The Benefits of Integrating Green Roof Systems Into the Milwaukee River Watershed

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Abstract

The general public often does not realize how their actions affect the ecosystem and watershed around them. Even through the expansion of cities and the laying of new highways, the quality of drinking water is altered. Many actions and changes affect the watershed, for example large sections of impervious paved areas shed water faster than green space often causing sewer overflows. The salts used on the roads and chemicals placed on lawns make their way through the watershed when it rains. Though things are not done with the intention to harm the environment, sometimes being uninformed as to how actions can start a chain reaction is the issue. Everything has an impact. With this in mind, the need to educate the general public about the watershed and its impacts became apparent. Green roofs, roofs with soil and vegetation, have many benefits for the environment and the watershed, including the ability to filter the air and water and reduce storm water run-off. The objective of this project was to research the impacts of green roofs and to generate a model that simulates some of these benefits in order to educate the general public about the advantages of integrating green roofs into the watershed.

1. Introduction

The Milwaukee River Watershed consists of 685 square miles of land containing streams, rivers, lakes and groundwater.[1] "Defined by nature's boundaries instead of political boundaries, a watershed is an area of land that captures water and drains it to a river or lake."[2] When it rains water travels across the land and pavement and collects sediments and substances, it progresses to streams then rivers and eventually ends up in Lake Michigan. Water that does not run off into the tributary, streams and rivers, will make its way through the soil to the water table, the upper limit of the portion of the ground wholly saturated with water. The watershed has an ecosystem that contains a wide range of plants and wild life, and the actions of people can alter the ecosystem. The water quality is affected by everything we do, from the chemicals used on farms and lawns to the salts, oils and fluids left by cars on streets and parking lots. Commercial and industrial activity can affect the watershed by releasing toxins and chemicals into the environment. Even those that are released into the air make their way back to the water through rain cycles. The sediment of the Milwaukee River is contaminated with toxins, like mercury, from the tanning industry that use to be along the river in the past. Construction of homes, laying of concrete and asphalt, agricultural uses, animal waste, pesticides and herbicides, run off from impervious surfaces and more all relate to the health of a drainage basin. As cities expand and more natural habitat gives way to buildings and streets, a strain is placed on our environment. The watershed is altered and its effects trickle throughout the ecosystem.

So what can be done? As cities grow and there is increasingly less green space, the effects of urbanization take a toll on the environment. Green roof systems are a beneficial way to bring vegetation back into the city and help restore balance to the environment. A green roof refers to a roofing system that contains a living layer of vegetation and soil. The basic components contained in a green roof system are: waterproofing membrane, drainage system, filter layer, soil layer and vegetation layer. The benefits of green roofs have long since been recognized in history from the hanging gardens of Babylon and the ziggurats of ancient Mesopotamia, to the Norwegian sod roofs still in existence in Norway.[3] Green roofs have been apart of European architecture for a long time and are

beginning to spread to North America. “In North America, the benefits of green roof technologies are poorly understood and the market remains immature, despite the efforts of several industry leaders. In Europe however, these technologies have become very well established. This has been the direct result of government legislative and financial support, at both the state and municipal level. Such support recognizes the many tangible and intangible public benefits of green roofs.”[4]

2. Green Roof Systems and the Milwaukee River Watershed

Green roof systems have many ecological and economical benefits. In regards to the Milwaukee River watershed, green roof systems can help both water quality and quantity. When rain hits impervious surfaces, such as concrete and asphalt, it sheds off directly into the city’s sewage system and it takes any impurities on that surface with it. Heavy rains have often exceeded Milwaukee’s sewers and wastewater treatment plants capacities causing semi-treated sewage to be released into lake Michigan. In efforts to alleviate this problem the Milwaukee Metropolitan Sewage District (MMSD) designed and managed the Deep Tunnel Project. The Deep Tunnel Project was designed for wastewater overflow containment. This allows the wastewater treatment plants to treat the water over time when a heavy rain exceeds the sewer system capabilities. The Deep Tunnel Project covers over 17 miles of excavated tunnels ranging from 17 to 32 feet in diameter.[5] The Deep Tunnel can hold 405 million gallons of water.[6] This extensive and expensive project took nine years to complete and cost the district’s water pollution abatement program $2.8 billion dollars. Though the Deep Tunnel drastically reduced the amount of overflows to the sewer system, it did not completely resolve the problem. There are still large amounts of semi-treated wastewater being released into Lake Michigan. On a dry day the treatment plants clean 200 million gallons of wastewater, storms can increase that amount 5, 6, 7 times or even more for larger storms.[7] The following graph, Figure 1, shows the estimated combined sewer overflows, CSO, after the Deep Tunnel was installed. In 1999, there was still an estimated 4 billion gallons of semi-treated sewage released into lake Michigan because of storms exceeding the capacity of the sewer system.[8]

