Water and the Architect: Architecture as Decentralized Water Management

Daniel A. Williamson
University of Nebraska-Lincoln, williamson.dan.allen@gmail.com

Follow this and additional works at: http://digitalcommons.unl.edu/archthesis
Part of the Architecture Commons

http://digitalcommons.unl.edu/archthesis/164

This Article is brought to you for free and open access by the Architecture Program at DigitalCommons@University of Nebraska - Lincoln. It has been accepted for inclusion in Theses from the Architecture Program by an authorized administrator of DigitalCommons@University of Nebraska - Lincoln.
water & the architect:
architecture as decentralized water management
by
Dan Williamson
Presented to the Faculty of
The College of Architecture at the University of Nebraska
In Partial Fulfillment of Requirements
For the Degree of Master of Architecture
Major: Architecture
Under the Supervision of David Karle & Sarah Thomas Karle
Lincoln, Nebraska
May 2013
abstract:
Water is the essence of life, a material, a resource, a commodity. It is volatile, fragile, devastating, nourishing and is ultimately spatial. The design of how water spatially inhabits, flows, and interacts with our built life has seen many forms, functions, systems, failures and successes. Over the course of history those who have had the opportunity to define our relationship with water has spread across numerous disciplines, and touched many professions. The architectural relationship with water has seen an unfortunate bifurcation over the past two centuries. It is this separation of architecture from adequately and actively engaging water management, primarily in urban situations, that the inherently spatial characteristics have been buried and hidden from daily social life. Through the presently discrete flows and management of urban water, we are socially unaware of its crucial importance to our life, as well as lifestyle. Architecture has the opportunity to realign its role in helping shape the course and flows of our urban waters, and ultimately reshape the spatial organization of the urban fabric towards a socially water conscious state.
water & the architect

architecture as decentralized water management

Dan Williamson :: M.Arch Thesis
David Karle & Sarah Thomas Karle
The role of the architect has been divorced from urban water management discourse.
This separation has limited the scope and potential of spatial, architectural opportunities.
The relationship between the architect and water management needs to be reconfigured to leverage new spatial, social, and architectural interventions. The continual resistant and centralized management of urban water
has proven to fall short. New decentralized strategies at the architectural scale need to be addressed. Through accepting water into the built environment, new spatial configurations will surface.
# Contents

<table>
<thead>
<tr>
<th>Scale</th>
<th>Page</th>
<th>Section</th>
</tr>
</thead>
<tbody>
<tr>
<td>book</td>
<td>2</td>
<td>Introduction</td>
</tr>
<tr>
<td>global</td>
<td>4</td>
<td>Water Management &amp; the Architect</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>Case Studies</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Japan::Tokyo</td>
</tr>
<tr>
<td></td>
<td></td>
<td>US::Washington DC</td>
</tr>
<tr>
<td></td>
<td></td>
<td>The Netherlands::Rotterdam</td>
</tr>
<tr>
<td>regional</td>
<td>26</td>
<td>The Great Lakes, Combined Sewer Overflows</td>
</tr>
<tr>
<td>city</td>
<td>38</td>
<td>Milwaukee, a Prototypical Opportunity</td>
</tr>
<tr>
<td>block</td>
<td>48</td>
<td>EPA &amp; Green Infrastructure Deficiences</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Open Space Strategies</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Normative Lot Strategies</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Aggregate Strategies</td>
</tr>
<tr>
<td>home</td>
<td>70</td>
<td>Infill: Water Core Home</td>
</tr>
<tr>
<td>book</td>
<td>92</td>
<td>References</td>
</tr>
</tbody>
</table>
Introduction

Water is...

Water is the essence of life, a material, a resource, a commodity. It is volatile, fragile, devastating, nourishing and is ultimately spatial. The design of how water spatially inhabits, flows, and interacts with our built life has seen many forms, functions, systems, failures and successes. Over the course of history those who have had the opportunity to define our relationship with water has spread across numerous disciplines, and touched many professions. The architectural relationship with water has seen an unfortunate bifurcation over the past two centuries. It is this separation of architecture from adequately and actively engaging water management, primarily in urban situations, that the inherently spatial characteristics have been buried and hidden from daily social life. Through the presently discrete flows and management of urban water, we are socially unaware of its crucial importance to our life, as well as lifestyle. Architecture has the opportunity to realign its role in helping shape the course and flows of our urban waters, and ultimately reshape the spatial organization of the urban fabric towards a socially water conscious state.

“Since the onset of urbanization millennia ago, cities were connected to water resources, which were their lifeline. Without this connection to water, there would be no cities, and ultimately, no life.”

-Vladimir Novotny
The discourse surrounding water is historically thick, politically charged, hotly debated, and meanders many disciplines, cultures, governing bodies, and individuals who all work towards strategies and interventions that forecast improved social, economic, and environmental situations. Vladimir Novotny is an awarded and established environmental and water resources engineer that provides a platform to understand how water management has historically transitioned in concept and practice. Novotny establishes four water management paradigms that start in the early BC and span to the present state. (The four paradigms, their respective time frames are illustrated ____). These paradigm shifts define a transition from monumental and visual water management, to hidden and discrete water management of the present.

Currently many developed cities are operating in the fourth paradigm with infrastructures design to accommodate fast conveyance and end of pipe treatment. These systems tend to be highly centralized and are subject to failures on catastrophic

“all the stuff around building we’ll make that the stuff that means you can call yourself an architect. In that moment we gave up what we do really well, and that is spatial thinking, because we got trapped into a paradigm ‘building’ instead of thinking about the complex spatial issues we have in our cities.”

-Gerard Reinmuth
levels. However, a fifth paradigm is also introduced by Novotny as a new shift that can be seen occurring presently in select nations and municipalities around the world. This fifth paradigm defines more decentralized strategies that incorporates visible green infrastructures as well as architecture that responds spatially to accepting water on site and at times internally.

Vladimir Novotny’s perspectives and insight are echoed through the lens of Urban Designer Iain White. White identifies what he calls a ‘technocentric’ attitude towards water management that has been the course of intervention over the past few centuries. Along with Novotny, White too identifies a paradigmatic shift underway, of which he calls ‘recognition of limits’ or ‘resilience’ as the leading discourse shaping new strategies and interventions employed by planners and urban designers.

These two cannons are joined with architecture of which is also in the course of re-definition in the last decade. Leon Von Schaik is a professor of architecture at the Royal Melbourne Institute of Technology who has identified the pigeonhole architecture has found itself trapped into within the past century or more. Schaik situates a reconfiguration of the architect not as designer of the object building, but rather as profession (a profession is a socially contracted, custody of a body of knowledge) based on the unique custody and competence of their spatial intelligence. The intersection of these three canons asserts this architectural thesis with the scope and effectiveness to liberate the architect from the building object to larger spatial concerns, such as those of urban water management.
Typical water system of many cities still today. The system is based on linear processes and centralized measures of water management.

