BACK TO NATURE: URBAN STRUCTURES EMBRACE PHILADELPHIA'S NEW STORMWATER MANAGEMENT REGULATIONS

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INTRODUCTION

Now in its first official year of operation, Philadelphia's "Green City, Clean Waters" program addresses the problem of stormwater flow into sewer systems that then overflow, polluting streams and rivers. Four institutional projects by SaylorGregg Architects are useful case studies of stormwater management techniques in urban buildings. Subsurface storage beds, extensive and intensive vegetated roofs, and other effective means of capturing stormwater and reducing heat islands in urban development are discussed.

KEYWORDS

stormwater, vegetated roof, impervious surface, heat island, subsurface storage

BACKGROUND

Flooding was on everyone's mind in the fall of 2012 as Hurricane Sandy struck New Jersey's shoreline and Lower Manhattan's subway tunnels filled with water. Sandy dumped more than a month's worth of rain over several days, but it was not torrential, and across most of the mid-Atlantic region the ground was able to absorb enough water to prevent major stream overflows.

More often in this area, devastating storm damage is caused by runoff from heavy rains coming downstream in a flood. Water flows directly from rooftops, off the pavement, and into the sewers. When the sewers fill up, they are designed to overflow into streams and rivers so as not to overwhelm treatment plants. But in urban areas where the streams and rivers have been covered over by development, and antiquarian sewer systems can't handle a 21st century population, water can overflow into the streets in dangerous and unhealthy surges. In New York City, which averages an overflow a week, a rainy day can mean more than 500 million gallons of dirty runoff pouring into waterways and streets.[3]

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This is a costly problem faced by many cities in the United States. While some have tried to solve it by expanding sewer systems and treatment plants, the City of Philadelphia's approach is to manage the water before it goes down the drain. Spurred on by the Federal Clean Water Act and the threat of a $10–15 billion cost to overhaul the city's sewer system, the Philadelphia Water Department developed its groundbreaking "Green City, Clean Waters" program, which seeks to reduce the volume of combined sewer overflows into the waterways through green stormwater infrastructure.

Now in its first official year, the 25-year, $2 billion plan has begun to have an effect on the streetscape. "We want to do anything we can to return to the way nature intended the water cycle to be," Philadelphia Water Commissioner Howard Neukrug has said.[4] In order to reduce impervious surfaces and trap stormwater before it reaches the sewer, the City is planting stormwater tree trenches, installing porous streets, and providing incentives for green roofs and other stormwater infrastructure. The impact of the program on the design of several urban building projects is the subject of this paper.

Greene Country Towne

The basic intent of Water Department's stormwater management regulations is to negate the impact of development on local streams and hydrology. This is accomplished by encouraging new development or re-development to capture the first inch of stormwater runoff for a given rain storm, also known as the Water Quality requirement. For larger storms, a site should contribute the same rate and volume of water as the pre-development condition. Typically, the largest storm that an undeveloped or "natural" site can capture and infiltrate is between the one-inch and ten-year storm event. This depends on the storage volume of soils, depth of soils, vegetation types, and severity of slopes.

According to environmental historian Adam Levine, in the 18th century and continuing into the 1940s, Philadelphia systematically filled in its tidal marshland and built over many of its streams, channeling them into the sewer system. "Where streams once flowed over open countryside, sewers now flow under city streets. In the process of this rural to urban transformation, more than 100 miles of streams were buried in some of the largest sewers in the city, up to 20 feet in diameter."[5] Naturally, the areas most prone to flooding are located along these former stream valleys.

Several projects designed or planned by SaylorGregg Architects are located in sensitive areas of the city, requiring careful management of stormwater. These projects are the University of Pennsylvania Museum of Archaeology and Anthropology Addition, The Franklin Institute Science Museum Karabots Pavilion, Chestnut Hill College, and the new headquarters for the International Alliance of Theatrical Stage Employees. In several of these projects, the primary means of dealing with stormwater is to catch it and begin its management on the roof.

