5 kilometers (3 miles) beneath it. Water that evaporates from the oceans and water systems of the continents goes into the atmosphere, creating a protective "envelope" around the planet. It turns into saturated water steams, which create clouds, and when those clouds cool, rain is formed. Stormwater falls to the earth's surface and infiltrates the soil, becoming ground water and recharging aquifers. This underground water, in turn, comes back to the earth's surface in the form of source points for creeks, streams and rivers. Surface water and ocean water then evaporate into the atmosphere, starting the cycle anew. (1.B)

Aquifer Recharge:

Most of the earth's fresh water, however, is stored in aquifers that are recharged by stormwater runoff, just below the surface or deeper down. This is called "groundwater," and it is 60 times greater in volume than the water that lies on the earth's surface. There are many types of groundwater, but the most important type for humans is "meteoric water" - moving groundwater that circulates as part of the hydrologic cycle, feeding surface water bodies. Underground water reservoirs, which are known as aquifers, are relatively stable because they are secured in bodies of rock. Many of them are closed systems - that is, they are not fed by meteoric water at all. Wells and boreholes drilled into aquifers are fairly secure sources of water because they tap into these large reservoirs, but to be useful over time, an aquifer must be replenished with new water at approximately the same rate as the rate of extraction. However, around the world, people are extracting groundwater too rapidly to supplement declining supplies of surface water. (1.B)

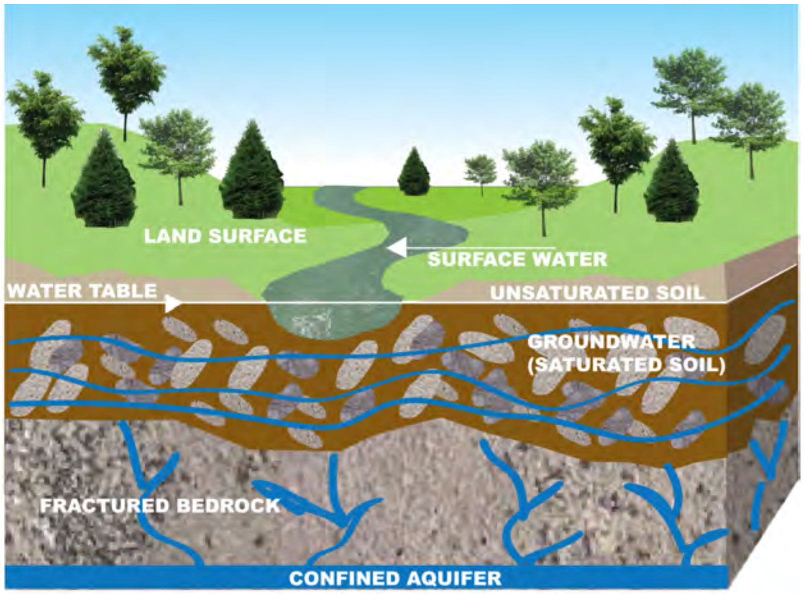

*Figure 1.2 - Illustration of relationship between surface water and ground water** adapted from illustrations found in the online booklet, "The Water Connection: Water Resources, Drought and the Hydrologic Cycle in North Carolina"*

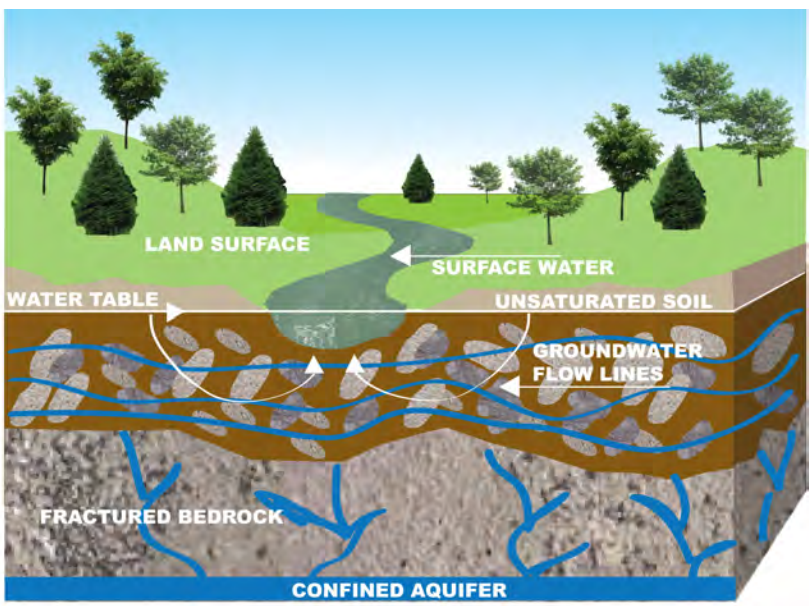

Figure 1.3 - Illustration of how surface water begins to become ground water adapted from illustrations found in the online booklet, "The Water Connection: Water Resources, Drought and the Hydrologic Cycle in North Carolina"*

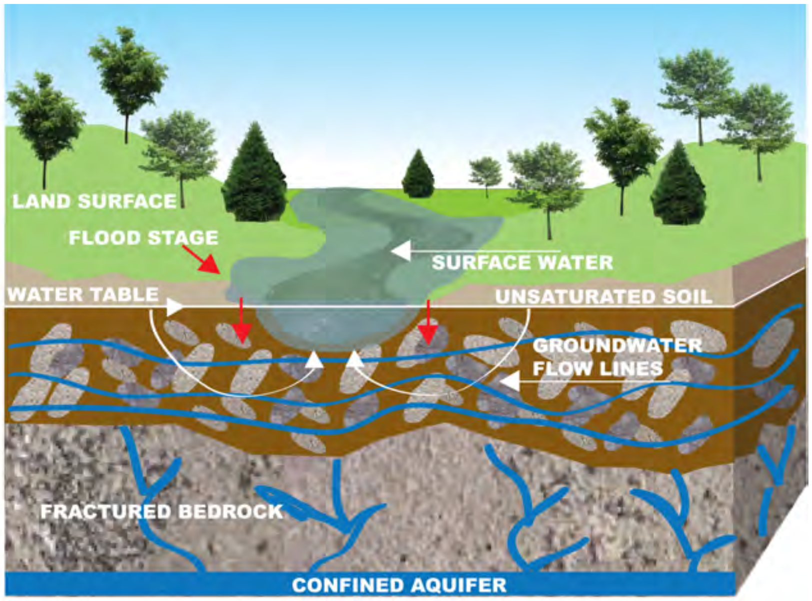

Figure 1.4 - Illustration of how flooding forces surface water into groundwater supplies adapted from illustrations found in the online booklet, "The Water Connection: Water Resources, Drought and the Hydrologic Cycle in North Carolina"*

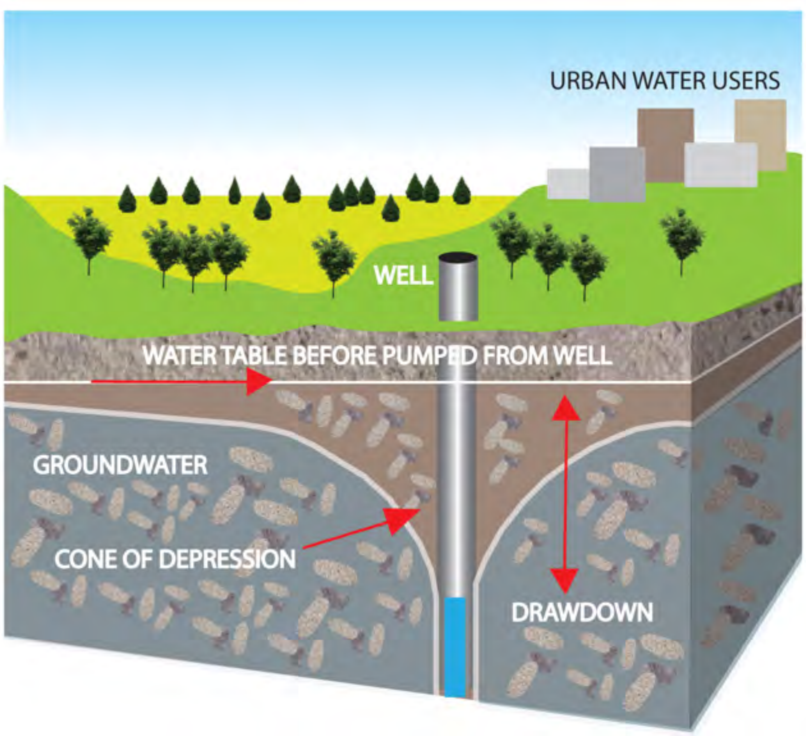

Figure 1.5 - Illustration of how urban wells drawdown ground water supplies adapted from illustrations found in the online booklet, "The Water Connection: Water Resources, Drought and the Hydrologic Cycle in North Carolina"*

In other words, some communities draw more water from their aquifers and other sources than is being naturally replenished by stormwater and surface water sources, leading to water shortage problems during times of low precipitation rates if they draw their potable water from wells.

Part II: The U.S. National Water Situation:

According to Sandra Postel, one of the authors of *The Post Carbon Reader*, the average U.S. resident consumes about 1,800 gallons per day. What this actually means is water is used in the production of a lot of the products U.S. residents consume, not necessarily that Americans use this much water on a daily basis for 'everyday activities' like cooking, drinking, bathing, washing clothes and dishes. Still, this is twice the global average. More conscious choices about what and how we consume water are essential for reducing our global water footprint. Doing more with less water is also up to individual consumers to shrink their personal water footprints (the amount of water used to produce all the things we buy and the amount of water we consume). (1.A)

Water for Homes, Irrigation, and Manufacturing:

In communities across the United States, water conservation remains the least expensive and most environmentally sound way of balancing water budgets - and its potential has barely been tapped. Many cities and towns have shown significant reductions in water use through relatively simple measures like repairing leaks in distribution systems, retrofitting homes and businesses with water-efficient fixtures and appliances, and promoting more efficient outdoor water use like installing gray water collection apparatus like cisterns and rain barrels to recycle stormwater for non-potable water use such as; washing clothes, flushing toilets, washing dishes, and irrigation. (1.A)

The total water use of the U.S. equals 410 billion gallons per day. Nearly two-thirds of the fresh groundwater withdrawals listed in the most recent USGS National Water Use Report were for irrigation. Irrigation is the largest use of fresh groundwater in 25 States. Nationwide, groundwater withdrawals for irrigation were about 3.5 times larger than groundwater withdrawals for public supply. (1.C)

Part III: The Southeastern Regional Water Situation:

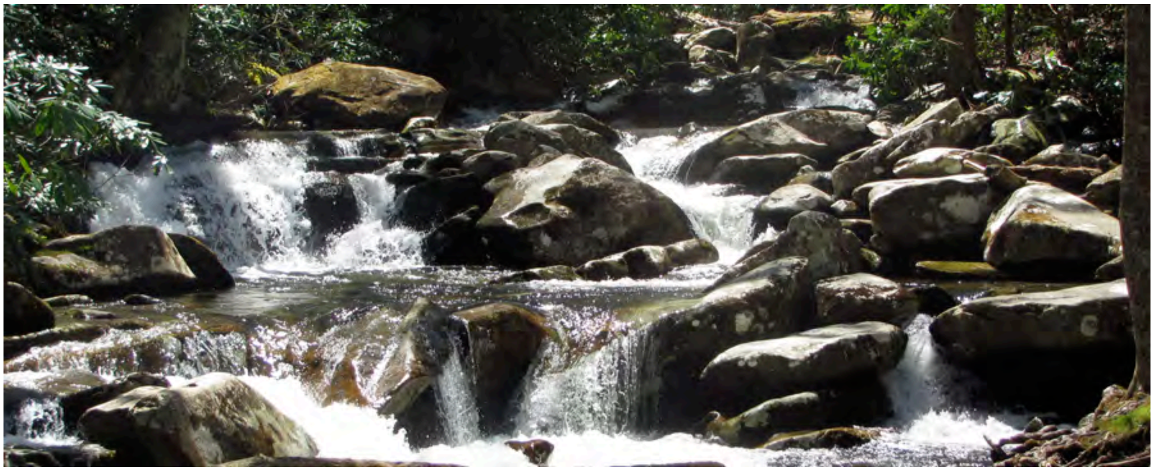

*Figure 1.6 - West Prong of the Little Pigeon River in The Great Smoky Mountains National Park **

The drought that has gripped the Southeast in recent years was not unprecedented and resulted from random weather events, not global warming, Columbia University researchers have concluded. They say its severe water shortages resulted from population growth more than rainfall patterns.

