Urban Transformations

A Phased Approach to Green Infrastructure Implementation at the University of Illinois at Chicago

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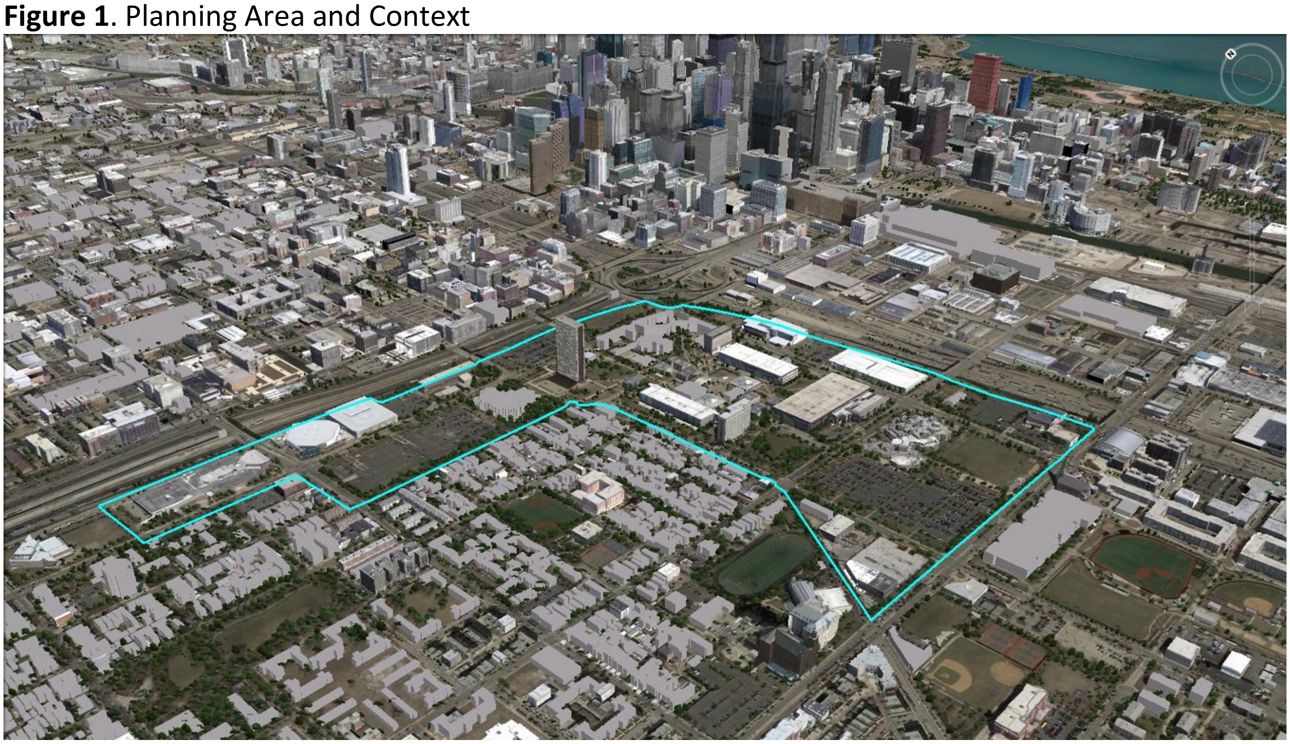
ABSTRACT