New Paradigm V water system with cyclical, decentralized strategies employed that increase the resilience of urban water designs.
Congress passes the Federal Water Pollution Control Act, commonly known as the Clean Water Act. The purpose of the Clean Water Act is to restore and maintain our nation’s waters by preventing pollution, providing assistance to publicly-owned wastewater treatment facilities, and maintaining the integrity of wetlands.
Japan
Asia
Case Study: Japan
Tokyo

Japan has historically been on the more advanced edge of methods of handling urban water in terms of defense. Their unique and extreme climate includes tsunamis, earthquakes, and heavy rains. This coupled with a rather restricting topography has resulted in very high densities within Tokyo. This stated, Tokyo was the last of the 3 precedent studies to implement sewers which was resultant of a lack of a centralized governing body. Also, due to the cultural private family ownership of land the ability to implement large infrastructural water systems is extremely difficult. However, Tokyo and the Japanese have innovated many flood defense systems and strategies. Culturally, the citizens of Tokyo have an good awareness of their geo-climatic environment, not typical of other cultures.

“Taking care of the living conditions has always been the task of the people and not of the government.”

“One of the great things the Dutch could learn from the Japanese is how to create public awareness.”

Rutger de Graaf & Fransje Hooimeijer
Urban Water in Japan
Economic
The typical dwelling life in the Japanese model is 15 years presenting both an economic constraint, yet a water management opportunity. The historically deep evolution of private land ownership has made regional water management interventions difficult.

Social
The living environment has always been the responsibility of the citizens in Tokyo. They effectively take part and help design the built environment most suitable for them. Ongoing urbanization continues to stress the resources and flows of the city.

Environmental
Tokyo has a long history of both fluvial and pluvial floods as well as the threats of earthquakes and typhoons. The moments of excess water have caused pollution and destructive issues throughout Tokyo’s existence.
Toilet recycling handwashing water for flushing.

Advertisement to bring awareness to decrease grease in pipes

Experimental sewer system in Tokyo designed to allow infiltration into soil
United States of America
Case Study: United States
Washington D.C.

The United States has somewhat lagged behind as far as innovative solutions to water management. In contrast to Tokyo and Rotterdam, Washington does not face as severe water threats from flood, however they are left to deal with difficult sewer overflow pollution. Currently increasing the capacity of the sewer system with expensive ‘deep tunnel’ projects is the main prevention efforts. But, efforts to begin the consideration of softer, green infrastructures are in motion. Washington DC, Portland, and Philadelphia represent three locations within the United States beginning to explore Paradigm V strategies.

“Though the Blue Plains Advanced Wastewater Treatment Plant is held to some of the most stringent regulatory requirements in the nation and has undergone almost $1 billion in technological upgrades, DC WASA is embarking on another $900 million project”

DC Water
CSO Biannual Report
Economic

Americans place economic concerns atop the list of issues facing the nation. These concerns include unemployment and lack of money within the top 5 economic concerns. Specifically DC has an aging infrastructure with a little budget.

> A 1.8 billion dollar investment in Stormwater Management would generate $265 in economic activity, and create 1.8 million jobs.

Social

Community based work, public health issues related to water management, educational initiatives & tours are enthusiastically encouraged and marketed by sewer districts as well as city officials.

Environmental

Combined Sewer Overflows and Stormwater management are the primary environmental concerns within DC and their vulnerability to flooding.

$2.6 Billion dollar Project *(Clean Rivers Project)*
- New tunnel boring machine for the deep tunnel project in D.C.

- Blue Plains advanced treatment plant in D.C.

- Inflatable sewer balloons to temporarily store water in sewer pipes.

- D.C. petition advocating for green infrastructure. They need to get EPA approval in order make green infrastructure a supported part of their water management design.
The Netherlands
The Netherlands has always been a country and culture embedded with unique and challenging water issues. Floods and subsidence have been at the top of those issues, which has resulted in the Netherlands having some of the most advanced and innovative water management tactics and methods. With climate change predictions of sea level rise and more extreme weather patterns, flooding and subsidence become an even greater challenge.

Rotterdam as a city has taken this challenge in a new way that has contrasted Dutch methods of the past. Traditionally, the Netherlands has attempted to keep water out through the intensive building of dikes and polders. However, they are now switching to an accepting attitude as they have realized the expense of their history defending against water. All across Rotterdam, as well as much of the Netherlands, they are looking for locations to store water to promote infiltration as well as reduce the contribution to inevitable flooding. Widening rivers, floating structures, parks & plaza designed to

“In Depth Case Study: The Netherlands
Rotterdam

“Rotterdam has decided to build within the city limits.”

“It’s no picnic to reconstruct Rotterdam’s sewerage system. Sewage pipes last around fifty years”

“building with nature, living with water”

Gemeente Rotterdam
Waterplan 2 Rotterdam
Issues:

Economic
Rotterdam has been on the top 5 busiest ports for hundreds of years and is continuing to supply millions of Europeans. However, with a decline in population a trickle down affect of the degradation of the economy is a concern.

Social
In the last few decades Rotterdam has experienced a large migration out of the city due in large part to housing prices and livability of the urban environment. With new residential urban developments and a connection between the south & north halves of the city is improving its attractiveness.

Environmental
Rotterdam is no different than the rest of the Netherlands, it has major flood concerns, as well as water quality/quantity within the city. The rising sea level and increasing extremes of weather patterns present the most pressing environmental issues for Rotterdam.
As these water issues are addressed in attempts to manage their water, store water are a few of the methods utilized in attempts to manage their water. Implementation plans, spatial thinkers se they develop policy and spatial thinkers to operate as a crucial integrated team approach with the need they demonstrate the importance of an they demonstrate the importance of an micro-watershed level. Also, the micro-watershed level. Also, \textbf{Kop Van Zuid & Stadshavens’ Knowledge Retention}\>

- Kop Van Zuid - 10,000 new homes in flood plain
- Stadshaven (City Docklands) - 13,000 new homes (5,000 floating)

\textbf{Attractive City}\>
- good residential environment
- safe and protected investments
- strong and lively economy

\textbf{2,500-2,500 inactive number of persons}\>
- retired
- students
- welfare
- working

\textbf{585,000-570,000 population}\>
- 2000
- 1998
- 1996
- 1994
- 1992
- 2002
- 2004
- 2006
- 2008
- 2010
- 2012
- 2014
- 2016
- 2018
- 2020

\textbf{Rotterdam, as a precedent study represents}\>
- the City of Rotterdam plans to place over 15,000 homes outside the protection of the dikes.

\textbf{Rotterdam faces an increasing unbalanced population due to a lack of affordable housing.}
Matrix of strategies, scales, and disciplines involved in Rotterdam:

- Type
  - Centralized
  - De-centralized

- Strategy
  - Storage
  - Space
  - Slow

- Scalar Arena
  - Regional
  - City
  - Block
  - Architecture

- Disciplines
  - Climate Change Experts
  - Landscape Architects
  - Minister of Public Housing
  - Director of the Rioned Foundation
  - Architects
  - Citizens
  - Arcadis Water Program
  - Civil Engineers
  - Economic Analysts
  - Dredging & Fishing Industry
  - Living with water foundation
  - Politicians
  - Hydologists
  - Urban Planners
  - ...
Storage strategies. Interventions that are able to flood and hold water in extreme events.

Water Plazas designed to flood

Floating parking structures

Space strategies. Design solutions that create more space for water to navigate to without the need to store or harvest it.

Roof systems that direct water to catchment spaces

Meandering conveyance to slow the transition of water

Daylighting rivers to increase space for water

Floating structures to allow more space for water and urbanization
How can a shift towards Paradigm V in the United States help re-align the role of the architect into current
water management discourse and intervention strategies?
The Great Lakes

Combined

The Great Lakes represent the largest collection of surface freshwater in the world. Combined, they support over 40 million people internationally in 7 States and 2 Provinces within the watershed. This megaregion over the past two centuries transitioned through paradigms of industrialization, urbanization, and de-industrialization driven by various economic, social, and environmental motives. Pollution has been a primary by-product of these urban processes, and only since the passing of the Clean Water Act of 1972 (CWA) has any significant investigation taken place.