Researchers cite census figures showing that in Georgia alone the population rose to 9.54 million in 2007 from 6.48 million in 1990. "At the root of the water supply problem in the Southeast is a growing population," they wrote. Richard Seagar, a climate expert at the Lamont-Doherty Earth Observatory led the study, said in an interview that when the drought struck, "people were wondering" whether climate change linked to a global increase in heat-trapping gases could be a cause. However, after studying data from weather instruments, computer models and measurements of tree rings, which reflect yearly rainfall, "our conclusion was this drought was pretty normal and pretty typical by standards of what has happened in the region over the century," Mr. Seager said. Similar droughts unfolded over the last thousand years, the researchers wrote. Regardless of climate change, they added, similar weather patterns can be expected regularly in the future, with similar results.

In an interview, Douglas LeComte, a drought specialist at the Climate Prediction Center of the National Weather Service, said the new report "makes sense." Although Weather Service records suggest the 2005-7 drought was the worst in the region since the

1950s, Mr. LeComte said, “we have had worse droughts before.” Some climate models developed by scientists predict that the Southeast will be wetter in a warming world. But the Columbia researchers said it would be unwise to view climate change as a potential solution to future water shortages. As the region’s temperature rises, there may be more rain, they wrote, but evaporation will increase, possibly leaving the area drier than ever. Mr. LeComte said that creating greater water storage capacity — say, in reservoirs — could mitigate drought effects in areas where population was rising. “I am not going to criticize any governments for what they did or did not do,” he said. “But if you have more people and the same amount of water storage, you are going to increase the impact of droughts.”

The researchers said rainfall patterns in the Southeast were linked only weakly to weather patterns like La Niña and El Niño, the oscillating warm and cold conditions in the eastern Pacific linked to precipitation rates in the Southwestern United States. Instead, they wrote, any variation in rainfall in the Southeast commonly “arises from internal atmospheric processes and is essentially unpredictable.” (1.D)

Part IV: Montreat's Fresh Water Situation:

*Figure 1.7 & 1.8 - Flat Creek - Montreat, NC **

Geology and the Occurrence of Groundwater:

Ground water occurs in rock openings that can be either primary or secondary fractures. Primary fractures occur when the rock is formed, such as the spaces between pebbles in a gravel bed. Secondary fractures occur after the rock is formed. Crystalline rocks, including granite, gneiss, and schist, have little pore space between the component grains. The openings which yield water in these rocks are secondary, and include joints, fractures, cleavage plains, planes of schistosity, bedding planes and solution channels. These are not uniformly distributed through the rock. Most of the ground water in Buncombe County and the Asheville area, which includes Montreat, occurs in secondary fractures. Some exceptions are water in local sand and gravel deposits.

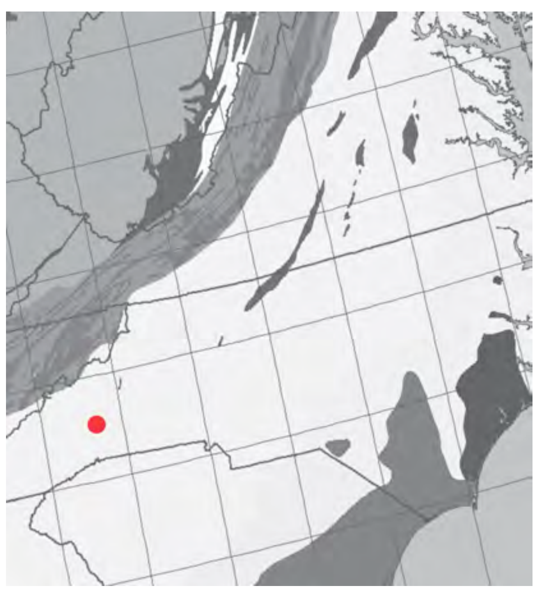

Figure 1.9 - Montreat's location within The Greater Piedmont Aquifer - adapted from a map found online at usgs.com

As mentioned earlier, an underground zone or layer which is a source of water is called an aquifer. Where the water is not confined beneath an impermeable layer of rock, the upper surface of the zone of saturation (known as the water table) is free to rise and fall with fluctuations in atmospheric pressure and precipitation rates. It is not a flat surface but generally reflects the irregularities of the topography under which is exists. The water table intersects ground level as springs, streams, lakes , and ponds. Where groundwater occurs only in irregularly distributed fractures and other secondary openings, the water table can be very irregular or discontinuous. (1.F)

The Current use of Groundwater in Buncombe County:

Drilled Wells:

Wells were first drilled in this area around 1910. The cable-tool, or percussion method, has been commonly used to this day. The air-percussion-rotary drill has been introduced to the mountain area in the last few years and has been considered to considered to be superior to the cable-tool method. A well drilled by an air rotary drill in a day may require more than a week to drill with a cable-tool drill. The wells in this area are drilled into unweathered bedrock, then cased to form a tight friction seal which seals off surface water. After the casing is set, the well is drilled into bedrock until an acceptable supply of water is obtained or the well is abandoned.

Effect of Topography on the Yields of Wells:

Topography is an important factor to be considered when selecting a well site. Wells drilled in valleys and draws are, on average, shallower but have higher yields than deeper wells dug on slopes or hillsides. This is due to the fact that the water table in valleys and draws my be closer to the surface than in wells on the sides of slopes.

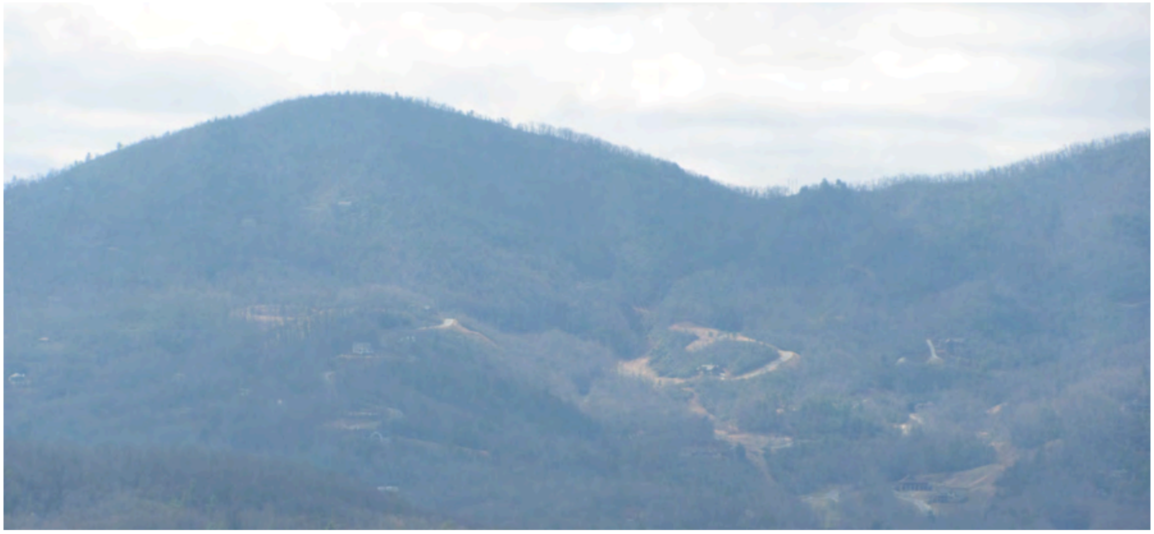

*Figure 1.10 - An example of severe slopes surrounding Montreat**

Also, valleys and draws follow pre-existing zones of fractures in rock, and water is stored and transmitted in fractures. (1.F)

Montreat's Current Official Approach to Stormwater Management:

Stormwater is the water that runs off of streets, parking lots, rooftops, and vegetated slopes whenever it rains. In most cases of urban development this stormwater is directed into nearby streams, storm drains, and ditches without passing through a water treatment plant. Stormwater run-off is a problem because it can carry pollutants from the surrounding landscape into local waterways. Metals, salts, oil, etc. from roads and parking lots; fertilizers and other products from golf courses and landscaping; pet waste; grease, soap, and other chemicals; anything that gets deposited on the pavement or sidewalk could eventually end up in a nearby stream. In addition to chemical and organic wastes, tons of sediment is carried down stream by stormwater run-off. In fact, sediment in streams is the #1 water pollutant in Western North Carolina today. Finally, many pollutants get into Montreat's surface water body system through unapproved connections to the stormwater system. According to experts in sustainable practices all drains in homes and businesses should be connected to a municipal sewer system or a septic system. But many are connected instead to the storm drainpipes. These connections are called illicit discharges.

These illicit discharges may be unintended and can be easily fixed once they are identified. All these pollutants that get carried by stormwater run-off are called non-point-source pollutants because they don't come from any single point of origin. Non-point source pollution is the greatest threat today to our nation's waters. In an effort to address this prevalent source of water pollution, the Federal Clean Water Act (CWA) requires local communities to manage stormwater run-off and to control non-point source pollutants. This is done through creation and implementation of local Stormwater Management Plans. Phase II of the Clean Water Act covers smaller cities and towns such as the Town of Montreat. As such, Montreat has been dubbed a "Phase II Community," The law requires us to submit a plan and receive a state permit to manage stormwater run-off, and to report regularly to the state on our adherence to the plan. Accordingly, Montreat developed a plan, and received its stormwater permit in July of 2005. In compliance with the Clean Water Act, this plan includes a variety of strategies for managing stormwater run-off. (1.E)

These include:

• Reducing run-off volume by adopting a post-construction run-off ordinance. This will encourage builders to include stormwater controls such as wetlands, grassed swales, porous pavement, cisterns, etc., in all new construction and re-development. These controls help direct rainwater into the ground, rather than running off the site and carrying pollutants. They are cost effective when included in the original construction design.

• Mapping the stormwater drainage system and developing a program to identify and correct illicit discharges. That is, redirecting potentially polluted runoff away from "clean" surface water bodies.

• Train Town staff to use pollution prevention measures in all local operations.

In addition to these strategies, an important part of the plan includes residential involvement - making information available to the public, offering opportunities for public participation in practical ways, and for public comment on the process of policy enactment and implementation. Montreat does a good job of this by including residents in a democratic system that determines what takes place in the community. For example, to facilitate public involvement, Montreat holds periodic public hearings and workshops to include public feedback and opinions. In addition, the Montreat Planning Board advises the Montreat Board of Commissioners on specific action steps for stormwater management. The town encourages interested citizens to attend meetings each month.

Furthermore, special programs and projects are scheduled throughout the year to restore and preserve the health of local streams. These special programs and projects include stream cleanups, storm drain stenciling, native species restoration, and Earth Day Celebration activities. Montreat encourages all its residents and business owners to get involved in these efforts. Montreat expresses a need for everyone to do his or her part in reducing non-point source pollutants and minimizing stormwater runoff from their home or business. The community even provides its people with steps they can employ to help; (1.E)

• Scoop up after your pet, most importantly on the grass.

• Apply fertilizers and other garden products sparingly. If anything ends up on a hard surface, sweep it back into the grass or dirt.

• Plant, mulch, or contain any areas of bare soil.

• Never dump anything down a storm drain. “Only rain down the drain.”

• Consider installing a rain garden, rain barrel, porous pavement, or other landscape feature to capture run-off from your roof and driveway.

• Make sure your business disposes of all liquid and solid waste appropriately. Make sure dumpsters are covered, and never dump anything -- liquid or trash --on the ground or pavement.

If you use chemicals, oil, solvents, etc., store them in good quality containers in a safe place. Only pour them in an area that has containment structures, such as a berm around the area, to catch spills. (1.E)

Chapter 2

Sustainable Communities and Low Impact Development

According to town officials, the Town of Montreat considers itself to be a "sustainable community," and rightfully so. This community was originally founded on the same principles that today's planners and landscape architects consider to be the characteristics that make a community 'sustainable.' At the time of Montreat's founding these building practices were common sense back when people had to live off the land and the available resources that surrounded them. The central theme which influenced this town's founders to attempt to find a balance between sustaining their survival and having little to no negative impact on the local natural environment was their belief system. As was touched on in the introduction to this paper, Montreat was founded by Members of The Presbyterian Church, and based on interviews conducted with members of this denomination, the Presbyterian Church believes that God gave man dominion over the earth not to conquer and develop, but to act as The Stewards of His Creation. As a result, by merely following their Belief System, the early founders and developers of Montreat inadvertently brought forth one of the first "sustainable communities" founded in Southern Appalachia. (2.B)

What is a Sustainable Community?