Vegetated Roof Systems

Green roofs have proved to be an immensely successful means of capturing stormwater and reducing heat islands in urban development. Vegetated roofs offer important features not present in a conventional membrane roof, including the following:

- Vegetation and soil layers protect the waterproof membrane from solar exposure, prolonging roof life.
- The soil insulates the building below.

- Vegetated roofs emit oxygen, improving air quality.
- They are an economical and low-impact way to manage, slow, and reduce stormwater runoff.
- Green roofs promote insect and bird life.
- They promote evaporation of some stormwater.
- They minimize thermal gradient differences between developed and undeveloped areas.

There are two types of vegetated green roofs: *extensive* and *intensive*. Both types require temporary irrigation for establishment of plant life communities. Following are the main features of each type:

> Extensive green roofs are typically not designed for foot traffic or occupancy except for maintenance. These assemblies are detailed to minimize the additional load on the roof structure (with only two inches to six inches of soil), have minimal plant diversity, and require minimal maintenance. These features result in the lowest capital cost of the two vegetated roof types.
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> Extensive roofs may also be placed in special tray systems that rest on the roof membrane, allowing for ease of replacement or access to the roof structure or to the roof membrane itself. Extensive roofs may turn brown over dry periods, but their dormant plants typically revive once precipitation returns or irrigation is initiated.
>
> Intensive green roofs may be accessible as walkable roof gardens, but this type of vegetated roof requires deeper soil, and therefore greater structural support than that of roofs that do not anticipate live loads of an occupied space. The deeper soil allows more plant diversity and requires higher maintenance than the extensive green roof. Soil depth is usually between eight and twenty-four inches and sometimes more if trees are to be planted. Intensive roofs are more attractive than extensive roofs during dry periods, and may be irrigated depending on soil depth, plant selection, and location.

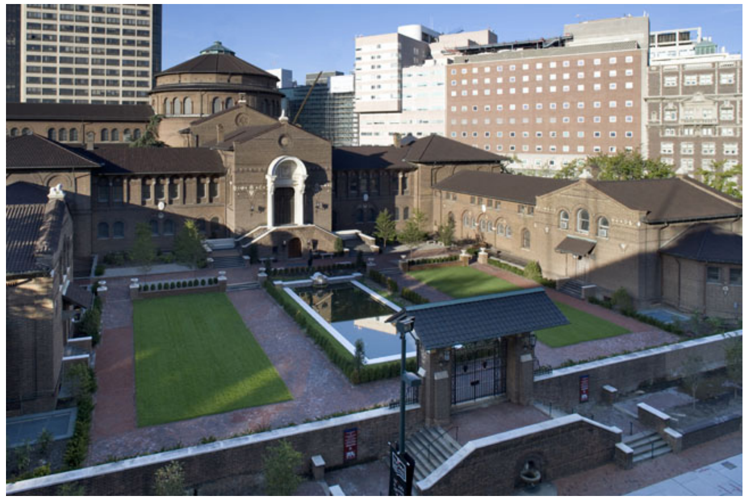
PROJECTS

University of Pennsylvania Museum of Archaeology and Anthropology

Planned and designed by Wilson Eyre, the University of Pennsylvania Museum of Archaeology and Anthropology[6] is an historic landmark that displays and stores a vast collection of archeological artifacts. Three gallery floors feature materials from Egypt, Mesopotamia, Canaan and Israel, Mesoamerica, Asia, and the ancient Mediterranean World, as well as artifacts from native peoples of the Americas and Africa. With an active exhibition schedule, a membership program, and extensive educational programming, the building near the Schuylkill River is continuously occupied by the public, researchers, and students (Figure 1).

Constructed in the early 1900s, the museum lacked adequate climate control for either the public or the collection, and in spite of several additions over the years, the museum also needed to accommodate growth in programs. The challenge of the design project, led by Marvin Waxman Consulting Engineers[7] with SaylorGregg as the architect, was to find new space for major mechanical rooms and for the growth of the conservation department, DNA laboratory, photography, exhibition preparation, archives, and miscellaneous support functions within a tight urban site (Figure 2).

