

Connecting the Drops: managing the effects of climate change on water in Seattle

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**Abstract**

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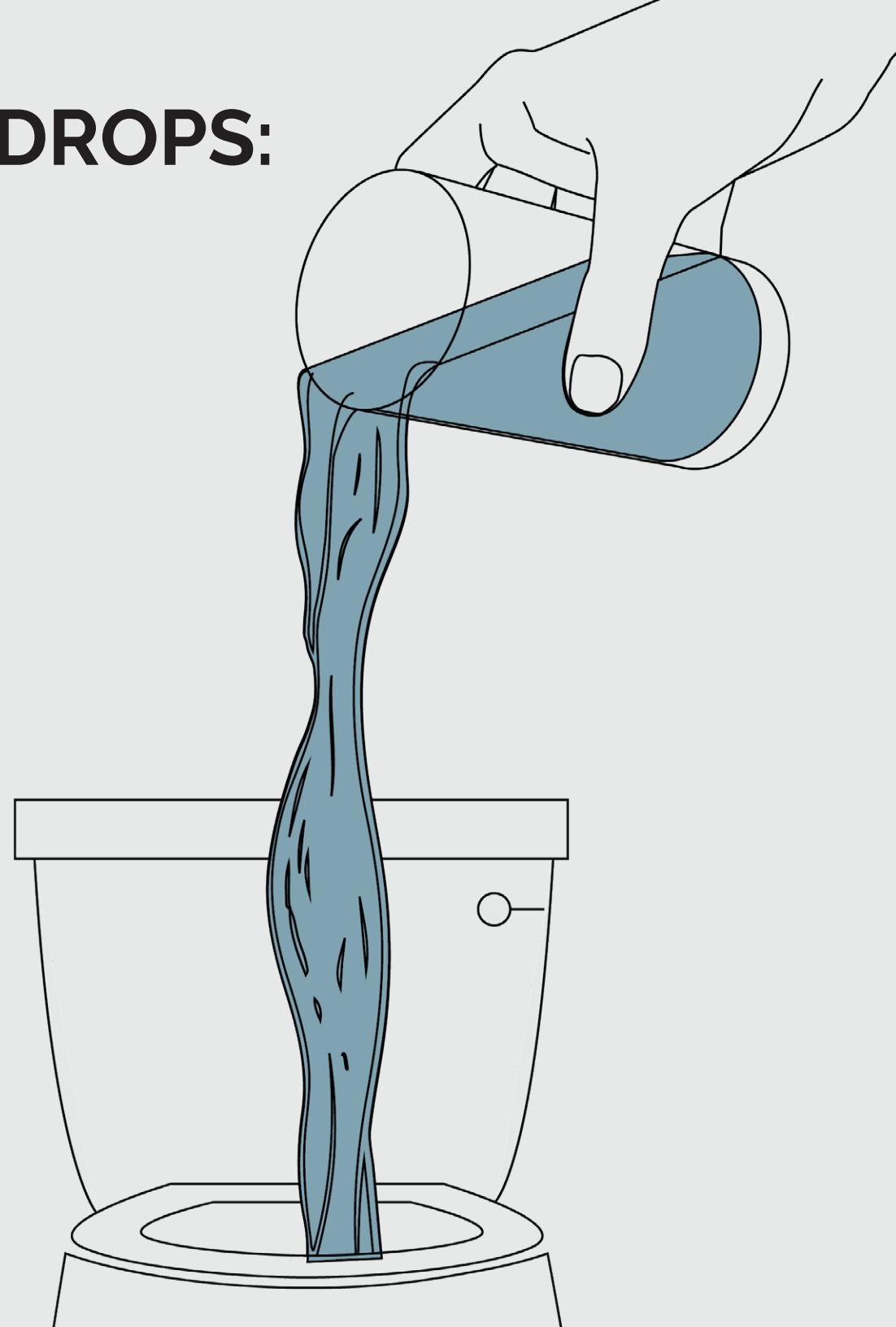
As climate change affects our water supplies, we must plan for a range of scenarios and delve into the dichotomous condition of a rainy city amid limited potable water supplies. This thesis explores how to reduce potable water demand, reduce wastewater discharge, and maintain healthy water bodies through water reuse, decentralized/semi-centralized infrastructures, systems-oriented water management, and educational initiatives. The tools explored here are a resource for climate-adapted water management and applied to the Georgetown neighborhood as an illustrative, case-specific example across single parcel, multi-parcel, right of way, and neighborhood scales.

This thesis explores potentials of water reuse as an adaptation to decreasing available water supply in the following three parts. The first research portion considers available information on climate change, Seattle's water system, and a case study from Melbourne, Australia that provides insight for American systems. The second design part focuses on applying these techniques in Seattle's Georgetown neighborhood across scales: small, single lots; right-of-way; and neighborhood. The final part discusses other avenues that could further develop this work in the future as well as reflections on the thesis process and resulting potentials for water management.



# CONNECTING THE DROPS:

MANAGING THE EFFECTS OF CLIMATE  
CHANGE ON WATER IN SEATTLE



Rachel Wells  
Master of Landscape Architecture 2019  
University of Washington



# ACKNOWLEDGMENTS

Thank you to my partner Ari, without your patience and support, this thesis could not have happened.

Thank you to my committee, Julie Johnson and Thaisa Way, who inspired me and always got me out of my creative funks and writers blocks.

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# INTRODUCTION

Approach & Goals

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# INTRODUCTION

The idea of a project on small-scale water infrastructure was born during Winter Quarter of 2018, in a design focusing on about community resilience. It originally focused on disaster recovery following an earthquake, or specifically what the city and its communities could do to prepare for and recover from "the really big one." The city disaster response documents include a passage that estimates it will take 30-90 days to restore clean drinking water, and three or more years to restore the sanitation system to current functionality. The water systems' vulnerability to disasters and studio focus on resilience naturally led to investigations into how to make Seattle's water system more resilient in response to other types of disasters, including climate change.

Climate change is not a natural disaster in the usual sense, where sudden and severe events cause local, regimental change but rather manifest as enduring, drastic changes happening on an extended time scale. The effects are not as reversible as the infrastructure damage from an earthquake and challenge the assumptions and change the tolerances our infrastructures rely on.

The problem of climate change is hundreds or thousands of small problems, some with large effects and some with smaller impacts that are waiting to be solved. It is incumbent on each individual, organization, and government to change the valuation surrounding resources like food, energy, clothing, and water, and then to introduce new practices to suit future conditions. Freshwater availability is becoming an increasingly challenging problem yet much of the water used in urban areas is not for human consumption. The increasing shortage of clean, freshwater mandates changes in how we value this finite resource.

This thesis is an exercise in developing of how I think about water, and the beginnings of where an institutional plan might begin. In order for everyone to have enough water to drink in coming decades, drinking water should only be used for consumption and other non-potable sources of water should be used for functions like toilet flushing, irrigation, industrial cooling, and washing clothes.

## Approach & Goals

This thesis on water reuse in Seattle is a hybrid between research and design framework. The research section reviews literature to synthesize current research on climate change and its impacts on Seattle's water system, as well as Water Sensitive Urban Design, an Australian concept of water management. The research investigates systems of water and how those play out across scales in a variety of contexts. These contexts develop a wider perspective and knowledge base about water management in the region while also supporting design. The design portion of this thesis focuses specifically on Seattle's Georgetown neighborhood, and how its specific conditions can be leveraged with scalable, decentralized infrastructures to increase neighborhood resilience. Ideally similar techniques and small infrastructures could be employed in other neighborhoods, though some interventions take on new forms in a place-specific context.

Understanding the most current information and predictions science has to offer helps build an understanding of how climate change impacts specific sectors. Most of these predictions are from global scale models that are subsequently tailored to regional scale. It is important to understand where climate models come from, how they are scaled down, how old they are, and which sets of assumptions they are based on in order to get an idea of their reliability on different systems.

It is especially important to understand the system affected, which in this case is Seattle's water

system. Seattle has extensive existing natural and built infrastructure that ensures clean water is available at any time, but there are many other interrelated systems that will change as the climate does. Some of these systems have direct influence on the water supply quantity, like groundwater and ecosystems, but other system influences are more difficult to anticipate. These conditions, like water rights and city politics, were an important part of visualizing where this project could grow.

A deep investigation of existing conditions and water management strategies in Seattle and beyond serves as starting place. These studies on current practices provides information on strengths, weaknesses, and where there is unrealized potential. Examining these practices can be achieved on a broad scale which can be explored through case studies. Melbourne, Australia serves as a case study that illuminates water conservation techniques and responses to climate change. There are significant overlaps political, environmental, and infrastructural conditions that relate to water conservation in Seattle.

The design portion of this thesis begins with traditional site analysis, then a design phase. The design phase takes the tools and contexts from the research portion and site analysis and seeks to integrate processes and infrastructures in Georgetown.

Georgetown presents an ideal location for proposals which seek to adapt to climate impacts for several reasons. Its prominent industrial uses produce a wide range of good, revenue, and jobs. However industrial

sites also produce a wide range of contaminants that need remediation. The proximity of the Duwamish River resulted in contamination of the river, groundwater, and sediments surrounding it. Flooding from stormwater and inadequate sewer infrastructure further pollute the neighborhood through stormwater runoff, industrial discharges, and combined sewer overflows. The combination of industrial and residential uses present in Georgetown make it an ideal neighborhood to pilot water management innovations. A willingness to experiment combined with its industrial, infrastructural, and hydrological challenges, the Georgetown neighborhood provides an environment to pilot multifunctional climate adaptations. To show compounding benefits, interventions look across spatial scales, size, scope, and time scales.

The following questions have guided these explorations:

- What are the best practices in managing water in the age of climate change in a way that continues to meet demand in Seattle and minimizes environmental impacts?
- How can water management theories and practices from both Seattle and throughout the world shape an effective strategy(ies) for this region?
- What do we know about the expected climate impacts in Seattle? How do they influence our water system? To what extent do current plans address adverse effects?
- How can design of places, processes, and systems facilitate more climate adapted water systems?

## Scope

South Seattle's Georgetown neighborhood has multiple complex, interwoven issues that make it a challenging place to introduce new infrastructure. The layered context and myriad of constraints make it easier to adapt water infrastructure to other places. Georgetown has been identified by multiple assessments as an area that needs improvement to meet safety standards for air, water, pollution, pedestrian, park, ecological health, disaster, equitability, and mobility. Multiple studies have promised improvements that have yet to be delivered. Some are planned, but there are opportunities to fulfill multiple goals for needed improvements that are not yet planned.

This project focuses on the Seattle water system, Georgetown's infrastructure, and its water source: the Cedar River, which is where Georgetown gets its water. This exploration seeks to understand how existing conditions have led to current circumstances. Modifying current practices and adopting new techniques shape a future plan that better prepares for the impacts of climate change.