A sustainable community is one that is economically, environmentally, and socially healthy, conservative and resilient, and founded on the premise of preserving its resources for generations to come. (2.A)

Management Goals for a Sustainable Community:

According to Woodrow W. Clark II, the author of the book *Sustainable Communities*, the management goals for a sustainable community include;

• replacing fragmented approaches that focus on and maximize one goal at the expense of the others with integrated solutions that maximize the sustained performance of the whole community

• creating a better quality of life for the whole community without compromising the wellbeing of other communities

• an effective governance supported by meaningful and broad-based citizen participation

• to adopt longer-term perspectives that focus on both the present and future, well beyond the next budget or election cycle

• to manage human, natural, and financial resources in order to meet current needs while conserving adequate resources available for future generations

Civic Goals for a Sustainable Community:

The civic goals for a sustainable community include; a better quality of life for the whole human community while minimizing impacts on the well being of other communities, effective governance supported by meaningful and broad-based citizen participation, and economic security.

Citizenship and Leadership for a Sustainable Community:

A sustainable community's success depends upon its members' commitment and involvement through; active, organized, and informed citizenship, inspiring, effective, and responsive leadership, and responsible, caring, and healthy community institutions, services, and businesses.

Conservation Goals for a Sustainable Community:

Any sustainable community should be concerned about conserving and preserving its own natural resources like; water, land, energy, and nonrenewable resources. To optimize sustainability, these communities should be concerned with the utilization of prevention strategies and appropriate technology to minimize pollution of environmental resources. For example, Montreat might be concerned about pollutants from mountain slope storm water runoff including; animal waste, soils, and soiled natural debris.

An essential characteristic of sustainability is the use of renewable resources no faster than their rate of renewal. Montreat protects its trees in public right of ways and limits the amount of land a resident can develop, to decrease contaminated runoff and prevent soil erosion on slopes.

Infrastructure that improves access to services and markets while minimizing without damage or degradation of the local environment, such as; the construction of new roads using impervious materials, directing excess runoff into local waterways or destroying existing wildlife habitats.

Social Goals for a Sustainable Community:

Social wellbeing is the possibly the most important cog in the machine that runs a sustainable community. There can be no true civilization, let alone civilizations willing to work together and make sacrifices toward living sustainably, if the satisfaction of basic human needs for clean air, water, nutritious and uncontaminated foods and camaraderie are not met first. Basically, social wellbeing and social equity go hand in hand. That means providing the following affordable provisions for quality health provision, care and treatment services for all community members. Also, social equity is key, this means providing the means for everyone to obtain safe and healthy and affordable housing, and equitable access to quality education services. In a sustainable community, the basic human rights of all community members must be respected and defended against injustices including exploitation and psychological and physical harm, just as our current civilization promises. Finally, protection, enhancement, and appreciation of community manifestations of cultural diversity, treasures, customs, and traditions have to be respected and recognized by all.

Economic Goals for a Sustainable Community:

Economic security is paramount in any society and it is no different in sustainable communities. There are several ways sustainable communities can achieve economic security that will last while using more sound practices than the methods which have been used in tradition society. These include allowing all community members to equitably benefit from of a strong and healthy community-centered economy, creating a diverse and financially viable economic base, reinvesting resources in the local economy, the maximization of local ownership of businesses, providing meaningful employment opportunities for all citizens, creating responsive and accessible job training and education programs that enable the workforce adjust to future needs, and supporting businesses that enhance community sustainability. (2.A)

Low Impact Development:

What is LID and how can it help to make an already supposedly sustainable community even more sustainable?

According to *"Low Impact Development: A Guidebook for North Carolina,"* written by researchers at North Carolina State University, low impact development is "an innovative approach to site development and stormwater management that aims to minimize impacts to the land, water, and air, while reducing infrastructure and maintenance costs and increasing marketability." (2.B)

LID Stormwater (Best Management Practices) BMPs:

In the case of Montreat, cost effectiveness is imperative to the construction and/or the installation of low impact development design solutions for managing stormwater runoff due to the fact that this small community has a very limited budget. LID Best Management Practices allow an LID project to achieve what is known as an annual predevelopment hydrologic budget ("pre-development budget"). Best Management Practices are the most effective and cost efficient when they are implemented by evaluating each specific situation in which they are to be deployed, ultimately implementing the most sensible solution in each specific situation in which stormwater run off it to be managed using these methods. (2.B)

LID and Ecology:

Low Impact Development is part of what is known in the development and stormwater management industries as a "Protective Development Approach." Interest in protective development approaches is growing not just in the Southeast, but all over the nation.

The main characteristic of LID that developers and planners find so appealing is that it has little to no effect on the natural environment in which it is implemented, preserving local ecologies while managing stormwater runoff.

Montreat, like all other communities in the state of North Carolina, is subject to the federal Clean Water Act. Under the Clean Water Act, one of the major responsibilities of state government is to protect, restore, and sustain the environmental integrity and use of its water resources. Good water quality and thriving fisheries are essential for sustaining the quality of life and continued economic growth of small communities like Montreat. Low impact development provides additional tools to protect water quality by optimizing the urban landscape to reduce and treat stormwater runoff. This is an important point that will be explored in further depth later in this document. (2.B)

The overall positive effects LID could have on a local ecological system include;

- The preservation of the integrity of ecological and biological systems
- The reduction of demands on water supply and the encouragement of natural groundwater recharge
- The protection of site and regional water quality by reducing sediment, nutrient, an toxic loads to water bodies
- The reduction of negative impacts by polluted run off on local terrestrial and aquatic plants and animals

• The preservation of trees and natural vegetation

LID and Stormwater Harvesting:

Low Impact Development BMPs and Water Harvesting Techniques go hand-in-hand as far as working together to achieve the common goal over aquifer recharge. That is, the more water is recycled on site, the less water is pulled from the aquifer, with the BMPs listed above, this research study will recommend the installation and usage of Water Harvesting techniques that would best fit Montreat at this time;

1.) Residential and Commercial Cisterns to harvest gray water

(Montreat residents are allowed to install cisterns outside their homes under North Carolina Codes) to be used for; toilets, laundry, and kitchen (dish washing)

2.) Rain-barrels for collecting water for irrigation

Chapter 3

Montreat; Context and Site Inventory

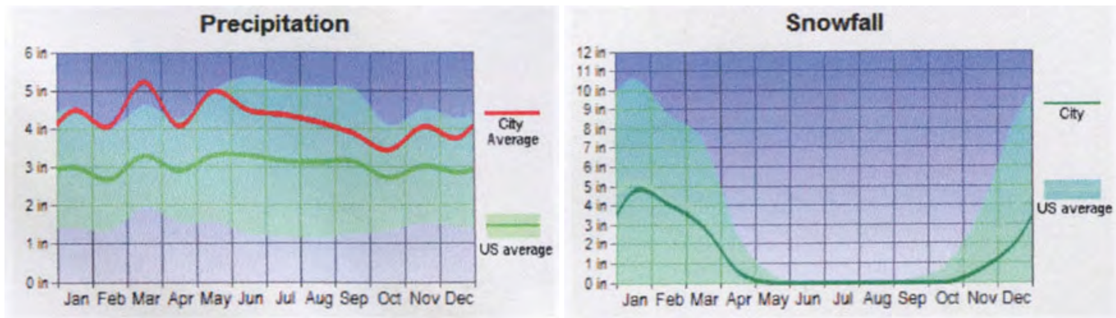

Figure 3.1 - Montreat Annual Precipitation Charts. townofmontreat.com

Montreat receives 40 to 50 inches of precipitation per year on average. However, Montreat sits in what the USGS considers to be a "Extreme Drought Zone," meaning that at all times, the community stands a moderate chance of experiencing a drought that could range from mild to severe. (3.E)

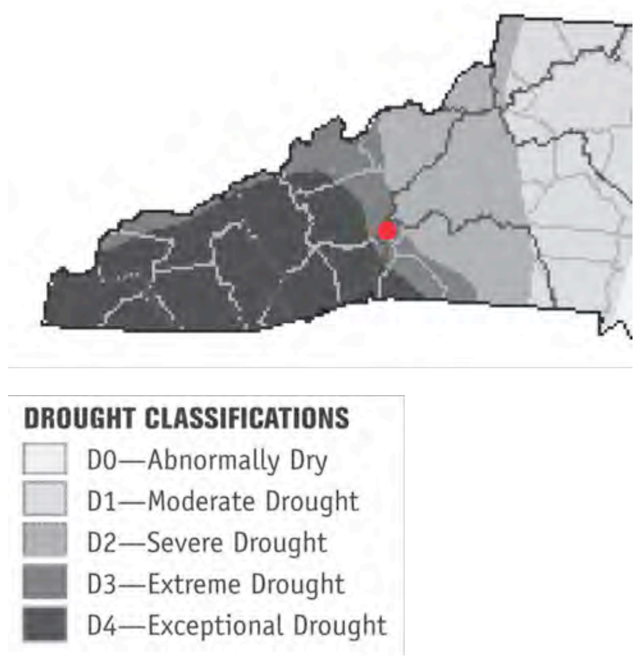

Figure 3.2 - Western North Carolina drought zone classifications. ncgs.com

Droughts in the Montreat area are common. In fact, Montreat did experience an extreme drought in the summer of 2010 that forced the community to switch over from its private well system to its access to Asheville's water grid in order to supply its residents and businesses with an adequate supply of fresh water. According to town officials, this was a costly endeavor for the community and the MRA would like to avoid consequences like this in the future. Hence the premise of this aquifer recharge research project.

Stormwater Treatment:

Montreat's stormwater run-off characteristics are directly affected by the loss of vegetation, impervious surfaces, hydrology, soil typology, and the steepness of slopes. The elimination of existing vegetation on hillsides during development exposes soils, allowing stormwater run-off to carry sediment into creeks and streams. Development on steep slopes exacerbates the problem in that the increased velocity of the stormwater run-off increases erosion. While much of Montreat is protected by a conservation easement, development remains a factor in erosion and stormwater management. Montreat is greatly impacted by its amount of impervious surface areas (roadways, rooftops, parking facilities and other hard surfaces) where rainfall and run-off are unable to be absorbed into soils. According to Planning and Urban Design Standards, impervious surfaces "preclude the infiltration of precipitation into soils and can significantly reduce groundwater recharge, subsequently lowering the water table, depleting groundwater supplies, and reducing ecologically important base flow to streams and wetlands." (3.A)

Pervious surfaces would be much better for Montreat's stormwater runoff concerns than the asphalt and concrete surfaces that are in place today. Pervious surfaces would allow stormwater and runoff to drain into the soil to be naturally filtered before entering stream systems.

*Figures 3.3 & 3.4 - Permeable pavement system in a park in downtown Montreat**

Montreat does possess a few features that help somewhat with stormwater treatment and run off infiltration, like; naturalized gutters along roadsides, a small amount of permeable pavement in a large park in the "downtown" area, and considerable swaths of turf on most of the softer slopes in the urbanized portion of the town helping somewhat to slow sheet flow and allow it to infiltrate local soils. Also, there is one natural feature in Montreat that helps to manage stormwater run off as far as capturing it and moving it out of the town. The natural web of creeks and streams that create an elaborate surface water system which not only helps to handle run off coming down the mountains slopes, but also helps to recharge the aquifer under Montreat. However, these surface water bodies are not enough to keep the aquifer supplied with the amount of fresh water the town needs through times of severe drought.

*Figures 3.5 & 3.6 - Existing stormwater runoff treatment examples in Montreat**

The storm water drainage system in Montreat is connected to a sewer system that runs to neighboring Asheville. Runoff from mountain slopes is allowed to enter existing stream system unfiltered. Runoff from roads and buildings flows into separate primarily open channel drainage system that join with the stream system in Montreat. Though the water quality tests of the stream system performed by Montreat College and the

Blackmountain community tests show good quality, it is hard for one to believe that the surface water running through these communities is not somewhat polluted. Instead of just letting all this valuable stormwater runoff enter the stream system and run out of town, it could be redirected into LID systems to recharge the aquifer. This sheet flow could be caught in retention ponds, "sponge parks," level spreaders, infiltration trenches, dry detention basins and a number of other LID BMPs.