Urban flooding in Chicago is chronic, systemic and costly. As urban water systems are increasingly stressed due to the combined effects of climate change, impervious land cover and resources limitations, there is a growing demand for scientifically-robust and politically-nuanced strategies for transitioning cities towards more sustainable water management practices (Ferguson et al., 2013a). The *Urban Transformations* planning process demonstrates an incremental, scalable, and adaptive approach to implementing green infrastructure in a highly urbanized context. The purpose of the *Urban Transformations* collaborative environmental planning effort was to engage an interdisciplinary team of students and university stakeholders in the development of a green infrastructure master plan for the 2014 Environmental Protection Agency's Campus RainWorks Challenge. The outcomes of this effort include a final green infrastructure master plan, a phased implementation plan and a Letter of Support from the Vice Chancellor for Administrative Services. As a high-impact public research institution located near the heart of a global city, the University of Illinois at Chicago's strategic institutional and geographic position makes the university an excellent place to test and scale-up this phased approach to green infrastructure implementation. When implemented, the *Urban Transformations* Green Infrastructure Master Plan will not only help mitigate urban flooding in Chicago, but will also contribute to regional, national and international dialogues on how cities can transition towards more sustainable and resilient water management practices.

Figure 1. Planning Area and Context



PROJECT CONTEXT

PLANNING PROCESS

From September 2014 to December 2014, the University of Illinois at Chicago (UIC) Campus RainWorks Challenge (RWC) Project Team (herein the project team) conducted a collaborative environmental planning process (Randolph, 2012) in order to develop a green infrastructure master plan for UIC's East Side (Design Board 1: Figure 1). The planning process consisted of five primary steps: 1) project scoping; 2) data collection and asset inventory; 3) collaborative green infrastructure network mapping; 4) green infrastructure master plan refinement; and 5) final design and submission.

During the project scoping, the geographic (i.e. UIC's East Side) and temporal (i.e. ten years) scope of the plan was defined, the project team was finalized, a purpose and needs statement was drafted, and a literature review was initiated. The project team intentionally deferred any final design and planning decisions until later stages to allow ideas and information to emerge throughout the planning processes.

The datasets used in *Urban Transformations* were collected through a variety of sources including: interviews with campus stakeholders, geographic information system (GIS) data layers accessed through the Office of Facilities and Space Planning and literature (e.g. UIC plans and policies and peer-reviewed articles on green infrastructure). Using GIS, these datasets were compiled into a series of overlay maps that characterized the planning area's (Figure 1) predevelopment and existing conditions (Figure 2).

These GIS maps were then overlaid and used in a collaborative green infrastructure network mapping context. Over the course of six planning and design workshops, 20 students (undergraduates and graduates) and faculty members from four disciplines collaborated in the design and phasing of an interconnected green infrastructure network on campus. The "Four Phases of Urban Transformation" concept emerged during this project step.

On December 3, 2014, Curtis Witek synthesized concepts from *Urban Transformations* with input from water management experts in Chicago into a policy essay on urban water management that was solicited by, and submitted to, the City of Chicago's Office of the Mayor. On December 8, 2014, the project team presented the *Urban Transformations Green Infrastructure Master Plan* (herein the master plan) to a group of UIC stakeholders including the Vice Chancellor for Administrative Affairs, the Associate Vice Chancellor for Student Affairs, the Director of Facilities and Space Planning, and the Associate Chancellor for Sustainability. In addition to Letter of Support from Vice Chancellor for Administrative Services (M17-Letter), letters of support were provided by the Head of UIC's Department of Urban Planning Policy and the RWC project's adviser. These letters support the interdisciplinary planning approach and the analytical robustness of the performance evaluation included in *Urban Transformations*. An award through EPA's RWC will greatly increase the likelihood of Urban Transformations' implementation by supporting the plan with funding, enhanced exposure and credibility.

ANALYSIS APPROACH

The EPA's National Stormwater Calculator was used to calculate the changes in stormwater runoff from the study area. The calculator uses the EPA Storm Water Management Model (SWMM) as its computational engine, permitting the rapid modeling and comparison of plausible stormwater management benefits that can be attained by different low impact development scenarios (herein green infrastructure). Outputs from the EPA National Stormwater Calculator include runoff reduction, changes in infiltration and evaporation rates, and reduction in impervious area. The EPA's Spreadsheet Tool for the Estimation of Pollutant Load (STEPL) was used to calculate the estimated changes in nutrient loads to the Metropolitan Water Reclamation District of Greater Chicago (MWRD) combined sewer system.

