Water, Water Everywhere

MARIA ARQUERO
University of Michigan

JEN MAIGRET
University of Michigan

INTRODUCTION

This paper explores disciplinary design agency and develops a trans-scalar methodological approach that critically re-imagines the future of the constructed environment in the Great Lakes Basin through the lens of water. Through the development of storm water cartographies, our research reveals a contemporary crisis wherein the water quality of the largest, liquid freshwater reserve in the world is at risk owing largely to the patterns (and surfaces) of urbanization within this vast watershed. Furthermore, this paper considers climate change projections that indicate the probable future stresses on existing water system feedback loops driven by intensifying precipitation events, expanding urbanization and decreasing lake levels.

This paper elaborates on the premise that the reconsideration of daily practices of design and construction of the built environment hold a key to establishing alternate futures to the scenario of sewer infrastructure failure and accelerated water quality decline.[1] The proposed multi-faceted method broaches the traditionally isolated disciplinary approaches to storm-water management systems. By unveiling the complex regulatory landscape and its operative structure, the evolving role of technology and the integration of material studies against GIS data collected and organized within watershed boundaries, this research targets the multiple scales that collectively affect water quality issues throughout the Great Lakes Basin. Furthermore, this approach positions design as the catalyst that synthesizes performance criteria with tactile intelligence and thereby models a pro-active methodology that contributes to ecological systems whose boundaries extend far beyond the building envelope.

THE WATER(S) OF THE GREAT LAKES BASIN

If you live within the Great Lakes Basin, then you are intimately connected with water. This region is perhaps best known for lakes Erie, Huron, Michigan, Ontario and Superior and the thousands of miles of iconic shorelines that define 18% of the world's freshwater supply.[2] Equally impressive are the hundreds of thousands of miles of rivers, streams, inland lakes and wetland edges that, in combination, render the more familiar political boundaries of the region recognizable even when only the water is drawn (Figure 1).

The magnitude of this water system has historically enabled some of the world's largest concentrations of industrial capacity and an important network of global waterborne shipping routes. At a regional level, the combination of climatic characteristics and precipitation distribution has fostered agricultural production, accounting for nearly 25% of Canada's entire production, the world's largest concentration of pulp and paper mills in the Fox River Valley of Lake Michigan, among other important economic drivers such as fisheries, mining and manufactur-

Figure 1. Lakes, Rivers and Wetlands

ing industries.[3] The volume of water that has driven this economy amounts to over 5,500 cubic miles—a quantity that would require over 3 billion mid-western water towers to contain it.

The Great Lakes ecosystem is also recognized as a mega-region within the United States and Canada with a total population exceeding 34 million.[4] The region accounts for roughly 10% of the population of the United States[5] and 30% of the population of Canada[6] unevenly distributed throughout the five watersheds. Yet, despite the immensity of this territory, the Great Lakes possess a level of fragility that belies their scale. This has been most notably evident in the Lake Erie Basin that contains the smallest of the lakes (in volume) and is the most densely populated, with more than 11 million inhabitants.

The Lake Erie and Lake Michigan basins have seen the greatest population growth rates since 1900 and presently support more than double the population of the other three lake basins combined. Furthermore, it is projected that population growth, following the patterns of current development, may accelerate the predicted outcomes of climate change, including increases of 2-4 degrees Celsius in average temperatures, with an overall effect of a more temperate climate, wetter summers and higher agricultural production potential.[7] Increased agricultural production has implications for non-point source pollution levels, erosion and water demand compounded by evidence predicting future declines in lake levels ranging from 1.5 feet to 6 feet by 2040, depending on the General Circulation Model used.[8,9] This combination of large scale climatic impacts on lake levels with increases in urbanization and agricultural production are harbingers of heightened tension between the constructed environment and the hydrology of this unusually water rich territory.

The complex landscape of policies and institutions regulating this fragile equilibrium only complicates and clouds the formation of problem solving approaches to these challenges. The waters of the Great Lakes Region seamlessly traverse the international boundary between the United States and Canada, are in contact with eight different states (on the American side) and a province (on the Canadian side). If political boundaries are parsed at a finer grain, the waters of the Great Lakes encompass hundreds of counties and thousands of cities and townships. These nested scales of political governance strongly shape a cartography of storm water infrastructure, policy and regulation that doesn't always align with the topographically biased watershed boundaries defined by streams, rivers, wetlands and lakes.