Following the passing of the CWA the International Joint Commission (IJC) and the United States Environmental Protection Agency (EPA) identified 43 specific Areas of Concern (AOC) within the Great Lakes watershed. An AOC was listed due to having at least one of fourteen possible Beneficial Uses impaired due to surface water pollution. Both point (Treatment Facilities, Hazardous Waste Sites, etc.) and Non-Point Source (Agriculture Run-off, Combined Sewer Overflows) were identified as the primary polluters. Since the initial listing of the 43 Areas, only 4 have been de-listed. Nearly all of the point-source polluters have been identified, corrected, and addressed. However, the continual threat to the quality of the water in the Great Lakes remains as the resultant overflows from Combined Sewer Systems (CSS) (see Combined Sewer box for more information).

Spatially combined sewer systems have historically contributed to defining urban form while also the culprit for many health issues, both environmental and human. Architecturally they are the conduit for the byproducts of program such as human feces, industrial discharge, etc. From an urban perspective they are a conveyance system for wet weather events. Presently these systems are over stressed with urbanization and are a catalyst for multiple disciplines to address in order to reduce the negative impacts of these systems during overflow conditions. They serve as a spatial opportunity for the architect to investigate new design strategies that reduce and improve the quality and quantity of water passing through the combined sewer conduit.
> The United States consumes 410 billion gallons of water a day. 85% is freshwater. 77% of that freshwater comes from surface resources.

> The Great Lakes hold 84% of all the surface freshwater in North America
Of the larger urban Areas of Concern within the Great Lakes, 7 are within the United States. All 7 of these urban areas have been experiencing a degrading population over the past 30 years due to environmental degradation as a result of human processes.
Combined Sewers

Combined sewer systems (CSS) are one of two typical sewer system designs, the other being separated sewer systems. CSS were initially employed in the US as the primary sewer system due primarily to their cost effective nature compared to separated sewers. Combined sewers are designed to convey both storm water and sanitary water in the same combined pipe. Prior to treatment plants, these combined conduits discharged directly into surface waters. However, since the early 1900’s treatment of these systems has become a mandated practice. The downfall with combined sewers is their overflow design. When the capacity of CSSs are be reached, overflow points are triggered which discharge directly into surface waters. This discharged effluent is extremely harmful to the environment, and subsequently is a human health risk. CSSs are have deceased being implemented for over half a century, however many city cores still rely on these systems.
Over 772 communities in the United States have a Combined Sewer Overflow problem, 84 are in the Great Lakes Watershed. This persisting threat to Great Lakes water quality has been identified to be a contributor to impairing the beneficial uses listed below.

- Restrictions on fish & wildlife consumption
- Bird or animal deformities or reproductive problems
- Tainting of fish & wildlife flavor
- Degradation of fish & wildlife populations
- Fish tumors or other deformities
- Degradation of benthos
- Restrictions on dredging activities
- Eutrophication or undesirable algae
- Restrictions on drinking water consumption, or taste & odor problems
- Beach closings
- Degradation of aesthetics
- Added costs to agriculture or industry
- Degradation of phytoplankton & zooplankton populations
- Loss of fish & wildlife habitat
Suburban Areas of Concern
population 25,000-150,000
1 AOC with allocated CSO funding

Urban Areas of Concern
population > 150,000
10 AOCs with allocated CSO funding

1. Buffalo River
2. Clinton River
3. Cuyahoga River
4. Detroit River
5. Fox River
6. Hamilton Harbor
7. Maumee River
8. Milwaukee Estuary
9. Niagara River
10. Rochester Embayment
11. Rouge River
12. St. Louis Bay
13. Thunder Bay
14. Toronto Region

1. Ashtabula River
2. Black River
3. Grand Calumet River
4. Mantisique River
5. Menominee River
6. Muskegon Lake
Rural Areas of Concern

population < 25,000
1 AOC with allocated CSO funding
2012 U.S. Water Prize

“When the Milwaukee Water Council formed in 2007, it was said that the strength of Milwaukee’s collective water cluster made it a World Water Hub. Today, thanks in large part to the work of the council, the Milwaukee region is now being mentioned alongside a handful of cities known to be world leaders in water technology.”

U.S. Water Alliance

2011 U.S. Water Prize

“MMSD’s holistic approach to water management works on a watershed level. MMSD’s cutting-edge pilot watershed-based permitting (WBP) focuses on a holistic, innovative geography-based approach to discharge permitting.”

U.S. Water Alliance
Milwaukee, Wisconsin is a prototypical opportunity to investigate paradigm V strategies.
Milwaukee
A prototypical location

Within the current remaining 39 Areas of Concern (AOCs), fifteen occur within a population of 150,000 or more and 10 have acknowledged, funded Combined Sewer Programs. These ten AOCs represent a focused set of urban, prototypical locations to investigate architectural, spatial opportunities.

Within the focused 10 AOCs, 7 are on United States soil of which all have experienced depleting populations since the latter half of the 20th Century. Shifts in the primary industrial economy after WWII, outsourcing of work, and the American sprawl have left the spatially built environment of many of these once booming cities in a state of degradation, both above and below ground. Combined Sewer Overflows (CSOs) in these cities have been addressed almost strictly from a centralized Paradigm IV (See Chapter 1) mentality exercising strategies that expand the over tapped capacities of aged sewers. These interventions have proven to be financially exhaustive and fall short of being fully successful in the reduction of CSOs.

Milwaukee is a recent recipient as a city of both a 2012 & 2011 U.S. Water prize from the United States Water Alliance. These awards recognize efforts of cities nationwide that are thinking, operating, and implementing creative effective water management solutions. However, Milwaukee still contributes billions of gallons of CSO into Lake Michigan and its tributaries yearly, thus demonstrating the persisting issue of their combined sewers.

Milwaukee faces three explicit issues that in essence are prototypical of other Areas of Concern within the Great Lakes watershed: Combined Sewer Overflows, Foreclosed Properties, and Re-vitalization development. Due mainly in part to de-industrialization and the Great Recession of 2008, Milwaukee has a high volume of foreclosures. To address this, the City of Milwaukee has received Federal funding through the Neighborhood Stability Program to re-vitalize and increase homeownership in two key, struggling areas within the city. The southern identified Neighborhood to be revitalized intersects with the Near South Side development plan.
Multiple agencies at multiple scales are aimed at reducing the number of combined sewer overflows that impact the Great Lakes Watershed.

Federal Players
- Environmental Protection Agency [EPA]
  - CSO Control Policy (1994)
  - United States Armed Forces - US Army Corps of Engineers

State Players
- Wisconsin Law
  - 281.63
  - “(1) Legislative findings. The legislature finds that state financial assistance for the elimination of combined sewer overflow to the waters of the state is a public purpose and a proper function of state government”

Municipality Players
- City of Milwaukee
  - Citywide Policy Plan
- Milwaukee Metropolitan Sewerage District
  - Responsible for river and lake water quality

Regional Players
- International Joint Commission
  - Remedial Action Plan

Great Lakes Watershed

Lake Michigan Watershed

Milwaukee County

United States
set forth by the City’s planning department. Concurrently, the Near South Side district lies between the Menomonee and Kinnickinnic Rivers, the location of numerous sewer outfalls. The intersection of Combined Sewer Overflows, Foreclosed Properties, and Re-vitalization development leverage an opportunity to spatially re-configure current water management practices through the architectural & open space investigation/intervention of existing block, lot, and home scales. New Catalytic solutions performed at these scales will positively impact the stress of the combined sewer system, thus improving the water quality of the Great Lakes watershed.