The design component of thesis examines how different scales of water systems and different tools can work together to achieve compounding benefits. The site design portions remain mostly conceptual, but design of the water systems vary in depth of inquiry. For example, where existing technologies exist or where collaboration with an engineer would be needed, designs are conceptual. In other areas, where I wanted to understand how pieces or systems fit together, functioned, or adapted, the design proposals are more developed.

## Site Selection

The thesis committee members, Thaisa Way and Julie Johnson, are leading a grant from the Bullitt Foundation, launched Autumn 2018. Titled “Leapfrogging the Right of Way,” this project seeks new ideas for using space in the public right of way that might be at home in the twenty-second century, bypassing the usual incremental processes of improvement. It includes a directive for water quality interventions and opportunities, so I chose this work as context for this thesis inquiry. The team includes a combination of private sector professionals, university faculty, students, and leading public officials from the City of Seattle. The interventions focus on two pilot neighborhoods, Crown Hill and Georgetown, which played a large role in my site selection.

Many project aspects have taken time to develop, and community desires shifted the project focus away from water specific interventions. My involvement with the team broadened my original scope beyond single-parcel strategies, and challenged me to think about what temporary water infrastructure might look like. I have proposed several temporary water quality interventions in the right of way, which I hope to continue to develop.



Figure 0.1: The sink at Equinox Studios in Georgetown, Seattle

## Critical Stance

Fresh water is integral to life in built and natural environments. The effects of climate change and environmental modifications are rapidly redistributing available fresh water in volume, geography, and seasonality. Utilities are under pressure to manage the need for water with growing urban populations, aging infrastructure, climate change, and limited monetary resources while minimizing environmental harm. These effects and pressures are important to incorporate into future water management planning to gain system flexibility. This flexibility gives greater resilience to the water supply under the uncertain conditions expected as climate change progresses.

Research into current water management strategies and the effects of climate change offers insight into current conditions and barriers. Applying this research as a foundation for design proposals strengthens applicability of systems interventions. Revealing the complexity of interconnected water systems highlights the value of current infrastructures in maintaining quality of life and public health. Better understanding of these systems can also suggest potential improvements.

There are many different ways to increase available water supply as current sources experience the effects of climate change. Of these possibilities, water reuse has high potential for non-potable water use that is already available in urban areas. Water reuse infrastructure overlays both gray and green infrastructures to manage both flood risk and water scarcity. Research and Australian water management theory (see Chapter 4) suggest highlighting synergies within and between existing

systems while helping anticipate future conditions. Design proposals based on this research explore new methods for remedying current challenges while adapting to future change.

Water reuse strategies represent an opportunity to harness an untapped resource and provide a constant supply of water not directly impacted by climate change. By exploring what is possible at different scales of intervention, the potential for water reuse to offset potable water use becomes apparent. To incorporate new water resources, institutions and members of the public must accommodate new practices through individual buy-in, regulatory reform, and greater comprehension of the value of water resources.

Achieving change implies an understanding of the finite nature of fresh, clean water. Explaining layers of water systems, climate impacts, and potential solutions exposes people to new ways of seeing and acting, which will help change the way people value and use water as they gain greater awareness of the issues surrounding water.

This thesis explores potentials of water reuse as an adaptation to decreasing available water supply in the following three parts. The first research portion considers available information on climate change, Seattle's water system, and a case study from Melbourne, Australia that provides insight for American systems. The second design part focuses on applying these techniques in Seattle's Georgetown neighborhood across scales: small, single lots; right-of-way; and neighborhood. The final part discusses other avenues that could further develop this work in the future as well as reflections on the thesis process and resulting potentials for water management

## Terms & Abbreviations

The following terms and abbreviations are used extensively throughout the document, so they are introduced here for context and clarity.

### Abbreviations:

af/yr - acre feet per year

ASLA - American Society of Landscape Architects

BMP(s) - best management practices

cfs - cubic feet per second

CIG - Climate Impacts Group (at University of Washington)

CIRC - Climate Impacts Research Consortium (at Oregon State University)

CSO - combined sewer overflow (area)

GI - green infrastructure

GSI - green stormwater infrastructure

IPCC - Intergovernmental Panel on Climate Change

LID - low impact development

mgd - million gallons per day

OWTS - onsite wastewater treatment system

ROW - right of way

SPU - Seattle Public Utilities

WSUD - water sensitive urban design

USGS - United States Geological Survey

### Terms:

**Resilient** - The ability of a system bounce back after stress and adapt or evolve to be stronger and less vulnerable to that stressor in the future

**Water Sensitive Urban Design** - an Australian philosophy for integrated water management, ecological resilience, and resource availability (see Chapter 4)

**Low Impact Development** - Water management techniques that slow or absorb water at the site scale.

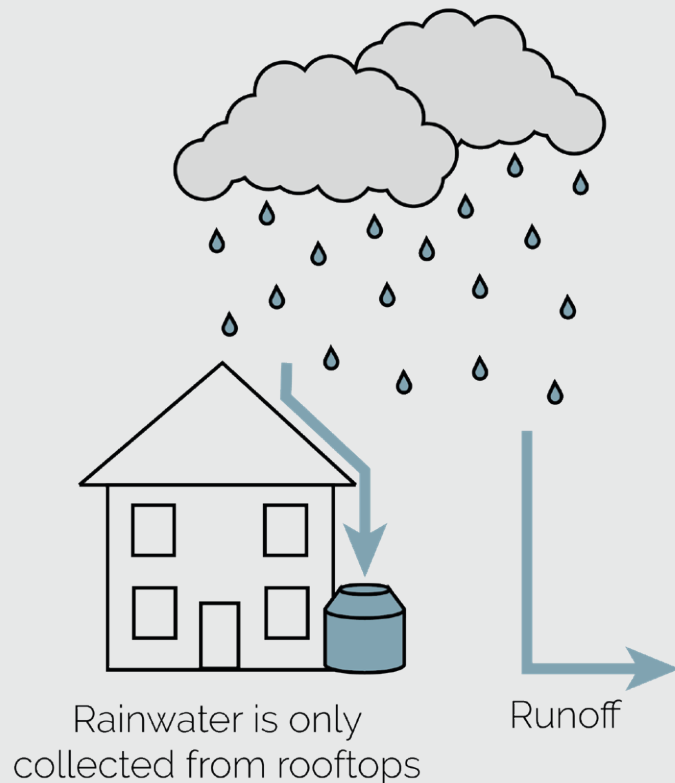
**One Water** - The philosophy that all water sources (including wastewater, stormwater, groundwater, rainwater, and surface water) have value and are integral parts of the urban water cycle [1].

**Integrated Water Management / Integrated Water Resource Management** - “a process which promotes the coordinated development and management of water, land and related resources, in order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems.” [2]

**Green Stormwater Infrastructure** - A type of distributed stormwater management that simulates natural hydrology [3]

**Effluent** - Water from a wastewater treatment plant, industrial discharge, stormwater outfall, or other urban structure entering a natural water body.

**Fit for purpose** - Water that is of sufficient quality for a specific use



**Figure 0.2:** Rainwater is legally classified as water that is collected from a rooftop in Washington state (19)

## Types of Water

**Raw** - water from rivers, lakes, and groundwater sources that has not been treated

**Potable** - drinking water: water that has been treated to strict standards that is safe to drink

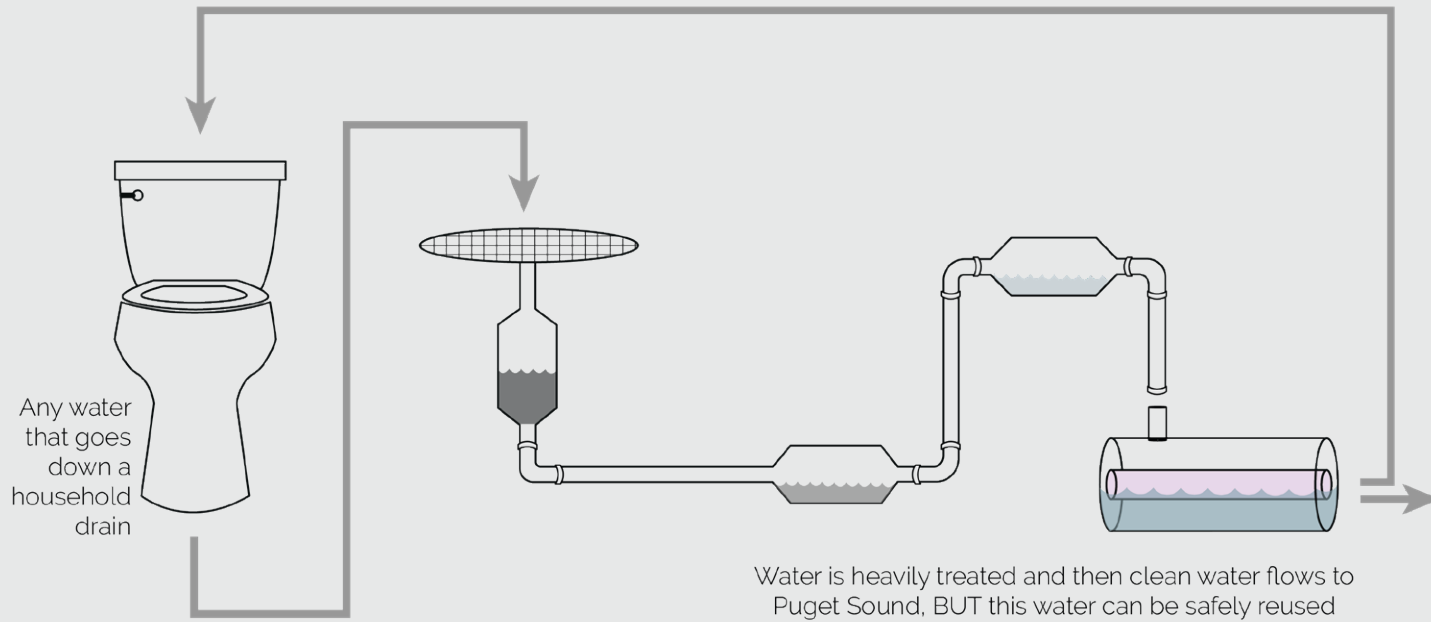
**Rain** - The State Department of Ecology in Washington has classified rainwater as water that has been specifically collected from a roof and is considered the cleanest form of untreated water. All other rain is currently considered wastewater [4]

**Stormwater** - Rain that falls on any surface other than a roof.

**Reclaimed** - Reclaimed water used to be wastewater and sewage but has been treated through multi-step processes to strict, specific standards. Washington recognizes reclaimed water classes A-D and specifies treatment standards and acceptable uses [5].

**Gray** - Graywater in Washington comes from bathroom sinks, laundry, showers, baths, and kitchen sinks and is currently the most difficult type of water to reuse under state law [6-8]

**Wastewater & Sewage** - The contents of toilets (sewage), industrial wastewater, and all non-roof rainwater. All sewage and some wastewater go to wastewater treatment plants before being discharged as effluent. All runoff in separated sewer districts and some of water in partially separated sewer districts discharges into the nearest water body without treatment.