WHEN CLEAR WATER TURNS GREY

Given the degree to which the Great Lakes Basin is saturated by water, a visitor might expect to encounter a rich vocabulary of terms as diverse as the geography from which they emerge. Surprisingly, such a nuanced appreciation for this resource is hindered by its ubiquity, and the threshold between water as resource and water as contaminated runoff is a distinction crudely shaped by pervasive layers of asphalt. From a hydrological point of view, urbanized landscapes are best described by a ubiquitous presence of impervious areas.

Imperviousness became recognized as the single most quantitatively defining index of environmental disturbance in 1994 when T.R. Schueler published a paper succinctly titled "The importance of imperviousness"[10] Of critical importance in this paper is the direct and explicit identification of imperviousness as a physical, constructed condition that can be quantified and managed across all scales and stages of land development. Interestingly, Schueler's attitude towards development is so intertwined with the lack of design diversity within contemporary construction practices that he is unable to separate the condition of development from a condition of imperviousness and states "imperviousness represents the imprint of development upon the landscape." Such predictability in construction practices also leads to the paper's findings that precisely associate land cover conditions with calculated percentages of imperviousness, each of which has associated stream quality impacts. These three categories include: 1-10% impervious cover (streams become sensitive), 11-25% impervious cover (streams are measurably impacted), and >26% impervious cover (streams are no longer able to support invertebrate diversity). Of these three classifications, all urbanized land cover types were found to measure greater than 26% imperviousness, thereby falling into the "non-supporting" category of stream impact. During the sixteen years since this publication, the literature has largely reinforced these measures and has widely adopted 10% imperviousness as the critical threshold above which negative water quality impacts are measurable[11].

Emerging from this is a body of work that evaluates existing Geographic Information System (GIS) analysis techniques used to translate aerial images into impervious coefficients depending on land cover conditions. The current range of accepted impervious coefficients (a number used to describe the predicted level of imperviousness associated with a particular land cover type) tellingly reveals that all Land Cover categories that describe a "constructed" condition have associated values ranging from 28% (low intensity developed) to 72% (high intensity developed) imperviousness. All these values are well above the 10% imperviousness mark, a critical indicator for the prediction of ecological health.[12] This means that all standard, contemporary construction practices have directly observable and measurable negative impacts on water quality and watershed ecological health. It also reveals a problematic schism between the disciplines participating in shaping the constructed environment and other disciplines studying "natural" systems by accepting the implicit assumption that standard building practices will remain consistent and will continue to drive increasing percentages of imperviousness in our watersheds. Furthermore, the majority of the research working towards decreased levels of imperviousness claim that reductions in development are the only avenue towards increased ecological health. This paper challenges this assumption and posits the question: How can the integration of design disciplines within stormwater management achieve 10% imperviousness