The stormwater runoff analysis takes into account the local soil conditions, topography, land cover and meteorology. Soil type and soil drainage information was obtained though the United States Department of Agriculture's (USDA) Natural Resources Conservation Service (NRCS) SSURGO database. Topography of the area was assumed to be mostly flat (having slopes of 2% and less); this was validated by the SSURGO database. Precipitation and evaporation rates were obtained from the National Weather Service's (NWS) National Climatic Data Center (NCDC). The climate data at Chicago's Midway Airport was chosen to be the most appropriate source of climate data for the site because of its proximity to the campus. The stormwater runoff analysis used 10 years of precipitation and evaporation data to simulate baseline conditions, as well as the future scenarios of the three phases.

Land cover and land use GIS data layers were gathered and assembled into a geodatabase, which were used to map and analyze existing campus conditions and the various green infrastructure implementation phases. This mapping exercise yielded an area of 141.6 acres. Design criteria for sizing green infrastructure were in accordance with local conditions, as well as stormwater management goals and requirements including the MWRD watershed management ordinance (WMO)[1], the City of Chicago's 2014 Stormwater Management Ordinance Manual[2], and the City of Chicago's Green Stormwater Infrastructure Strategy[3].

EXISTING CONDITIONS

The master plan area—UIC's "East Side" (Figure 2)—is located southwest of Chicago's "Loop" in the University Village and Little Italy neighborhoods. A GIS analysis revealed that UIC's East Side is composed of 70% impervious land covers. Running the baseline conditions through the EPA's Stormwater Calculator indicates that 70% of the annual precipitation that falls on the landscape becomes runoff into the MWRD combined sewer system. The campus' current biophysical arrangement (i.e. roofs, lawns, sidewalks, parking lots, etc.) is unable to manage the "first flush" (i.e. first inch of rain fall) of a 100-year, 24-hour storm event.

In light of these baseline conditions, the project team conceptualized, analyzed, planned, and designed a green infrastructure network on campus which will provide stormwater management and water quality improvements, in addition to numerous other co-benefits such as enhanced educational and recreational landscapes and sustainability.

1: http://www.mwrd.org/irj/portal/anonymous/managementordinance
2: http://www.cityofchicago.org/.../2014StormwaterManual.pdf
3: http://www.cityofchicago.org/city/en/progs/env/water.html

Figure 2. Existing Conditions (2014) for UIC's East Side

PROPOSED GREEN INFRASTRUCTURE MASTER PLAN

THE FOUR PHASES OF URBAN TRANSFORMATION

Urban landscapes cannot be transformed overnight. Once established or installed, the institutional and physical structures that compose a city's urban fabric (e.g. zoning ordinances, street layout, and water infrastructure) are highly rigid and difficult to change. Complex socio-ecological problems like urban flooding require planning and management approaches that both operate within and transform a city's interrelated biophysical, socio-technical and socio-economic systems. Recognizing the deficiency of conventional approaches to urban infrastructure and operational challenges (e.g. linear problem solving, system optimization), an incremental and adaptive approach was developed to support the implementation of the master plan. The strategic, incremental, and adaptive approach to green infrastructure implementation that was developed for *Urban Transformations* can be transferred to virtually any functional scale—from a university campus or neighborhood to a mega-region. The project team framed this approach as "The Four Phases of Urban Transformation," which are: 1) Demonstrate; 2) Optimize & Adapt; 3) Integrate; and 4) Transform.

PHASE 1: Demonstrate (2015-2017)

Increasing general awareness is the first step in transitioning towards any new planning paradigm, concept or approach. UIC should initiate (or restart) collaborative, interdepartmental processes intended to cultivate a collective understanding of the campus' water management problems. Doing so would yield a shared vision for a sustainable and resilient future as well as align goals for working towards that vision. Although green infrastructure demonstration projects are often criticized for being expensive, ineffective and uncoordinated, they are critical for generating public awareness, and advancing the science needed for more efficient design. The first phase *of Urban Transformations* is focused on the demonstration of green infrastructure (Design Board 2: Figure 7).