**Figure 0.3:** Overview of the activated sludge treatment process. Sewage goes through multiple stages of treatment before being discharged as effluent or reused as reclaimed water.



**Figure 0.4:** Types of graywater acceptable for reuse. Kitchen sink water is also considered graywater but contains more pathogens.

## End Notes

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# CHAPTER 1

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# LANDSCAPE THEORY

*The New Landscape Declaration* & the Role of the Landscape Architect

Critique on *The New Landscape Declaration*

ASLA Roundtable

An Academic's View

A Practitioner's View

History of Thought

*1966 Declaration of Concern*

Ian McHarg

Susan Herrington

*The New Landscape Declaration*, Climate Change, & this Thesis

## LANDSCAPE THEORY

This section focuses on critique and philosophical context surrounding *The New Landscape Declaration*. *The New Landscape Declaration* is the subject of debate within professional circles and among practitioners, as are the exact role and scope a landscape architect has and should have in addressing sustainability and humanitarian concerns. These debates are helpful in coalescing the field overall but could impose limitations on the breadth of focus areas landscape architecture currently offers, which vary according to each region's needs. *The New Landscape Declaration* and contemporary interpretations see skills and ideas in landscape architects that can contribute to climate adaptation.

## ***The New Landscape Declaration & the Role of the Landscape Architect***

The climate emergency everyone faces requires every profession to mitigate and adapt to climate change and take action to address the unprecedented environmental damage that has been accruing since the Industrial Revolution. Damage to waterways and other natural systems that interface and support urban areas are under increasing stress from the effects of climate change and increasing populations. Though there is great concern for both socio-cultural issues and environmental health among landscape architects, common practice struggles to remedy ecological imbalances. This review focuses on *The New Landscape Declaration* as a set of goals for remaking common practices to benefit a wider group of people and environments.

In 2016, landscape architects assembled in Philadelphia again to create a new vision for landscape architects on the fiftieth anniversary of the *Declaration of Concern*, a directive that implores landscape architecture to address environmental degradation and reintroduce natural processes into urban lifestyles. The *New Landscape Declaration* outlines humanity as a part of nature and describes practices where landscape architects negotiate and shape the land with intention to benefit all living things. The declaration recognizes the challenges climate change poses in juxtaposition with a capitalistic, consumption-based society where inequity is rampant. *The New Landscape Declaration* calls on landscape architects to mitigate and adapt to climate change through collaboration and contextual, holistic design and to take action to remedy human and environmental damages. It calls on the profession to change and adapt by increasing scope and by finding new ways to uphold environmental and social ideals, embolden the profession, and negotiate the complex needs of multiple stakeholders [1].

While *The New Landscape Declaration* presents appropriate goals, it does not define actionable steps to achieve them. Thus the onus is placed on individuals and companies to find ways to fulfill these long term goals, often requiring professionals to balance more tangible problems such as personal advancement and budgetary concerns. Businesses are, by the scope of contracts, distanced from human and environmental needs. Many projects are constrained from sustainable, equitable action by reluctance to change, the seeming insignificance of a single project, client preferences, budget, system behavior [2], or lack consensus on exactly what the goals of *The New Landscape Declaration* lay out. For these major reasons (among others), *The New Landscape Declaration* and the field at large have been the subject of recent debates on the direction the field should take.

## Critique on *The New Landscape Declaration*

The following section provides critiques of *The New Landscape Declaration* from within the profession since it was published. Critiques include those from an ASLA roundtable and two landscape architecture scholars and educators.

### ASLA Roundtable

Critiques of the *New Landscape Declaration* were discussed by the American Society of Landscape Architects (ASLA) at the 2016 national conference. In private practice, practitioners voice criticisms on deemphasizing aesthetics, failing to respond to ambitious ideals of students and young professionals, perpetuating class and race funding gaps, and sacrificing ideals for short-term profits [3,4].

Alongside the above criticisms are calls to action in engaging with a changing climate, ecology, science, and diversity; moving beyond traditional roles; highlighting ecosystem services, public awareness, and pilot projects as ways to test new ideas; maintaining a lightheartedness in the face of these issues [3,4]. These critiques are grounded in the perspective that landscape architects are called to capitalize on their ability to translate knowledge and expertise into built, evidence-based, yet beautiful spaces and processes while addressing broader issues.

## An Academic's View

In his critique of *The New Landscape Declaration* and the profession at large, Richard Weller (Department Chair at University of Pennsylvania) discusses the theory and professional steps that have brought landscape architecture to its current state in his 2019 article, "Has Landscape Architecture Failed?." His insights offer a helpful in-depth look at the context surrounding landscape architecture practice and the beginning of a vision for the future [5]. He argues that there is a disconnect between envisioning green, living systems integrating with habits and preferences in people's daily lives and the fragmented, limited set of tools much of common practice offers.

*The New Landscape Declaration* was intended to redraft the professions *Declaration of Concern* on its fiftieth anniversary. However, Weller writes that the decision to rewrite it is complicated by the events of the last fifty-three years. While increasing urbanization, environmental degradation, and climate change were not as well understood in 1966, those same concerns and crises that were outlined in the original declaration continue. Both declarations see landscape architecture as a key to solving these global problems, yet impacts of climate change have only intensified in the intervening years. Weller presents his views (1) that landscape architecture is a young and small profession with (2) an incompletely defined scope. By remedying these issues, he argues the profession could engage in a more productive debate about the landscape architect's role in tackling worldly problems [5].

Weller suggests that the idea that landscape architecture is the key to solving the ongoing climate crisis, which is unreasonable and unrealistic [5]. *The New Landscape Declaration* seems more intent on encouraging cross collaboration between fields to address climate catastrophes and the built environments' role in creating them [1].

As Weller suggests, landscape architecture can be a contributor and participant in the type of dynamic changes that are needed if we do as the *The New Landscape Declaration* suggests and expand the scope of practice beyond aesthetic and fragmented design projects [1,5].

Weller highlights the struggle in defining the role of the landscape architect. From the Olmsted brothers' carefully manipulated, pastoral parks, to James Corner's ideas that landscape and theory should be rooted in phenomenological and cultural experiences rather than from prescriptive approaches. The Olmsteds and Corner are known for their parks more than urban environments or solutions to problems, and relegate much of landscape theory to creation of open spaces and aesthetic representation [5]. This reputation of the field severely handicaps professional practice by limiting their scope and places bounds on academic practice by stunting theoretical exploration.

Weller's critique focuses on the role of landscape architecture in climate adaptation and environmental concerns while giving a condensed history of the thinking that led to *The New Landscape Declaration*. The incremental improvements that have been made have not been enough to curb environmental harm and it is time to move beyond the scope of common practice.

## An Practitioner's View

In his 2019 article "Design and the Green New Deal," Billy Fleming discusses the disconnect between landscape practice and a series of goals that have been outlined by landscape architects, which include those in *The New Landscape Declaration*, Ian McHarg's philosophies, and the so called "starkatects" of our time. Fleming is critical of landscape architecture's current scope and argues that participation in The Green New Deal can elevate the scope and impact landscape architecture professionals can have [6]

Fleming scrutinizes the self-importance landscape architecture has achieved from its own practitioners and interrogates the positive environmental changes practitioners have claimed. Even the most notable projects, such as SCAPE's Oystertecture, are small in scope because sites are fragmented, funding is limited, and power structures continue to reinforce inequities. He describes modern practice as dependent on wealthy client interests and site, rather than the contextually and publicly informed design processes held as ideal. While extremely critical of current practices, his and others' call to remake landscape architecture into a profession that also serves public interest, broad infrastructure systems, and human necessity appeal to those grappling with the major issues of our time: equity and climate change [6].

Though critical of *The New Landscape Declaration*, Fleming is trying to provoke bolder action amongst landscape professionals, just as *The Declaration* suggests. For Fleming, landscape architecture is failing to act to meet the climate crises we face. Rather than continually restarting goals and engaging in unproductive debates, Fleming suggests reengaging with the socio-political movements happening now. Fleming observes that landscape architecture has been absent from recent turmoil and has sought instead to depoliticize the field

to the extent that landscape architects rarely part of policymaking. He observes that this is most evident in ASLA's recent refusal to endorse the Green New Deal, the first American proposal to approach the changes necessary to survive climate change [6].

The Green New Deal suggests collaboration, series of experimental projects, and widespread investment in infrastructure and public works; the kind of projects that designers dream of. When Fleming asked for their endorsement at a conference, the national ASLA leadership (in Fleming's view) was too concerned about offending climate deniers and serving wealthy clients to be interested. In failing to endorse the Green New Deal, the ASLA passes on a significant opportunity for landscape architecture to fulfill its goals of systematic environmental and human impacts. This also limits the scope of landscape architecture in curtaining the possible support and funding of truly public spaces, infrastructures, and human and environmental needs [6]. It ensures that any of these projects that landscape architects find time and energy to pursue will be done for free while continuing to contribute to problems they are supposed to be solving during paid hours for wealthy clientele.

The critique Fleming presents verbalizes concerns that landscape architecture has valuable insight that it is not offering and given an opportunity to offer beyond the site, single-project scale. The Green New Deal supposes substantial investment in infrastructure that has potential to pivot landscape architecture practice to be more systemic, should it receive the institutional support necessary. Without the support of professional organizations, individual landscape architects insert themselves into climate mitigation conversations, but may find it difficult to shift professional scope without institutional support.

## History of Thought

As landscape architects continue to grapple with their role, it helps to understand the path of historical thought around the two declarations. The 1966 *Declaration of Concern* that inspired *The New Landscape Declaration* was spurred by Ian McHarg, who maintains extensive influence on academic and professional practices and the role of landscape architects in many places. While many of these contributions are considered positive, there are problematic aspects to his legacy which are eloquently described by Susan Herrington in her article "The Nature of Ian McHarg's Science" [7]. McHarg inspired many in the field with his love of ecology and the natural environment. His inspirations came from both his experiences and other thinkers that came before him. By examining the evolution of thinking behind *The New Landscape Declaration*, we are better equipped to argue for positive change while preserving valuable legacies.

## 1966 Declaration of Concern

The original *Declaration of Concern* was written in 1966 by six landscape architects: Campbell Miller, Grady Clay, Ian McHarg, Charles Hammond, George Patton, and John Simonds. They met in Philadelphia to discuss their concerns for the American landscape and released a declaration intended to galvanize their colleagues into action. Concern over pollution and exploitation of natural resources is synchronous with the 1960s environmental movement. The cohort saw people's experience separating from the natural environment, which had previously been a vital part of everyone's lives [8]. They argue that knowledge and valuation of natural resources disintegrates as urbanization, consumption, and resource exploitation accelerates [8].

McHarg and company primarily suggest two solutions: a greater understanding of our environment and a need for more landscape architects. A better understanding of the environment, they argue, helps people use resources wisely and develop according to means at hand. More landscape architects could shepherd and encourage awareness of natural processes and conditions. Overall, it is a proposal for better knowledge sharing and generation through collaboration, education, and research [7].