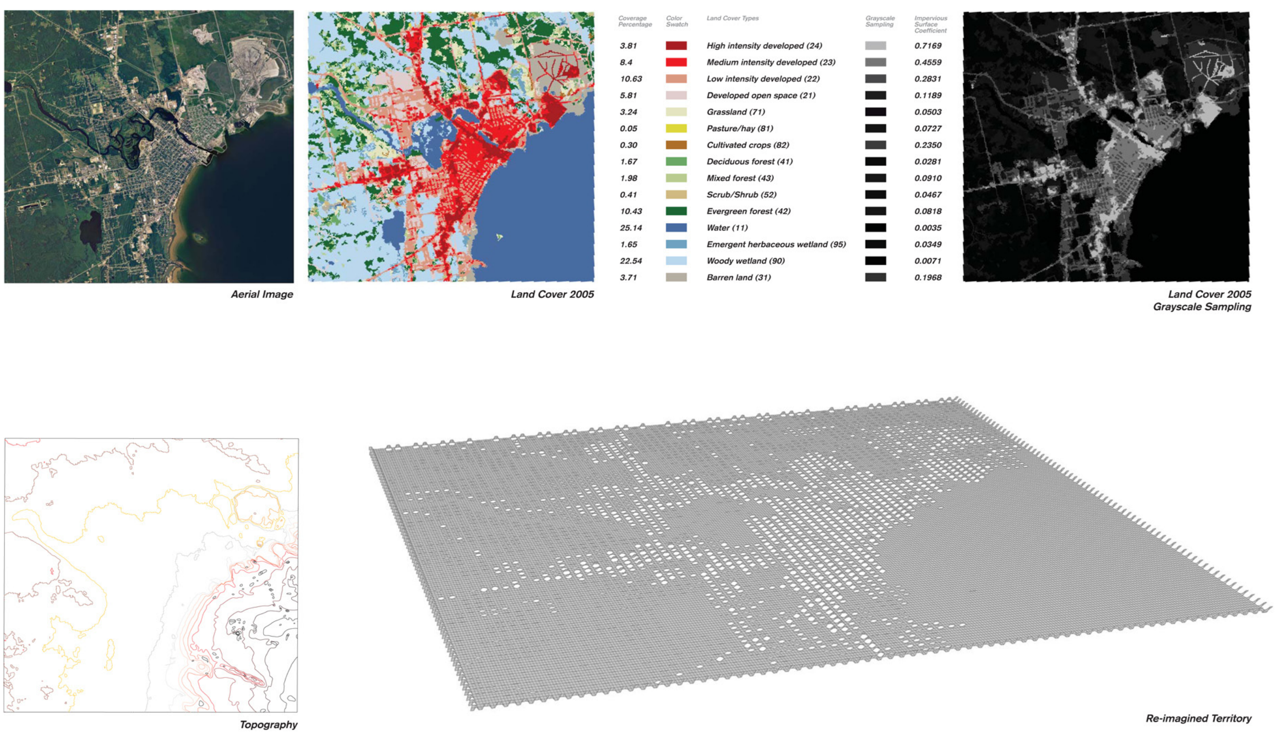

Figure 2. Land Cover and Imperviousness

targets by redefining new patterns of development, construction assemblies and/or material technologies rather than distancing construction professionals further through resistance to all development or acceptance of the status-quo?

THE PROBLEM WITH THROWING IT ALL AWAY

To further accentuate the urgency of investing in a new paradigm of making, we need look no further than at the existing sewer infrastructure in our region. If you live within an urbanized area of the Great Lakes Basin, then your sewage is probably carried to a waste-water treatment facility by way of an archaic system of pipes that additionally transport storm water. The Great Lakes Basin hosts the largest number of combined sewer systems (CSOs) and sanitary sewer overflows (SSOs) in the United States, both examples of combined transport systems.[13] While this fact may seem banal, the future health of the water within the Great Lakes ecosystem depends as much upon an understanding of how the infrastructure of waste-water works as it depends upon changing attitudes about imperviousness. Just as current development patterns fall within categories of imperviousness that have measurable impact on stream health, the degree to which our urban environments shed water also affects the loads carried by this infrastructure.

The physical infrastructure of CSOs and SSOs ties together the collection of sanitary wastewater (domestic sewage from homes as well as industrial and commercial wastewater) and storm water through either a single pipe or parallel pipes, respectively, that are carried to a wastewater treatment plant. These facilities operate at a high expense driven by energy demands, and treating different levels of polluted water with the same process results in unnecessarily inefficient practices. While the original design of these systems was intended to create an efficiency of infrastructure, the volume of storm water run off from vast impervious surfaces in our urban areas today was never anticipated. Instead, the volumes of water contributed by surface runoff to wastewater infrastructure during a rain storm more than doubles the typical capacities handled on a dry day. As a result, heavy rainstorms commonly overwhelm storm water collection systems and threaten the proper functioning of municipal wastewater facilities. The emergency design "solution" to this problem (in both CSO and SSO systems) are diversion valves that are triggered to release untreated effluent directly into a waterway in lieu of overwhelming and damaging a waste water facility's infrastructure—an occurrence known as an outfall. In a December 15, 2000 report to Congress, the EPA estimated that between 853 and 890 billion gallons of untreated, combined sewage and storm water are released directly into the nation's waterways each year as a direct result of outfalls.[14]