FIGURE 1. Historic quarter-acre landscaped courtyard of the Penn Museum re-constructed atop 21,000 square feet of new underground interior space. (Photo: Tom Crane)



The solution was to build beneath the quarter-acre, landscaped courtyard in front of the museum. The Italianate courtyard garden, also designed by Eyre, features clipped hedges, lawn panels, flowering cherry trees, Tiffany tiles, and marble and brick pathways located around a reflecting pool with koi and water lilies. A complex multi-phased project, the courtyard was fully excavated with the existing museum walls secured by underpinning (Figure 3).

FIGURE 2. Building Section through new underground addition of the Penn Museum. (Courtesy SaylorGregg Architects)

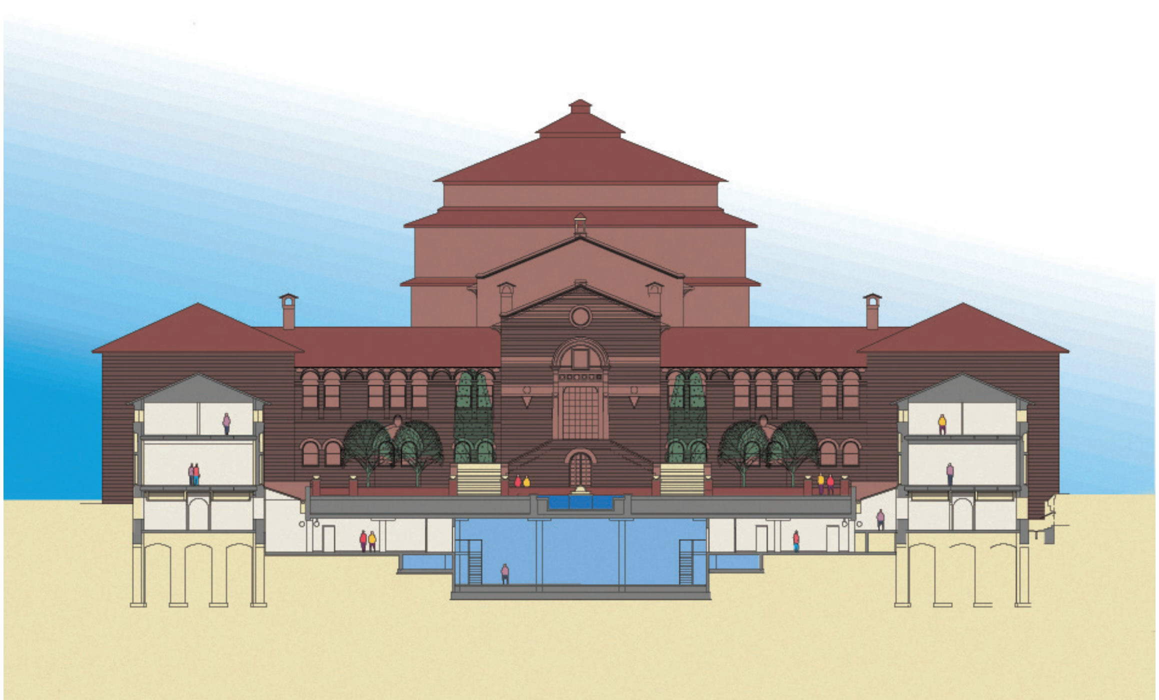


FIGURE 3. Existing courtyard of the Penn Museum removed during construction to accommodate 21,000 square feet of new underground interior space. (Courtesy SaylorGregg Architects)

Expansive new underground floor areas were captured below the garden, creating new central mechanical systems support rooms and space for museum programs. Angled skylights bring much natural light to subterranean work areas. Internally, all galleries, public spaces, and work areas of the museum can now be climate controlled and restored with new lighting and finishes.

The courtyard is now an intensive vegetated roof garden. Fully irrigated, soil depth is typically thirty-six inches, however, greater depths are provided at specific locations to accommodate the cherry trees that provide color and shade while complementing the museum's dramatic facade. The museum's rich architectural details are revealed anew, framed by a garden that retains the style, elegance and features of Eyre's original design while updating it for current uses. The green roof atop the new underground building resulted in no additional impervious surface for this city building, even though 21,000 square feet of new interior space was realized.