## Ian McHarg

*Design with Nature*, published in 1969, is still considered by some as one of the quintessential influences in landscape architecture. The book is an exploration into the relationship between humans and the natural environment and argues for extensive familiarity with ecological context. McHarg saw connections within and between natural systems and advocated for ecological presence in cities and parks through his system of mapping. McHarg's mapping technique involved gathering much hydrological, geological, other environmental, and social data, attributing values to each condition and assigning colored shading accordingly. He overlaid the map layers as a means to visually determine the best places for development [9]. He presents the overlay technique and hierarchies of suitability as objective, though land value costs, suburban development, travel by car, and many others are highly value-laden and subjective in their desirability and subjectivity.

*Design with Nature* inspires planners, landscape architects, and other ecological designers to value and steward nature. It was written in context of the environmental movement and reflects values of both suburbanization and restoration of native landscapes. McHarg was fascinated with ecology's potential role in shaping the world and the juxtaposition of urban and natural landscapes [8]. Techniques in mapping and ecology drawn from McHarg's work continue to be used and taught, despite the subjectivity and irrationality of his methods, which are critiqued by Susan Herrington.

## Susan Herrington

In her 2010 article, “The Nature of Ian McHarg’s Science” landscape architecture scholar Susan Herrington attempts to reconcile Ian McHarg’s contributions to the field of landscape architecture. McHarg encouraged landscape architects to use science to understand the natural world, including ecology, forestry, hydrology, and other natural sciences. McHarg argued that science shows the most orderly way to design for every system. He coined his own theory, *creative fitting*, based on selected, out-of-context theories of evolution and ideal environments to justify his design process. Like Charles Elliot, he championed overlay mapping as an objective justification for development, stacking layers of ecological and social data on top of each other. Unfortunately he paid scant attention to socio-political context and failed to realize the subjective nature of data and the rating system he used [7].

Herrington maintains that McHarg has made many positive contributions to landscape architecture, but that understanding his biases helps future practitioners evolve the state of knowledge. While McHarg’s ideas about science were not always totally factual, he argued for increased understanding of the landscape through ecology and other sciences [9]. Greater understanding of scientific principals give landscape architects a better grasp of how designs interact with other systems such as hydrological, social, and ecological.

## ***The New Landscape Declaration, Climate Change, & this Thesis***

*The New Landscape Declaration* gives direction to the loosely defined field of landscape architecture by laying out several major issues and associated goals. However, landscape architects struggle with the broad scope of environmental and social problems that affect all fields. Finding ways to address and lessen the negative impacts humans have on each other and the environment can feel insurmountable. To find ways forward I believe that all professionals and organizations must look for ways to build more robust and resilient systems at all scales.

In built environments there are many distinct different movements and certifications trying to address some of these problems in programs such as LEED, International Living Futures, SEED, SalmonSafe, etc., which often work within existing structures to find more sustainable foci. These effects are needed but nevertheless may fall far short of the sweeping environmental changes necessary to prevent billions of deaths (mostly among the poor and unrepresented) as a result of climate change [10]. It is difficult to motivate and advocate for changes that resolve injustice and environmental harm without seeing consequences of unsustainable choices. Yet there is significant potential in the sum of individual actions that lessen the scale of climate impacts.

In landscape architecture, issues surrounding water and ecology are discussed often. Both water, ecology, and other systems are being transformed by climate change: ecosystems are changing, biomes are moving, invasive species are inhabiting land and water, temperatures are increasing, and pollution continues. Climate-influencing systems interrelate, and landscape architects have skills to see and describe these relationships. There are potential roles in translating scientific

findings into understandable and approachable content, reaching across disciplinary divides, rethinking infrastructure, collaborating with communities, finding actionable steps that individuals can take, and working toward policy change.

Finding a place in the struggle against climate change is becoming more specialized as the body of scientific knowledge increases.

Choosing a focus allows impacts in a specific area to be greater and increasingly targeted. Of the (known) effects of climate change, water is most appealing as it touches ecology and social justice; is the foundation for life. Water is also one of the most resources impacted by climate change in terms of quantity, quality, who has rights to it, precipitation, carbon balance, etc., but is still managed in most of the world in the same ways that it was hundreds of years ago.

In connection to water, landscape architects currently work managing stormwater and in preserving or restoring natural systems. These are two important facets of water management that can better connect to the wider field of water resource management. While often the purview of hydrologists, ecologists, and engineers, movements toward more holistic water management (discussed in Chapter 4), provide opportunities to expand landscape architects' role.

For those in developed nations, water appears as if it is a continuous, inexhaustible resource, available at any tap, anytime, while drains carry waste away. People are divorced from the consequences of consuming and polluting water. Until there is a water shortage and people are forced to conserve, few think about their water consumption. Until salmon and orca die in increasing numbers, few think or know about the sewage and toxic chemicals we dump into our waterways. In reconnecting consequences with actions, Seattleites may be inspired to change not just because it is the

right thing to do, but because social, environmental, and economic benefits result.

It is timely to advance landscape practices to fit the modern world and ensure that humans and the environment have access to the quality and quantity of water needed to help life thrive. This thesis is the beginnings of efforts to change how water is valued, which I see as part of the new scope suggested by *The New Landscape Declaration*. It is an investigation into current practices in both Seattle and Melbourne, the state of water systems and climate changes expected effects in Seattle, and a design exploration into how small infrastructures can scale to create large impacts.

## End Notes

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## **CHAPTER 2**

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# **WATER USE & THE SEATTLE WATER SYSTEM**

History of the Seattle Water System

The Modern Water System

Water Rights

Water Use

Water Law

# THE SEATTLE WATER SYSTEM

In understanding the need to conserve water, it is important to understand where water goes and where it comes from, and why it cannot be drawn endlessly from the same sources. The history the Seattle water system explains why Seattle's water is some of the purest and least treated in the country, which makes it superior to all other sources for human consumption. However, potable water currently services all uses in Seattle. As greater variability in water supplies occurs, greater flexibility will be needed in the ways people use water to preserve drinking water for that specific purpose.

## A Brief History of the Water System

The City of Seattle established the Seattle Water Department, the precursor to Seattle Public Utilities, in 1890 to provide a municipal drinking water system due to increasing disease rates, pollution, and the Great Fire of 1889. During the Great Fire, water pressure from the fire hydrants was too poor to put our fires, so most of downtown burned down. Pollution and disease were increasing, so Seattle voted to create a public utility [1,2]. The Seattle Water Department amalgamated private water companies' service areas and infrastructure, some of which is still in use today. Seattle opted to use the remote Cedar River as its water source, and bought much of the land surrounding the new reservoir, but since 1945 has owned over 99% of it [1-5].

Once the Upper Cedar River was selected as Seattle's water source, the city laid over 22 miles of pipe, taking the next decade to complete. The first pipeline supplied water to residents on January 10th, 1901, through wood stave pipes without sanitation because of its purity [1,2,4]. Over the next few decades, additional development near the watershed and increasing concern over public health led to introduction of basic water treatment. It was not until late 1914 or early 1915 that basic chlorination devices and simple physical filters were installed at the water intake at Landsburg Dam [6]. These basic sanitation measures substantially improved public health and virtually eliminated waterborne diseases in the area and remains important in protecting public health.

As Seattle grew, so did its water needs, and in 1962, the South Fork of the Tolt River system was brought into service to provide water to North Seattle and Eastside customers [7]. The Lake Forest Park Reservoir, as part of that

system, became the reservoir at the highest elevation. It allowed North Seattle and the Eastside to be fed by gravity rather than pumps. It was originally thought that the North Fork of the Tolt would be developed into an additional reservoir near the end of the twentieth century. However, water conservation efforts and technological advances allowed for a decline in water use per capita since the 1960s [8,9].

Though conservation efforts were quite successful, population growth in the 1980s demanded a search for additional water sources, though this source did not need to supply large volumes. Seattle Public Utilities (SPU) incorporated the Highline Well Fields into the city's portfolio of water resources in 1985-86. The well fields, capable of supplying a mere 10 mgd for several months, are still used during summers when we experience high water demand accompanied by water scarcity [8].

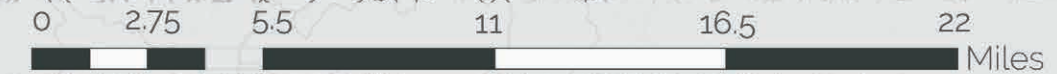
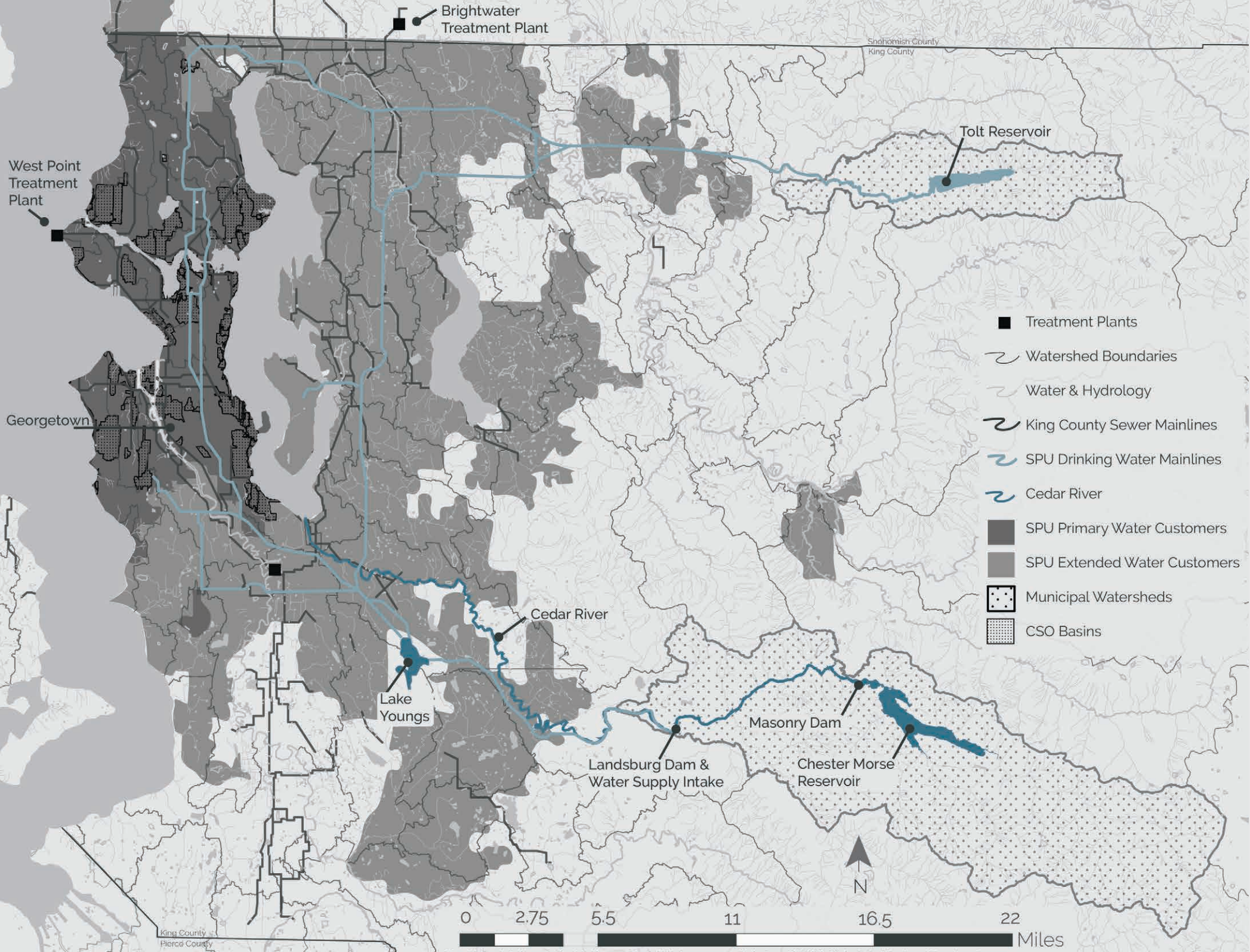
The 1987 drought led to several important solutions for supplying water in times of shortage, which are still the main adaptations Seattle Public Utilities uses today. Chester Morse Lake dropped below the level that feeds the Cedar River by gravity (1,532 feet). The temporary solution, mounting pumps onto barges to move water from Masonry Pool to the Cedar River, was made a permanent addition in 2017 with the Morse Lake Pump Plant. Though pumping can decrease water levels in the Chester Morse and Masonry Pool to a point detrimental to fish, the pumping plant can manage instream flows to preserve populations in the river [8,10]. This drought also marked obligatory water conservation, including a ban on lawn irrigation, which saves 47 mgd and has taken hold as part of general culture and formally as a part of the Water Shortage Contingency Plan [8].