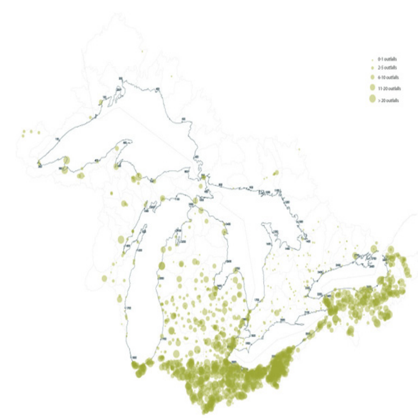

Figure 3. Patterns of outfalls

Figure 4. Waste Water Treatment Plants

The obvious health and environmental consequences of untreated sewage and industrial effluent flooding our waterways is even more compelling if we realize the degree to which this loop can be mitigated through design. If storm water did not enter the infrastructural system, then municipal wastewater treatment plants would be able to consistently and effectively deal with the volumes of residential and industrial effluent presently being piped to them. Preventing storm water from entering the loop equates to the elimination of outfalls. Intelligently handling storm water requires municipalities to demand that development achieve levels of porosity that collectively contribute to the long-term health of our watershed.

DISCIPLINARY AGENCIES OF HYDROPHYLIC DESIGN

Perhaps the most important lesson to be learned from observing our constructed landscapes from the point of view of water is the mismatch between hydrologically operable boundaries and professional disciplinary boundaries. The current disciplinary practices engaged in the construction of the built environment (not exclusive to but including Landscape Architecture, Architecture, Urban Planning and Civil Engineering) primarily problem-solve independently or in rapid succession rather than collectively or collaboratively. While each of these disciplines represents an important confluence of knowledge, methods and technology, there is a growing interest in and need for more synthetic approaches that foster resonance over the dissonance that often arises from the accumulation of singular, myopic solutions.

For example, landscape architecture and civil engineering have traditionally played a central role in the mitigation, filtration and redistribution of storm water throughout urban, suburban and rural areas. At present, parking lots are a ubiquitous example of a site of overlap between the two disciplines and despite occasional exemplar projects are also a significant contributor to storm water perviousness. Across a broader spectrum, landscape architecture can be credited with devoting attention to making public water infrastructure visible as an approach towards addressing storm water challenges.[15] This has led to the emergence of a rich set of urban, naturalized and riverine public space and green infrastructure award-winning interventions. The 2010 ASLA General Design Awards reflect this disciplinary direction including an award of excellence given to Turenscape's "Shanghai Houtan Park: Landscape as a Living System" and honor awards given to projects including Michael Van Valkenburgh Associate's "Connecticut Water Treatment Facility" and James Corner Field Operations (project lead) with Diller, Scofidio Renfro's "High Line".[16] Each of these projects exhibits notable innovation both within the defined project boundaries and in relationship to broader ambitions of ecological integration. Yet, until there are established expectations that design practitioners contribute methodologically distinct but critically important urban approaches, large-scale watershed management will continue to exclude research practices that fall outside of strict scientific methods.

Likewise, urban planning has traditionally played a protective role in regulating the relationship between existing water bodies, wetlands and development through the negotiation of complex systems of land ownership rights. In the end, this work is overshadowed by impacts associated with a heritage of sprawl after more than half a century of uncontrolled suburban development. Alternately, if land use policy were to be driven by performance standards, including minimum storm water regulations, future developments might be held responsible for unintended, yet clearly documented, outcomes that detrimentally affect others residing outside of the development's property lines. With different approaches, there is no question that civil engineers, landscape architects and urban planners will continue to engage water as the core element in any intervention and collectively represent significant disciplinary resources that are greatly underutilized.

As a discipline, architecture has traditionally engaged water either hydrophobically (how to get water off of and keep water out of buildings) or experientially (how to leverage the play of light on water). More recently, there is an emerging interest in the potential of surfaces and tectonic assemblies to perform dynamically in response to external factors. This work primarily leverages advances in software and fabrication technologies that enable links to be made between inputs and design outcomes, typically described as parametric design.[17] In several notable cases, environmental systems (including light, water, temperature, humidity) have been identified as potent, timely inputs from which generative designs can emerge. Likewise, our research has identified a set of circumstances driven by the intersection between rain water and urbanized, constructed surfaces from which instructional data has been collected, organized and analyzed as a means to establish a precise set of parameters in anticipation of contributing to this line of architectural research.