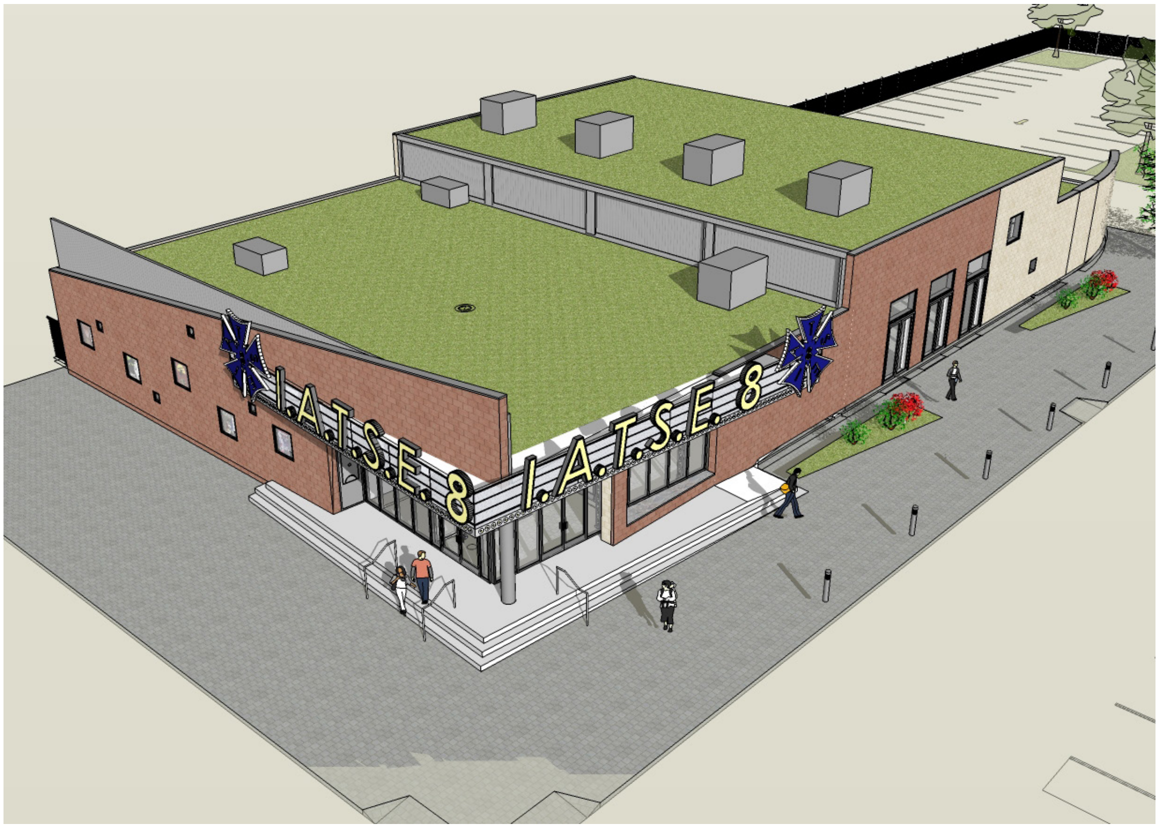
International Alliance of Theatrical Stage Employees

On a reclaimed brownfield site in South Philadelphia, SaylorGregg and Urban Engineers[8] designed a new headquarters and education center for the local union of the International Alliance of Theatrical Stage Employees, Moving Picture Technicians, Artists and Allied Crafts[9], known informally as Local 8. Founded in 1893 as a union of stage hands, Local 8 now includes craftspeople in every branch of the entertainment industry including film, television, casinos, conventions, and computer technology (Figure 4).

The new building is an 11,150-square-foot structure with offices and state-of-the-art training rooms on a 45,150 square foot site. In addition to accommodating the administrative requirements of the leadership and the educational needs of the membership, over half of the building was constructed to serve as revenue-generating banquet facilities during off hours. A kitchen and prep area is used by a professional caterer for food service operations.

