Urban Filtration
Architecture as Watershed

Corey Griffin
Portland State University

"EPA estimates that about 850 billion gallons of untreated wastewater and storm water are released as combined sewer overflow each year in the United States."[1] As the urban population in the United States is estimated to increase by more than 20% by 2030,[2] aging urban infrastructure, particularly that infrastructure associated with water, will be overtaxed. Many water and sewer systems in our urban centers are at least 100 years old and simply not designed to meet contemporary demands and environmental standards, such as combined sewers that mix sewage and storm water. Replacing or upgrading the existing infrastructure is economically challenging as municipal revenues decline and funding is prioritized to meet the needs of new development at the periphery of urban areas. Consequently, a new model for how the urban-built environment meets its water needs is required.

Instead of connecting new urban buildings to existing water and sewage lines, these structures can provide an incremental improvement to the existing infrastructure, serving itself and surrounding buildings by filtering, processing, and utilizing waste and storm water. More importantly, the architecture of these urban filters must provide tangible connections between building users and the resources they use. Strategies that mimic the filtration of water in nature, such as principals employed by living machines, should be prioritized over those that rely on conventional, energy-intensive mechanical or chemical treatments. By integrating plant-based filtration systems throughout its height and area, a single building can act as watershed for its surroundings through the catchment, purification, and percolation of water.

AGING INFRASTRUCTURE

There are two types of sewer systems primarily used in the United States: combined sewer systems and sanitary sewer systems. Combined sewer systems (CSS) use a single pipe system to transfer both sewage and storm water to wastewater-treatment facilities, while sanitary sewer systems maintain separate systems for sewage and storm water. CCS were commonly used before the twentieth century, particularly in urban areas near a lake or river. This is due to the design of CSS to discharge any flow that exceeded the capacity of the system into nearby surface waters. This type of discharge is called a combined sewer overflow (CSO) and typically occurs when rain, snowmelt, or other surface runoff is present. A CSO can occur during dry periods, as well as due to sediment or other solids building up in pipes, temporarily reducing the capacity of the system. According to the U.S. Environmental Protection Agency (EPA), CCS still serve 772 communities and 40 million people in the United States. Accordingly, CSOs account for roughly 7% of the sewage discharged annually.[3] The other 93% is discharged as treated wastewater.

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Despite action taken by the EPA in the early 1990s to curb CSOs, it is difficult to believe that municipalities are still discharging sewage into rivers and lakes. The environmental consequences of this pollution are profound and endanger both human health and the biological viability of rivers and lakes. Bacteria, other disease-causing pathogens, and pollutants are a threat to humans through physical contact, ingestion, and inhalation of contaminated water. Oxygen-depleting substances and suspended solids can make waterways uninhabitable for fish and other aquatic life. Fish caught in waters affected by CSOs can be toxic for human consumption. Due to the impacts of this pollution, the residents of urban areas are physically disconnected from nearby bodies of water whose only value now is the vistas they can provide.

CASE STUDY

Portland, Oregon, is known for public transit, green buildings, and smart urban growth, and as a result, it was chosen as the most sustainable city in the United States in 2008.[4] Despite the abundance of water from more than 37 inches of rainfall, the snowpack on nearby mountains, as well as the Columbia and Willamette Rivers, Portland has its own water crisis. Not only is the Willamette River, which runs through Portland's center, an EPA Superfund site due to decades of manufacturing and port activities in the lower basin but also the river is still regularly polluted by CSOs. During the summer of 2009 (May 15 to October 15), the Portland Bureau of Environmental Services issued seven CSO advisories due to rainstorms. Eight CSO advisories were issued during the summer of 2010 and five during the summer of 2011.[5] During past rainy winter seasons, Environmental Services issued a general seasonal advisory through which the public is asked to avoid all recreational activities in the river. Overall, it is estimated that there were a total of 50 CSO events in 2011.[6] While residents and visitors frequently use the parks and paths along the edges of the Willamette River, exceedingly few people go into the river itself, even in some type of boat, due to the smell and appearance of the water even when there is no CSO advisory.

These CSOs occurred despite significant efforts by the city of Portland to reduce runoff into the CCS over the past 20 years. Costing $146 million, a series of "Cornerstone Projects" diverted more than 2 billion gallons of storm water through a series of projects including water sewer separation, storm water sump installation, downspout disconnection, and stream

Figure 1: CSO warning sign on the Eastbank Esplanade of the Willamette River with downtown Portland, Oregon, in the background (photograph by author).