Lake Michigan

Milwaukee Estuary Area of Concern

Combined Sewer System Area

Combined sewer outfalls

City of Milwaukee boundary
Conceptual relationship between strategies, scales, and goals that define spatial, architectural interventions.
Lot Opportunities:
The scale of the lot presents numerous opportunities to adjust, alter, remove, and create new spatial interventions to operate within a decentralized, paradigm V, water management system.

Block Opportunities:
Various opportunities within the block scale can define a series of public sector interventions that will positively impact the strain on the combined sewer system. The block itself can be seen as a functional component of the decentralized water management strategy.
Conceptual relationship between strategies, scales, and goals that define spatial, architectural interventions.

- **Clean**
  - Metric: Quality
    - (e. coli, fecal coliform, & oxygen levels)
  - Metric: Flow
    - (gallons/hour)
  - Metric: Capacity
    - (gallons)

- **Cleaner and lesser** volumes of water entering the combined sewer

- **Cleaner and lesser** volumes of water entering the combined sewer

**Mandates:**
- required avg levels of discharged water quality
- limits set to discharge flows & amounts
- required amount of water to be held on site during wet weather events.

**Incentives:**
- financial assistance to reach newer mandates

- **Cleaner and lesser** volumes of water entering the combined sewer

> Each strategy has an associated metric that will measure the successes of each.

> New required mandates that addresses each strategy will force new spatial interventions to be implemented towards reaching the defined goal. Financial incentives are also employed to ensure new, more progressive mandates can be reached.
What impact do already funded, normative, and aggregate strategies within the block, lot, and home
scale have towards cleaner and lesser volumes of water entering the combined sewer?
EPA & Green Infrastructure Deficiencies
Normative Interventions

The Near South Side (NSS) Area within the Milwaukee City-wide development plan highlights a prototypical location to investigate the spatial opportunities of reducing the impact and reliance on Combined Sewer Systems. Lesser quantities and cleaner water entering the combined sewer system serves as the conceptual and obtainable goal in order to measure success. Within the NSS, a prototypical block serves as the foundation for research and architectural intervention aimed at reaching the conceptual goal. In order to refine this goal, detailed and thorough data defining the prototypical dimensions of precipitation, physical block, lot, and home dimensions, as well as habitation dimensions (internal water use) are established. With this data and understanding, a more precise goal of the capture and treatment of the first one inch of any wet weather event can define a metric to assess design interventions.

Currently, The United States Environmental Protection Agency (EPA) is in the infant stages of investigating the impact and use of Green Infrastructures to become critical components within water management systems and strategies. These decentralized strategies vary in scale, effectiveness, affordability, and include both private and public options. Municipalities can receive EPA funding through an approved application to implement these strategies in their current water management designs. In the following pages, these normative strategies are executed within the prototypical situation to evaluate and analyze their impact.
Prototypical Conditions

Precipitation Dimensions

A precipitation event is characterized by both its total depth and by the time period over which the rain occurs, the duration. The most severe damage can be caused by short, deep storm.

### Milwaukee, WI:
- Avg. Yearly Precipitation: 34.8" (Aug. 6, 1986)
- Avg. Yearly Snowfall: 52.4"
- Record 24/hr event: 6.8"
- Avg. Yearly Precipitation: 34.8"

```
<table>
<thead>
<tr>
<th>Inches Precipitation</th>
<th>0.5</th>
<th>1.0</th>
<th>1.5</th>
<th>2.0</th>
<th>2.5</th>
<th>3.0</th>
<th>3.5</th>
<th>4.0</th>
<th>4.5</th>
<th>5.0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Volume / Lot (cu. ft)</td>
<td>228</td>
<td>457</td>
<td>685</td>
<td>913</td>
<td>1,141</td>
<td>1,370</td>
<td>1,598</td>
<td>1,826</td>
<td>3,196</td>
<td></td>
</tr>
<tr>
<td>Volume / Lot (gal)</td>
<td>1,689</td>
<td>3,378</td>
<td>5,676</td>
<td>8,445</td>
<td>10,134</td>
<td>11,823</td>
<td>13,512</td>
<td>15,201</td>
<td>23,647</td>
<td></td>
</tr>
<tr>
<td>Volume / Block (cu. ft)</td>
<td>8,217</td>
<td>16,434</td>
<td>24,651</td>
<td>32,868</td>
<td>41,085</td>
<td>49,302</td>
<td>57,519</td>
<td>65,736</td>
<td>115,038</td>
<td></td>
</tr>
<tr>
<td>Volume / Block (gal)</td>
<td>608,061</td>
<td>121,612</td>
<td>182,417</td>
<td>243,223</td>
<td>304,029</td>
<td>364,835</td>
<td>425,641</td>
<td>486,446</td>
<td>851,281</td>
<td></td>
</tr>
</tbody>
</table>
```

If existing conditions were calibrated to retain on site (block & lot combined) the 1st inch of precipitation, 90% of wet weather events could be removed from adversely affecting the combined sewer system, thus preventing reducing combined sewer overflows and improving receiving water quality.

Habitation Dimensions

### Average American Family:
- # of persons: 4
- Gallons of water per day: 300
- Loads of Laundry per yr: 300
- Cost / 5 gallons of water: $0.01

```
<table>
<thead>
<tr>
<th>Fixtures / Appliances</th>
<th>Toilet</th>
<th>Washers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Uses / Day</td>
<td>3.5</td>
<td>22</td>
</tr>
<tr>
<td>Total Gallons</td>
<td>77</td>
<td></td>
</tr>
<tr>
<td>Good</td>
<td>1</td>
<td>22</td>
</tr>
<tr>
<td>Total Gallons</td>
<td>22</td>
<td></td>
</tr>
<tr>
<td>Poor</td>
<td>23</td>
<td>0.8</td>
</tr>
<tr>
<td>Total Gallons</td>
<td>18.4</td>
<td></td>
</tr>
</tbody>
</table>
```

```
<table>
<thead>
<tr>
<th>Distribution- gallons [%]</th>
<th>Toilet</th>
<th>Shower</th>
<th>Faucet</th>
<th>Leaks</th>
<th>Washer</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>80 gallons [26.7%]</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>50 gallons [16.8%]</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>42 gallons [15.7%]</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>42 gallons [13.7%]</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15 gallons [5.3%]</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
```

“Rain events of greater than 1 inch in a 24 hour period are expected to increase by seven events per decade, and rain events greater than 2 inches are expected to increase by three per decade… Changes in the distribution of rainfall may result in an increase in the frequency of intense storms that deliver high amounts of precipitation over short periods of time.”
Matrix of normative, EPA funded, or aggregate solutions at three identified scales. These interventions all aim to reduce the impact on the combined sewer system while also improving the social and economic environment of the existing blocks.
Permeable Pavement

Component

- **Type**: Pervious Concrete
- **Lifespan**: 20-40 years
- **Typically 15-20% porosity**
- **Rate**: (3-5 gal/min) / sq. ft.
- **Cost**: $2.00-5.00 / sq. ft.
- **Minimum**: None
- **Maximum**: None

**Description:**
Porous pavement can reduce and infiltrate surface runoff through its permeable surface into a stone or filter media below. Runoff then percolates into the ground, is conveyed offsite as part of a stormwater system, or is collected and contained for future use. Pervious pavement can be asphalt, concrete or pavers, but differs from traditional pavement because it excludes fine material and instead provides pore spaces that store and pass water.

