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Sustainable Design as a Way of Thinking: Suzanne Sowinski
Graduate Paper 1: "A Pattern Language"
July 9, 2008

Stormwater Treatment Gardens: Outline of Paper

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Stormwater Treatment Gardens

Overview of Operational Function in Local Environment
I can remember playing barefoot on the driveway with my sisters as a child, stomping in streams of hose-water and puddles on the hot pavement beneath my feet, and watching it run down to the end of the driveway, curl around the sidewalk, and disappear into a drain. Sometimes on those hot summer days our puddles would be dwarfed by massive rivers flowing down the driveway during an afternoon thunderstorm. Summer storms and periods of rain, which bring relief from heat and provide critical nourishment for trees, often have a negative impact on the built environment.

Vegetation in residential and urban areas is not as dense a natural forest system, and soil cannot fully absorb rainwater. Rainwater cascades down buildings with torrential force, unlike forests where tree branches break the fall of water, spreading it more evenly across the soil where it is naturally absorbed. As a result, buildings, pavement, and cars create a hostile environment for rain and water has nowhere to go except down: carrying toxins, eroding soil, and flowing over surfaces, making its way underground and into larger waterways.

On a daily, seasonal, and yearly basis the small-medium sized city of Cambridge, Massachusetts, struggles to manage stormwater runoff in an effective way. Like other cities, Cambridge has pockets of buildings characterized by high quality design: impeccable roofing, gutters, and drainage systems that carry water to sewers efficiently and with little damage to building and grounds. Even with this in place overflow of sewers can still occur. On a large scale, managing stormwater run-off in a sustainable way continues to be one of several operational functions requiring innovative problem solving. New sustainable design mechanisms as well as an understanding of short and long-term effects that runoff incurs on the natural environment are imperative in the search for a solution to what has become an ingrained pattern in the design world.

A LEED-certified building owned by Harvard University on Oxford Street has a system of gutters that direct water into strategically placed drains located in the grass surrounding the building. There is a small amount of landscaping around the base of the building that catches some of the runoff, but even with such systems in place, there is still excess stormwater that runs off of this building. Furthermore, like many others, small, brightly colored flags dot the lawn reminding pedestrians that the grass has been treated with chemicals.

While Lesley College and Harvard University have more open land between buildings, Harvard Square, located in a one-mile radius of both campuses, is densely built and streets are lined with storefronts. Many alleyways cut between the buildings, providing small transitional spaces that allow for an escape from the busy main streets. Drains are located in these alleyways, so that when water cascades down building walls and comes shooting out of gutters it flows directly into the drains. Moss grows on bricks surrounding the drains: a small sign of vegetation signaling a wet area.

In heavy rains street flooding and sewer overflow can lead to runoff that reaches the Charles River, which is flanked by Storrow Drive on the southwest bank and Memorial Drive on the north, closer to Harvard Square. The Charles River is frequented by boaters and rowers, and is home to a diverse wildlife habitat.

Problem Pattern Summary

The recurring pattern manifests itself in the building design of roofs, gutters, and drainage systems, which, even when built at their best, simply direct water off of a building and into the streets, where water then flows into a drain, through a sewer system, and arrives at a water treatment plant (in some cases it flows directly into a main waterway such as a bay, river, or ocean).

Functional problems with this process of water disposal include poor design mechanisms, damage to buildings, erosion of soil, and water pollution. Water damage to buildings, such as basement flooding and water permeation in building walls can lead to the growth of mold and mildew, both of which aggravate certain health conditions including asthma in children.

Flat roofs with poor grading, uneven walkways, streets, and parking areas surrounding buildings allow water to collect and erode building materials. When large amounts of water flow heavily down building walls and out of gutters, the pressure of such movement erodes soil. This can be particularly damaging to the roots of trees, which require a healthy topsoil to maintain growth. Finally, water pollution due to stormwater runoff poses the greatest hazard to water quality, affecting human health.