DEFINING A HYDROPHYLIC DESIGN APPROACH

This research presents a methodological approach to pervious, multi-scalar, hydrophilic design strategies. In defining a hydrophilic design approach that has the capacity to transcend disciplinary boundaries, it is of utmost importance to develop precise working methods that distinguish the unique characteristics of our contributions within a systematic, transparent approach that can be adopted and adapted by others. The work presented, to date, represents the methods used to initiate a long-term research trajectory. As such, the primary emphasis on design parameters currently resides within the development and analysis of foundational data, primarily collected, organized and manipulated through the use of GIS techniques and watershed analyses. The use of GIS technologies, however, has been approached and designed with the explicit intention of fostering prototypical design techniques (at an architectural scale) through the integration of software platform techniques (enabling the input of performance parameters exported from initial GIS analyses). As such, the design of feedback loops between different technological platforms is key in facilitating watershed biased design techniques.

Upon the initiation of this research, we were generously granted access to a rich database developed by the Great Lakes GIS Project (supported by the Institute for Fisheries Research, Michigan Department of Natural Resources Fisheries Research Division and the University of Michigan School of Natural Resources and Environment). At the outset, discussions surrounding the motivations behind the establishment of the Great Lakes GIS Project revealed a strong aquatic bias in the dataset. While the research emerging from this body of work was tangentially concerned with the effects of land management on lake organisms, the GIS data included very few layers representing terrestrial descriptions. It was therefore important that the initial data set be reorganized and recalibrated to collect and manage information including land cover, topography, hydrography, soils, and inland water quality measurements (obtained from a variety of sources including but not limited to the US Environmental Protection Agency, the US Geological Survey, and the Earth Sciences Sector of Natural Resources Canada).

Initial mappings established a broad view of the water systems throughout the Great Lakes Basin, and output basic physiographic conditions in the form of a bathymetrical/topographical model (at a scale of 1:62,500), organized by the five lake watershed basins rather than political boundaries. Using this as a framework from which to consider continuities throughout the watersheds, five shoreline drawings were developed. In each of these the shoreline was established as a "false" datum against which to pair inland conditions against measured water quality conditions. Individually, each drawing includes the location of all major rivers emptying into the lakes, the location and population of cities situated within a mile of the lake and begins to chart EPA designated Areas of Concern against their terrestrial cartographies (Figure 3). Further analyses looked at the nature of the sewer infrastructure systems, including the location of waste-water treatment facilities and the number of outfalls or failures induced by storm water mismanagement (as shown in Figures 3 and 4).

A series of visits to target areas in the region initiated the compilation of more detailed visual and material clues in order to shape a taxonomy of water typologies to augment the broad scale GIS analyses. Several areas emerged as areas of interest throughout initial map analyses, and three cities (Alpena, Muskegon and Detroit, Michigan) were selected (in part owing to their relative proximity to three different lakes: Huron, Michigan and Erie, respectively). Each of these three sites emerged in the selection process, in part, owing to the presence and intensity of conditions of storm water infrastructure "failure." After closer inspection, and a chance encounter with an outfall occurrence in Alpena, the watershed tied to Detroit, Michigan presented the greatest diversity of existing land cover conditions and the most frequent cycle of outfall events. At present, this watershed has been extracted from the larger dataset to enable a closer study of the same systems analyzed across the Great Lakes. In so doing, our approach aims to develop methods of analysis and design extrapolation that can leverage a single data set across multiple, nested scales.

At the scale of a rivershed, information extracted from the U.S. EPA's impaired waters database can be understood in relationship to a more local culture of water use. While the definition and establishment of impaired waters is complex, the basic premise is that the water is considered too polluted to support extraction for drinking or recreational activities (such as swimming or fishing). Levels of acceptability are established variably by states, counties, cities or authorized tribes yet arising from this tangle of bureaucracy is the consistent and frequent classification of impaired waterways. In the state of Michigan, a map drawn with only the impaired waterways is robust enough to recognize otherwise familiar geographies. Similarly, when urbanized areas are drawn with only impervious surface analyses activated, the outcome is predictably similar to the transportation maps most drivers are accustomed to reading. Understanding how this situation is regulated within a complex legislative landscape is both opaque and circuitous: from the Great Lakes Water Quality Agreement, to the Clean Water Act, to various state initiated storm water programs, city-wide best management practices (BMPs) or low impact development (LID) strategies information is simultaneously excessive and impenetrable relative to everyday construction management decisions. In response, this research proposal is especially sensitive to the lack of visual communication or graphic standards that could aid in describing trade-off relationships tied to design decisions. Building on this identified need to facilitate the access of information through visualization techniques, our research approach has evolved to encompass a policy matrix (simplifying water regu-