**Upkeep:**
> Maintenance inspection once a year
> Vacuum sweep 4 times a year

Construction

**Water**: The amount of rainfall or snow-melt to be designed for. This volume helps design the depth of the course aggregate layer.

**Porous Concrete/Asphalt [P.C.]:** Course surface layer that allows water to infiltrate into substrate.
- **Depth**: 5-8 inches
- **Void Percentage**: 15-20%
- **Infiltration Rate**: (3-5 gal/min) / sq. ft.

**Course Stone Aggregate Substrate [C.A.]:** The primary storage bed for stormwater runoff in the porous concrete paving system. *note: the base of this layer must be a minimum of 24” above the seasonal high water table or bedrock.
- **Depth**: 12-36” (Varies based on design volume)
- **Void Percentage**: 25-40%

**Uncompacted Sub-grade**: The earthen soil uncompacted, this includes no machinery allowed over the design area.
- **Infiltration Rate**: Specific to soil type

Exploded axon diagram

Construction diagram

Plan
Isolated
Back to Back Lot Calculations
(33’ lot width)

A Edges:
width (total): 6 ft
Depth of [P.C.]: 6” (15% void)
Capacity: 14.9 cu.ft. (110 gals)
Depth of [C.A.]: 18” (30% void)
Capacity: 89.1 cu.ft. (659 gals)
Total Capacity: 769 gallons
Cost: $400-1000

B Middle:
width (total): 4 ft
Depth of [P.C.]: 6” (15% void)
Capacity: 9.9 cu.ft. (73 gals)
Depth of [C.A.]: 18” (30% void)
Capacity: 59.4 cu.ft. (439 gals)
Total Capacity: 512 gallons
Cost: $270-670

C All:
width (total): 20 ft
Depth of [P.C.]: 6” (15% void)
Capacity: 49.5 cu.ft. (366 gals)
Depth of [C.A.]: 18” (30% void)
Capacity: 297.0 cu.ft. (2200 gals)
Total Capacity: 2566 gallons
Cost: $1,325-3,400

Aggregate
Entire Block Calculations
620 ft. block Length
.5” storm = 60,800 gals

A Alley All:
Total Capacity: 48,174 gallons
Cost: $96,200 - 245,000
% of .5” storm: 80%

B Street Parking:
Total Capacity: 36,053 gallons
Cost: $72,000 - 182,000
% of .5” storm: 60%

C Alley All + Street Parking:
Total Capacity: 84,227 gallons
Cost: $168,200 - 425,400
% of .5” storm: 140%

< Porous concrete, when applied to the entire alley and on-street parking can handle almost a capacity of a .75” storm. However, Porous concrete is in its infancy and is known to be difficult to install with complete consistency. Continual maintenance and initial installation costs yield porous concrete as a somewhat effective solution, but financially strenuous.
Rain Garden

Component

Type: Rain Garden
Lifespan: N/A (requires seasonal upkeep)
Rate: 1-3 gals / sq. ft.
Cost: $3-12 / sq. ft.
Minimum: 10’ from structural foundation
Maximum: None

Description:
Rain gardens are gardens that are watered by collected or pooled stormwater runoff, slowly infiltrating it into the ground along root pathways. They are typically planted with wildflowers and deep-rooted native vegetation, which helps infiltrate rain channeled to them from roofs, driveways, yards and other impervious surfaces. They can be placed near downspouts on homes (although away from building foundations and sewer laterals), and are an excellent means of removing pollutants from stormwater runoff. They should be slightly depressed to adequately hold and infiltrate stormwater runoff.

Upkeep:
> Seasonal weeding
> Seasonal trimming

Construction

1. Clearance: There needs to be a minimum of 10 ft between the start of the Rain Garden and any home/garage structural footing.
2. Dimensions: The depth & width of the rain garden depends on designed capacity and slope of existing lawn. Soil characteristics also help define the depth of the garden.
3. Berm: A berm is created at the low end of the garden to help contain and store water during a wet weather event. Generally no new earthen material is needed to create this berm.
4. Vegetation: Plant selection should include deep rooted native plants. Plant lists include wildflowers and low shrubs typically.

Safe offset diagram

Typical construction section
Rain Gardens are an extremely effective solution to clean, slow, and store water. However, they require a substantial amount of space to yield this effectiveness and due to the narrow and densely packed lots of the prototypical block, the space needed to handle a 1" storm would require the entirety of the private sector’s open space. Furthermore, there is little to no space in the exiting public sector of the block to implement Rain Gardens effectively. The Rain Garden, although a good intervention in strategy, does not have the capability to make an effective impact without major spatial changes to the existing conditions.
Green Street

Component

Type: Green Street
Lifespan: N/A
Rate: 3-17 gal / sq. ft.
Cost: $250/each
Tree Types:
Minimum:
Maximum:

Description:
Green alleys, streets and parking lots are typically in the public right-of-way and can provide a combination of different benefits designed to channel, infiltrate and evaporate rainwater. They include permeable pavement, sidewalk planters, landscaped medians and bio-swales, inlet restrictors, greenways and trees (as described above), and can also take advantage of recycled materials.

Construction

1 Porus Pavement: Rate of 4 gallons per square foot at a cost of $0.35 gallon of storage.

2 Rain Garden: Rate of 2 gallons per square foot at a cost of $3.75 per gallon of storage.

3 Stormwater Tree: Unknown rate when linked to storm event, however holds up to 500 gallons per year.
< The Green Street intervention could handle up to an entire 0.5" storm and completely transform the social quality of the exiting blocks. However, they are comparable to porous concrete in their financial strain and would reduce the size of the street to make space for the rain gardens and storm water trees. Potentially a lane of on-street parking would need to be eliminated to have enough space to implement correctly, while still not being able to handle an entire 1" storm.
Rain Barrel

**Component**

- **Type:** Rain Barrel  
  Lifespan: 20 years  
  Capacity: 40-80 gallons  
  Cost: $45-190/each

**Description:**

Rain Barrels collect rainwater that falls on your roof and stores it, so you don’t lose it to street runoff and drainage. Rather, you can use that clean, soft water with no chlorine, lime, or calcium however you want, effectively saving money. By catching the water from your roof, a rain barrel reduces the amount of rain flow going into the sewage system during wet weather events. Water should not stay stagnant in the barrels longer than two weeks.

**Construction**

1. **Heavy Duty Plastic Barrel:** Typically a one-piece low density polyethylene construction ranging in volume capacity from 15-55 gallons.
2. **Downspout Connection:** The existing downspout is modified to connect to the new plastic barrel with flexible tubing.
3. **Drainage Spigot:** A drain at the bottom gives access to the relatively clean water stored in the barrel.