Investments in green infrastructure demonstration projects should be targeted towards highly-visible and cost-effective projects in order to increase awareness and support for green infrastructure and to maximize the potential for successful projects. Monitoring systems should be integrated into initial demonstration projects to permit learning (Blackmore and Jiggins, 2007) and adaptive management.

PHASE 2: Optimize & Adapt (2018-2020)

Once several demonstration projects have been installed and multi-seasonal monitoring data has been collected, UIC campus planners and managers will have the observational data needed to optimize the system and adapt to emergent patterns and changing conditions. New green infrastructure investments and installations should expand on successful projects from Phase 1. The reversion of unsuccessful installations back to conventional infrastructure or land uses—if cost-effective—is also permitted in such an adaptive management approach.

The collection of high-quality and highly-resolved time-series data during Phase 1 will greatly enhance the capacity for planners to apply an adaptive management approach. The data can also be leveraged when applying for grants funding allocated for green stormwater infrastructure, watershed improvements and environmental education (e.g. Chi-Cal Rivers[1] Fund, Sustain Our Great Lakes[2], Section 319 Funds[3]).

One strategic green infrastructure opportunity is the former Commonwealth Edison (ComEd) electrical transformer site that UIC is currently acquiring. The master plan recommends remediating the site and transforming it into a stormwater wetland (Design Board 1: Figure 2). This type of design illustrates the transformative change these projects seek to initiate.

PHASE 3: Integrate (2021-2025)

By the end of Phase 3, green infrastructure—both the biophysical infrastructure and planning concept--should be integrated into UIC's campus management and institutionalized into the university's governance. Green infrastructure should be considered in all building standards, planned maintenance projects and capital improvement and master planning processes. Through demonstration, optimization, and adaptation used in Phase 1 and Phase 2, the university community has been introduced to green infrastructure and will hopefully support its further installation on campus. Educational signage and public outreach campaigns during previous phases can help build this support. Building such support can translate into increased willingness of the various stakeholders to allocate a larger portion of the university's budget to the installation of green infrastructure. The development of a long-term comprehensive plan for integrated green and conventional infrastructure capital improvement projects will also expand

1: http://www.nfwf.org/chi-cal/Pages/home.aspx
2: http://www.sustainourgreatlakes.org/Apply.aspx
3: http://water.epa.gov/polwaste/nps/319hfunds.cfm

the university's access to grant funding and other forms of assistance and innovative, market-based financing (e.g. stormwater retention credit trading system).

PHASE 4: Transform (2025+)

As the title would suggest, the ultimate goal of this master plan is to *transform* UIC's campus from one that suppresses natural hydrological and ecological functions, to one that reconciles these functions with social processes and educational goals that the university must support. Much of this transformative change will emerge incrementally as the green infrastructure network evolves and expands, and as institutional support accumulates over time.

The main product to result from this collaborative planning process was the master plan for UIC's East Side (Design Board 1: Figure 1). In additional to providing substantial stormwater management benefits, the implementation of this master plan would tell a powerful story of how ecological, hydrological, and social processes can be reconciled within the context of a highly urbanized and modernist campus.

EXPECTED OUTCOMES

ANALYSIS OF BENEFITS

There is a growing body of qualitative and quantitative evidence suggesting that supplementing conventional stormwater infrastructure systems with green infrastructure can deliver positive economic, social and environmental benefits (e.g. EPA, 2014; Jaffe et al, 2010). Although this plan focuses primarily on stormwater management benefits and water quality improvements, there are a variety of co-benefits such as new educational and recreational landscapes, and marketing and sustainability benefits that can be obtained by implementing this master plan.