As an expression of Local 8's background in theater, the main entrance is designed as a contemporary interpretation of a classic marquee. Programmable illumination is achieved

FIGURE 4. The International Alliance of Theatrical Stage Employees Local 8 headquarters has a 0.22 acre lightweight extensive vegetated roof. (Courtesy SaylorGregg)



through the incorporation of a high-tech, fiber-optic lighting system that can glow in brilliant white or pulsate in a rainbow of color.

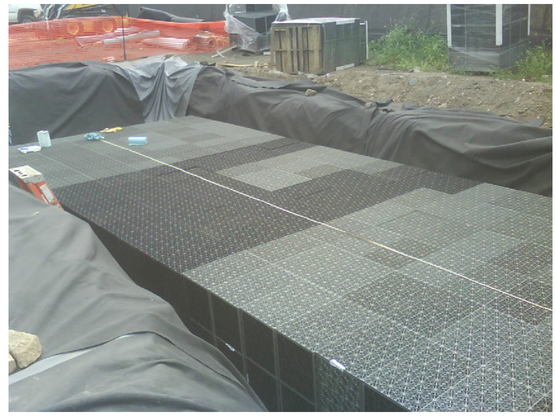
To address the city of Philadelphia's requirements for stormwater management, the one-story structure incorporates a 0.22-acre lightweight extensive vegetated roof with a 3.5-inch growth medium. This, along with six small planted areas at grade, reduces the property's existing impervious area by 29%—promoting evaporation as well as deaccelerating runoff into the municipal storm sewer (Figure 5).

A subsurface detention system of rain tanks was designed to capture and slowly release the runoff from impervious areas as required by the city's new code. Since the site is a reclaimed brownfield with soil-to-groundwater contamination a potential problem, the designers ruled out the use of infiltration practices (Figure 6).

Located beneath a sixty-five space parking lot and paved walks, the structural subsurface detention system is 13.49 feet wide and 87.67 feet long, with a tank depth of 2.89 feet. It accounts for 402 rain tanks with a capacity for larger storm events of 3,320 cubic feet and is lined with an impermeable geosynthetic due to existing on-site lead contamination. Native vegetation is planted around the site. The combination of the stormwater best management practices reduces the peak rate of runoff from the site for the two-year storm event by 0.7 cubic feet per second.

FIGURE 5. Lightweight extensive vegetated roof at the International Alliance of Theatrical Stage Employees Local 8 headquarters 10 months after installation . . . becoming established. (Courtesy Roofmeadow)

FIGURE 6. Subsurface rain tank detention system during installation prior to wrapping at the International Alliance of Theatrical Stage Employees Local 8 headquarters. (Courtesy SaylorGregg)



The Franklin Institute

One of the oldest centers of science education in the United States, The Franklin Institute was founded in 1824 as The Franklin Institute of the State of Pennsylvania for the Promotion of the Mechanic Arts.[10] It moved into the Institute's classical beaux-arts building on the Benjamin Franklin Parkway, designed by architect John T. Windrim, in 1934. Its mission is to inspire an understanding of, and passion for, science and technology learning.

In 2011, The Franklin Institute received a $10 million gift, the largest in its history, to help construct an ambitious new state-of-the-art addition on the south side of the building. This is the first major expansion project for the museum in more than two decades. The 53,000-square-foot Karabots Pavilion, to be completed in 2014, will contain a multi-room exhibit on neuroscience entitled "Your Brain," a modern conference center, an expanded education center with integrated learning technologies, a climate-controlled gallery for traveling exhibitions, and a large, sunlit atrium for visitor circulation.

The addition addresses the museum's multiple programmatic needs while also respecting the style of the original building. The exterior of the new wing will be clad in the same Indiana limestone as the original building, but also incorporates decidedly modern features, such as a dramatic stainless steel kinetic "shimmer wall" by the artist Ned Kahn that "makes wind visible," and extensive landscaping that mitigates stormwater drainage (Figure 7).