**Figure 2.1:** A wood stave pipe used to carry Seattle's water in the early 1900s (1)



**Figure 2.2:** Morse Lake Pumping Plant (2)



Graphic by Julia Brasch, Sophie Krause, Rachel Wells

Data from WAGDA, State Dpt of Ecology, King County

Full Requirements Contract Holders	
• Bothell, City of	• Water District No. 20
• Cedar River Water and Sewer District	• Water District No. 45
• Coal Creek Utility District	• Water District No. 49
• Duvall, City of	• Water District No.119
• Mercer Island, City of	• Water District No.125
• North City Water District	• Woodinville Water District
• Soos Creek Water and Sewer District	
Partial Requirements Contract Holders	
• Highline Water District	• Renton, City of
• Olympic View Water and Sewer District	• Water District No. 90
Block Contract Holders	
• Cascade Water Alliance (Cascade) <sup>1</sup>	• Northshore Utility District
Mitigation Water	
• North Bend, City of <sup>2</sup>	

<sup>1</sup> Individual members of the Cascade Water Alliance are the cities of Bellevue, Issaquah, Kirkland, Redmond, Tukwila, Sammamish Plateau Water, and Skyway Water and Sewer Districts.

<sup>2</sup> Purchases mitigation water from Boxley Creek that is not treated.

**Figure 2.3:** SPU block contract holders. These cities and municipalities purchase part or all of their drinking water from SPU (3)

## Today's Water System

Today, SPU's regional drinking water system supplies over a million people including the City of Seattle and 20 wholesale customers (including the Cascade Water Alliance) and comprises of over 1,800 miles of water pipelines [10]. The city maintains a total of 15 reservoirs, nine of which are within the City of Seattle, though two of those (Volunteer and Roosevelt) are decommissioned and currently only serve as emergency or nonpotable capacity [10,11].

Though population has increased markedly in the past decade, water demand has stayed constant due to increases in water use efficiency. This decline in per capita water use is from water saving appliances and fixing leaks is attributed to the Saving Water Partnership. The Saving Water Partnership includes the City of Seattle and all wholesale customers except

**Figure 2.4:** (opposite) SPU's current regional water supply system (data from 4-6)

**Figure 2.5:** Saving Water Partnership initiatives in 2019 (3)

Education and Technical Assistance
<ul style="list-style-type: none"> <li>• Classroom presentations for K-12 grade students</li> <li>• Outreach at community festivals and events</li> <li>• Water efficient gardening classes for residents</li> <li>• Garden hotline to answer questions about water-efficient gardening and other topics</li> <li>• Landscape professional training</li> <li>• Gardening brochures and fact sheets</li> <li>• Technical assistance to residential and commercial customers on irrigation efficiency</li> <li>• Technical assistance to commercial customers on indoor efficiency</li> <li>• Website full of information, tips, rebate information, etc (<a href="http://www.savingwater.org">www.savingwater.org</a>)</li> <li>• How-to-videos on conservation topics</li> <li>• Conservation hotline (206-684-SAVE)</li> </ul>
Financial Incentives
<ul style="list-style-type: none"> <li>• Toilet rebates for single family, multifamily, and commercial customers</li> <li>• Irrigation system rebates for single family, multifamily, and commercial customers</li> <li>• Urinal rebates for commercial customers</li> <li>• Commercial dishwasher rebates</li> <li>• Commercial ice machine rebates</li> <li>• Commercial food steamer rebates</li> <li>• Coin-operated clothes washer rebates</li> <li>• Cooling tower improvement rebates</li> <li>• Rebates up to 50% of installed cost for all other commercial water-related equipment</li> </ul>

for the City of North Bend and Cascade Water Alliance. The Saving Water Partnership provides a combination of education and financial incentives for more efficient water use, including rebates for water efficient appliances like low-flow toilets, aerators, and sprinkler systems [10]. These incentives are usually around \$100 and cover part, but not all of the cost of new appliances and other water saving technologies [12].

The Saving Water Partnership's initiative into providing water-efficient appliances has been successful enough to offset the effects of recent population growth. More stringent plumbing codes also require more water-efficient toilets in new construction and renovation [10,13]. These factors have kept water demand constant, even though the population of King County has grown considerably over the last decade.

Overall, the Cedar River supplies approximately 70%

of the water supply and the Tolt the remaining 30%, with the well fields supporting high summer demand. In times of shortage and during future pressures, the Cedar River System will be under greater stress from overall water demand. Since this thesis case study site is in Georgetown, Seattle, which is typically supplied by Cedar River water, in-depth analysis will focus on the Cedar River Systems.

## Drinking Water Treatment

The protections afforded to the Cedar River Watershed allows for minimal treatment necessary to attain water of drinking quality. The strictly restricted land around the reservoir protect natural forest and freshwater ecologies, which provide treatment benefits. Nevertheless, the water receives different treatments at different points in the system to ensure public safety. The raw water first receives treatment at the Landsburg Diversion, starting with chlorination (sodium hypochlorite) to disinfect and stop nuisance pests like algae from transferring to Lake Youngs and the Cedar Water Treatment Facility. The water is also fluoridated (hydrofluorosilicic acid) at Landsburg. These two chemical additives serve as pretreatment [11].

Once the water receives pretreatment at Landsburg, the water flows some twenty-odd further miles where it arrives at the Cedar Water Treatment Facility in Renton, WA (or just north of Lake Youngs). The Cedar Water Treatment Facility, completed in 2004, employs some additional sanitation to ensure that all viruses and parasites are eliminated. In series, these are ozone, UV light, and chlorine, which are typically the processes used in the final step of water treatment, which are known as tertiary or advanced treatment methods. The Cedar Water Treatment Facility also used additional treatment for taste, quality, and appearance. Additional treatments received are liquid oxygen, which improves and expedites treatment performance by settling organic contaminants and turbidity; lime to adjust pH; and sodium bisulfite, which helps remove excess chlorine from the water. These treatments ensure water is of high quality. This system uses one of the least intensive treatment processes for in the world, while maintaining high quality water [11,14].

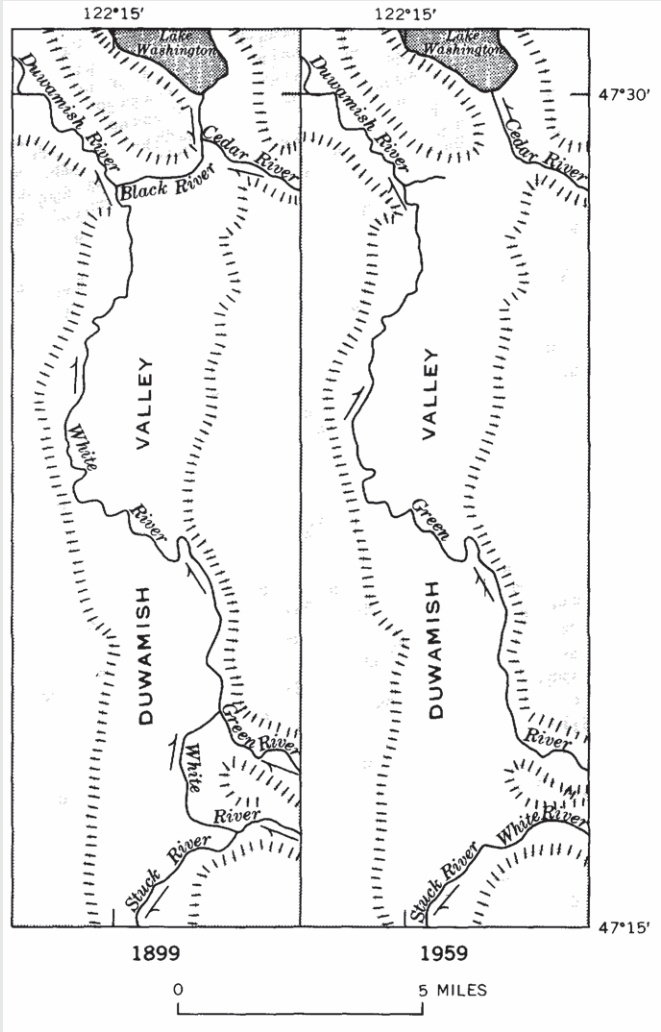
Once the water has been treated, it moves through the Seattle pipe system where it is stored and piped to consumers. Water flows to reservoirs that use additional chlorine (sodium hypochlorite) for regular flushing and maintaining residual chlorine levels to prevent the growth of pathogens. The in-town reservoirs act as short-term storage for only a few days. Water is then delivered to customers and used. It then goes to one of three wastewater treatment plants for sewage treatment before being discharged into Puget Sound.

### The Cedar River & Water Rights

The City of Seattle claimed the water in the Cedar River before the state had established many of its laws governing instream flows and other water rights issues. The water rights have been grandfathered in or have adapted to modern water laws in Washington. Today SPU has claim to about 40% of the water from the Cedar River (336,650 af/yr or approx. 300 mgd) [15,16]. If Seattle were to use their entire claim, streamflows would be insufficient to provide stream habitat for fish and to prevent saltwater intrusion into Lake Union and Lake Washington through the Hiram M. Chittenden (Ballard) Locks [17]. Therefore, even though Seattle has claim to additional water, it cannot be used because of legal agreements and ecological needs.