The project team coupled modeling outputs from the EPA National Stormwater Calculator with a green infrastructure asset inventory map, stakeholder interviews, consultation with experts, and a collaborative green infrastructure planning process to craft a green infrastructure master plan for UIC's East Side that balances effectiveness with feasibility.

ANALYSIS RESULTS

Inputting the calculated green infrastructure areas for each phase into the EPA Stormwater Calculator produced the results contained in Table 1. Rain gardens and infiltration basins had capture ratios of 100%, meaning that the ratio of the green infrastructure's area to the impervious area that drains onto it was assumed to be 100%; for street planters the capture ratio was 63% (due to variations in street drainage design and topography. For permeable pavement a 100% capture ratio (conversion of 100% of the pavement to permeable) was used. These ratios were then applied by the Stormwater Calculator to the area of green infrastructure implementation. To check the sensitivity of the calculated results to the selection of capture ratio, the Size for Design Storm (Size for DS) option was explored in the calculator. Using the same areas of green infrastructure implementation as phase 3, the Size for DS option automatically adjusts the capture ratios for the user. This resulted in: 59% capture ratio for rain gardens, 45% capture ratio for infiltration basins, 72% capture ratio for street planters, and 100% capture ratio for porous pavement. The 24-hour, 100-year storm (7.58 inches for Northeastern Illinois) was chosen as the design storm (Huff and Angel, 1989). The results show that runoff decreased with each phase of implementation and has decreased nearly 25% annually by the end of phase 3 implementation. Additionally, these results do not vary significantly due to the selection of the capture ratio. The 25% annual runoff volume reduction is a reduction of 92.5 acre-feet of runoff. Currently the MWRD is under a consent decree with the U.S. federal government to treat 2 million gallons of stormwater using green infrastructure in the next 5 years, 5 million gallons in the next 10 years, and 10 million gallons of stormwater runoff using green infrastructure by 15 years after the consent decree (Corfman, 2014; Water World, 2014).

Full implementation of the *Urban Transformations* Green Infrastructure Master Plan will yield a reduction of 92.5 acre-feet of runoff annually, which is approximately equal to 30 million gallons of stormwater runoff reduction. This means that *Urban Transformations* will not only help the MWRD achieve its consent decree mandates in the next 15 years, but would also capture 3 times the amount of stormwater that UIC would be required if subject to the MWRD's Watershed Management Ordinance. Notably the storage capacity of the MWRD's traditional stormwater infrastructure, the tunnel and reservoir plan (TARP), will be 15.15 billion gallons of stormwater at completion in 2029 (MWRD, 2013b). Therefore, capturing 15 million gallons of stormwater represents capturing one tenth of a percent of the future total capacity of the TARP system.