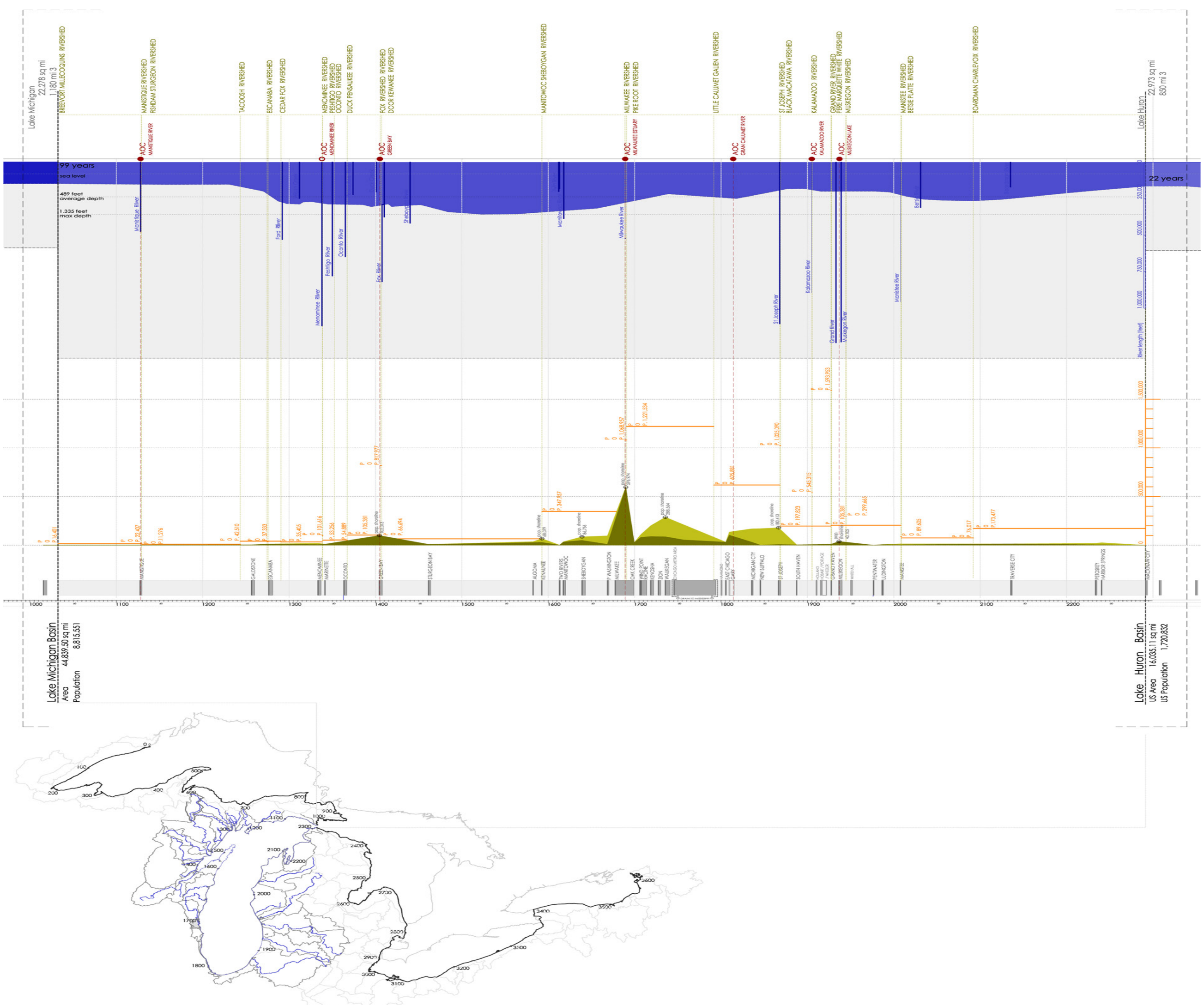

Figure 5. Unfolding Water Systems

lations that span international, state, county and citywide jurisdictions) intended for designers.