Though the water supply in the Upper French Broad Watershed for the most part, adequate for the needs of Montreat, some residents are practicing Rainwater Harvesting techniques for residential irrigation.

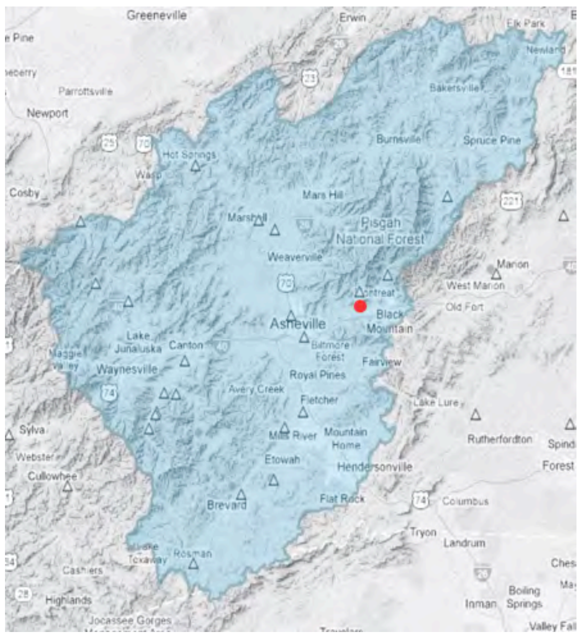

Figure 3.7 - Upper French Broad Watershed - adapted from a map found at maps.google.com

Residents get “incentive points” for collecting rainwater for multiple uses in relation to how much land they are allowed to purchase. The way in which residents may use their "incentive points" is restrained by town building codes. For instance, no matter how many incentive points a residents earns, only so much of their property may be developed per square foot in relation to the amount of incentive points they have earned. For example, if a resident harvests a given amount of rainwater for irrigation, etc. they are permitted to develop a percentage of their land related to the amount of rainwater they recycle. Currently, there is only one cistern in place for the use of gray water for irrigation and toilet water because only one resident has taken interest in this program at this point additionally the initial costs of implementing this system are relatively high. Montreat could use its tax incentives to offer an affordable cistern installation plan for its residents and make wide usage of this opportunity.

Montreat Town Reservoir:

Montreat originally got its water from a man-made reservoir off Assembly Drive on the edge of Montreat's residential area. This reservoir still exists today, but it is not being used to supply the town with water, though it is connected to a pump house and water filtration system. Instead it is being used as Wildlife Refuge and fishery to breed brown and brook trout to be introduced into Montreat's stream system.

*Figures 3.8 & 3.9 - Montreat town reservoir**

Stream System Protection:

It is Montreat town code to maintain 20 foot wide riparian zones along the stream system of Flat Creek along and the town does a good job of maintaining these, helping to prevent contaminated run off and sediment from entering local streams. These riparian zones help not only to slow down run off to be filtered by plants in riparian zones but also help to keep contaminants from paved surfaces, roof tops and natural sediments out of surface water bodies. Healthy riparian zones also slow down run off to give it a chance to infiltrate the soils around these surface water bodies helping to encourage aquifer recharge. However, these riparian zones are only mandated to be maintained along the developed areas of Montreat that Flat Creek flows through. (3.A)

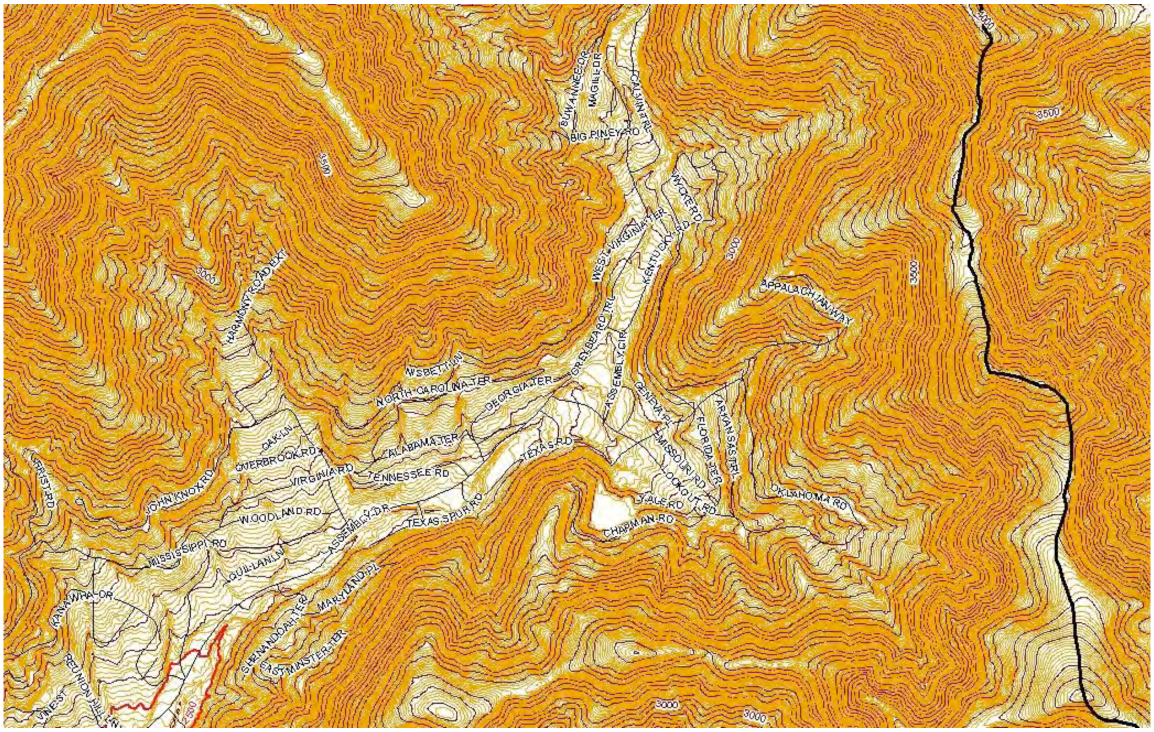

Figure 3.10 - Plan view of topography surrounding the downtown area of Montreat - ncgs.com

The above topography map shows the surrounding topography of Montreat. The topo lines are at 100 foot intervals, showing that the topography surrounding Montreat is extremely steep, creating a problem relating to stormwater.

As this map illustrates, the urbanized areas of Montreat rest in a valley surrounded by steep mountain slopes in the shape of a "horse-shoe." This means that stormwater run off is flowing into Montreat's urban center from three sides down steep mountain slopes during a rain event making Montreat's urban center "ground zero" for a barrage of high-speed, possibly sediment loaded run off. This is an important point that will be explored further in the next chapter.

Chapter 4

Montreat's Geological and Soil Conditions

Southeastern Appalachia, in which the Blue Ridge Mountain Range is located, has its own unique geological make up and subsequently its own unique soils.

*Figure 4.1 - An exposed soil profile in Montreat**

The Town of Montreat would benefit greatly from the implementation of Low Impact Development Best Management Practices landscape design patterns. The strategic placement of these techniques would slow or even stop stormwater runoff enough to have a positive effect on the recharge of the Montreat aquifer. As it turns out the local soils typology and geological characteristics would be very conducive to the cost effective installation of select LID BMPs.

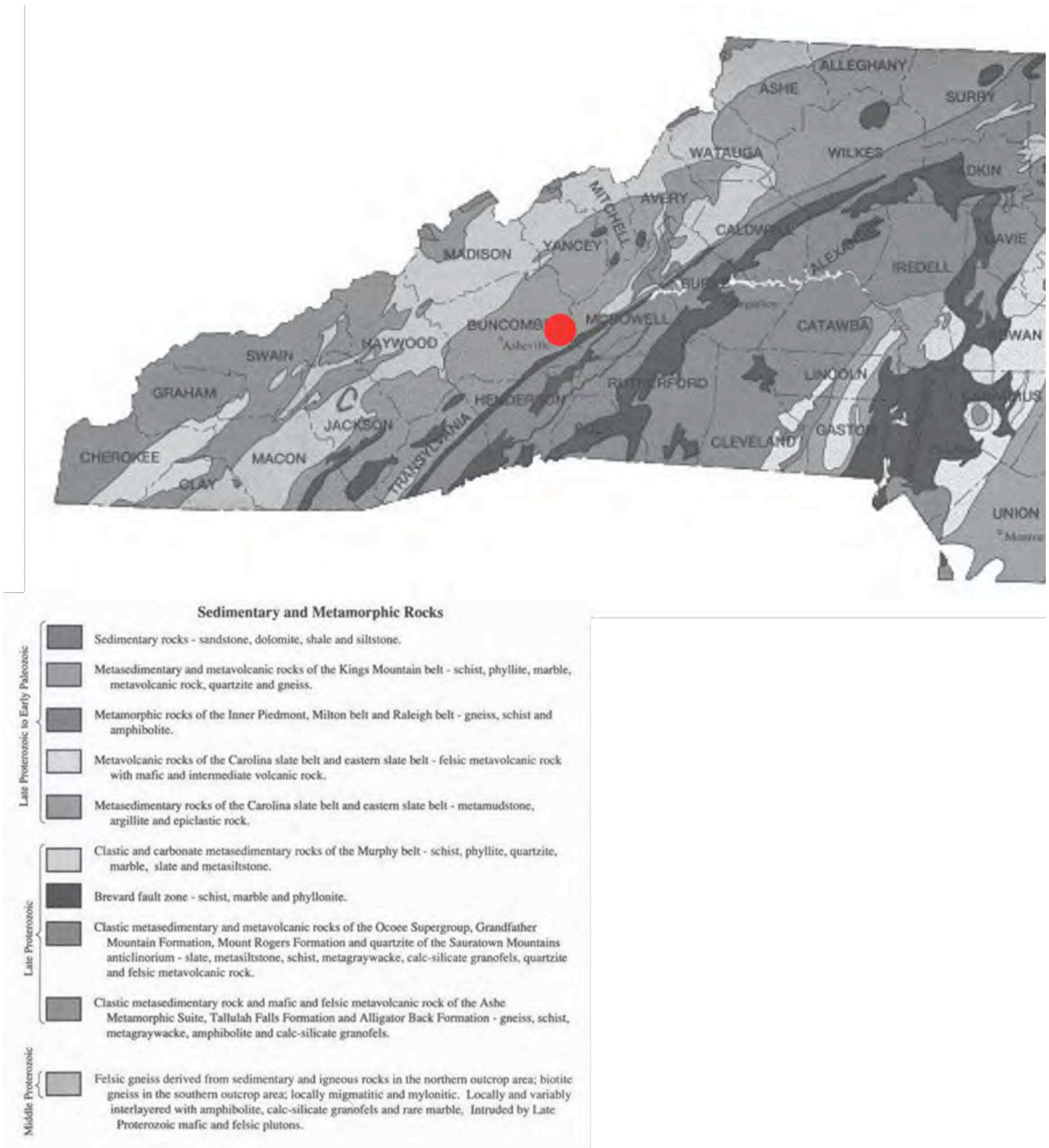

Figure 4.2 - Western North Carolina Geological Survey - ncgs.com

The geological characteristics of Montreat are as follows; the town sits on a Regolith-Fractured Crystalline Rock Aquifer System, which means that stormwater run off that has the chance to infiltrate Montreat's soil, drains through fractures in the bedrock underneath the local soil profile and collects in the aquifer Montreat has dropped its wells into. (4.C)

Principle Rock Units:

The rocks in the Asheville area, which includes Montreat, are chiefly gneiss and schist, with subordinate occurrences of granite rock, along with basic intrusives, and minor occurrences of other conglomerates.

Observation Wells and Springs:

Thirty-five wells and springs were originally selected for monthly water level and flow measurements in Buncombe County. The purpose of observation wells and springs is to supply information on changes in the water table, or, in artesian wells.

Effect of Depth of Drilling on Yields of Wells:

Ground water in the Asheville area occurs chiefly in fractures and openings in rocks. Fractures become smaller and diminish with depth, so that the chances of finding water decrease as wells are drilled deeper into bedrock. The maximum depths to which water filled fractures in this area of western North Carolina that share these geological characteristics is not known, but it most likely depends on local rock type and structure.