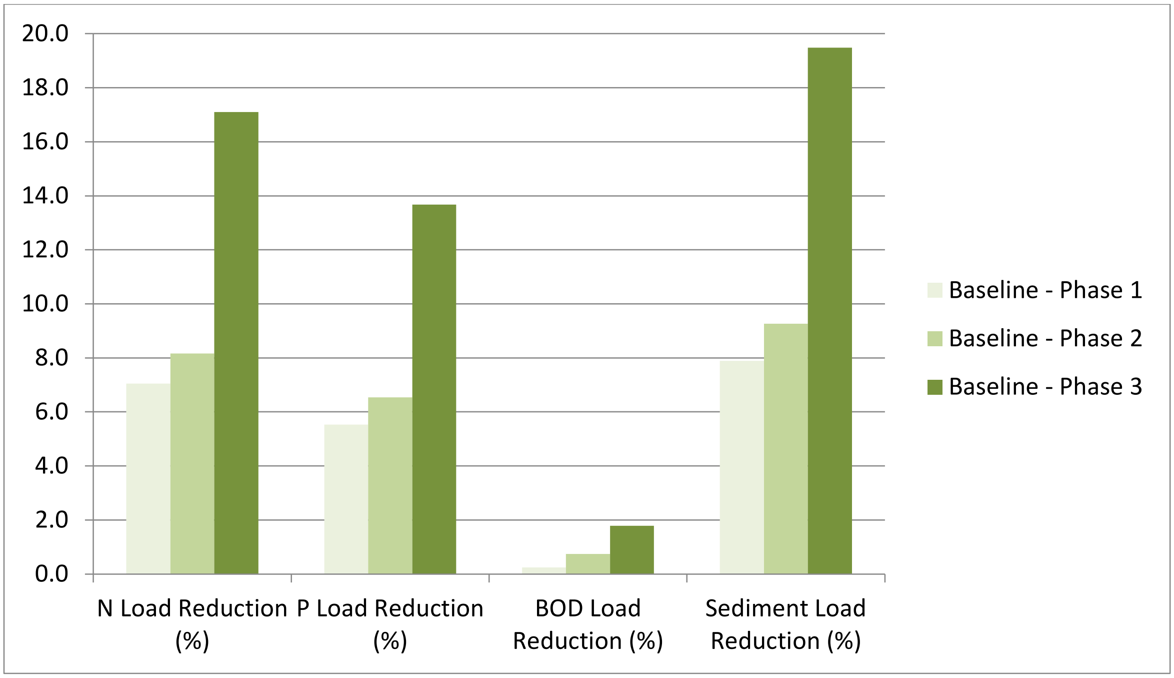
Table 1. EPA Stormwater Calculator Benefits by Phase

	Baseline	**Phase 1**	**Phase 2**	**Phase 3**	**Phase 3 Size for DS**
Average Annual Rainfall (in.)	45.97	45.97	45.97	45.97	45.97
Average Annual Runoff (in.)	32.19	29.62	28.34	24.52	24.35
100 Year Storm Runoff (in.)	5.40	5.00	4.85	4.35	4.15
Annual Runoff %	70.0	64.0	61.0	53.0	53.0
Annual Infiltration %	20.0	26.0	28.0	35.0	35.0
Evaporation %	10.0	10.0	11.0	12.0	12.0
Annual Runoff Volume (acre-ft)	379.842	349.516	334.412	289.336	287.330
Reduction in Volume %	-	8.0	12.0	23.8	24.4
100 Year Storm Runoff Volume (acre-ft)	63.675	58.958	57.190	51.294	48.935
Reduction in 100 Year Storm Runoff Volume %	-	7.4	10.2	19.4	23.1

1 acre = 43,560 feet; 1 acre-foot = 43,560 ft^3 = 325,851.429 US gallons

The water quality analysis results from STEPL indicate a 17% reduction in nitrogen (N) loading, 14% reduction in phosphorus loading, 2% reduction in biological oxygen demand (BOD) loading, and a 20% reduction in sediment loading from baseline conditions to the full implementation of green infrastructure described in phase 3. The incremental reduction in nutrient and sediment loading from baseline to each phase is presented in Figure 3.

Figure 3. Nutrient and Sediment Load Reduction by Phase



COSTS

To assess the feasibility and likelihood of implementation of this phased approach, the cost of construction and maintenance were calculated for each type of green infrastructure (e.g. rain garden, green roof, infiltration basin, permeable pavement). Information on the cost per square-foot of green infrastructure type was obtained from the Center for Neighborhood Technology (CNT), a nonprofit “think-and-do-tank” that is a national leader in developing sustainable urban solutions. CNT’s Green Values® National Stormwater Management Calculator provides low, mid, and high cost estimates for green infrastructure implementation and maintenance (CNT, 2014). The costs as calculated and presented here use the mid value to project the cost of the phases. The cost for the construction and maintenance is broken into three phases with a total of $21,244,802 for this project (Design Board 2: Figure 6). The assumptions of this analysis are that the green infrastructure projects are implemented within the first year of the phase, with maintenance needing to be conducted for the rest of the phase. The maintenance costs are additive over the phases. The total construction and maintenance costs over the full design period are presented. Current projections of costs are calculated using the midrange values for both cost categories.