Capturing stormwater is important to the Institute, to whom sustainability is "a vital ideal." A national leader in sustainability and climate change research, the Institute believes,

> We must focus on meeting the needs of today without compromising the future. Our society must be built to last, and endure without damaging the environment. We must recognize our resources are limited, and dedicate our efforts to making sure future generations will have access to these resources. When possible, we must counter-act the damage already made.[11]

FIGURE 7. South elevation of the new Karabots Pavilion at the Franklin Institute, with terrace and rain garden at grade and kinetic "shimmer wall" above. (Drawing Art & Design Studios)

The project also involves ground-level landscaping that is as much a laboratory as it is a garden. Designed by SaylorGregg's landscape consultant Andropogon Associates[12], the 2,400-square-foot terrace and adjacent rain garden contain a landscape-integrated system of subsurface storage beds and regionally appropriate rain garden plants that will actively manage the stormwater generated by the building addition with no additional impact to the city's sewer system (Figure 8).

The site soils did not allow for infiltration, the test results having produced a rate of 0 to 1/4 inch per hour, which is below the acceptable Philadelphia Water Department minimum levels. But through a combination of rain gardens and subsurface detention, the post-development runoff rates for the additional impervious surfaces were reduced to pre-development runoff conditions. The rain tanks provided subsurface storage volume of about 7 feet wide by 47 feet long by 3 feet deep, accommodating a capacity of roughly 900 cubic feet for larger storm events.

Andropogon's solution manages stormwater, supports a diverse healthy landscape, enhances and ensures safe pedestrian traffic, and provides the Institute with didactic opportunities to acquaint the public with urban hydrology and natural systems. "We designed the terrace to be an extension of the interior spaces of the addition that functions independently from the building's main entrance," Andropogon's José Alminaña explains. A fence of vertical pipes embedded in the rain garden invisibly separates the grounds from the public sidewalk. The landscape provides a great amenity for both the Institution and the adjacent neighborhood.

A vegetated roof for the addition and other areas of the Museum has been evaluated and is being considered for the future. The project is expected to earn LEED silver (Figure 9).

FIGURE 8. Roof leader scupper ten inches above grade serving rain garden at the Franklin Institute. (Courtesy Andropogon)