Analysis of Environmental Impact Caused by Problem Pattern

As we consider the environmental impact caused by the problem pattern identified above, we must acknowledge that water, as a soluble substance, picks up particles as it travels its course. Subsequently, toxins found on roofs, building walls, soil, lawns, gardens, sidewalks, and streets will be picked up and carried along by the flow of water during a rainstorm. While the process of "runoff" is slightly different with regard to agriculture and chemicals found on conventional farms, the idea of soil runoff is consistent with the built environment: if there are pesticides and fertilizers on lawns, rainwater carries these toxins into our sewer systems. Furthermore, paved areas around buildings (including streets and parking lots) absorb solar energy and generate thermal pollution by heating stormwater runoff, creating waterways that are hostile to cold-water fish.[i] (1)

Where do toxins in runoff originate?

Toxins in runoff originate from building and land surfaces as water hits a building and travels down. To begin with, roofs and building sides may contain asbestos or lead.[ii] (2) Contaminated soil and lawn turf are the greatest contributors to pollution in runoff, and sidewalks and streets can also add chemicals such as gasoline. In Alex Wilson's article "Natural Landscaping: Native Plants and Planting Strategies for Green Development," from BuildingGreen.com, he writes that Americans use more fertilizers on their lawns than India uses on food crops.[iii] (3) Furthermore, the production of nitrogen lawn fertilizers, 40%-60% of which end up in surface or groundwater, require an energy intensive process to be manufactured. Such nitrogen fertilizers are produced through a conversion process in which air-borne molecular nitrogen is converted into ammonia through the Haber-Bosch process. This requires approximately 18,000 Btus per pound (41 GJ/tonne) of primary energy input.[iv] (4)

Not only does the process of conversion leave a large carbon footprint, but the majority of the fertilizers often end up as runoff. Wilson also tells us that this high percentage of chemicals lost to groundwater is compounded by the even starker fact that lawns in the U.S. are treated with 67 million pounds of pesticides annually, and that we apply more pesticides to our lawns than our farms: "between 3.2 and 9.8 pounds per acre vs. an average of 2.7 pounds per acre for agricultural lands."[v] (5)

How do they reach humans?

As the toxins travel in the stormwater runoff they eventually reach a water treatment plant where chemicals are sorted out and disposed of responsibly, or they reach natural water systems like rivers and bays, if no treatment plant is established. Untreated water flowing directly into natural sources such as the ocean causes immediate harm to the ecosystem and living organisms (plant and animal), which are negatively affected by the toxicity of chemicals. Danger exists even with water treatment facilities in the form of CSOs "combined sewage overflows" in which sewers designed to carry sewage and stormwater to treatment plants overflow during a flash flood.

In these instances, treatment plants and sewers are overloaded and combined wastes flow directly to surface waters, such as steams and rivers.[vi] (6) In the article "Building and the Environment: The Numbers," by Alex Wilson and Peter Yost, we learn that there are 950 U.S. communities with combined sewer systems, including New York City and Philadelphia, which means that combined sewage overflows are a very real problem in big cities.

There are 42 million people living in U.S. communities with combined sewer systems, and there is a discharge of 1.2 trillion gallons of raw sewage in the U.S. each year.[vii] (7) Finally, keeping chemicals out of the groundwater is important too because such contaminants would eventually make their way to surface waters, as groundwater surfaces in springs, which flow into larger bodies of water.[viii] (8)

How do they affect humans?

Chemicals found in fertilizers and pesticides used on lawns are highly toxic and detrimental to biomarine organisms and people. Human health is affected primarily when toxins poison water that is used for drinking and washing. In Wilson's article on natural landscaping he states that "…of 30 commonly used lawn pesticides, 13 are probable or known carcinogens, 14 are linked with birth defects, 18 have reproductive effects, 20 may cause liver or kidney damage, 18 are considered neurotoxins, and 11 are known or suspected endocrine disrupters."[ix] (9)

This fact is alarming given the frequency with which CSOs occur, polluting surface waters with toxic sewage waste. It is also worth mentioning the role Superfund Sites play in the problem of toxic runoff. Superfund Sites are toxic waste sites that have been identified by the Environmental Protection Agency (EPA) as areas where "the threat to humans from dangerous and sometimes carcinogenic substances is 'not under control.'"[x] (10) For example, in Middlesex County, New Jersey, buried toxins leak from the soil of a 12-acre site into the Raritan River.[xi] (11) This introduces carcinogens into a main artery of water.