Before European settlers arrived the Cedar River originally flowed into the Duwamish and Black Rivers and then the Puget Sound. The river was diverted in 1917 to provide an outlet for Lake Washington for the Ballard Locks to promote industry [18]. Much like other rivers in the region, it was extensively modified for human gain. Now, the Cedar River contributes between 50 and 70 percent of annual inflows into Lake Washington depending on which estimate is used. The City of Seattle claims 50% [19], the USGS claims 65% [17], and the Army Corps of Engineers claims 70% [20], while the Sammamish River contributes the remaining amount. Consistent inflow allows ecological and human systems to function despite major alterations, which may not be available if too much water is drawn from the Cedar River Basin in the future.

Nearly all of the water in the Cedar-Sammamish



**Figure 2.6:** Duwamish River flows before and after human modification (7)

watershed is already allocated through water rights claims, which comprise both surficial and groundwater sources [21]. These claims are a "use it or lose it" right, where the full quantity of the water right must be used at least every five years or that portion is forfeit. This policy can incentivize water waste to preserve the legal water right. Under Washington state law, the most senior/oldest water right has first draw [22]. The old claims can draw the full amount allocated, even if more junior users cannot draw any water. This rule has led to additional regulations that make sure each right holder can draw a portion of their claim, which has led to increasingly complex water law outside the scope of this thesis. Water rights claims were originally written to require people to put the water to "beneficial use," which did not include ecological requirements. Once the importance of instream flows were understood, the State Water Trust was created and acts as a water right holder for instream flows and other ecological purposes [22–24].

Seattle Public Utilities has the oldest right to Cedar River water, but if it were to acquire new rights, those rights would be junior to all other existing claims. There are over 1,000 claims in the Cedar-Sammamish Water basin, most of which allocate only small amounts of water. Acquiring other claims new water rights and would represent negligible gain in available water resources [25]. An additional large claim from the same basin could also put additional strain on the Cedar River, which is already struggling to maintain its anadromous fish and fishery populations. Such a claim would certainly violate instream flow agreements and ecological protection laws.

In order to protect vulnerable and endangered salmon populations, the City of Seattle agreed to the Instream Flow Agreement in 2000, where SPU ensures that water and

instream flows are managed in a way that supports fish populations. This was primarily a result of concerns after Chinook salmon were declared a threatened species in 1999 [18]. City officials agreed to provide a minimum of 80-330 cubic feet per second depending on the season in average years and 70-200 cubic feet per second in times of shortage (assumed to be one out of every ten years) [15]. The Muckleshoot Indian Tribe did not sign the Instream Flow Agreement citing its incompleteness. The objections to the 2000 Instream Flow Agreement, which based annual peak and mean flows off the water year 1990, a flood year. Muckleshoot objections were based on flow shortages that occurred during droughts in 1987 and 1992 that severely impacted tribal fishing rights and overall fish stocks, but were not adequately addressed by the agreement in 2000 [20].

After several years of negotiations, the City of Seattle and the Muckleshoot Tribe reached an agreement in 2006 that guaranteed instream flows through 2050. The basics of the agreement are that Seattle will limit its withdrawals for the city water supply to 124 million gallons per day (mgd) or 230 cubic feet per second (cfs) on an annual average, or between one-third to one-half of its claim. Additional water is transferred to the Washington State Water Trust for instream and environmental flows. This agreement declares that Seattle will continue to pursue aggressive water conservation efforts as a way to preserve potable supply through the Saving Water Partnership as a way of upholding the agreement [15,19]. This reflects the most explicit shift away from continuing to draw on the existing water rights claim on the Cedar River or from pursuing new water rights claims, dams, and pipelines. SPU committed to working toward more efficient water use through

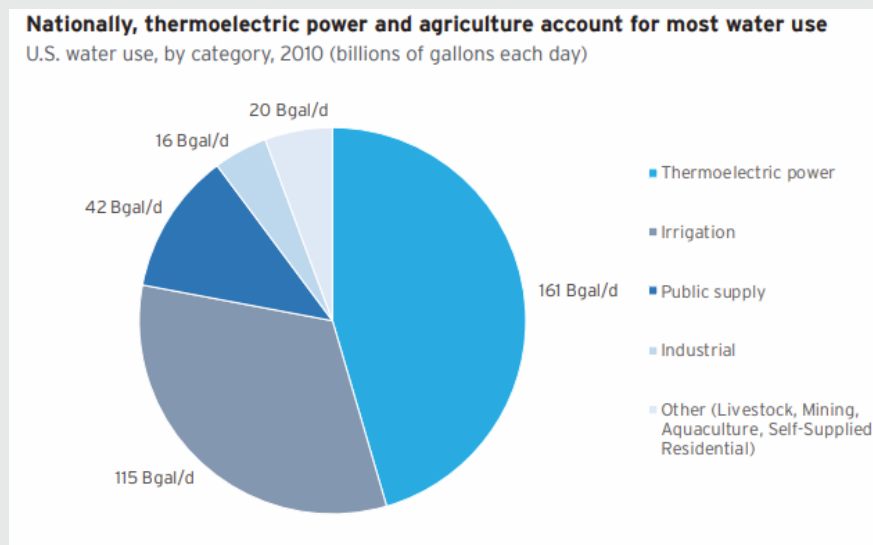
conservation as a way to avoid drawing on new water sources or further exploiting its existing claims.

The limit on withdrawals, other existing water rights, and the two instream flow agreements limit the amount of water SPU can draw from the Cedar River, even in times of shortage. These limits are intended to protect vulnerable species and preserve outflow from the Ballard Locks and help clean Lakes Washington and Union by flushing out polluted waters. However, the limits also prevent Seattle from accessing its water right volume in full, decreasing flexibility in available water supply resilience. If water demand increases significantly or shortage(s) occur, little additional water can be drawn from the Cedar River despite Seattle's water rights claim.

A decrease in flexibility in the Cedar River water system makes the overall system less resilient to stressors. The loss of variability in available supply is not being fully met simply by conserving water, water-efficient appliances, or fixing leaks in the system. It is likely to lead to more water use restrictions in the future, which asks customers to choose which functions are necessary. While this is helpful in reducing unnecessary water use, when pursued aggressively, water use restrictions ask people to do without certain water uses on a regular basis. Access to additional water sources gives consumers a range of options in using water, ensuring they consider their water use. Reuse avoids the necessity of asking people to sacrifice uses like gardening or bathing during shortages and gives the overall system greater resilience when applied across scales.

Estimating the amount of water that can be conserved is subjective based on the utility's perceptions of the necessity of each water use. It is also difficult to anticipate the volume

of water future efficiency improvements will have, though SPU's demand projections depend on these estimates. These estimates are the basis of the claim that Seattle does not need to diversify its water resources and need to be revisited.



**Figure 2.7:** Water use by sector in the United States in 2010 (8)

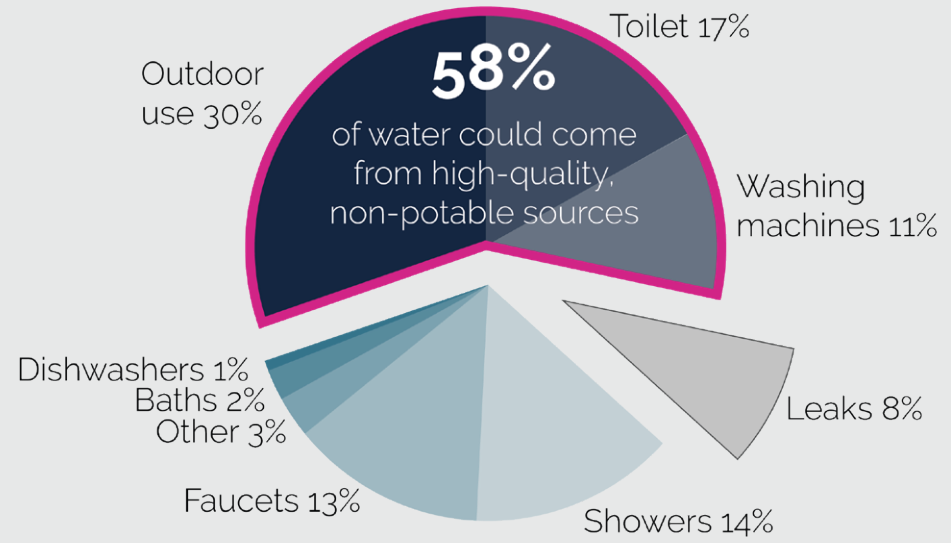
and use water in a relatively centralized locations compared to geographical distribution of other uses. Utilities represent a significant portion of freshwater withdrawals and can demonstrate efficacy of new techniques while maintaining a sustainable water footprint.

Most water users in Seattle are commercial/residential, though SPU also distributes to agricultural and industrial users. As of 2013, half of all SPU water went to wholesale customers and while further use breakdowns are not publicly available uses are assumed to be similar to Seattle retail customers. Inside the city of Seattle, about 40% of water went to single-family residences, about 40% to business/industrial/commercial use, and about 20% to multi-family residential users [27]. For the purposes of this thesis, multi-family residences without a commercial component will be considered "residential" because applicable strategies significantly overlap.

## Water Use

Understanding how water is used can help determine suitability for water reuse. Not all water can be reused, but areas that have both a supply of reusable water and a demand for water where a potable source is not necessary, can reduce their potable water consumption through water reuse. The vast majority of freshwater withdrawals do not require a potable source of water. However, reusing water requires pre-existing effluent availability within the system from a very large water user or urban area. Therefore, municipal utilities have great potential to better use available freshwater through reuse.

Water use in the United States can be broadly defined by four categories: agricultural, industrial, power generation, and commercial/residential [26]. All sectors combined contribute to water stress in a region and present opportunities for more efficient water use. However, public utilities withdraw



**Figure 2.8:** Average Seattle single-family water use, assuming 96 gallons of water used per day (data from 9-10)

Mixed use buildings will be considered as both commercial and residential based on those building components respectively.

SPU does not specifically publish end uses for water outside of single-family residential, but the US EPA does publish typical, countrywide, commercial uses. They publish statistics on office buildings, hospitals, hotels, restaurants, and educational institutions. These uses help us understand which water uses could be more efficient or replaced by nonpotable water. Of particular interest in Georgetown are end uses in office buildings, restaurants, and educational institutions [28].