MAINTENANCE

Maintenance is critical in maintaining the effectiveness of green infrastructure once it is installed. In addition to planning for maintenance before determining the design for each site, certain practices consistently managed throughout the project phasing. Permeable pavement needs maintenance to keep plants from rooting into the pavement, monitoring and maintenance of the infiltration rates (vacuum sweep once to twice annually), and snow removal with a rubber blade or by sweeping. Bioswales (i.e. infiltration basins) need to have monitoring to ensure that infiltration is happening within 72 hours; monthly mowing, weeding, and trash removal helps in this respect. Additionally, the infiltration rates should be monitored during snow melt and heavy rain conditions. Rain gardens (i.e. wetlands) need to be checked every couple of weeks to see that water is being retained appropriately such that wetland vegetation is supported. They should also be inspected in the winter to make sure that unfrozen water is not stagnant; the water should not be stagnant in a wetland. Seasonal mowing of emergent areas as well as removal of weeds, woody growth, and trash help ensure that the wetland maintains its effectiveness. Green roofs need fertilization, weeding, and care during the first 12-15 months after installation. Continued inspections should be done to check for leaks, cracks, dead plants, and blocked drains. This will maintain the efficacy of the green roof and the structural soundness of the roof itself.

Green infrastructure designs will be selected that optimize efficiency while minimizing maintenance. For instance, intensive (thinner soil layer, consists of few species of plants) green roofs instead of extensive (thicker soil layer, consists of large variety of plants) green roofs are recommended for campus. Intensive green roofs require less soil, produce less structural concern, and generally have lower maintenance costs. Additionally, continued institutional awareness and management of green infrastructure projects is critical to the long-term functioning of such dynamic infrastructure. Over time, an institution can forget where they have green infrastructure that needs managing. Educational signage can help maintain consistent knowledge of green infrastructure and as well as provide public awareness for the green infrastructure that is around them.

FEASIBILITY

Although the *Urban Transformations* Green Infrastructure Master Plan presented is ambitious, the phased approach leverages an incremental scaling-up of green infrastructure projects and financing options, which greatly increases the plan’s feasibility. The most difficult phase of such transitional projects is often the beginning. Phase 1 allows green infrastructure to gradually be implemented in key connection points around campus. These projects will demonstrate the immediate benefits to students and the broader university community in a way that does not disrupt university life. Phase 2 expands on successful Phase 1 projects and begins linking fragmented green infrastructure installations into an integrated network. Phase 3 will complete this integrated green infrastructure network. Through Phase 3 and Phase 4 the network will have gradually transformed a modernist campus into a landscape where social, hydrological, and ecological systems are restored and reconciled.

Cost and maintenance issues are often cited as concerns mediating a community's decision to implement green infrastructure. Phasing the implementation of green infrastructure helps to mitigate these concerns. Additionally, green infrastructure alternatives can be integrated into planned maintenance improvements, such as sidewalk repairs. Over time, the costs of maintaining conventional infrastructure (e.g., lawns) can be shifted into the installation and maintenance of green infrastructure. The Vice Chancellor for Administrative Affairs' recommendation to integrate *Urban Transformations* into UIC's building standards, planned maintenance projects, and capital and master planning efforts was a critical step for achieving plan implementation.

HIGH WATER TABLE AND CLAY SOIL

The water table on UIC's East Side lies approximately 2-6 feet below the surface according to information from the National Resources Conservation Service (NRCS) Web Soil Survey (NRCS, 2014). In many areas, the clay and loamy soil prevents significant drawdown of the water table due to low hydraulic conductivity. These soil conditions limit the efficacy of green infrastructure to provide infiltration and storage benefits. Given these conditions, most green infrastructure projects on campus will need an underdrain to help transport excess water to other nearby storage locations (i.e. stormwater wetlands) and eventually the sewer system. In locations with no additional nearby storage to redirect water to, green infrastructure projects would be less effective and therefore less likely to be installed.