Toxins in soil are carried to surface waters by groundwater movement and stormwater runoff. It is important to note, as mentioned in the introduction, that stormwater flowing off of a building moves across surface areas with much more force than if it was simply falling onto a canopy of trees, and the force with which the water moves contributes to the faster and more direct flow of chemicals into sewers and waterways.

Problems to be Solved

This analysis suggests several problems to be solved:

1. An effective way to direct water off of buildings so that it does not leak into building walls and basements causing growth of mold and mildew, which leads to human health difficulties.

2. An effective way to minimize the amount of stormwater flowing off of buildings and into drains and sewer systems, which can otherwise lead to overflow.

3. An effective way to slow down the rate and force at which water cascades off of a building and hits the ground, causing soil erosion and disruption of latent toxins/chemicals.

4. An effort on the part of architects and landscape architects to ban the use of non-organic fertilizers and chemical pesticides.

5. Preventing groundwater and surface water contamination from stormwater runoff and Combined Sewage Overflows.

6. Ensuring the safety and health of residents.

Pattern Solution Summary

The problems identified by the pattern of stormwater runoff require a solution that can be applied to a range of building types; including residential, commercial, and mixed-use facilities. Such a solution must also be feasible in various regions and with regard to weather patterns. The solution is to build Stormwater Treatment Gardens that will be located close to buildings, and in the case of densely populated blocks, in alleyways. Stormwater Treatment Gardens can range in size, but should be at least 6 feet by 6 feet to allow for water retention space. In the case of smaller areas such as alleyways, multiple treatment gardens may be necessary, while larger open spaces may only require one large Stormwater Treatment Garden.

Similar to greywater treatment systems, Stormwater Treatment Gardens will be strategically placed within proximity to the opening of gutters where water flow is strongest. They should not be placed directly beneath a gutter or waterspout, but can be angled on the downslope, or in the path by which water flows away from the building.

Specifically, Stormwater Treatment Gardens should be placed in an area between the waterspout and drain, as they work off of the basis that water flows from a building with such force that is creates small rivulets of water. The advantage to the force of flow here is that water can be *directed* to the Stormwater Treatment Garden accordingly.

When building a Stormwater Treatment Garden, the land must be graded to create a slight decline around the edges of the garden. This allows for the flow of water into the garden, as the edges are pitched at a slight obtuse angle. Using stone or another solid building material to maintain a slope without causing erosion will be necessary. The garden itself must have water-friendly plants that filter contaminants, absorb some of the water, and re-integrate stormwater into groundwater.

Indigenous plant species must be used to ensure successful growth, and placement of the garden (sun vs. shade) will also affect the choice of plants. One option is to build a Stormwater Treatment Garden that mimics wetland systems, a large-scale filter found in nature. At Clackamas High School in Oregon, the LEED certified school building has a water drainage system where biofiltration occurs in facilitated retention areas adjacent to existing wetlands.[xii] (12)

In terms of design, Stormwater Treatment Gardens may need to be stepped, allowing for a first, outer ring just beneath the pitched edges that contains gravel for initial filtering. The next stepped ring, one layer lower, might include water friendly plants like coreopsis, pennywort, unicorn juncos,[xiii] (13) and black-eyed susans. Water would flow through the gravel, onto the second ring, and down into the main basin of plants, which might include ferns, skunk cabbage, cranberry, colic root, pickerel weed, cardinal flower,[xiv] (14) and cimicifuga.[xv] (15)

Water friendly shrubs and trees can be planted close to the Stormwater Treatment Garden. Shrubs might include winterberry, willow shrubs, European cranberry bush, and the spicebush; while tree varieties such as red maples, river birch, willow, swamp white oak, and pin oak flourish near water sites. Stormwater Treatment Gardens will certainly vary between temperate zones, and can be built in drier spots as well as those frequented by rainstorms.

Stormwater Treatment Gardens allow for water remediation, as well as slow and divert excess water from street drains, preventing sewage overflow and generating clean water.

Execution of Pattern Solution
Successful implementation of Stormwater Treatment Gardens will require architects, engineers, and landscape architects to understand the following:

1. There is a possibility for implementation of Stormwater Treatment Gardens in both existing and future building construction.

2. It is necessary to understand the course that water will take once it hits the building. This includes an understanding of the building's roof, square footage, gutter system, location of drains, and existing landscape.