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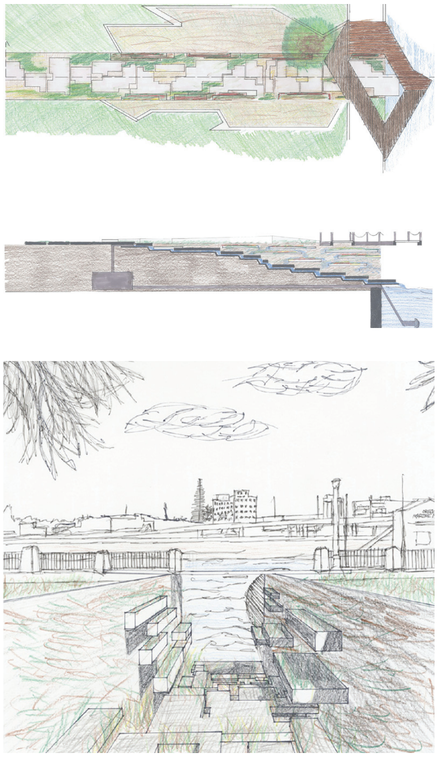

Figure 2: One-week introductory project to transform a small section of the river's edge to improve water quality through a landscape-integrated, gravity-fed living machine (images by Nic Saarinen).

diversion.[7] The city has also encouraged the construction of ecoroofs on new and existing buildings to decrease storm water runoff. As of May 2011, 288 ecoroofs had been installed, accounting for 14 acres of vegetation.[8] The city of Portland just completed a 20-year program to reduce CSO discharge by 96% by installing a 14-foot-diameter pipeline along the west bank of the Willamette River and a 22-foot-diameter pipeline along the east bank. These pipelines will carry water to a new treatment plant downriver. The "Big Pipe" project cost $1.4 billion, which is being passed onto residents through utility bills. In 1991, the average household paid $14 a month for sewer and storm water service.[9] As of December 2008, the average monthly sewer and storm water service charge was $49.90,[10] and this fee will be increased to almost $60 by 2013, or more than four times that in 1991.[11] Despite this extraordinary investment in new infrastructure, it is still anticipated that there will be an average of four CSOs each winter and one every third summer.[12]

Even if the cost of these large infrastructure projects can be justified, their success in reducing sewage released into the Willamette River is not guaranteed. In November of 2009, a wastewater-treatment plant upriver from Portland in Oregon City experienced a power outage for six hours, during which time 3 million gallons of raw sewage was discharged in the Willamette River. A construction accident on August 9, 2010, caused a blocked sewer pipe to discharge 1,400 gallons of raw sewage into the river over the course of an hour. An estimated 3,000 gallons of raw sewage accidentally spilled into the river near downtown on May 30, 2012, due to maintenance work at a pump station that is part of the Big Pipe project. These examples show the dangers of an increasing centralized wastewater-treatment infrastructure that relies on large singular paths and facilities. Through human error or other uncontrollable circumstances, a significant amount of sewage can still be discharged into the river.

Furthermore, this increase in infrastructure size, e.g., the Big Pipe, is analogous to the widening of freeways. As traffic reaches capacity, a freeway is widened and traffic is reduced temporarily. The increased capacity encourages greater use of the freeway, or the population using the freeway increases until the traffic is as bad as it was before the widening. As the population of the urban center continues to increase, even new, seemingly oversized water infrastructure will reach its capacity, requiring another significant investment of resources. A decentralized approach in which the architecture of urban office buildings could actively contribute to the filtration of waste and storm water could reduce the cost of water treatment by incrementally increasing the infrastructure need as new buildings are constructed. This decentralized system could sustain a loss of a single filter without discharging significant amounts of sewage into surface water.

DESIGN INTERVENTION

During a recent 10-week spring quarter, students in their final undergraduate studio at Portland State University were asked to design a 60,000-square-foot Center for Urban Ecology at the edge of downtown Portland, adjacent to Gov. Tom McCall Waterfront Park and the Willamette

River. The studio was taught by an architecture faculty member, a practicing architect whose award-winning work focuses on the intersections of architecture, landscape, and ecology and a practicing landscape architect who was a pioneer in green roofs, storm water retention gardens, and edible landscapes in Portland. This interdisciplinary teaching team was critical in expanding the students' considerations about the role of architecture as part of complex urban ecologies and ensured the students addressed the full range of associated multidisciplinary issues. The proposed building was to be a combination of retail, office, and laboratory spaces for a series of commercial, government, and academic tenants who are all associated with issues of urban ecology. The students were expected to contribute positively to their urban ecology and engage people in these ecologies as realistically as possible within the constraint of an office building in order for their projects to be relevant models for future development.