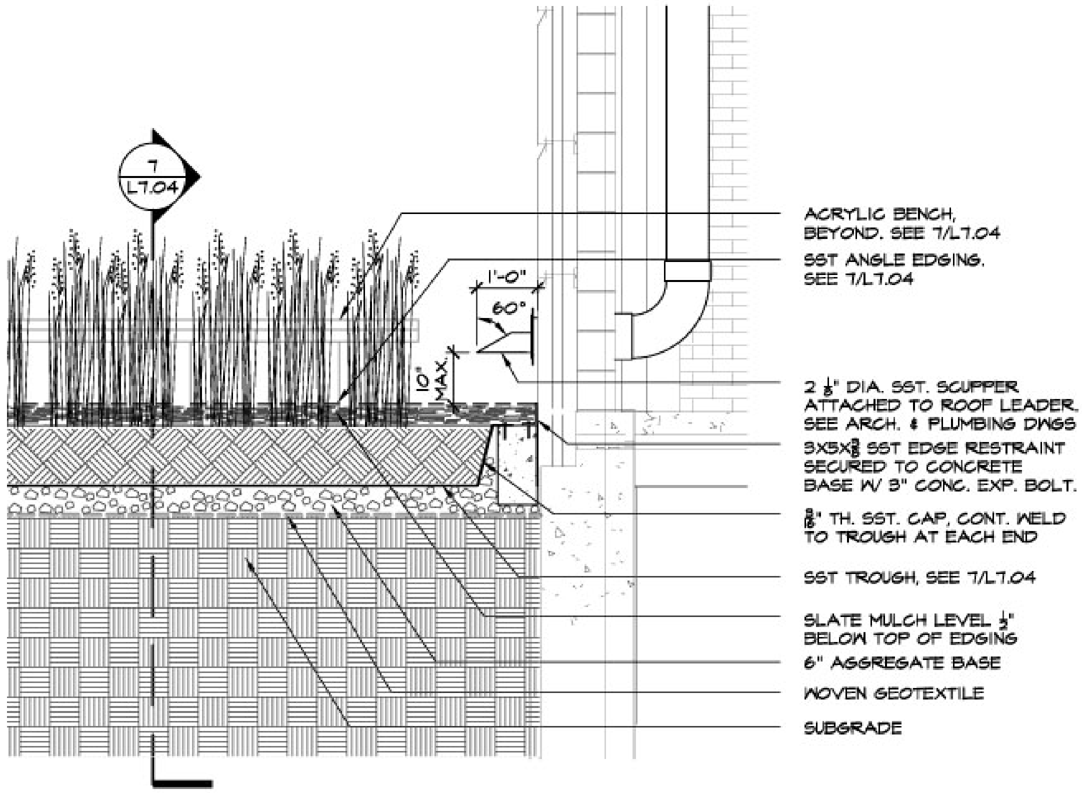


FIGURE 9. Proposed vegetated roofs on portions of the entire Franklin Institute building complex where structurally feasible. (Courtesy SaylorGregg)

Chestnut Hill College

Located on the northwestern edge of the Philadelphia City limits overlooking the Wissahickon Creek, Chestnut Hill College was founded in 1924 by the Sisters of St. Joseph.[13] Its mission is to provide students with "holistic education in an inclusive Catholic community marked by academic excellence, shared responsibility, personal and professional growth, service to one another and to the global community, and concern for the earth." The beautiful forty-five-acre campus expanded by thirty acres in 2006 when Sugarloaf Hill, a property across Germantown Avenue from the main campus, was acquired.

The master plan developed by SaylorGregg and Andropogon Associates derived from the College's desire to increase enrollment from approximately 1900 to 2900 students without negatively impacting the surrounding residential neighborhood and the volatile floodplain. Recognizing the dynamic setting of the two parcels, the master plan leverages the assets of the hills, the woods, the open greens, the creek, and the historic architecture to weave "The College on Two Hills" into one unified campus with the Wissahickon at its heart (Figure 10).

According to the Wissahickon Watershed Ordinance, impervious surface on Sugarloaf Hill cannot exceed 20% of the entire parcel. There is no such restriction on impervious surface on the main campus. However, the presence of both the 100-year floodplain and the floodway confine development. Each campus has a different stormwater management regulatory hurdle to meet.

For the master planning purposes, Andropogon used the ten-year, 24-hour storm event volume of 5.28 inches as the target storage volume for capture and infiltration. Each campus

FIGURE 10. Proposed Sugarloaf Hill campus of Chestnut Hill College in the foreground and original main campus beyond. Portions of new roofs to be vegetated "green" systems. (Drawing Art & Design Studios)

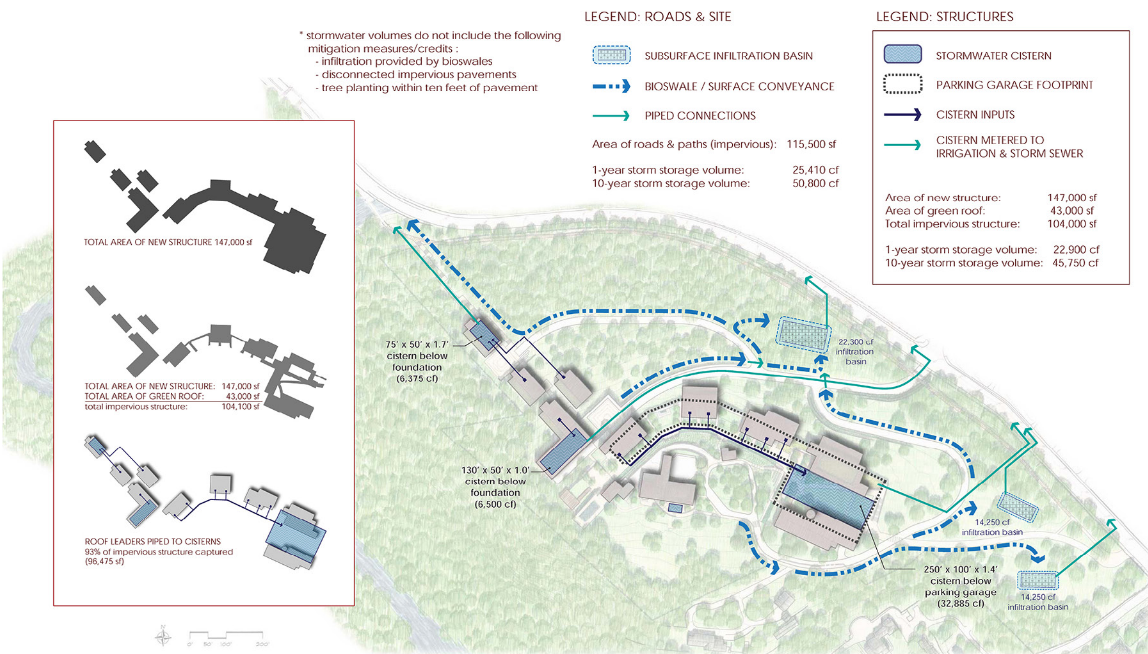
FIGURE 11. Proposed Sugarloaf Hill campus buildings of Chestnut Hill College atop parking structure and storm water cistern. (Courtesy Andropogon)