Thirty-two of the wells inventoried in this area are 200 feet deep or more. The deepest well was drilled to 950 feet. Approximate yields are known for 25 of the deep wells; the others are reportedly adequate for domestic use. The yields range from less than gallon pre minute to 55 gallons per minute, averaging 9.8 gallons per minute (gpm), or about two-thirds the average yields in the area. The average yield per foot of the deep wells is 0.034 gpm, which is about one third the average yield in this area. (4.D)

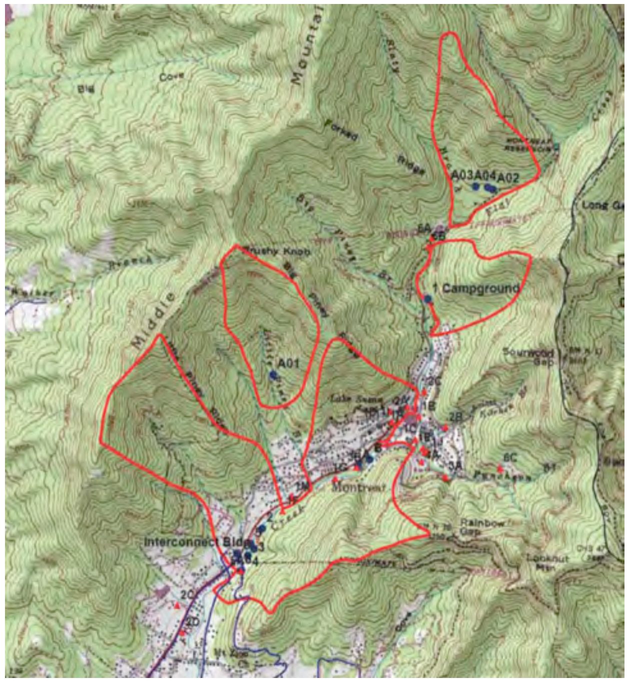

Figure 4.3 - Montreat well locations and well protection areas - townofmontreat.com

Water-Supply Sanitation:

Many of the springs used in this area derive their water from the area of contact between soil and bedrock, also known as "soil parent material," that is, as certain types of underlying bedrock weather and erode, depending on the type of parent material (bedrock) they produce certain types of soil profiles/ layers of earth from underlying bedrock up to the surface, determining the surface soil layer from bedrock to subsoil to topsoil to plant litter (utmost surface of soil layer, includes all types of plant life), i.e.; clay-loam, silt-loam, sandy-silt-clay profile, etc.

*Figure 4.4 - Eroded riparian zone along Flat Creek in downtown Montreat**

This type of spring is considered safe for human consumption only if its watershed is totally free of possible sources of contamination such as; privies, septic tanks, barns, hog-lots, etc. Montreat has actually "outlawed" the use of septic tanks within town limits in order to help keep its watershed clean.

Local seepage and surface drainage into wells can be avoided by proper location and construction. Wells should be located away from possible sources of contamination and should be in such a position that drainage from such sources is away from the well. (4.D)

Today in Montreat, the well drilling codes have changed dramatically. Currently, no wells are permitted to be dug within 1000 feet of exposed surface water entities such as creeks and streams. Though it has been officially reported by the EPA and its ECHO that these surface water bodies are without any contamination, the fact that no wells are allowed to be dug near them prompts the question as to whether or not Montreat's creeks and stream are as clean as they are reputed to be.

Sanitary considerations like what exists around the site chosen for a well like runoff from structure roof tops, wildlife waste, rotting vegetation, etc. may indicate a site choice for a well site which may not be the best available location for drawing the most sanitary water possible out of the groundwater supply.

Montreat Soil Survey:

Soil Characteristics of Montreat Area:

Most of the soils found in the Montreat area are very stony, Ashe-Cleveland-rock outcrop complex, the majority of which sit on 15 -30 percent slopes except for in the flatter valley area, which is mostly developed urban land. Soils found in urban areas have become highly compacted due to development and aren't as porous as the soils in the natural areas surrounding it. (4.B)

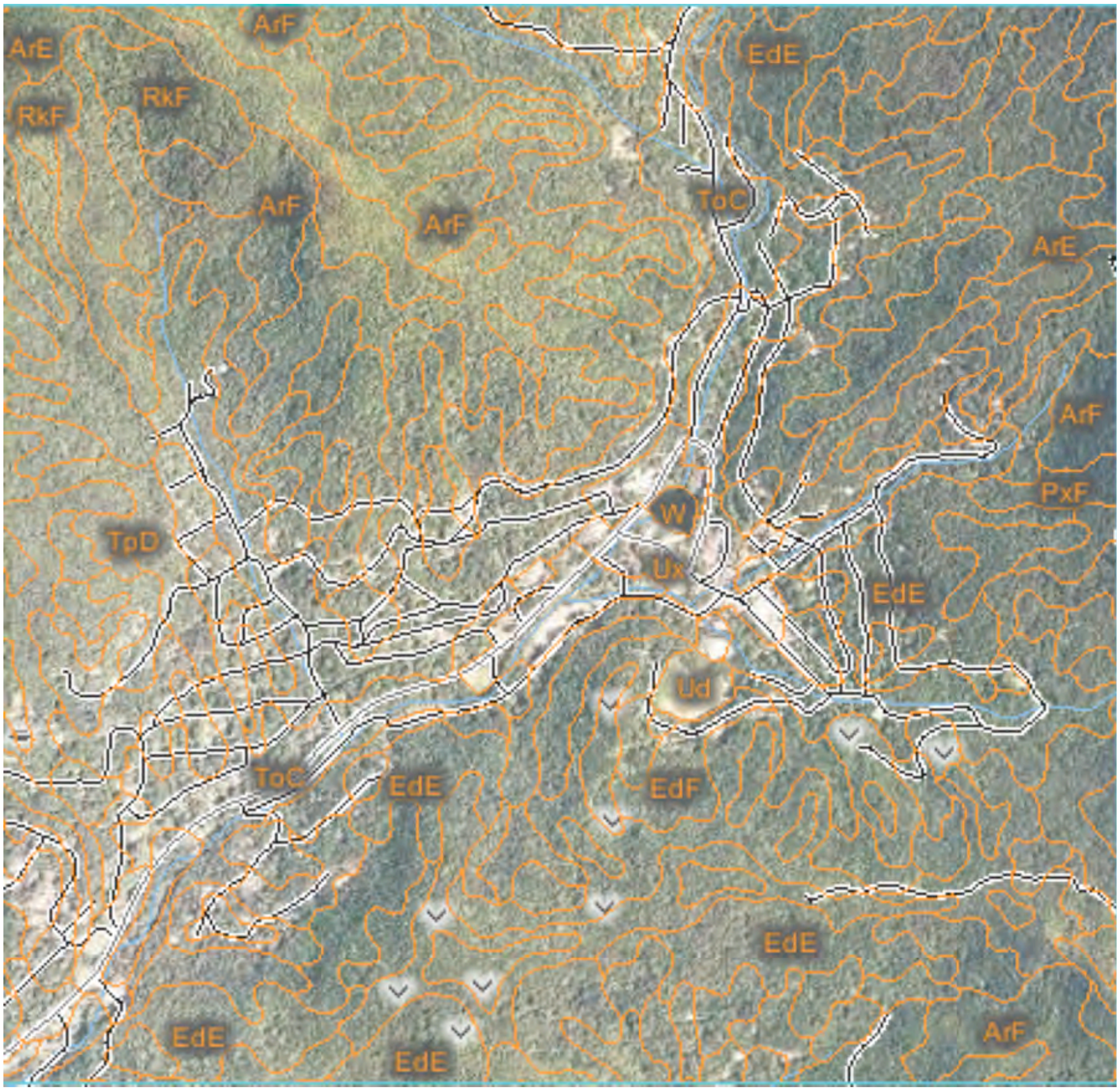

Figure 4.5 - Montreat area soil map - usgs.com

Soil Map Defined:
Soil Types Found in Research Area:

• EdE = Edneyville-Chestnut complex, 30 to 50 percent slopes, stony, covers approximately 268 acres.

• ToC = Toecane-Tusquitee complex, 8 to 15 percent slopes, bouldery, covers approximately 78 acres.

• Ux = Urban land, covers approximately 18 acres.

• W = Water, covers approximately 2 acres.

By cross-referencing geological surveys with soil surveys it was possible to delineate where the implementation of LID BMPs will have a positive effect on stormwater infiltration and subsequently local aquifer recharge.

Why LID in Montreat?

Stormwater run off is leaving Montreat before it has a chance to infiltrate the soil and recharge the aquifer under Montreat by running at high speeds down the surrounding mountain slopes. This runoff ultimately joins surface water bodies, the creek and stream system, and is washed down stream into other communities and larger local water bodies.

As mentioned earlier, currently Montreat's only source of aquifer recharge is a system of above ground creeks and streams and well system from which the local community draws its fresh water. Unfortunately, due the circumstances described in the previous paragraph, stormwater run off in Montreat is not getting a chance to infiltrate local soils because it is moving so fast off of developed areas. This is disrupting the recharge of the aquifer from which Montreat gets its potable water.

In the next chapter, the benefits of implementing LID Best Management Practices in strategically chosen areas in Montreat to positively effect local aquifer recharge will be explored, along with exactly where and why this will help.

Chapter 5

Low Impact Development- Best Management Practices in Montreat

Before the Best Management Practices of Low Impact Development in the Montreat area are explored and explained, examining some precedents in other similar contexts where the installation of these design patterns have been successful will help to validate suggested stormwater management solutions for Montreat. The following "precedents" or case studies discuss two communities very close to and similar to Montreat in geography and physical characteristics (Drover's Road Preserve and the North Carolina Arboretum) to help to illustrate how LID BMPs will have positive effects in Montreat.

Precedents/ Case Studies:

The following Case Study Information was Obtained from Low Impact Development: A Guidebook for North Carolina. North Carolina State University. June 2009. North Carolina Cooperative Extension.

A.) Drover's Road Preserve, Buncombe County, NC -

Introduction:

Drover's Road Preserve is a large residential development that sits on a 186-acre tract of land in rural Buncombe County, near Asheville, North Carolina. This site shares many similar characteristics to Montreat, including its soil types. In fact, both of these precedents share very similar soil characteristics with Montreat as they are both located in the immediate area. These sites have a sandy clay loam soil type with a rocky profile conducive to water infiltration.

During the planning process, the developers chose to protect the site's natural resources (just as the original developers of Montreat did over a hundred years ago) and historical past, as well as to provide a model to the local community of a different way of developing land. At the time this community was developed, there was little regulation of development in the county; no stormwater ordinance, no stream buffer protection requirements, and no zoning requirements. This means that developers could have easily maximized profits, but instead approached the development from a preservation standpoint. The site has astounding views (as does Montreat) and the only limiting factor for housing density was soil properties for placement of on-site septic systems (an allowance Montreat does not permit).

The planners focused on developing an overall plan to address multiple goals, including conservation design and LID. Their plans for this site included site design and layout, stormwater management planning, oversight of road and stormwater management construction, and the development of a restrictive set of rules and guidelines fitting the overall vision for the site (similar to building codes and agreements enforced in Montreat today).

Drover's Road project partners wanted to protect the areas natural and water resources, and create something beneficial for the community. Of particular importance to them were several seeps, springs, and creeks on the site. These water resources were in good condition, as they possessed stable banks and few sedimentary problems.

During the planning process, designers realized that Dover's Road owners were only familiar with conventional stormwater management techniques. An early recommendation from Equinox was to eliminate the "curb and gutter" approach and use roadside swales instead; the cost savings of this technique could then be used to include additional innovative stormwater practices to support LID goals and to further protect water resources. As will be discussed further later in this chapter, Montreat already employs roadside swales.

The realization of Drover's Road Preserve began with an extensive site analysis including an inventory of the site's hydrology, scenery, natural heritage, soils and topography, and proximity to other protected areas. The areas for development that were decided upon favored areas with slopes of less than 20%, and areas with former disturbance.

Drover's Road Preserve: Site Stormwater Management

The design team elected to use stormwater management practices to protect the site's water resources, minimize erosion risks, and reduce pollutant loads in stormwater run off. This site uses the following techniques and BMPs:

- Roadside Swales with erosion control matting
- Two bioretention cells
- A stormwater wetland
- A meadow into which run off is directed for infiltration
- Stream buffers and minimization of stream crossings
- Limited clearing
- Limited impervious surfaces

The non-structural practices include; stream buffers, limited disturbances, and an infiltration meadow.