**Impact**

- **Isolated:** Single Barrel  
  > Capacity (gallons): 50  
  > Typ. Roof Area (sq. ft.): 1,200  
  > Plan Area (sq. ft.): 990  
  > Typ. Precipitation (gallons): 620  
  > Cost: $100

- **Aggregate:** 36 Lots (2 Barrels each)  
  > Capacity (gallons): 3,600  
  > Typ. Roof Area (sq. ft.): 43,200  
  > Plan Area (sq. ft.): 35,640  
  > Typ. Precipitation (gallons): 22,320  
  > Cost: $45,000

--- % of Storm Captured: 16%  
(considering only roof water)

**Overflow Outlet:** A top-mounted overflow allows excess to be discharged to lawn, street, or directly to storm sewer.
Rainwater Bladder/Pillow

**Component**
- **Type:** Flexible Rainwater Bladder
- **Lifespan:** 20-50 years
- **Capacity:** 25-210,000 gallon
- **Applicable size:** 100 gallon (66” x 48” x 9”)
- **Cost:** $2,500 / 1000 gallon kit

**Description:** Flexible rain water storage tanks are a unique and economical way to store and collect rainwater for your location. Designed with a low profile, these tanks are often used in locations such as under decks, in basements, in crawl spaces and in other locations where space or height is limited. Flexible tanks can be constructed with either a standard water compatible fabric or a water fabric that meets FDA and NSF 61 requirements.

**Construction**
- **Storage Vessel:** Horizontal pillows come in standard sizes as well as can be custom made for specific locations.
- **Filtration System:** The filtration system requires routine attention after every storm to keep it working properly.
- **Pump:** Depending on price this pump can either be manually switched on or can be be fully automated.

**Impact [1.0” Storm]**
- **Isolated:** Front & Rear porches
  - **Capacity (gallons):** 500
  - **Typ. Roof Area (sq. ft.):** 1,200
  - **Plan Area (sq. ft.):** 990
  - **Typ. Precipitation (gallons):** 620
  - **Cost:** $1,250

- **Aggregate:** 36 Lots
  - **Capacity (gallons):** 18,000
  - **Typ. Roof Area (sq. ft.):** 43,200
  - **Plan Area (sq. ft.):** 35,640
  - **Typ. Precipitation (gallons):** 22,320
  - **Cost:** $45,000

----> % of Storm Captured: 80%
[considering only roof water]

**Overflow:** An overflow pipe that is connected to another avenue of discharge makes sure water will not back up once the bladder capacity is reached.

---

Rainwater Bladders and Pillows are becoming more and more common as an alternative means to large cisterns to hold and harvest rainwater. They are extremely versatile and very effective in their capacity to handle large wet weather events. However, they tend to be limited to only the water that lands on the roofs that is convey to the pillows through downspouts, which is only 1/3 or less of the water that impacts a block during wet weather events. Rainwater Bladders and Pillows also continue to disguise and hide water out of sight, and usually do not increase a communities awareness of water management.
Underground Cisterns are a very effective solution to holding and harvesting rainwater. They have a wide range of capacities that are able to handle basically any design load desired. However, these tend to be very expensive to implement and require sustainable earthwork to install. Underground Cisterns also continue to hide water management out of sight, reducing the public awareness of their presence.

**Component**

**Type:** Underground Rainwater Cistern  
**Lifespan:** 20-50 years  
**Capacity:** Variable (500-2,500 gallon typical)  
**Cost:** $1,000-10,000/each  

**Description:** Rainwater harvesting encompasses the capture and storage of rainwater. It also includes the ability to reuse stored rainwater for appropriate uses, primarily gardening and lawn watering. Harvesting not only includes the collection systems, but also the rain barrels and cisterns used to store the water. Rain barrels and cisterns are similar, although cisterns tend to be relatively large and sometimes are installed underground.

**Impact**

**1.0” Storm**

- **Isolated:** Single Barrel  
  - Capacity (gallons): 1,000  
  - Typ. Roof Area (sq. ft.): 1,200  
  - Plan Area (sq. ft.): 990  
  - Typ. Precipitation (gallons): 620  
  - Cost (tank only): $1,800  

- **Aggregate:** 36 Lots  
  - Capacity (gallons): 36,000  
  - Typ. Roof Area (sq. ft.): 43,200  
  - Plan Area (sq. ft.): 35,640  
  - Typ. Precipitation - roof (gallons): 22,320  
  - Cost: $64,800

- % of Storm Captured: 160%  

[considering only roof water]

**Construction**

1. **Heavy Duty Plastic Storage Vessel:** Typically a polyethylene construction ranging in volume capacity from 500-2500 gallons.

2. **Downspout Connection:** The existing downspout is modified to connect to the new plastic barrel with flexible tubing.

3. **Rainwater Filter:** Prior to entering the storage portion, water transitions through a filter to ensure quality.

4. **Home Connection:** A drain at the bottom gives access to the relatively clean water stored in the barrel.

5. **Overflow Outlet:** A top mounted overflow allows excess to be discharged to lawn, street, or directly to storm sewer.
**Above Ground Cistern**

**Component**

- **Type:** Above Rainwater Cistern
- **Lifespan:** 20-50 years
- **Capacity:** Variable (500-3000 gallon typical)
- **Cost:** $1,000-10,000/each

**Description:**
Rainwater harvesting encompasses the capture and storage of rainwater. It also includes the ability to reuse stored rainwater for appropriate uses, primarily gardening and lawn watering. Harvesting not only includes the collection systems, but also the rain barrels and cisterns used to store the water. Rain barrels and cisterns are similar, although cisterns tend to be relatively large and sometimes are installed underground.

**Impact** [1.0" Storm]

- **Isolated:** Single vessel
  - > Capacity (gallons): 1000
  - > Typ. Roof Area (sq. ft.): 1200
  - > Plan Area (sq. ft.): 990
  - > Typ. Precipitation (gallons): 620
  - > Cost (vessel only): $1500

- **Aggregate:** 36 Lots, Single vessel
  - > Capacity (gallons): 36000
  - > Typ. Roof Area (sq. ft.): 43200
  - > Plan Area (sq. ft.): 35640
  - > Typ. Precipitation - roof (gallons): 22320
  - > Cost: $54000

---

**Construction**

- **Storage Vessel:** Constructed of a variety of materials that range from aluminum to wooden. Typically range in residential capacity of 500 gallons to 3000 gallons.

- **Water Inlet:** A vertical connection is made at the top of the vessel to the existing gutter system.

- **Drainage Spigot:** A drain at the bottom gives access to the relatively clean water stored in the barrel.

---

**Above Ground Cisterns** are just as effective as their underground counterpart, however they vary in that they require substantial above ground space to implement. They do a better job of making visible their water management intentions, but they are only capable of holding and filtering water that lands on the roof, which is 1/3 of the water experienced on the lot.
Design Intervention

**Design:** Corrugated Plastic Roofing

Description: Employing a corrugated roofing material horizontally on a pitched roof creates numerous small gutters across the surface of the roof that slow the shedding of water to the gutter system.

**Storage:** Slow, Clean

Effective Rate: Roof pitch dependant

> Pitch Range:
> Rate Range:

Cost: $30-40

Lifespan: Lifetime warranty

Dimensions: 26” x 96”

Construction

1. **Corrugated Plastic Roofing:** The corrugated plastic roofing operates when designed to be horizontal, rather than vertical, can hold water in "mini-gutters" along the entire surface of the roof.

2. **Closures Channels:** The water is then channeled at a restricted rate to the traditional gutter system.

3. **Existing Roof Construction:** The existing roof structure can be used as is. The removal of shingles is all that is suggested.