has a similar conceptual stormwater design: capture as much stormwater from rooftops as possible (the cleanest means of collecting rainwater) and direct it to a centralized cistern located in the foundation of the new development. The cistern is intended to infiltrate captured water back into the ground (Figure 11).

Recent geotechnical investigations show ample soil horizons above the water table to accommodate infiltration on both campuses. This technique of storage and slow release reduces or eliminates the large pulse of water (usually somewhat dirty with salts and oils and too warm to carry much oxygen) from new development to the Wissahickon Creek.

The most significant new building planned on the main campus will be a Student Center built atop a multi-level, 550-car parking structure. This will allow for the addition of much needed student activity space while removing a significant amount of existing surface parking impervious coverage from the floodplain. On the Sugarloaf property, the key structure will be a 450-car parking structure partially submerged into the hillside and topped with a vegetated roof and new college buildings. The architectural style and arrangement will draw from the main campus for its materials, proportions, and sequence of courtyards, each with a unique character. To maintain the historic hill town ambiance, the new construction and parking structure will be fully screened from the residential neighborhood by strategic siting and native landscaping.

FIGURE 12. Chestnut Hill College's proposed Sugarloaf Hill campus storm water cistern system. (Courtesy Andropogon)



Although porous pavement is an effective means of infiltrating water directly into soils, it was ruled out for these two structures and the surrounds. Porous pavement cannot occur on grades over 5% or where vehicular traffic is expected to be heavy, particularly where cars might be executing turns that can grind and shift porous asphalt or concrete (Figure 12).

Green roofs will effectively store stormwater and delay a stormwater pulse to the Wissahickon. Chestnut Hill College's intensive green roofs will be greater than 18" in soil depth so that they can store water volumes greater than the 1 year event and provide useful recreation campus spaces.

CONCLUSION

As in 772 other cities in the United States, Philadelphia's sewer system collects wastewater and storm runoff in the same pipes.[14] Lessening the impact and frequency of overflows is the focus of the Philadelphia Water Department's "Green City, Clean Waters" program, which has planted trees in median strips, rain gardens in parks, stormwater bump-outs at intersections, and other green stormwater infrastructure along streets and in other public spaces, in addition to regulating development.

Vegetated roofs and rain gardens, as these four projects illustrate, can slow down stormwater runoff and give aging sewer systems a break. As Levine suggests, "No city can ever go all the way back to nature, without tearing down all its structures, removing all its pipes, and restoring its streams and replanting what once grew here. But going back even part way, greening the city as we try to clean up our streams, is a good step in the right direction."[15]

NOTES

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Peter Saylor and Bill Gregg head up SaylorGregg Architects, a nationally-recognized design firm that provides full architectural services as well as planning, programming, and interior design from its office in Philadelphia. The firm specializes in higher education and cultural work and has completed award-winning projects throughout the United States, including the New Mexico History Museum, Logan Museum at Beloit College, Duke University School of Law, Lang Performing Arts Center at Swarthmore College, and the Pennsylvania Academy of the Fine Arts, among many others. To learn more about SaylorGregg, please visit www.saylorgregg.com.