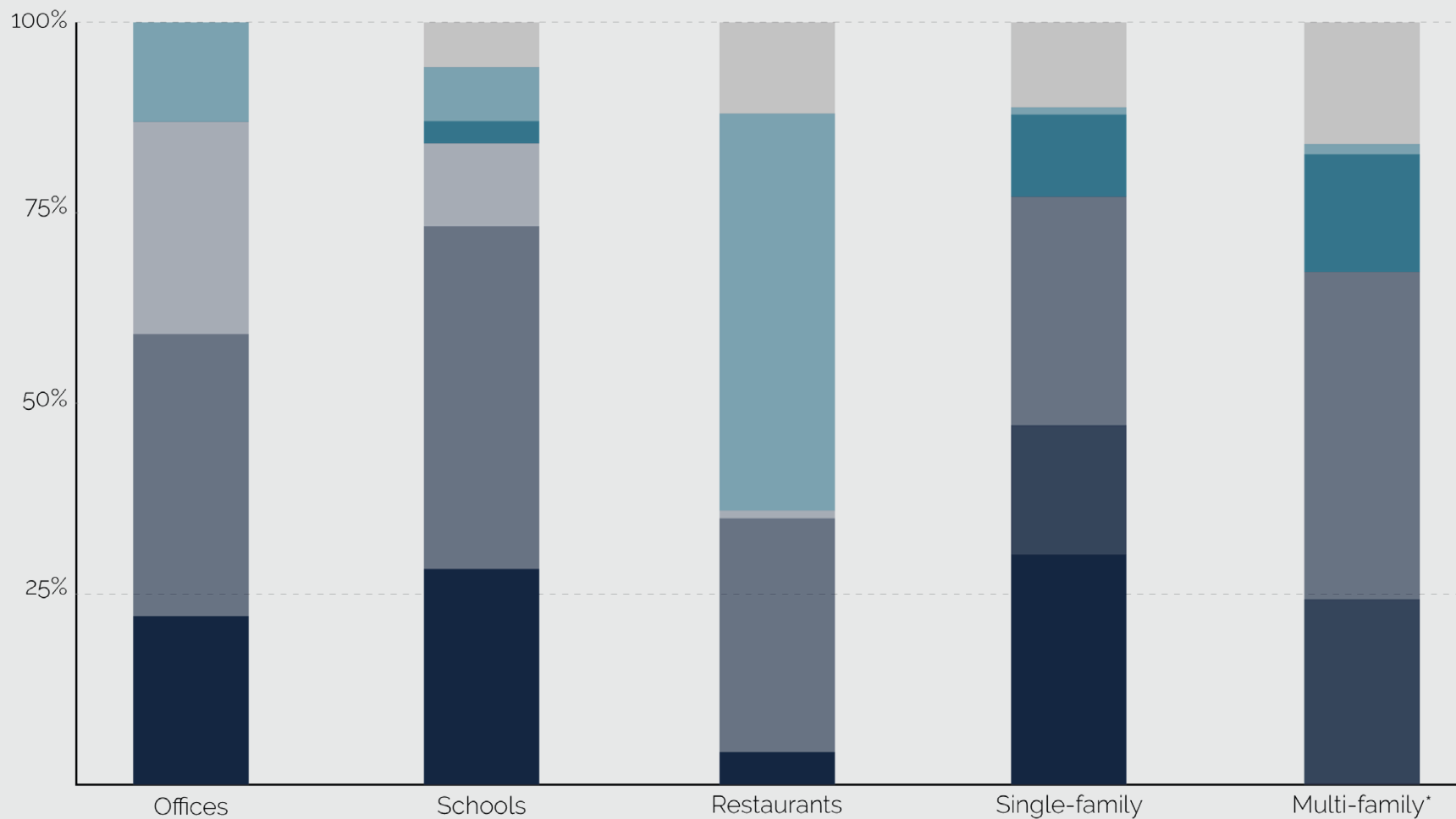
Water use statistics for residential end uses from Seattle and several other utilities around the country are available from 2016 through the Water Research Foundation and the Saving Water Partnership [29]. According to the report, 30% of water is used outdoors, leaving toilets as the single largest use of

potable water indoors at 17%. The proportion rises to 24% if only indoor water use is considered. In any environment, even low flow toilets, this is an astounding proportion of expensive, clean, drinking water to flush away, likely without ever having anyone come into contact with it.

Other uses that could be partially or fully replaced by nonpotable water sources are heating and cooling, irrigation, and washing machines. These uses represent over half of potable water use in commercial and residential capacities and clearly demonstrate an opportunity to drastically reduce resource overexploitation.

# Comparing Average Water Use Between Residential and Commercial Customers

- Other inc. leaks
- Kitchen
- Laundry
- Heating & Cooling
- Bathroom
- Toilet
- Outdoor



Derived from data from SPU, the Saving Water Partnership, EPA Water Sense

\* Multi-family metrics are not publicly available and are based off single-family residential minus outdoor use

Figure 2.9: Comparison between residential and commercial water end uses (data from 9-11)

## Water Use Laws

As water scarcity grows, water laws are likely to change to allow more ways to reuse water in the state of Washington, as it has in other places [30,31]. Water reuse laws have already started to progress with rainwater reuse and reclaimed water use. While the uses are still restrictive, they add additional sources to water resource portfolios. Many of the challenges in legalizing water reuse come from a public health perspective and aim to restrict access to any nonpotable water [32,33]. These laws emphasize eliminating any possible contact with nonpotable water, so any water not of drinking quality lacks differentiation of quality and is considered wastewater.

In early 2018, the state of Washington adopted a reclaimed water rule that allows reclaimed water to be used in industrial, commercial, and public capacities. This includes water in water features with public access, apartment building toilets, landscape irrigation, food irrigation, commercial washing machines, and release to water bodies, but still prohibits residential uses [35]. This act begins the process of diversifying water source portfolios while protecting public health by giving people a chance to get used to this new way of treating water and can serve as the basis for future reforms.

Reclaimed and rainwater cover the same uses under Washington laws, but for different user groups. Reclaimed water can be used in commercial, mixed use, industrial, and public settings, but cannot be used in homes [33]. Conversely, initiatives to reuse rainwater, legalized in 2009 [34] have been targeted toward homeowners where irrigation is the encouraged use through the RainWise program [34]. Overlap is emerging between residential and commercial/mix-use

buildings with rainwater harvesting. New buildings must minimize discharges based on the 2016 (Seattle) Stormwater Code [35], which has led to more buildings collecting rainwater for outdoor use. Allowing more flexibility in which properties and which people can use which types of water would add additional opportunities for reuse and help wider adoption throughout the city.

## Legal Options for Water Reuse in Washington as of 2019

	Residential	Commercial	Industrial	Agricultural
Rainwater	x*	x*	x*	x*
Graywater				
Reclaimed Water		x*	x*	x*
Wastewater and Sewage	x <sup>1</sup>			x <sup>1</sup>
Runoff	x <sup>2</sup>	x <sup>2</sup>		

- 1 Rural single-family residences and farms can treat sewage onsite through septic systems or other OSS (onsite sewage systems)
  - 2 Runoff can be collected in rain gardens or other permeable strategies where soils support infiltration
- \* There are caveats to the legality of all uses

**Figure 2.10:** Legality of water reuse from various sources in 2019 (12-20)

While graywater is technically legal in the state of Washington, it must adhere to Class A reclaimed water standards, not stored longer than 24 hours, and be treated using activated sludge wastewater treatment techniques which are difficult to apply on site. Together, these restrictions make graywater functionally (nearly) impossible [36].

The way water is used and regulated in Washington today means that most uses in the state are provided from ground or surficial sources. Pressures from demand and climate change will put increasing strain on these resources. To adapt, utilities will have to find other ways of meeting water demand through new freshwater sources, desalination, or water reuse. Because of Seattle's water quality, incorporating new sources could have a detrimental effect on water quality. To preserve this water for drinking and human contact, other functions can reuse water.

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## **CHAPTER 3**

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# **CLIMATE CHANGE & RESPONSES IN SEATTLE & THE PACIFIC NORTHWEST**

Effects of Climate Change in the Pacific Northwest

Effects on Hydrology

Uncertainty in Climate Modeling

Utility Response to Climate Change

# CLIMATE CHANGE IN THE PACIFIC NORTHWEST

## Effects of Climate Change in the Pacific Northwest

During the 20<sup>th</sup> century, the Pacific Northwest has experienced a 1.3 degrees Fahrenheit increase over pre-industrial levels as a result of climate change [1]. Temperature increases are associated with numerous effects from desertification to flooding. Climate scientists understand what many of these effects will be but have yet to describe the full scope of the consequences the expected changes will have [1,2]. As climate scientists gather more information and refine models, predictions generally become more fine-grained and more accurate, enabling groups and individuals to respond precisely to expected effects. Many unknowns still exist, but as the warming trends caused by greenhouse gas emissions continue, we will indeed experience associated effects. These effects and estimations are as follows:

- less spring and summer snow melt due to declining snowpack and snow accumulation. An 80+% decrease is expected by 2080, though some scenarios show no snowpack at all [2-7]
- earlier spring melts (1-2 months) [2,3,5-7]
- greater flood risks [2,5,7]
- declining streamflows in the summer, increasing streamflows in the winter [3,5,6] — Climate Impacts Group predicts ~ 30% decline in summer flows by midcentury [2,7]
- declining soil moisture and groundwater tables [3,5,7]
- increased evapotranspiration [3,5]
- higher fire potential throughout the state. Natural areas will have a one in three chance of burning instead of a one in twenty chance in the 20th century) [2,5,6,8,9]

- increased extreme precipitation events are forecasted to increase 22+% for 20 year events by midcentury [2,5,6,8,10,11]
- decline in water quality, including higher stream temperatures, lower dissolved oxygen, increased turbidity, increased by variable sediment, nutrient, pollutant loads [2,4,5]

The Pacific Northwest currently experiences 30-35 inches per year of precipitation [12]. During the twenty-first century, average overall precipitation in the Northwest may decrease slightly, increase slightly (est. 5-10%), or stay the same depending on the climate model [3,11,13]. Precipitation is expected to increase at high elevations and decrease at low elevations, which is thought to account for some of this discrepancy according to the Oregon Climate Change Research Institute (at Oregon State University) and Climate Impacts Group (at University of Washington). Most of the precipitation falls in the winter now, and nearly all of it is expected to fall in the winter in the future, leaving summers increasingly dry [4].

If winter precipitation falls as rain, rather than snow, it will drain into the river systems much more quickly, which poses challenges for flood management and water storage. This will also result in lower summer flows and warmer stream temperatures, increasing stressors on already vulnerable salmon populations and forests [6,8,10,11]. Much of the summer instream flow will depend on groundwater flows, which will also be stressed by the increasing summer dryness, heat, and water demands, though climate impacts on groundwater are not fully understood [7,12].

To complicate water management strategies and climate modeling further, the region has high geographic

variability and is subject to several different climate variations. El Niño/Southern Oscillation has a period of between 2 and 7 years and the Pacific Decadal Oscillation has a period of between 20 and 30 years. Either or both of these can shift precipitation up to 20% and temperatures as much as 1 degree Celsius in either direction [3]. Shorter-term climate patterns further alter hydrological response and are dependent on geomorphological and hydrographical conditions in each watershed. This makes overall, expected, average climate more difficult to quantify [2].