Diagram: Small quantities of water can be held in the horizontal channels created by the corrugations of the plastic.

Exploded Construction Axon: Things to explain

Impact [1.0" Storm]

**Isolated:** 8:12 Pitch Roof

> Typ. Roof Area (sq. ft.): 1,200
> Plan Area (sq. ft.): 990
> Typ. Precipitation (gallons): 620
> Roof Capacity
> Single Groove (gallons): 0.93
> Total Capacity (gallons): 37.2
> Cost (lbs): 308

**Aggregate:** 36 roofs, 8:12 avg. Pitch Roof

> Roof Area (sq. ft.): 43,200
> Plan Area (sq. ft.): 35,640
> Typ. Precipitation (gallons): 22,320
> Total Capacity (gallons): 1,340
> % of Storm Captured (considering only roof water): 6%

**Isolated:** 6:12 Pitch Roof

> Typ. Roof Area (sq. ft.): 1,100
> Plan Area (sq. ft.): 990
> Typ. Precipitation (gallons): 620
> Roof Capacity
> Single Groove (gallons): 3.10
> Total Capacity (gallons): 110
> Cost (lbs): 913

**Aggregate:** 36 roofs, 6:12 avg. Pitch Roof

> Roof Area (sq. ft.): x,xxx
> Plan Area (sq. ft.): x,xxx
> Typ. Precipitation (gallons): 35,640
> Total Capacity (gallons): 1,340
> % of Storm Captured (considering only roof water): 18%

Implemented
Rainscreen Storage

**Designed Intervention**

**Design:** PVC tubes arrayed along the facade and connected to multiple downspouts allows water to discharge serve both as a rainscreen, as well as a storage space. Water from the roof and facade is discharged at a controlled rate into filtration system to enhance the quality of the rainwater.

**Storage, Slow, Clean**

*Effective Rate: 0.396 gal / sq. ft.*

**Cost:** $30-40

**Lifespan:** Lifetime warranty

**Dimensions:** 26” x 96”

---

Through utilizing the vertical space of a façade, a hybrid rain screen and storage system has the capability to hold over 2,000 gallons (comparable to a typical cistern) and is a cost effective solution when needing to replace aged façade cladding. The Rain screen Storage is less expensive than implementing a cistern and using conventional cladding systems combined. Again, as with the other aggregate solutions, they are only able to impact 1/3 of the water (roof water) that affects the lot during wet weather events.

---

**Impact [1.0" Storm]**

**Isolated:** long facade

- Single facade area (sq. ft.): 910
- Horizontal tube capacity (gal/sq. ft.): 0.396
- Total Horizontal tube capacity (gallons): 360
- Vertical tube capacity (gal / linear ft.): 0.253
- Total Vertical tube capacity (gallons): 41
- Cost: $x,xxx
- Total storage capacity (gallons): 401
- Typ. Roof precipitation (gallons): 620

---

**% of Storm Captured:** 65%

(considering only roof water & 1 facade)

**Aggregate:** 36 homes, 2 long facades/home

- Facade area (sq. ft.): 65,520
- Horizontal tube capacity (gal/sq. ft.): 0.396
- Total Horizontal tube capacity (gallons): 25,945
- Vertical tube capacity (gal / linear ft.): 0.253
- Total Vertical tube capacity (gallons): 1,476
- Cost: $x,xxx
- Total storage capacity (gallons): 27,421
- Typ. Roof precipitation (gallons): 22,320

---

**% of Storm Captured:** 130%

(considering only roof water)

---

**Implemented**

- Normal flow of water
- Storage of water in rainscreen

---

Dan Williamson: M.Arch Thesis
> A water stack design is an effective solution as it locates water storage and harvesting near the internal uses of water. This becomes a visual cue within the lot of where water use is occurring and can noticeably bring awareness to a new water management strategy. Once again, the solution is limited to roof water, however, it becomes a very effective solution with respect to both capacity, performance, and space efficiency.

## Water Stack

### Designed Intervention

**Design:** Harvesting water can become more effective at the location of stacked bathrooms. This can allow for narrow vertical storage which can then be used as for internal toilet flushes as a grey water system. Coupled with this system is a set of vertical filtration “Shelves” that filter and slow the overflow capacity of the vertical storage vessels.

**Storage, Slow, Clean Effective Rate:** Based on allowable width and depth of stack.

**Dimensions:** 24” x 56”

### Impact [1.0” Storm]

**Isolated:** Single home
- Vessel capacity - each (gallons): 315
- Total vessel capacity (gallons): 630
- Plan Area (sq. ft.): 1,200
- Cost: $x,xxx
- $ Saved / 1 inch: $1.24
- $ Saved / year (35”): $43.40
  ----> % of Storm Captured: 102%

**Aggregate:** 6 non-stacked homes, 30 stacked homes
- Vessel capacity - each (gallons): 320
- Total vessel capacity (gallons): 2,120
- Plan Area (sq. ft.): 4,200
- Cost: $x,xxx
- $ Saved / 1 inch: $1.24
- $ Saved / year (35”): $43.40
  ----> % of Storm Captured: 95%

### Construction

1. **Vertical Storage Vessel:** Embedded in a free-standing, wood-framed addition outside the location of the stacked bathrooms.
2. **Overflow Piping:** And overflow is designed to discharge into a vertical series of vertical shelves once the storage vessel has reached capacity.
3. **Vertical Filtration Shelves:** Overflown water trickles and meanders downward through a filtration system.
4. **Wood Framing:** A simple timber frame supports the vessels as well as encloses them.
5. **Exterior Cladding:** A wood rainscreen cladding to allow drainage from facade surface.
6. **Stacked Bathrooms:** Located near the location of stacked water-use spaces within the home.
Stacked Water

Designed Intervention

**Design:** Within attic spaces 2 conditions typically exist: Occupied space or void space. The void space can be taken advantage of to intervene space for water storage. Through precise location above stacked bathrooms or kitchens, stored water can effectively be stored for internal use.

**Storage, Slow, Clean**

*Effective Rate: 1*

*Dimensions: 42” x 216” x 6”*

---

**Impact**

*1.0” Storm*

<table>
<thead>
<tr>
<th>Isolated: Single home</th>
<th>Aggregate: 36 homes</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt; Vessel capacity - each (gallons): 235</td>
<td>&gt; Vessel capacity - each (gallons): 8,460</td>
</tr>
<tr>
<td>&gt; Typ. Roof Area (sq. ft.): 1,200</td>
<td>&gt; Typ. Roof Area (sq. ft.): 43,200</td>
</tr>
<tr>
<td>&gt; Plan Area (sq. ft.): 990</td>
<td>&gt; Plan Area (sq. ft.): 35,640</td>
</tr>
<tr>
<td>&gt; Flushed / vessel: 67</td>
<td>&gt; Flushed / vessel: 67</td>
</tr>
<tr>
<td>&gt; Cost: $x,xxx</td>
<td>&gt; Cost: $x,xxx</td>
</tr>
<tr>
<td>&gt; $ Saved / 1 inch: $0.47</td>
<td>&gt; $ Saved / 1 inch: $1.24</td>
</tr>
<tr>
<td>&gt; $ Saved / year (35 ”): $43.40</td>
<td>&gt; $ Saved / year (35 ”): $43.40</td>
</tr>
</tbody>
</table>

---

<table>
<thead>
<tr>
<th>% of Storm Captured: 38%</th>
<th>% of Storm Captured: 38%</th>
</tr>
</thead>
<tbody>
<tr>
<td>(considering only roof water)</td>
<td>(considering only roof water)</td>
</tr>
</tbody>
</table>

---

**Construction**

1. **Roof Storage Vessel:** Roof cut out is designed to hold water in the vacant space of the roof rafters.