At the beginning of the course, the students were specifically asked to research one aspect of urban ecology that would be the focus of their investigations and eventual design intervention. These strategies were focused in three areas—water quality, flora, and food production—and included rainwater collection, graywater reuse, living machines, bioswales, biochar, green walls, green roofs, wildlife habitat, and different types of agriculture (soil-based, hydroponic, and aeroponic). This research consisted of understanding both the larger biological, chemical, physical, and ecological issues involved and how buildings in general contribute to this aspect of ecology. The students looked at the status quo in the urban environment and how could it be improved through architecture. After understanding the larger issue, students described how the urban ecology strategy they chose contributes to or improves the ecological condition using diagrammatic plans, sections, and axonometric drawings. Students presented three built (or unbuilt) case studies of their chosen strategy. About one-third of the students focused on urban agriculture, one-third focused on issues of plant and wildlife habitat, and the final third focused on water quality.

Before attempting to integrate their research into a building, students were asked during a one-week charrette to insert "disruptive, strange, beautiful, and possibly educational experiences" using one or more of the urban ecology strategies researched into everyday life along the sidewalk connecting the corner of Naito Parkway at Pine Street (the corner of the proposed site for the Center for Urban Ecology) to the edge of the Willamette River through the riverfront park. Students were asked to focus their energies on a few meaningful design moves. These exercises were reviewed by all of the instructors and provided a springboard for how to create meaningful interactions between people, architecture, and ecological systems in their architecture.

Due to the project site's proximity to the Willamette River, all four of the students who explored issues related to water focused on how to remediate the river by reducing storm water runoff and CSOs. Each of the interventions posited that if the strategies in this single building could be duplicated in future construction throughout downtown and beyond, the water quality

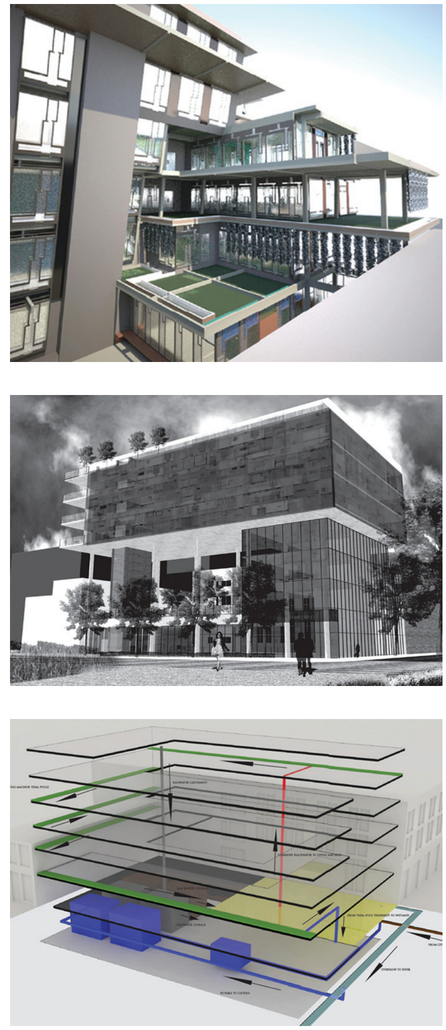

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Figure 3: Three projects focusing on water quality as it related to larger issues of urban ecology and CSOs. From left to right: Filtering storm water through a series of waterfalls and basins, a vegetated storm water storage pool for the ground plane with program spaces above the ground and replacing sidewalks with wooden boardwalks, and a diagram highlighting how an entire building can act as a living machine for part of the downtown urban core (images left to right by Nic Saarinen, Javier Figueroa, and Cory Trano).