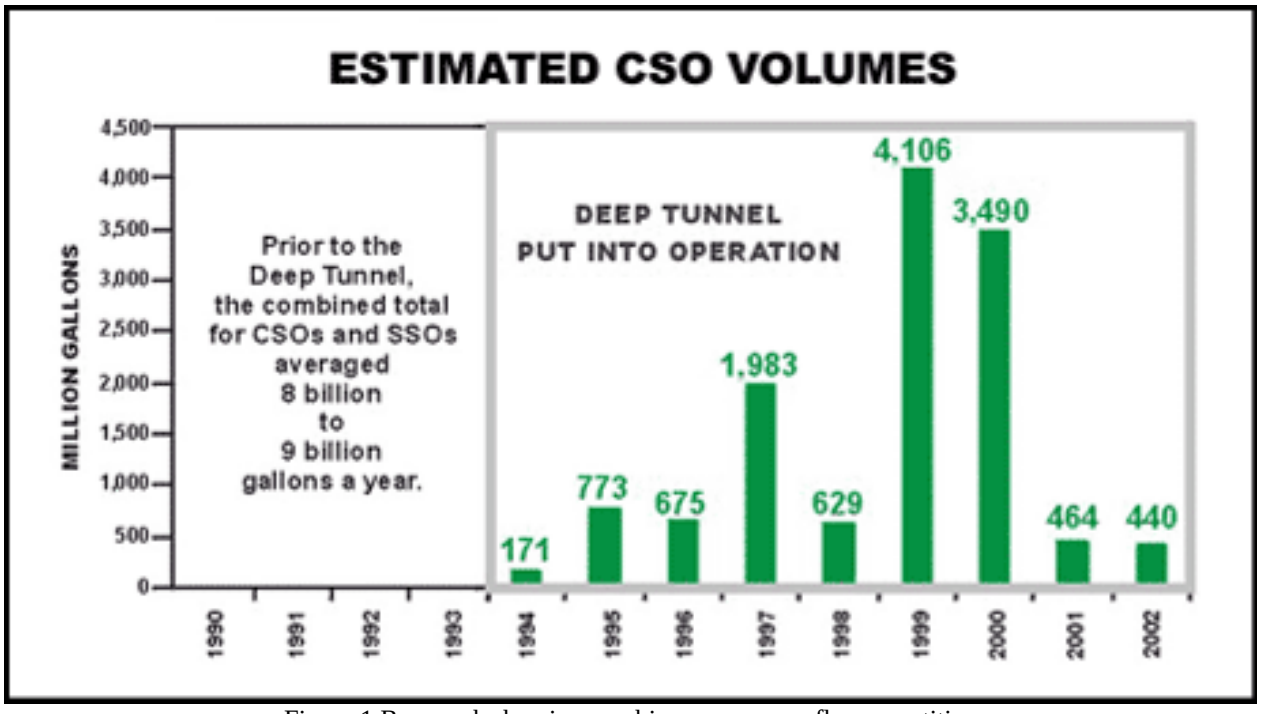


Figure 1 Bar graph showing combines sewer overflow quantities

Yet what else could be done to reduce overflows? While the project was a large-scale action, companies and city occupants can undertake many initiatives that will reduce water run-off, reduce the amounts of contaminants in the water and help the environment.

2.1 types of green roof

There are two basic types of green roofs, intensive and extensive. Intensive green roofs refer to a roof with at least 1ft of soil. They usually range from 200 to 500 lb/ft^2, the equivalent to paving slab or vehicle surface.[9] This heavy load needs to be taken into account when designing a building. Substantial structural changes are required to fit an existing building with an intensive green roof. Intensive green roofs can contain a large variety of vegetation from grass to trees. Intensive green roofs are often used for recreation and can be accessible to the buildings occupants. The range of plant medium does require moderate maintenance.

The second type of green roof is an extensive green roof. Extensive green roofs are characterized by 1 to 5 inches of soil. Extensive green roofs generally weigh 60 to 150 lb/ft^2, the equivalent of a gravel surface.[10] Extensive green roofs can accommodate shrubs, grasses and low-lying plants. It usually is not designed for use but can be if desired. Little maintenance is required to keep up an extensive green roof.