In steep sloped areas, permanent erosion control matting was used in place of riprap; the matting product allows grass to grow up through its matrix. In areas with less steep slopes, a biodegradable matting was used. Having grass-lined swales instead of riprap allows for more infiltration, filtering, and uptake of pollutants.

Drover's Road Preserve Cost Considerations

One of the most important benefits that came out of this project was establishing the conservation easement, which provided a substantial tax break to the project partners. The tax break allowed them to accept a lower profit margin and to carry their vision of a more balanced development with a natural setting. Many of the LID practices employed also provided cost savings:

- Steep slopes were avoided because they are more expensive to grade and stabilize

• A cluster design and reduced road width, both of which decrease paving costs, and a decrease in impervious area also reduced the cost of stormwater treatment by reducing run off volume.

• Lower-cost grass swales replaced more expensive curbs and gutters.

• Minimal stream crossings, reduced costs for infrastructure design, construction, and plan approval.

Protection of the site's water resources was an objective that overrode costs from the beginning. During the planning process, designers recommended adding stormwater BMPs to enhance water resource protection and provided cost estimates showing that the savings from curb and gutter elimination would actually balance the cost of installing the BMPs and save money in the long run. (5.A)

Drover's Road Preserve: Potential LID BMP Techniques

This case study illustrates the following LID design processes that can be implemented if a site is being freshly developed:

1. Set project goals and objectives and identify the program.
2. Inventory, assess, and analyze the site.
3. Review and revise the program based on site constraints.
4. Develop proposals and evaluate.
5. Revise and model.
6. Revise and remodel.
7. Apply regulatory requirements.
8. Model stormwater.
9. Revise and remodel.

This case study also incorporated LID design patterns that can be employed in either a site context that is being newly developed or one that already exists:

• Limit site disturbance, clearing, and grading to the smallest area possible.

• Use preservation to gain more benefits (environmental and economic) than are possible from creation or mitigation.

• Consolidate natural open space areas whenever possible.

• Incorporate natural filter strips, vegetated areas, channels, and curb inlets in rights-of-way, landscaped areas, and traffic islands.
• Take advantage of existing waterways, vegetated areas, and amenable soil conditions to direct, absorb, clean , recharge, or store water; reduce air pollution; provide wildlife habitat; and add natural amenity value to a development.
• Design impervious areas for the minimum paved area length and width needed to support their intended use.
• Design for hydrology.
• Design for multiple functions.
• Disconnect impervious areas.

This precedent provides a good example of incorporating a balance between LID stormwater management goals and other sustainable design strategies.

B.) North Carolina Arboretum, Ashville, NC -
Introduction:

The North Carolina Arboretum in Asheville is the site of several model projects that demonstrate how stormwater can be effectively managed to protect the health of the environment and help to recharge ground water reserves. This case study actually includes two cooperatively designed and constructed projects that are the subject of regularly scheduled tours and workshops for both professionals and non-professionals.

North Carolina Arboretum: Site Assessment and Design

While preparing the concept master plan for one of the sites within the Arboretum known as "the Brent Creek site" designers explored and evaluated the location on foot to thoughtfully locate roads, buildings, and gardens to minimally impact Brent Creek and the existing landscape. At the time this project was being explored by a design team in 1986, LID principles and practices were not being discussed.

The other site at the arboretum where LID BMPs were installed is at what is known as the Operations Center. The Operations Center was completed in 2004 and several retrofits following low impact development principles and practices were employed as the site was developed.

LID at the Operations Center

The North Carolina Arboretum's Operations Center is approximately 10,000 square feet and was built using low impact development techniques. At the Operations Center a green roof, rain garden, rain pockets, permeable parking, a cistern, a wetland pool system, turf reinforced swales, and a level spreader function together to treat stormwater run off before it enters a jurisdictional wetland and eventually Bent Creek. Because Bent Creek is a trout stream, it is critical that even treated stormwater run off be sufficiently cooled before being released.

Stormwater at the operations center is treated by at least two integrated practices, a green roof that drains into a rain garden at the base of the building and onto the level spreader. Some roof run off is treated in rain pockets, the wetland pools, and the turf reinforced swales. The wetland pools also collect run off from the center's lawn and permeably paved and gravel parking areas before draining into the swale. The wetland pools were designed to remain inundated at times and are planted with native species that tolerate periodic flooding. The rain pockets are also planted with indigenous species that can withstand variable drought and inundated cycles.

The level spreader was the final LID BMP at the Operations Center to be tested. The function of the level spreader is to disperse the high velocity of run off, which can cause erosion. The level spreader at the Operations Center is a large fabric "sock" that is filled with mulch and an indigenous seed mix and is sited to intercept and diffuse run off. Run off fills the area behind the spreader then flows evenly over the crest, or lip, of the spreader. A less damaging sheet of water flows into the riparian buffer.

Selected LID Solutions for Montreat:

As were listed in Chapter II of this study, there are certain LID BMPs that have been cleared for use by North Carolina code. These include, but are not limited to the LID BMPs chosen for implementation in Montreat:

• man-made wetlands

• sponge park

• level spreaders

• infiltration trenches

• roadside swales

• injection well

After researching the physiological conditions found in Montreat and cross referencing the following LID BMPs have been chosen to be implemented in specific sites throughout the community; roadside swales, pocket wetlands and/or "sponge parks," level spreaders, infiltration trenches, a dry retention basin and an injection well

Montreat BMPs: Where and Why:

In order to delineate the most effective locations to install LID BMPs in Montreat extensive geologic and soil survey research was conducted in this area. To sum up the information put forth in the previous chapter, all of the soil and geological conditions throughout the Montreat area are well suited for the implementation of LID BMPs. Though the geology of an area bears some importance on the effectiveness of LID implementation, it is the soil conditions of a given area that are most important in determining the effectiveness of installing LID BMP design patterns. If a soil profile is found to be impermeable and water is unable to infiltrate it enough to reach the profile's underlying bedrock, then that area is not well suited for LID BMPs intended for aquifer recharge. The soil profile in which an LID BMP is installed must allow captured water to infiltrate all the way down to the underlying bedrock in order to effectively recharge an aquifer because groundwater is stored in fractures in the bedrock and it is this water that is tapped by wells.

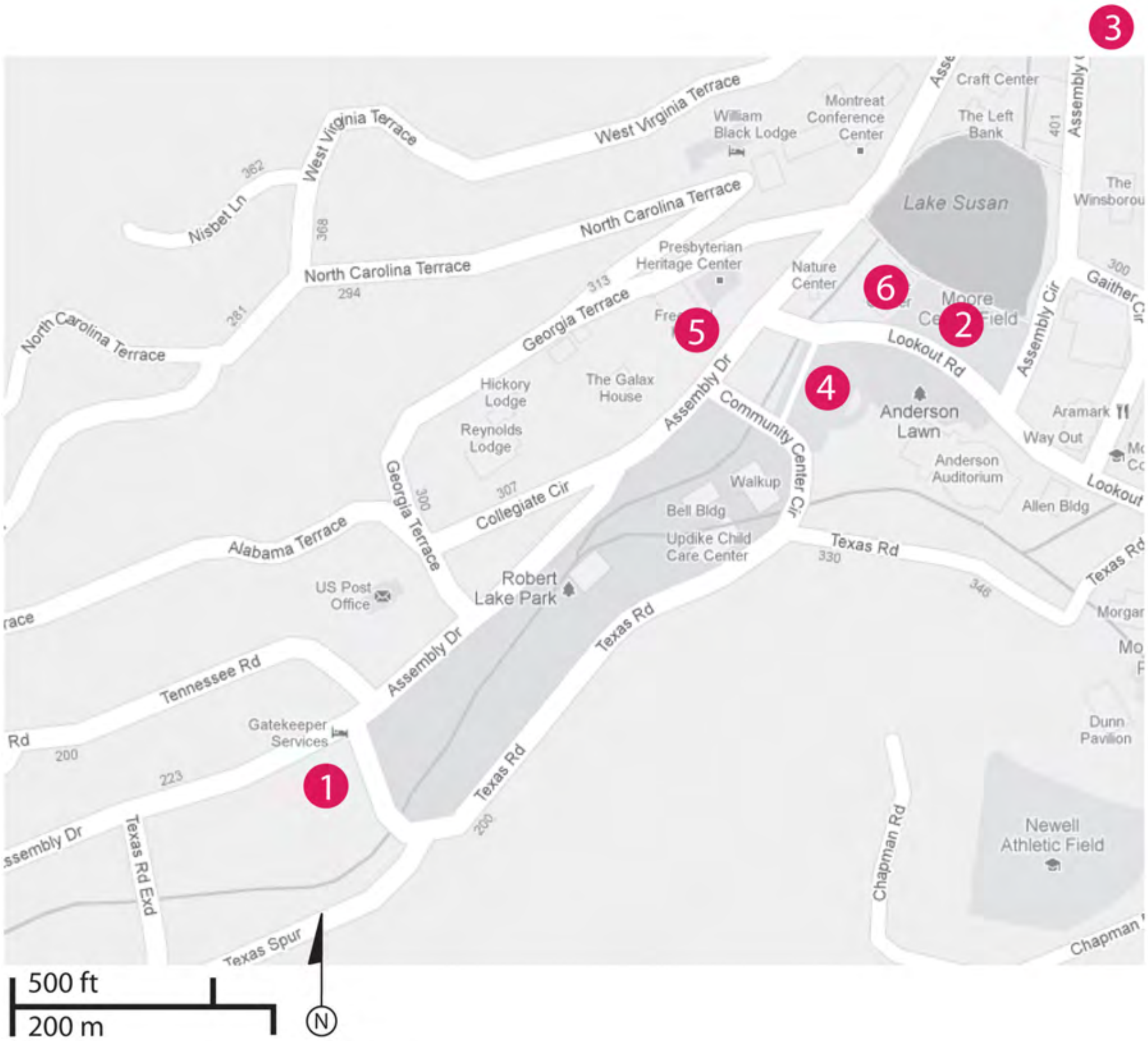

Figure 5.1 - Locations chosen for LID BMPs in the downtown Montreat area - adapted from a map found at maps.google.com*

1.) MAN-MADE WETLAND / PARK

2.) SPONGE PARK

3.) RESERVOIR INJECTION WELL (NOT VISIBLE ON THIS MAP)

4.) INFILTRATION TRENCHES

5.) ROADSIDE SWALES

6.) LEVEL SPREADERS

Recharge Solution 1: Small Baseball Field - Man-Made Wetland & Park

*Figure 5.2 - A rarely used baseball field at the "bottom" of the "funnel" Montreat's physiology creates**

This small baseball field sits at the entrance to the community, on nearly flat ground at the base of a gradual slope that leads to downtown Montreat. It is located at the "bottom" of the massive "funnel" shape the physiology of the Montreat area creates. As stormwater runoff comes down the surrounding mountain slopes, this location is the last "stop-gap" before this runoff leaves the Montreat area. This makes it a great location for a man-made wetland to catch and absorb large amounts of runoff headed down hill and out of town.

By redeveloping this baseball field to create a stormwater catchment facility Montreat would lose 50% of its active recreation facilities as there is only one other ball-field in the community. Because of this, passive recreation is recommended as simply adding a boardwalk with some benches to a wetland provides many opportunities for walking, enjoying the environment and even educational opportunities.

A "park" setting could be created in this location in addition to a functioning wetland allowing this spot to serve two beneficial purposes.

*Figure 5.3 - Perspective illustration of a man-made wetland/ park**

*See Plate 1 for section detail

Recharge Solution 2: Large Undeveloped Area in Downtown Montreat - Sponge Park

*Figure 5.4 - Site for proposed sponge park**

This area is located just below the berm that retains the southern end of Lake Susan. It would appear as though this spot has suffered due to stagnated runoff as its turf cover is severely weathered, but this could be due to a combination of stormwater damage and foot traffic from the nearby college. This area would be conducive to what is known as a "sponge park."

The driving concept behind the design of a sponge park is basically the same as that of a man-made wetland with a few amenities added. The main difference is that the stormwater runoff catchment and/or treatment areas would be mostly concealed under constructed areas like seating areas, circulation paths, plazas, recreation areas and other "standard" park programming.