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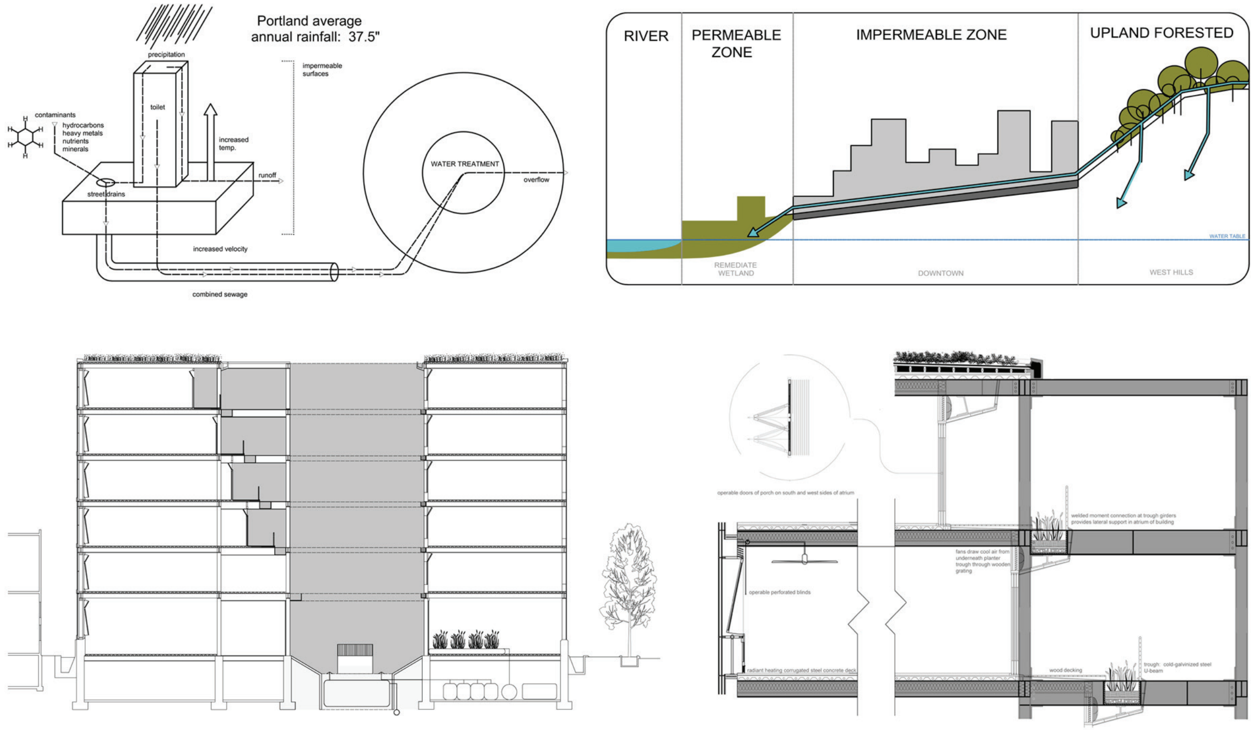

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Figure 4. Diagrams explaining the current problem with the combined sewer and how the introduction of a permeable zone between downtown and the river could address these problems (above). A section and detailed section through the proposed Center for Urban Ecology, highlighting the distributed plant-based filtration system, green roof, and other water-filtration systems at the ground level. The detailed section highlights the conventional construction coupled with the vertical watershed intervention throughout the building (images by Dan Walker).

Figure 5. Perspective of the Center for Urban Ecology as a vertical watershed (image by Dan Walker).

of the river could be significantly improved. Two of the students focused on collecting storm water from adjacent buildings and streets. The first focused on filtering the water through a series of waterfalls and basins. The second covered the vast majority of the ground plane with a vegetated storage pool, raising many of the program spaces above the ground and replacing pavement with wooden boardwalks. Both projects strove to reduce the amount of storm water sent to the sewer as well as filter the storm water so that it could be discharged directly into the river.

The third student inverted the combined sewer process by routing a nearby sewer line into his project, cleaning the blackwater using a large living machine in the basement and pumping the resulting graywater to the roof. Here the graywater mixes with storm runoff and other graywater from the building. This combined water travels through a series of vegetated troughs formed out of the concrete floors until it reaches the ground and is clean enough to be discharged directly into the river. As new buildings are erected throughout the downtown, they could be equipped with similar systems, creating a distributed water-treatment infrastructure.

The most radical of the four proposals suggests leaving the center of downtown unaltered and creating a permeable zone at the river's edge through the conversion of the existing park and a boulevard along the river's edge back into a wetland. This strategy uses the scale of a watershed to address issues of storm water runoff and exploits the natural topography of downtown by creating a new interface between downtown and the river. The boundary between this new flood park and the impermeable urban core would be a series of vertical watersheds based on his proposal for the urban ecology center. The role of the new permeable zone is to slow the flow of runoff and filter it as much as possible before it enters the river. The buildings in this zone serve a similar function for slowing and filtering water that falls within this zone. Green roofs and stepped, vegetated troughs built into the structural steel frame of the building allow for an adequate distance for the water to be cleaned and then stored for use in the building. A living machine on the ground floor treats sewage from the building and serves as a demonstration center to the public.

CONCLUSION

Architects and architecture students must look beyond the boundaries of their site and to unglamorous aspects of the built environment, such as wastewater-treatment infrastructure, in order to address pressing environmental challenges. A distributed infrastructure—water supply, waste treatment, or electricity generation—housed within our architecture challenges the mega-projects of civil engineers by providing incremental, cost-effective, and adaptive solutions to meeting the resource needs of future urban populations. By showcasing systems typically hidden, we can remove the disconnect between user and resource. By doing so, we can make individuals acutely aware of how their decisions affect the environment around them. ◆

ENDNOTES

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