The Garden Room in Shorewood, Wisconsin, Figure 2, has an excellent example of an intensive green roof. It covers 1,900 ft^2 of the roof and has a soil depth of 18 inches. The green roof accommodates a large variety of plants ranging from perennials and roses to evergreen shrubs and small ornamental trees. “The structural analysis determined the existing footings of the building were not sufficient to take this additional load so interior columns on new footings were designed to transfer the garden roof load to the ground.”[11] Owner Deborah Kern said, “Gardens in the sky have always fascinated me. They are a delightful, hidden surprise and a joy to visit.”[12]

Figure 2 The Garden Room, example of an intensive green roof system

2.2 green roof benefits

The benefits of green roof systems can be subdivided into two categories, ecological and economical. Economically, green roofs can provide the building owner or company monetary savings. When a green roof is installed on a building there is a layer of soil and vegetation that does several things for the building. First, the soil and vegetation protect the water proofing membrane of the roof from UV radiation, mechanical damage and harsh weather environments.[13] This will extend the life of the roof, which results in lower maintenance and replacement cost over the life of the building.

As an incentive to build more environmentally friendly structures, many European countries have reduced rain taxes or storm water management fees for buildings with green roof systems. In the United States, the cost of storm sewer system construction and maintenance is paid by taxes. Many cities have grant programs for green roof systems and the EPA’s Clean Water Act Section can help fund green roof installation.[14]

The soil layer in a green roof can also provide a range of thermal insulation, which can result in reduced energy consumption and initial equipment size. A standard roofing system has a dark surface, which absorbs heat from the sun during the day and emanates it back at night. Theses large fluctuations in temperature often cause damage to the roofing membrane and increase the energy consumption of the heating and cooling equipment. The green roof's soil layer helps by reducing thermal transfer across the roof. A study done by the National Research Council of Canada tested a green roof and a standard roof system. It was found that the green roof system regulated the fluctuation in temperature. This can be seen in Figure 3. Heat flow was measured with heat flux transducers implanted in each roof section. "These transducers were calibrated such that positive heat flow represents heat entering the roof at the installed location while negative heat flow means heat is leaving the roof"[15] The reduction in thermal transfer across the roof decreases the demand on the cooling and heating equipment. The HVAC equipment can then be sized for a smaller peak load resulting in savings not only on energy consumption but also on initial equipment costs. The vegetation also provides shade from heat and protection against wind.

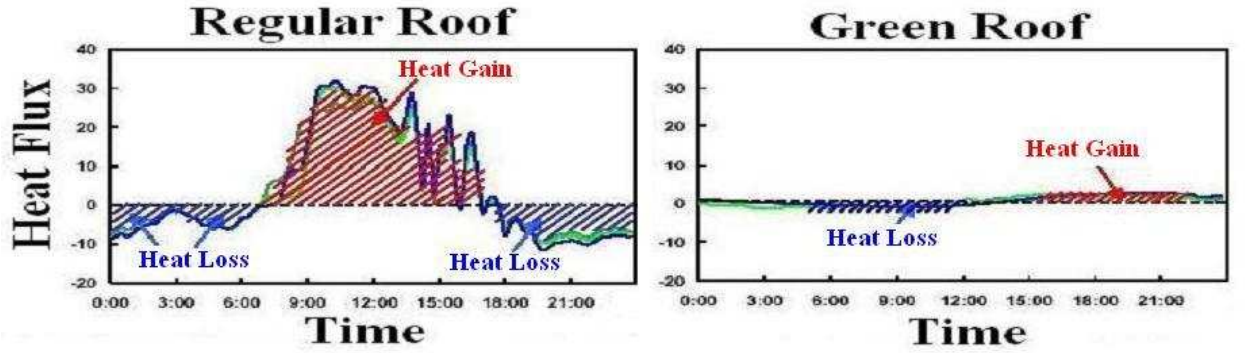


Figure 3 Heat flow through the roofing systems on a summer day (July 16, 2001) indicated that the green roof reduced the heat floe through the roofing system significantly.

Green roofs can also provide acoustic insulation. This is beneficial for areas that may be near interstates, industrial factories, or airports. The soil forms a sound insulator that can reduce the sound by 8 dB on an average. The soil and vegetation absorb sound instead of reflecting it, so that it reduces sound from exterior sources.[16]

Green roofs also often utilize recycled materials, which help the environment. And they overall provide aesthetic value, which has been tested to show psychological benefits for the city occupants.