*See "Plate 2" for section detail

Recharge Solution 3: Roadsides Throughout Montreat - Roadside Swales

*Figure 5.5 - Site for proposed roadside swale**

In order to prevent polluted runoff flowing across roads from entering local surface water bodies before it can be slowed and allowed to infiltrate soils where it can be filtered to a degree and allowed to enter the aquifer, roadside swales show be employed where ever possible along roadsides throughout Montreat.

Unfortunately, the roadside conditions found in most of the area do not allow for the installation of roadside swales, however there are some opportunities available like those shown in Figures 5.5 - 5.7.

In order for these roadside swales to help with infiltration swales containing small check dams within them would be necessary. Otherwise these swales would only serve to help runoff to move downhill and out of the area at a rapid rate.

*Figure 5.6 - Site for proposed roadside swale**

*Figure 5.7 - Site for proposed roadside swale**

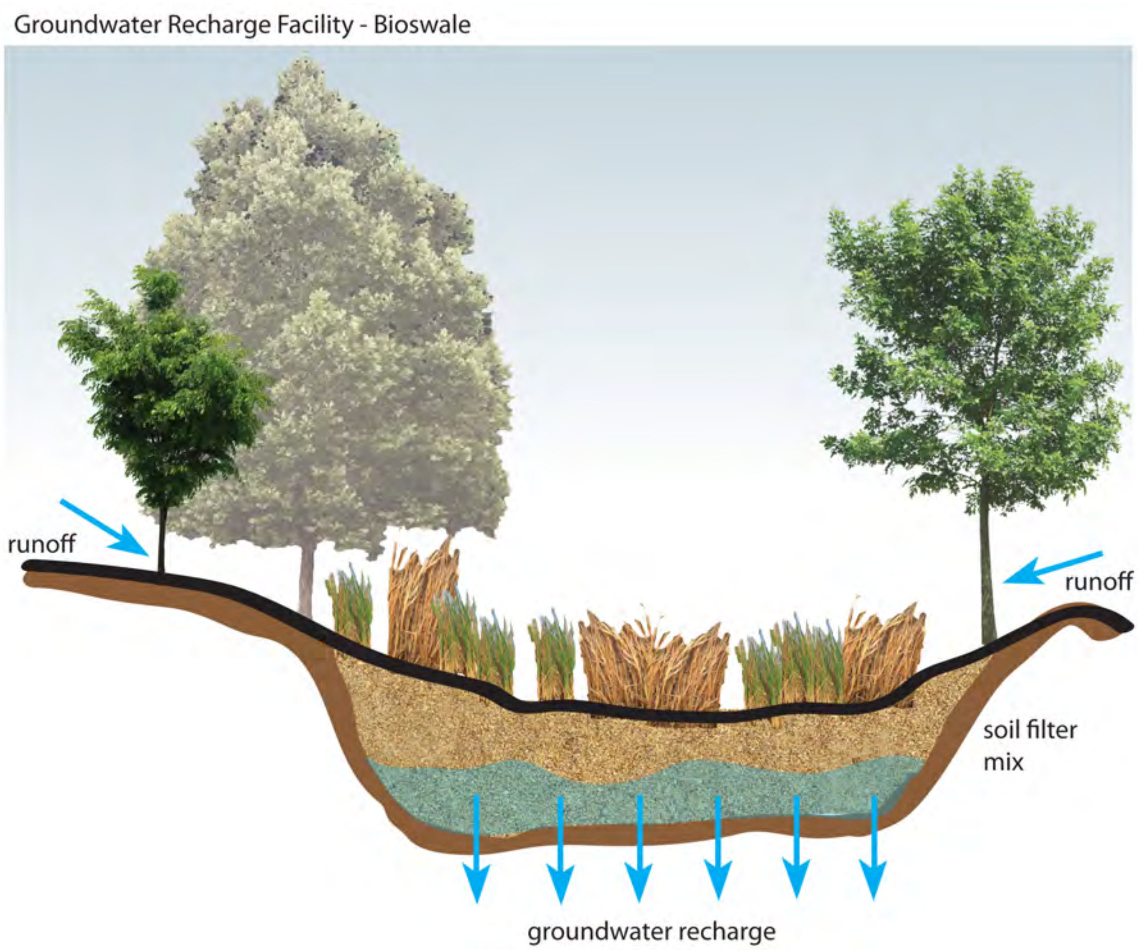

*Figure 5.8 - Illustration of swale**

*See Plate 3 for section detail

Recharge Solution 4: Infiltration Trenches

*Figure 5.9 -Location for proposed infiltration trench**

The downtown Montreat area contains large amounts of paved area for vehicle circulation and parking. The edges of these large paved areas are in disrepair (as shown above) and allow potentially contaminated stormwater to runoff, untreated, directly into nearby Flat Creek. The existing situation has no form of any techniques to direct or slow this runoff and it is allowed to move freely and at potential high rates of speed directly into Flat Creek without being given a chance to slow down and infiltrate the soils in the riparian zone between paved surface edges and Flat Creek.

The installation of a perforated curb system to direct runoff into infiltration trenches like the one pictured below would help to slow runoff from these paved surfaces, allow it infiltrate the soils around this area helping to recharge groundwater supplies, while also allowing for overflow in the event of a flood.

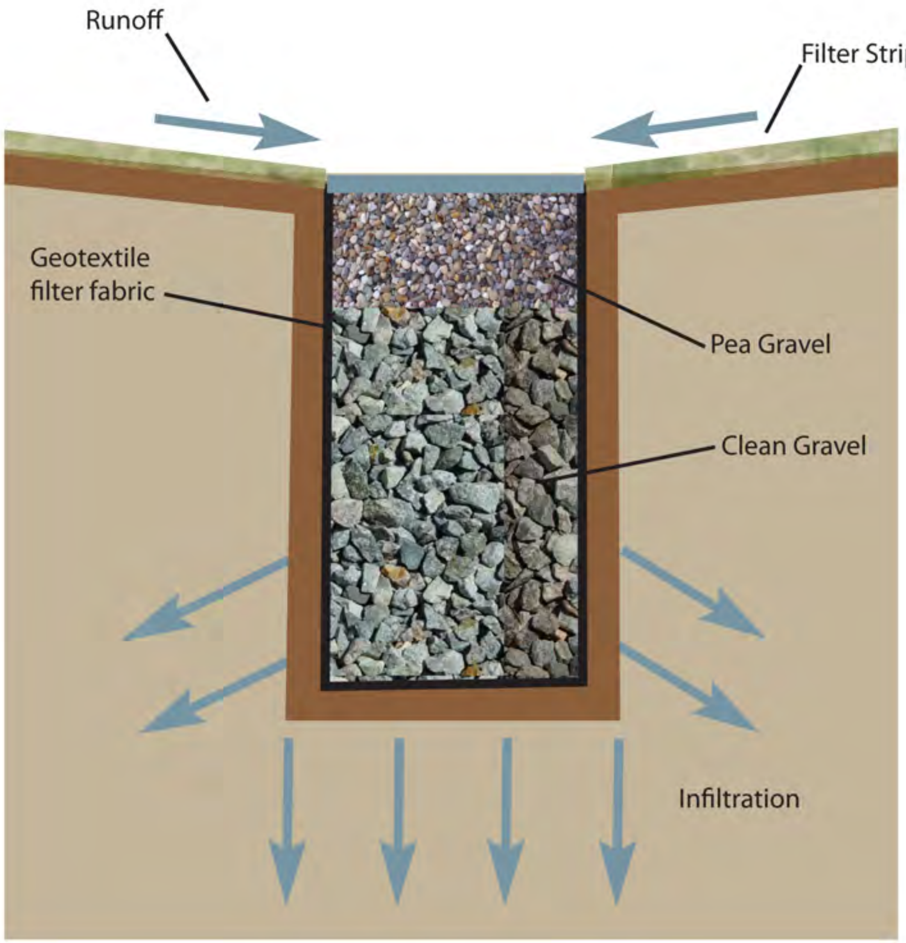

Figure 5.10 - Illustration of infiltration trench - illustration based on a diagram found in reference (5-B)*

*See "Plate 3" for section detail

Recharge Solution 5: Level Spreaders

*Figure 5.11 - Make-shift level spreader in downtown Montreat**

Level spreaders like the ones shown above and below are a great inexpensive option for controlling stromwater runoff and giving it a chance to slow down and even be stopped in some cases and allowed to infiltrate soils.

Functioning almost like check dams, level spreaders stop the flow of runoff to a certain point, but also allow for overflow in the vent of a flood. (See Figure 5.12)

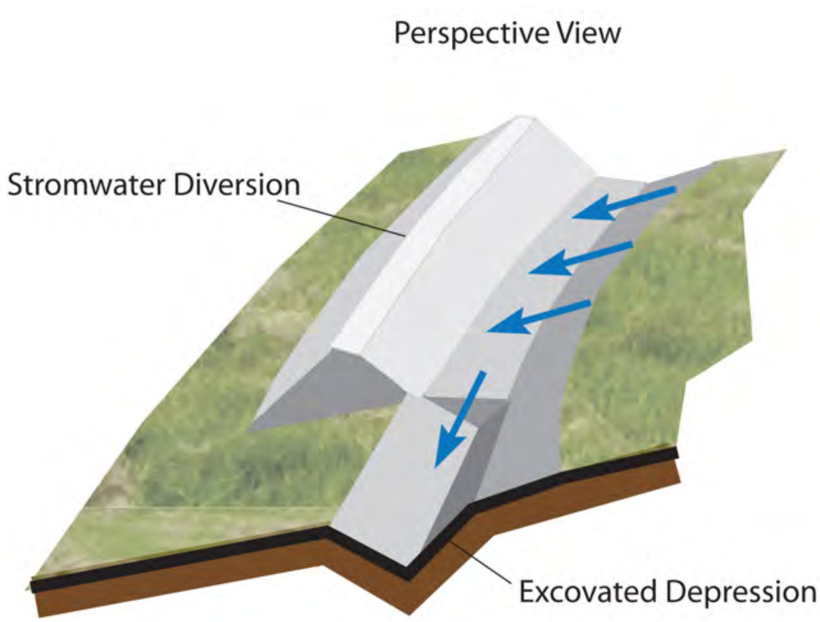

Figure 5.12 - Illustration of a level spreader - based on an illustration found in reference (5.B)*

Recharge Solution 6: Injection Well

*Figure 5.13 - Montreat town reservoir**

Montreat has a great opportunity to install an injection well in its unused reservoir to ramp up groundwater recharge. This reservoir collects a lot of water from the nearby creek and stream systems as well as capturing runoff from surrounding mountain slopes.

An illustration of how an injection well work can be found below. Basically, a well is drilled at the deepest point of the water body and the "mouth" to the well is placed just below the surface of the water. This allows water to flow into the well and the underlying aquifer as rain, runoff, and stream flow raise water levels in the reservoir high enough to be "injected" into the well.