3. The location of surrounding buildings must be considered. This will help determine the size of the Stormwater Treatment Garden, and whether or not it will be shared with other buildings.

4. There must be an understanding of the garden's specified benefits. If the property uses fertilizers and pesticides, the garden will function to help filter these toxins. If chemicals are not used on building grounds, the garden will still function to filter other toxins that may be present in lesser quantities. The garden will also function to prevent excess water from traveling to street drains and flooding sewer systems.

5. There must be an understanding of the health benefits the garden provides, as it diverts toxins from surface and groundwater.

6. The garden must be graded appropriately to allow for some version of stepping or water-catching.

7. The garden must be placed between gutters and drains, in the path of heaviest water flow.

8. Plants must be chosen carefully with respect to temperate regions, shade, and sun.

Subsequent Patterns
Design and integration of the Stormwater Treatment Garden into a building's landscape requires a future in-depth analysis of its relation to existing patterns. Consideration of these other patterns ultimately means consideration of the building, and this is absolutely necessary if the garden is to compliment the character of the building design. Patterns we might consider in a future analysis include the following, in summary:

Courtyards Which Live
In the case of residences or large buildings with adjacent courtyards, placement of Stormwater Treatment Gardens must be chosen in accordance with the courtyard. One idea is to build the garden inside the courtyard, or just beyond it, allowing for the Stormwater Treatment Garden to be partially seen from inside the courtyard, encouraging the courtyard to "give at least a glimpse of some other space beyond."[xvi] (16)

Cascades of Roofs
As "many beautiful buildings have the form of a cascade: a tumbling arrangement of wings and lower wings and smaller rooms and sheds…"[xvii] (17) architects must consider how the gutter and drainage systems on a building will compliment the roof, and how water's natural tendency to move downward echoes the design of cascading roofs. With this in mind, the architect needs to consider how the gutters will effectively allow water to flow to the Stormwater Treatment Garden.

Arcades
As arcades "must be felt as an extension of the building interior and therefore covered,"[xviii] (18) it is important to consider whether the Stormwater Treatment Garden will be placed closer to the building, or farther away, depending on the architect's intent to showcase the garden for pedestrian viewing, or to hide it away from sight, directing water farther away from the building.

Path Shape
If the architect is aiming for an alleyway that is to be "made into the kind of place where you stay, rather than the kind of place you move through,"[xix] (19) than building a Stormwater Treatment Garden that interrupts the middle of the alley path, such as a crescent shaped garden (see attached images, Figure 3) is feasible.

Activity Pockets
If the architect is building Stormwater Treatment Gardens in an area with a piazza or public space surrounded by buildings, they want to consider how to make a garden that sits along the edge of the space, close to the buildings and gutter systems, and which attracts activity. In this case the garden will be designed with an emphasis on aesthetic appeal, as the garden may become "a pocket of activity."[xx] (20)

Conclusion
Stormwater Treatment Gardens address a pattern of poorly managed stormwater runoff systems on buildings, a pattern consistent among residential, commercial, and mixed use facilities that leads to sewage overflow, contamination of surface and groundwater, and damage to human health. The feasibility of pattern solution implementation rests on an understanding of biofiltration processes necessary to slow down and treat contaminated water, in addition to a knowledge of human health consequences of Combined Sewage Overflows, environmental impact of soil contaminants, drainage engineering, and integration with existing architectural patterns.

Bibliography

- Alexander, Christopher, Sara Ishikawa, et. al.,"A Pattern Language: Towns, Buildings, Construction." Center for Environmental Structure, Berkley, CA, Oxford University Press, New York, l977.

-Holmberg, David, "At Some Superfund Sites, Toxic Legacies Linger." New Jersey. The New York Times, January 20, 2008.

-Puckett, Josh. "Greywater." EnergyFarms.net, June 3, 2008.

- Sapien, Joaquin, "Human Exposure 'Uncontrolled' at 114 Superfund Sites: EPA Secrecy About Sites' Toxic Danger Extends Even to Senators' Inquiries." Washington. The Center for Public Integrity.org, May 18, 2007.

-Wilson, Alex. "Natural Landscaping: Native Plants and Planting Strategies for Green Development." Environmental Building News, BuildingGreen.com, July 1, 2005.