In concert, the policy matrix, geographic analyses and watershed biased drawings establish a narrower set of storm water performance criteria that represent the common denominator across multiple vantage points. This work facilitates future design work by clarifying current practices against desired future outcomes. This approach distills and identifies "keystone" components that bear an exaggerated burden in storm water management and allows for the establishment of targeted designs taking the form of typological prototypes throughout the watershed. Paired with the knowledge of optimal impervious surface maximums (10%), prototype design (such as parking lots, building facades, roadways, etc) can be approached with specific criteria in mind yet the flexibility to accommodate vastly divergent contextual considerations.

In conclusion, initial analyses at the scale of the Great Lakes Basin enabled later elaborations of design opportunities stemming from a close reading of storm water criteria.

The use of GIS mapping techniques provided a platform from which to gather data collected across many disciplines to be brought together and reorganized to empower designers (architects, landscape architects, urban planners, etc) who are otherwise peripheral in contemporary watershed management practices yet fundamentally critical to a synthetic approach. This research also recognizes that the role of imperviousness in overall watershed health points to the necessity to consider alternative construction practices as fundamental design tools. Collectively, the proposed multi-faceted approach agglutinate a set of key components influencing urban ecologies in general and storm water management in particular. By making visible the manifold relationships that exist between water and the constructed environment, we position quantitative analysis and relational data networks (typical of Geographic Information Systems) in the realm of design.

ENDNOTES

1 Elizabeth A. Brabec, J.D., "Imperviousness and Land-Use Policy: Toward an Effective Approach to Watershed Planning," *Journal of Hydrologic Engineering* v. 14, n. 4 (April 2009): 426.

2 *Government of Canada and United States Environmental Protection Agency, The Great Lakes: An Environmental Atlas and Resource Book, 3rd ed.,* (Toronto, Ontario and Great Lakes National Program Office, Chicago, Illinois, 1995), 3.

3 Ibid., 25.

4 America 2050, "Megaregions," Great Lakes, at http://www.america2050.org/great_lakes.html (accessed on September 1, 2010).

5 U.S. Census 1990, Database C90STF3C1, Level: Nation.

6 Statistics Canada, Population and Dwelling Counts for Canada, Provinces and Territories, 1991 and 1996 Censuses - 100% Data.

7 Brent M. Lofgren, "Global Warming Effects On Great Lakes Water: More Precipitation but Less Water?" *Proceedings*, 18th Conferenece on Hydrology, 8th Annual Meeting of the American Meteorlogical Society, (Seattle, WA, January 11-15, 2004).

8 K. Hayhoe, K. Cherkauer, N. Schlegal, J. VanDorn, S. Vavrus, and D. Wuebbles, "Introduction: Assessing the effects of climate change on Chicago and the Great Lakes," *Journal of Great Lakes Research*, v. 36, supp. 2: 1-6.

9 Ibid., 7-21.

10 T.R. Schueler, "The importance of imperviousness," *Watershed Protection Practices*, v. 1, n.3, (1994): 100-111.

11 Glenn E. Moglen, "Hydrology and Impervious Areas," in *Journal of Hydrologic Engineering*, v. 14, n. 4, (April 2009): 303.

12 Anna Chabaeva, Daniel L. Civco, and James D. Hurd, "Assessment of Impervious Surface Estimation Techniques," *Journal of Hydrologic Engineering*, v. 14, n. 4, (April 2009): 377-388.

13 "Report to Congress: Impacts and Control of CSOs and SSOs," August 2004, United States Environmental Protection Agency Office of Water: EPA 833-R-04-001, www.epa.gov/npdes (accessed June 21, 2010).

14 Ibid.

15 Chris Reed, "The Agency of Ecology," *Ecological Urbanism,* (Baden,Switzerland, Lars Müller Publishers: 2010), 328-329.

16 2010 ASLA Professional Awards, http://www.asla.org/2010awards/index.html (accessed November 8, 2010)

17 Michael Meredith, "Never Enough," *Control to Design: Parametric/Algorithmic Architecture,* (Barcelona, Actar 2008), 6.