UNIVERSITY CONSTRUCTION AND IMAGE

The University's 50-year plan was considered during the *Urban Transformations* planning process. In general, any campus areas with new construction planned for the future was considered off limits for green infrastructure. This limited the proposed area that could be treated by green infrastructure, but decreases the number of contested projects and thus increases the master plan's feasibility.

The UIC campus was designed by the Skidmore, Owings, and Merrill architect Walter Netsch. As this campus is a living monument to Netsch's work, there are limitations to what areas can be developed. All changes must be approved by the master planning committee or the committee representing the architect's legacy. However, it should be noted that as the university transforms over the phases of this project, the university's image will change to reflect a more stormwater-friendly campus, and thus any other proposed changes in later phases will be more in line with the future path of the campus and its construction or renovation. Moreover, the project team believes that the integration of Chicago's native prairie landscape into UIC's modernist campus will create a powerful juxtaposition and enhance the University's image.

OPPORTUNITIES

UIC's East Side is unique in that it is a large, urban, well-defined campus with a fair amount of open space. Other universities in highly urbanized areas do not have the luxury of such a well-defined and open campus space (e.g. New York University, Northwestern University's downtown Chicago campus). UIC's administration recognizes this as an opportunity to improve the aesthetics of the current open space and to capitalize on UIC's unique qualities. UIC is also accessible to downtown Chicago through a variety of mass transit options, providing opportunities for site-scale and city-scale green infrastructure integration. UIC's close proximity to downtown Chicago exposes the university to the millions of people who visit Chicago each year. Chicago's status as an international travel destination along with UIC's stature as a research institution, poises the university as a highly visible institution with the ability to affect large scale change. Institutionalizing the master plan will help UIC's administration to position the university as a global leader in advancing the knowledge, designs, and policies necessary to implement of green infrastructure across disciplines and spatial scales.

BARRIERS AND CHALLENGES

Although UIC is poised to become a leader in advancing green infrastructure, there are practical and technical issues that need to be addressed. Currently there is a lack of data pertaining to the design life and long-term efficacy of green infrastructure installations. Additionally, the master plan is limited by the cold winter climate of the region. Phase 1 of the master plan is a critical step in advancing the knowledge of what works for UIC's bio-geophysical conditions.

CONCLUSION

In closing, *Urban Transformations* does not simply present an integrated green infrastructure master plan for an urban campus. *Urban Transformations* presents a strategic, incremental and adaptive approach for implementing green infrastructure that can be scaled-up to virtually any operational scale. As urban landscapes and water systems are increasingly stressed due to the impacts of climate change, impermeable land cover and resource limitations, there is a critical need for innovative planning and engineering approaches that celebrate and leverage ecological and social complexity rather than suppress it. *Urban Transformations* presents one such approach.

"The Four Phases of Urban Transformation" concept exemplifies the type of innovative and adaptive approach to planning, design, and governance that is needed in order to build more resilient and livable cities. UIC's fortuitous geographic and institutional position within Chicago's makes the University an excellent place to test and scale-up this approach to green infrastructure implementation. When implemented, *Urban Transformations* will not only help manage urban flooding on campus, but will also facilitate the transition of Chicago's and the region's water system towards more sustainable and resilient water planning and management.

Water is critical to life. Indeed, the health and resiliency of any campus, city or region is dependent on the availability of fresh water. It is increasingly apparent that we must transform our cities so that they may treat water as a life-giving resource rather than a waste product. Such an ambitious project, however, will require a concerted effort that crosses disciplines, scales and even paradigms to tell a new story about water and cities. *Urban Transformations* tells a small part of this much bigger story.

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