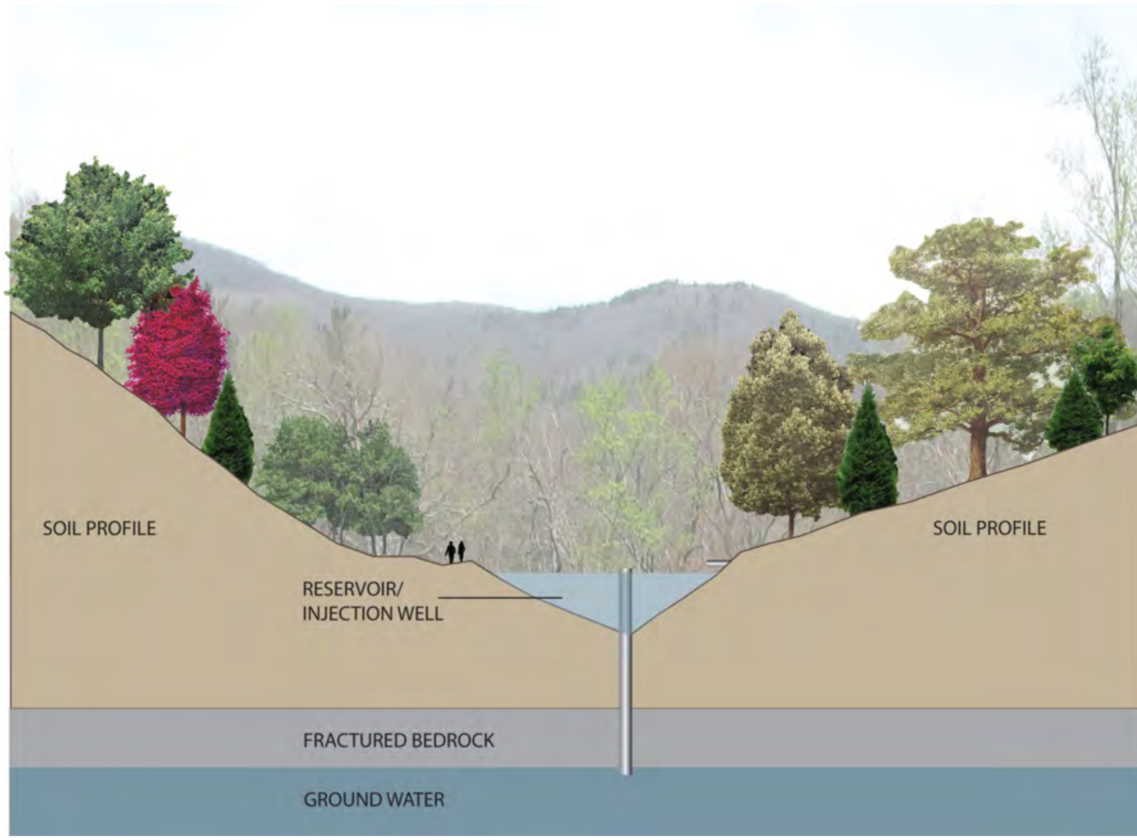

*Figure 5.14 -Illustration of proposed injection well in Montreat town reservoir**

Chapter 6

A Method for Evaluating the Cost Effectiveness of Low Impact Development in Montreat:

Introduction:

This chapter summarizes an independent quantitative investigation conducted with a singular goal in mind; to develop a method for evaluating the cost effectiveness of implementing low impact development design patterns in Montreat.

One simple method for accomplishing this would be to compare the costs of installing conventional or "hard construction" solutions versus installing LID or "soft construction" solutions. For example, one could get a cost estimate for installing a conventional storm water treatment structure like a standard retention basin, and then get a cost estimate for installing a low impact development storm water treatment solution like a manmade wetland and compare the two bottom lines. However, this study seeks to go a few steps further than just comparing bottom lines.

In order to develop a method for the analysis of how effective and less expensive LID BMPs would be for positively effecting ground water recharge in Montreat, LID methods will be compared to one another, rather than compared to conventional storm water treatment methods, to quantify these methods within their own category. In order to quantify the cost effectiveness of installing LID BMPs in Montreat, it will be necessary to examine the LID design patterns chosen in this thesis as far as cost of installation versus effectiveness of controlling storm water.

Below is an equation generrally used to measure the amount of storm water runoff is occurring in a given area. This is the first step in determining the cost effectiveness of LID BMPs for a given circumstance.

Soil Conservation Service (SCS) runoff curve number (CN) method

Curve Number (CN):

The runoff curve number (also called a curve number or simply CN) is an empirical parameter used in hydrology for predicting direct runoff or infiltration from rainfall excess. The curve number method was developed by the United States Department of Agriculture (USDA) Natural Resources Conservation Service, which was formerly called the Soil Conservation Service or SCS. The number is still popularly known as a "SCS runoff curve number" in the literature. The runoff curve number was developed from an empirical analysis of runoff from small catchments and hill slope plots monitored by the USDA. It is widely used and is an efficient method for determining the approximate amount of direct runoff from a rainfall event in a particular area.

* The runoff curve number is based on the area's hydrologic soil group, land use, treatment and hydrologic condition. References, such as from USDA indicate the runoff curve numbers for characteristic land cover descriptions and a hydrologic soil group. (6.B)

The SCS Runoff CN method is a mathematical method for estimating amounts of runoff produced by a rain event in a given area. The equation is

$$Q = \frac{(P-I_a)^2}{(P-I_a) + S}$$

where

Q = runoff (in inches)
P = rainfall (in inches)
S = potential maximum retention after runoff begins (in inches)
I_a = initial abstraction (in inches)

Initial abstraction includes all the losses of water before runoff begins. It includes water retained in surface depressions, water stored in vegetation, evaporation, and infiltration. I_a is highly variable, but is generally correlated with soil and ground cover characteristics. (6.B)

The benefit of reduced stormwater runoff through the implementation of LID BMPs

The first step in placing a value on the water benefits from LID is to determine the volume of rainfall (in gallons) retained on site; this number becomes the resource unit for water benefits. When working through these calculations, keep in mind that some of the ranges given are based on site-specific amount of rainfall. (6.A)

Reduced Water Treatment Needs

For urban areas like downtown Montreat with combined sewer systems (CSS), stormwater runoff entering the system combines with wastewater and flows to a facility in Asheville for treatment. One simple approach to placing a value on the reduction in stormwater runoff for these areas is an avoided cost approach. Runoff reduction is at least as valuable as the amount that would be spent by the local stormwater utility to treat that runoff. In this case, the valuation equation is simply:

runoff reduced (gal) x avoided cost per gallon ($/gal)

= avoided stormwater treatment costs ($)

Many site-specific variables that affect the monetary values involved, such as soil types, rainfall distribution patterns, peak flow rates and local materials costs.

conventional cost of structure ($/SF)

total area of structure (SF)

= total expenditure for conventional approach ($)

total expenditure for conventional approach ($)

% retained = avoided cost savings ($)

(6.B)

How LID BMPs are less expensive than hard construction techniques:

LID BMPs save more money than conventional approaches through reduced infrastructure and site preparation work. That is, it takes less labor and preparation to get a selected site ready for the installation of an LID BMP than it does for a conventional storm water runoff control technique. Case studies show at least a 25 to 30% reduction in costs associated with site development, storm water fees, and maintenance for residential developments that use LID BMP techniques. These savings are achieved by reductions in clearing, grading, pipes, ponds, inlets, curbs, paving, etc.

It is impractical to make broad generalizations about costs because of the inherent variability between sites and the complexity of management issues. Although initial construction costs for LID BMPs may be higher than initial costs for conventional storm water practices, this initial expense is often offset by cost savings in operations and maintenance. These savings are possible because the maintenance of LID BMP features can generally incorporated into regular landscaping maintenance activities and do not require expensive training or hiring of a separate contractor for maintenance crew.

Montreat is unique, based on the site's soil conditions, topography, existing vegetation, land availability, etc. Actual costs will vary greatly based on the character of the individual site and the creativity of the designer.

Finally, costs are relative and considerations vary based on the project. For example, if Montreat were to retrofit 1/8 of its area with LID infiltration practices, does the community perceive this as a loss of the use of open space or a benefit in the fact that there is now less open space to maintain?

LID BMPs are economical. They cost less than conventional storm water management practices to install and maintain, in part, because of fewer pipe and below-ground infrastructure requirements. But, the benefits do not stop here. The associated vegetation also offers human and wildlife "quality of life" opportunities by greening the area, and thus contributing to livability, value, sense of place, and aesthetics. This myriad of benefits also includes enhancing property values, greater marketability, improved wildlife habitat, thermal pollution reduction, energy savings, enhanced wetlands protection, and decreased flooding, all topics the Town of Montreat is conscious of.

The cost effectiveness of these decisions can be determined and proven through a method of cross-referencing how effective a given LID BMP is at controlling storm water runoff and achieving the goal it was implemented to achieve, with the actual monetary cost of installing said LID BMP and its life span, as was explained previously. Important factors to be taken into account when trying to frame the cost effectiveness of using LID BMPs instead of conventional hard construction techniques are the life of the product (that is, the longevity of the materials used in the construction of each given LID BMP), and the product's effectiveness at controlling runoff for the reason it is employed. (6.A)

Examples of calculating runoff infiltration in 2 proposed LID BMPs

Example 1:

Detailed CN Calculation for 1acre baseball field/ proposed man-made wetland park.

Given:
- One-acre recreational lot (43,560 square feet) / semi-pervious compacted turf
- Conventional CN= 68 (From TR-55 Table 2.2a-Runoff curve numbers for urban areas (6-2))
- Curve numbers in table

Procedure:
Step 1: Determine percentage of each land cover occurring on site and the CN associated with each land cover.

Land Use = 1 Acre Baseball Field (4,3560 SF)	CN	% of Site	Land Coverage (SF)
Infield	89	20	8,172
Outfield	80	60	26,136
Wooded Area	77	20	8,172

Step 2: Calculate composite custom CN (using Equation A.1 found in the appendix of reference (6-2))

$$CN_c = \frac{89 \text{ x } 8{,}172 + 80 \text{ x } 26.136 + 77 \text{ x } 8{,}172}{43{,}560}$$

CN_c = 79

The conclusion reached in this equation is that an LID custom CN of 79 is higher than the conventional CN of 68 for a predevelopment site like the one-acre baseball field studied in this example. This means that if the suggested manmade wetland / park were to be employed in this area water would indeed penetrate the soil at a higher rate.

Example 2:

Detailed CN Calculation for .5 acre open area/ proposed sponge park

Given:
• One-half acre recreational lot (21,780 square feet) / semi-pervious compacted turf
• Conventional CN of 68
• Curve number in table

Land Use = One-Half Acre Open Space	CN	% of Site	Land Coverage (SF)
Open Space (Good Condition)	84	100	2,1780

CN = 84

The conclusion reached in this equation is that an LID custom CN of 84 is higher than the conventional CN of 68 for a predevelopment site like the one-half acre open space studied in this example. This means that if the suggested sponge park were to be employed in this area water would indeed penetrate the soil at a higher rate.

Limitations

The equations listed above and the applied examples are accurate and are sound ways of determining the stormwater management benefits of implementing LID design techniques which would in turn save money on stromwater management in various ways. However, without conducting a thorough and detailed cost estimation of soft construction materials involved, determining the exact amount of stormwater to be managed, measuring the value of these systems to residents, and other variables, etc. an absolutely accurate cost benefit figure can not be obtained without further study.

Conclusion

If stormwater management is a challenge for any given area, it is important to understand that if low impact development design patterns are implemented where most effective in and around the town of Montreat, sufficient volumes of stormwater can be slowed and captured to positively effect this community's ground water supply, improving aquifer recharge in this area, thereby reducing the town's need to draw on outside sources of fresh water during a drought.

If the low impact development design techniques found to be the most effective and cost efficient for this location are implemented, Montreat's ground water supply will be positively affected improving aquifer recharge.

This quantitative study was conducted over the period of several months in response to a problem presented to the author by Administrators of a town named Montreat located in the Blue Ridge Mountains in North Carolina. The problem this study attempts to solve is insufficient aquifer recharge within Montreat, which in the past has lead to the over draining of the local well system during times of drought. Anytime this happens it is a problem for the residents of Montreat because the community has to then draw its potable water from pipelines connected to nearby Asheville. This is an expense that puts a strain on a town with a very limited budget like Montreat.

In order to solve the problem of insufficient aquifer recharge in this area research of storm water management techniques known as low impact development (LID) was conducted. Research was focused specifically on those LID methods that slow down or stop stormwater runoff and allow it to infiltrate the soil and replenish ground water supplies. An in-depth, site-specific analysis helped to locate where in the this area these strategies should be implemented to be most effective.

Based on this research a site-specific plan involving several different LID design solutions was developed to better manage stormwater runoff in Montreat and help recharge the community's aquifers.

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Vita:

James Adam Gobrecht was born at The University of Tennessee Medical Center in Knoxville Tennessee, on 2 August 1977, the second born son of Penelope Ann Little and Robert Steven Gobrecht, Sr. After earning his diploma from Farragut High School in 1995, he entered the work force and for nearly the next five years he worked as a carpenter, framer, and landscaper. In 1999 he decided to begin his college career at Pellissippi State Technical Community College in Knoxville where he studied visual communications and received his Associates Degree in May 2002. For the next three years he pursued a career in advertising, creating newspaper and magazine ads and catalogs for a major merchandising company in the Knoxville area. He made the decision to further advance his education in the spring of 2005 and enrolled at The University of Tennessee at Knoxville in the fall of that same year. He earned a Bachelor of Science Degree in May 2009. In June of 2009 he entered The Graduate College of Architecture and Design at The University of Tennessee at Knoxville.