Green roofs also provide ecological benefits. Vegetation has many benefits to the environment. The vegetation medium has the ability to use heat from the sun and water to turn carbon dioxide into oxygen through photosynthesis. "A one and one-half square-foot area of green-leaf surface supplies enough oxygen, through photosynthesis, to supply one person's requirements for an entire year."[17]

"Roots hold soil in place and prevent erosion, thus preventing sedimentation of nearby waterways. Plant roots, and their attached enzymes and mycorrhizal fungi, filter and treat rainwater as it percolated through the ground."[18] "The nutrients phosphorus, nitrogen, zinc, copper, and sulfur have been shown to be absorbed and translocated to the host by mycorrhizal fungi."[19]

Urban Heat Island effect plagues cities because of their large areas of dark surfaces like roofs and asphalt, they absorb heat from the sun all day. The Urban Heat Island effect describes the larger temperatures in urbanized areas compared to surrounding areas with larger amount of vegetation. Leaves of vegetation use evapotranspiration to collect dust from the air and heat to evaporate moisture, which reduces the outside temperature. "Evapotranspiration occurs when plants secrete or "transpire" water through the pores in their leaves."[20] The water then uses up heat when it evaporates and cools the air, leaving the green roof at a lower ambient temperature through out the day. Adding more vegetation to cities will help reduce the Urban Heat Island effect, which in turn reduces greenhouse gas emissions and smog.

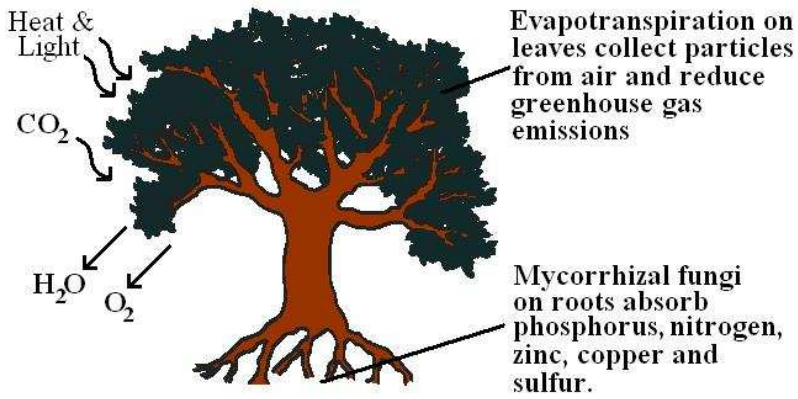


Figure 4 Illustrates benefits of vegetation

One of the greater benefits of green roofs is their ability to reduce the quantity and rate of rainwater run-off. The soil and vegetation collect and use rain water. "In metropolitan areas with buildings and streets comprising 75 to 100% impervious surface cover, rain water is distributed much differently. A staggering 75% of the rainwater becomes surface run off."[21] Green roofs, on the other hand, absorb and use water. After the soil has been saturated it will slowly let out rainwater run off. The resulting run off contains less contaminant because the soil and vegetations can filter rainwater as it percolates through.

3. Project Objectives

Why then, with all of the benefits that green roofs provide, aren't they more common? There is an abundance of information on green roofs, but often the information is not practical and applicable to general public. The information is often in another language or not expressed in terms that the general public would understand. Initially, Schlitz Audubon was interested in making an interactive model of the watershed to educate the public. The Research Experience for Undergraduates program at the Milwaukee School of Engineering further carried out this idea. I choose the rainwater run-off aspect of watersheds to do further research on. The goal of this research is to investigate the concepts of green roofs and develop an effective model that can educate the general public on the positive impact green roof systems can have on the Milwaukee River Watershed. In order to accomplish this goal an extensive research of green roof systems was done.

3.1 model concepts

It's commonly said that if a picture is worth a thousand words, then a model is worth a thousand pictures. What better reason than to use a model to educate the general public on green roof systems? The model concept for this project was to produce a working model that would show how rainfall is shed off of a regular roof, absorbed by the green roof and travels through the sewer system. The model would compare a green roof to a standard roof and demonstrate the green roofs abilities to reduce rain water run-off quantity and rate and filter the run-off. The model would consist of a cross section of a house that had half of the roof with characteristics of a standard roofing system and the other half a green roof system. Rain would then be simulated on top of the house. The green roof side would be able to collect a percentage of the rainfall to show how the plants and soils would absorb and use water. The excess rainfall, and the water shed from the regular roof would each travel to a sewer system underneath the house. There the different levels of water in the sewer would show the reduced rainwater run-off from the green roof. The model would be 2D, like an ant farm display.