-Wilson, Alex and Peter Yost, "Buildings and the Environment: The Numbers." Environmental Building News, BuildingGreen.com, May 1, 2001.

- Wilson, Alex with Rachel Navaro, "Driving to Green Buildings: The Transportation Energy Intensity of Buildings." Environmental Building News, BuildingGreen.com, September 1, 2007.

-Websites:
www.rainwatercollection.com
www.usgbc.org: http://leedcasestudies.usgbc.org/overview.cfm?ProjectID=196
www.weymouthnj.org/wetlands_plants.htm
www.waysidegardens.com

Endnotes

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[i] 1. Wilson, Alex with Rachel Navaro, "Driving to Green Buildings: The Transportation Energy Intensity of Buildings." Environmental Building News, BuildingGreen.com, September 1, 2007. Page 4.
[ii] 2. www.rainwatercollection.com
[iii] 3. Wilson, Alex. "Natural Landscaping: Native Plants and Planting Strategies for Green Development." Environmental Building News, BuildingGreen.com, July 1, 2005. Page 2.
[iv] 4. Wilson, Alex. "Natural Landscaping: Native Plants and Planting Strategies for Green Development." Environmental Building News, BuildingGreen.com, July 1, 2005. Page 2.
[v] 5. Wilson, Alex. "Natural Landscaping: Native Plants and Planting Strategies for Green Development." Environmental Building News, BuildingGreen.com, July 1, 2005. Page 2.
[vi] 6. Wilson, Alex and Peter Yost, "Buildings and the Environment: The Numbers." Environmental Building News, BuildingGreen.com, May 1, 2001. Page 4.

[vii] 7. Wilson, Alex and Peter Yost, "Buildings and the Environment: The Numbers." Environmental Building News, BuildingGreen.com, May 1, 2001. Page 4.
[viii] 8. Wilson, Alex. "Natural Landscaping: Native Plants and Planting Strategies for Green Development." Environmental Building News, BuildingGreen.com, July 1, 2005. Page 3.
[ix] 9. Wilson, Alex. "Natural Landscaping: Native Plants and Planting Strategies for Green Development." Environmental Building News, BuildingGreen.com, July 1, 2005. Page 2.
[x] 10. Sapien, Joaquin, "Human Exposure 'Uncontrolled' at 114 Superfund Sites: EPA Secrecy About Sites' Toxic Danger Extends Even to Senators' Inquiries." Washington. The Center for Public Integrity.org, May 18, 2007. Page 1.
[xi] 11. Holmberg, David, "At Some Superfund Sites, Toxic Legacies Linger." New Jersey. The New York Times, January 20, 2008. Page 2.
[xii] 12. http://leedcasestudies.usgbc.org/overview.cfm?ProjectID=196
[xiii] 13. Puckett, Josh. "Greywater." EnergyFarms.net, June 3, 2008.
[xiv] 14. www.weymouthnj.org/wetlands_plants.htm
[xv] 15. www.waysidegardens.com
[xvi] 16. Alexander, Christopher, Sara Ishikawa, et. al.,"A Pattern Language: Towns, Buildings, Construction." Center for Environmental Structure, Berkley, CA, Oxford University Press, New York, l977. Page 563.
[xvii] 17. Alexander, Christopher, Sara Ishikawa, et. al.,"A Pattern Language: Towns, Buildings, Construction." Center for Environmental Structure, Berkley, CA, Oxford University Press, New York, l977. Page 566.
[xviii] 18. Alexander, Christopher, Sara Ishikawa, et. al.,"A Pattern Language: Towns, Buildings, Construction." Center for Environmental Structure, Berkley, CA, Oxford University Press, New York, l977. Page 582.
[xix] 19. Alexander, Christopher, Sara Ishikawa, et. al.,"A Pattern Language: Towns, Buildings, Construction." Center for Environmental Structure, Berkley, CA, Oxford University Press, New York, l977. Page 590.
[xx] 20. Alexander, Christopher, Sara Ishikawa, et. al.,"A Pattern Language: Towns, Buildings, Construction." Center for Environmental Structure, Berkley, CA, Oxford University Press, New York, l977. Page 600.

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