2. **Structural Reinforcement:** Due to the heavy weight of collecting water, extra structure is necessary to accommodate the added stresses.

3. **Stacked Bathrooms:** Located near the location of stacked water-use spaces within the home.

---

<Very similar in concept to the water stack, this intervention locates water storage and harvesting vessels in void attic space. This is a very space efficient strategy, however it would require the home owner to re-enforce the structure underneath the storage vessels. The stacked water is limited to roof water, however, it becomes a viable solution when home owners are looking to expand their home and re-enforcing structure becomes more of a reality.
Mandates:
- required avg levels of discharged water quality
- limits set to discharge flows & amounts
- required amount of water to be held on site during wet weather events.

Incentives:
financial assistance to reach newer mandates
Cleaner and lesser volumes of water entering the combined sewer

Goals

Impact

Assessment

The funded, normative and aggregate strategies executed and analyzed above are unable to fully accomplish a goal of capturing or treating the first full inch of a wet weather event. Although some strategies come close, their resultant cost and maintenance tend to be high. The implemented strategies are at times unstable and can be unreliable if they are to be solely responsible for the wet weather goal. Understanding the shortcomings of these strategies, however, can inform new spatial operations that utilize certain aspects examined above. Through re-conceptualizing the spatial organization of the lot, new architectural solutions can be explored.
Normative, EPA funded, and aggregate solutions are not enough to adequately reduce the impact on Combined Sewer Systems. This condition leverages an opportunity for blighted and compromised
homes to serve as catalytic opportunities to explore new spatial operations that create cleaner and lesser volumes of water entering the combined sewer.
Existing urban residential blocks, lots, and homes that rely on Combined Sewer Systems (See Regional scale Chapter) need to be spatially re-configured and architecturally address water performance while also serving as better social environments that acknowledge the presence and importance of water within our built environment. Through decentralized water management and paradigm V discourse (See Chapter 1), existing urban residential developments need to leverage new spatial strategies to socially, economically, and environmentally perform beyond the reliance on aging infrastructures.

Infill: Water Core Home is a designed system of a prototypical lot that leverages internal and external spatial strategies that aim to reduce the quantity and improve the quality of the water that reaches the combined sewer system. Through the following pages the design strategies, concepts, and motives of the Water Core Home will demonstrate the impact of this decentralized system on the prototypical home, lot, and block.
> The prototypical lot needs to address the variables identified on the right. New construction within the exiting fabric needs to reach these goals in order to make an adequate impact within a decentralized water management system.

> The exiting condition presents a constant to measure new interventions against. New lot organization needs to respond to existing parameters, as well as existing adjacent lots.
Numerous spatial iterations demonstrate an array of possible lot organizations. Iterations highlighted by a reach the defined goals for rain capture, rain garden, and habitation square footage. The highlighted iterations inform the need for an extensive linear rain garden that stretches to both ends of the lot to allow for overflows in both directions. Also, a narrow meeting of the ground in either a foundation wall or pile will result in more space for the necessary rain garden space to exist. Finally, a car port should replace the need for a full garage which spatially and visually opens up the narrow lot as well as increases the horizontal space for the linear rain garden.
Internally, there are three spaces that use water within the home: Laundry room, Bathroom, and Kitchen. The diagram at the right tracks the water as it is collected from a roof system and dispersed through the home.
From understanding the spaces and uses of water within the home, a central core of those spaces is created to maximize the transfer of water efficiency. This Water Core system responds simultaneously to the internal while also reacting consciously to external flows to of linear rain garden and overflow conveyance components.
> **Linear Rain Garden:**
From the lot analysis, a narrow linear rain garden that has the ability to overflow on either end of the lot will yield the most successful initial organization element to inform the initial massing of the home.

> **Narrow Foundation:**
A narrow foundation responds to the need for the linear rain garden which also creates a lighter relationship in the way the home meets the ground. This strategy also allows for a deeper home and increases the spatial volume between lots.
< Water Core Location: The Water Core is located directly above the foundation due primarily to the increased weight that will occur from storing water. Functionally, the Water Core and be positioned anywhere along the narrow foundation its final position can then be influenced by external factors such as the rain garden.

> Water Core & Rain Garden Relationship: The Water Core is located with respect to the optimized location of the neighboring potential rain gardens. Locating the Core here allows the initial overflows during extreme wet weather events to be into the largest portion of the rain gardens.
1. Initial Massing: The typical square footage needed for a family of 4 is massed in two floors with respect to the narrow foundation.

2. Enlarge Roof: The roof is enlarged to catch a greater quantity of water, therefore being able to store, clean, and slow more water.

3. Form Roof: The roof is formally shaped to direct water to the Water Core of the home.

4. Pull Back Massing: The top ends of the massing are pulled back to increase the external spatial volume, therefore increasing the amount of external, vertical open space which is currently strained in existing lots.
Roofing

1. Cladding: A corrugated roofing system serves as a lightweight cladding system that conveys water effectively to internal storage location, and overflow.

2. Wood Fascia: A light wood fascia compliments the underside of the roof and facade rain-screen and providing a light colored outdoor ceiling.

3. Glulam Truss: Glulam trusses with tapered ends are utilized to achieve a large cantilevered roof system that can catch and direct a large quantity of precipitation.

Shell


8. Rain-screen Drainage Layer: The existing downspout is modified to connect to the new plastic barrel with flexible tubing.

9. Wood Rain-screen Slats: A drain at the bottom gives access to the relatively clean water stored in the barrel.

10. Overflow Cascading Gutters: A drain at the bottom gives access to the relatively clean water stored in the barrel.

11. View port Windows: A drain at the bottom gives access to the relatively clean water stored in the barrel.

12. Frosted Windows: A drain at the bottom gives access to the relatively clean water stored in the barrel.

Grounding

4. Flooring: A hardwood floor on the entrance level creates a warm interior space while acting serving as a reminder to the water performative rain-screen of the facade.

5. Heavy Timber Floor Truss: Heavy timbers are employed to achieve a small five foot cantilever of the entire home which allows for a larger rain garden.

6. Foundation Walls: A narrow foundation wall system serves as the grounding of the home as well as operates initially as an unfinished basement.
Scalar Water System
Water Core Home leverages new spatial motives for architecture and re-aligns the scope of the architect beyond the issues of the object building. The water issues that Water Core Home focuses on re-introduces the architect back into a role within the urban water management team. Architecture becomes decentralized infrastructure, and the social importance and awareness of water in our built environment can be resurrected from the hidden, discrete, aging, and fragile network operating unknowingly underneath the urban fabric.
References


Acknowledgements

Mentors
David Karle
Sarah Thomas Karle

Faculty Critiques
Steve Hardy
Jeff Day
Brian Kelly
Bret Betnar
Kim Wilson
Tim Hemsath

UNL Resources
Sarah Michaels
Zhenghong Tang
Steven Rodie

UWM Resources
James Wasley
Karen Sands
Carolyn Esswein

Professional Resources
Andy Szatko
Cameron Barradale

Peer Assistance
Tristan Vetter
William Pekojski
Tara Meador

Family Assistance
Dennis Williamson
Barbara Williamson