The second aspect of green roofs contained in the model, is the ability to filter certain contaminants out of the water. A color change is used to represent the filtration. A pH indicator is used to produce the color change. Phenolphthalein was the chosen indicator for this model, though other indicators could be used depending on the medium used to produce the pH changes. Phenolphthalein is colorless when acidic and red when basic, the pH range is 8.2 to 9.8.[22] The indicator is added to the water in the reservoir with the pump. A small amount of ammonia is added to the water to change the indicator to a pink color. The more indicator added, the stronger the color pink becomes. In the green roof side of the model an acid medium is placed, like lemon slices. The water that falls on the

green roof side becomes more acid and the indicator changes from pink to clear. Therefore, the water exiting the green roof side would be clear, representing the absorption of contaminants.

The green roof side of the model had a reservoir that would hold a certain amount of water to represent the soil and plant absorption. Once the reservoir was filled the rainwater would begin to run off the roof and proceed to the sewer system. The full reservoir represents the soil saturation, the point where the soil can hold no more water and begins to shed water.

To produce the rain like effect for the model, sixteen small tubes with pinch valves were inserted into the top of the model. Then with the use of small plumbing tees, the tubes were reduced to one that connected to a garden pump, 60 gallons per hour. When turned on the garden pump would fill all of the tubes and created a pressure behind the clamps, forcing water to drip out of the tubes "making rain".

The model was designed in AutoCAD. A laser cutter was used to cut the pieces out of 1/8-inch acrylic and styrene. The acrylic was annealed after being cut and then the model was assembled. The finished product can be seen in Figure 5a and b.

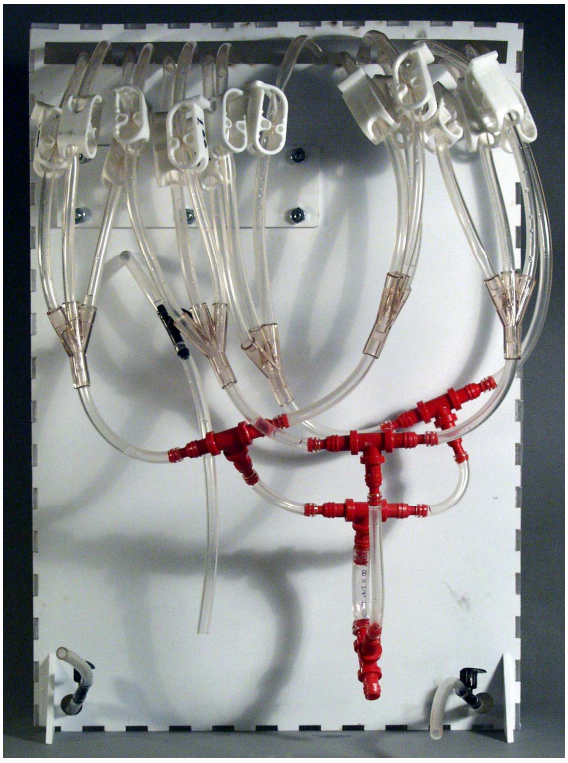
a)  b) 

Figure 5a) Front of Model b) Back of Model

The rapid prototyping machines were not used to make this model due to the current resins. Since the model would be in constant contact with water it was important for the model to be water tight and water resistant. The current resins and materials used by the rapid prototyping would deform and warp when exposed to water, making them unfavorable for this model application.

4. Results:

In conclusion, green roofs provide many benefits for the environment. Green roofs can help alleviate some of the watershed issues by reducing rainwater run-off rates and quantities and filtering some contaminants out of the rainwater run-off. Making the general public aware of how their actions can ripple though the ecosystem and educating them about their watershed can help make our environment a better place.

Furthermore, Models are an excellent way to educate the public and can demonstrate ideas and concepts better than pictures and words often can. The model, though a prototype, ran as expected and demonstrated the desired benefits of green roof systems. Creating a sealed environment was a difficult task but the model was mostly leak proof. The simulation of rain was a great accomplishment, which delivered a wonderful effect for the model.

5. Acknowledgement:

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