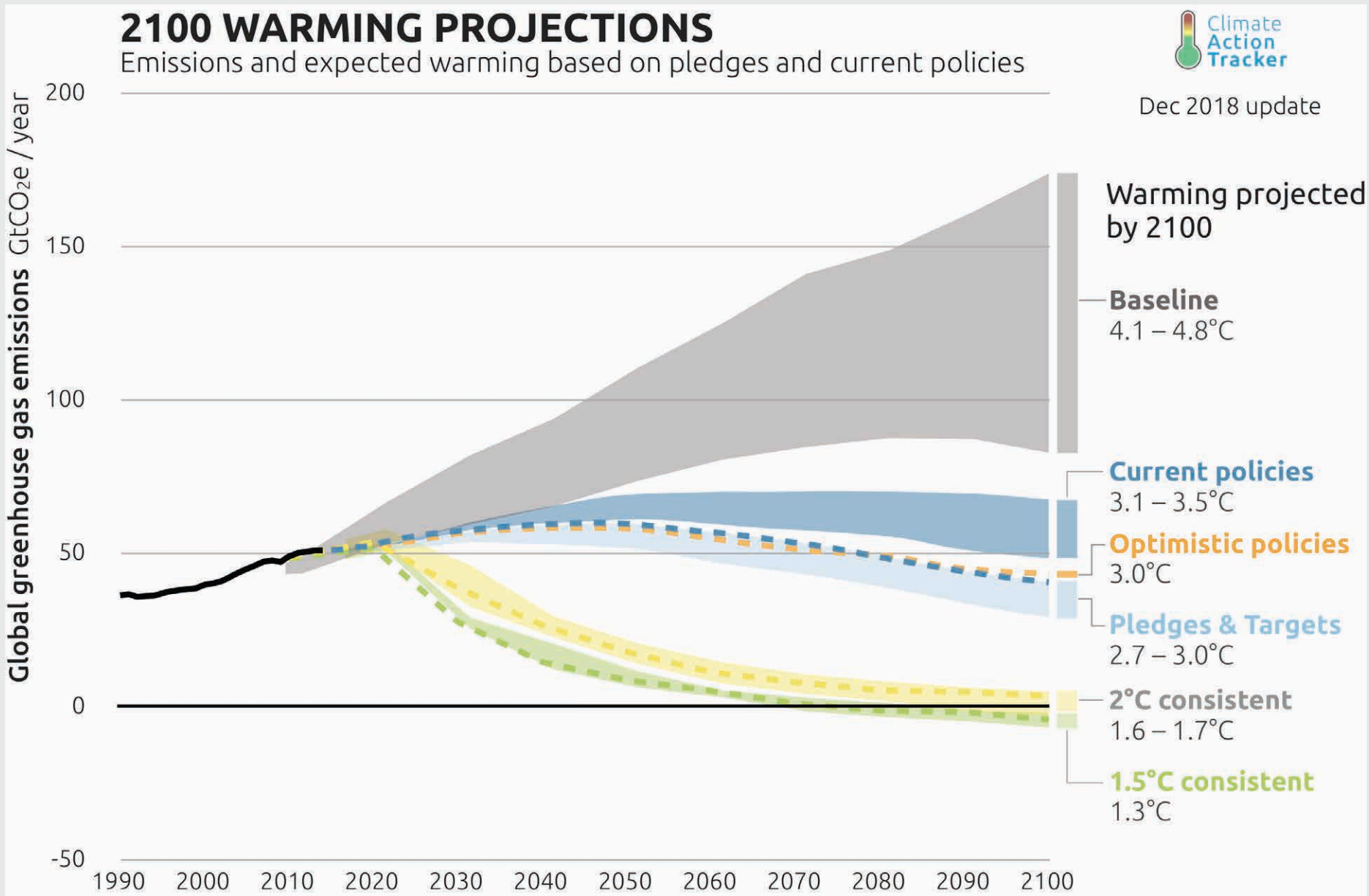
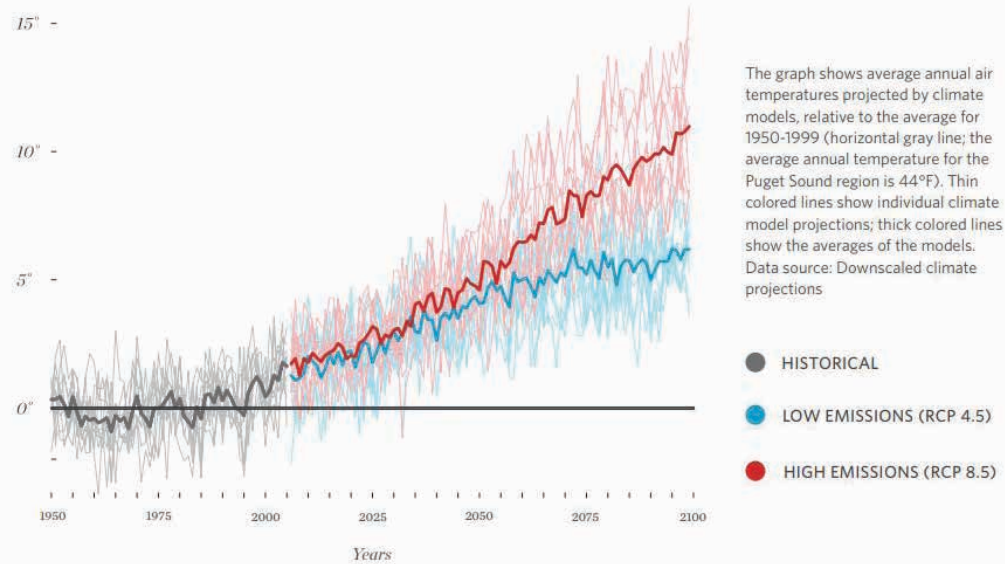


Figure 3.1: Global climate projections based on current goals and policies under the Paris Agreement (21)

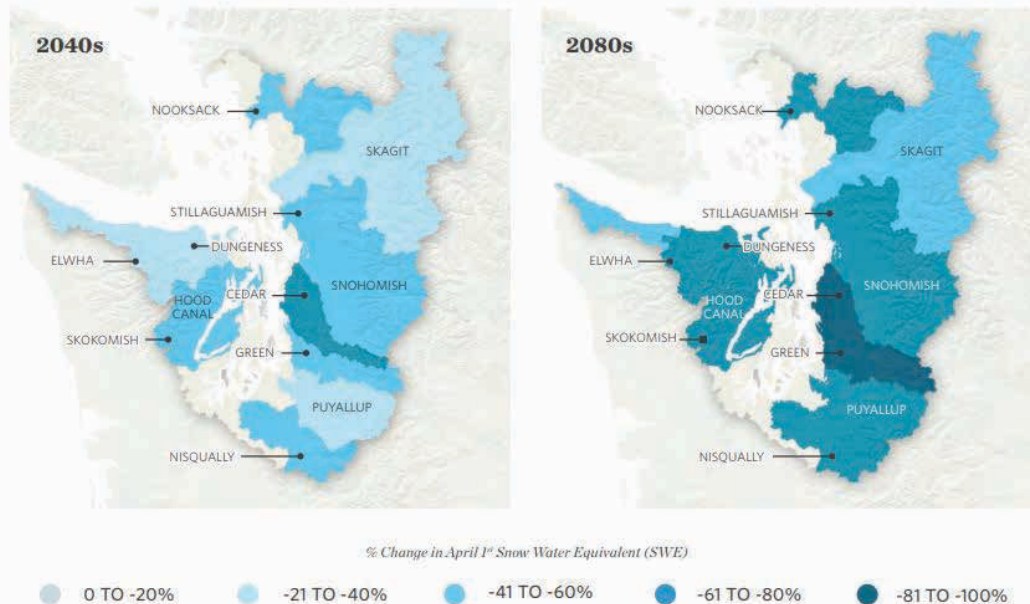
**AVERAGE ANNUAL TEMPERATURES IN THE PUGET SOUND REGION ARE PROJECTED TO INCREASE RAPIDLY IN THE COMING DECADES**

{ Temperature difference relative to 1950-1999 average }



**Figure 3.2:** Regional warming projections for Puget Sound. RCP 4.5 is consistent with 1.8 degrees Celsius and RCP 8.5 is consistent with 3.7 degrees Celsius in overall warming. SPU projections use RCP 8.5 through 2050 in the 2019 Water System Plan. (3.22)

**APRIL 1<sup>ST</sup> SNOWPACK CHANGES**



**Figure 3.3:** Projected changes in snowpack in the Puget Sound region as of 2017 (23)

## Effects on Hydrology

The Pacific Northwest is deservedly recognized for its rainy, dreary winters. Its position between the Pacific Coast and the Cascade Range means it receives significant precipitation as clouds are forced up the mountains and drop their water over the region. It can appear that Seattle is swimming in water, both literally and figuratively. Despite the abundance of rainfall, none of the precipitation that the city receives is used in our water supply.

Both the Tolt and Cedar Rivers are currently mixed precipitation dominant (rain and snow based on season and elevation). They are particularly susceptible to hydro-geographical changes including winter flooding and higher summer stream temperatures with low flows [2]. These mixed precipitation watershed will become rain-dominant watersheds in the coming years, as precipitation falls more as rain than snow because of temperature increases [4].

On the West Coast, 2015 is thought to be a likely example of conditions in the future. The low snow accumulations and hotter summer temperatures experienced in 2015 are likely to become normalized conditions by the mid-21st century [8]. In 2015, precipitation was near normal, but resulted in drought and water use restrictions because of the low snowpack accumulation due to warm winter temperatures [8].

There are several challenges posed by years with little snowpack like 2015. Individual dry summers are challenging for salmon populations and for managing water resources. A wet winter may cause flooding, salmon egg scour, and other issues. This illustrates how a future where a norm of dry years/

summers will present problems, even when wet winters do occur. Over the latter half of the 20th century, streamflows have already shown significant declines of >29% in a majority of streams in the Pacific Northwest [10]. This trend is expected to continue and changes in the water budget will be needed to maintain streamflows.

This decline in streamflows with the prevalence of dry years and/or dry summers without support of snowmelt also has significant implications in water storage. Few reservoirs, irrigation systems, or water supply systems in the region have multi-year storage, with most storing much less than a year's worth of water. Expected future conditions indicate that current reservoir storage in the Pacific Northwest may be too small to support environmental streamflows and summer use [10]. Managing reservoir levels to capture enough winter runoff to meet summer demands while maintaining enough storage to minimize winter flood risks will become increasingly challenging as precipitation predictability decreases. The increases in extreme events and high flow variability are likely to damage existing infrastructure which will require more maintenance in the future [2].

SPU currently relies on snowpack to act as an additional, natural water storage feature. Snow melts over the summer and is estimated to contribute upwards of 70% of total stream discharge [4]. As we experience more of the effects of climate change, more precipitation, even in the mountains, will fall as rain [14]. This shift will cause reservoir levels in the winter to spike, but spring and summer inflows will decline as snowpack disappears [2].

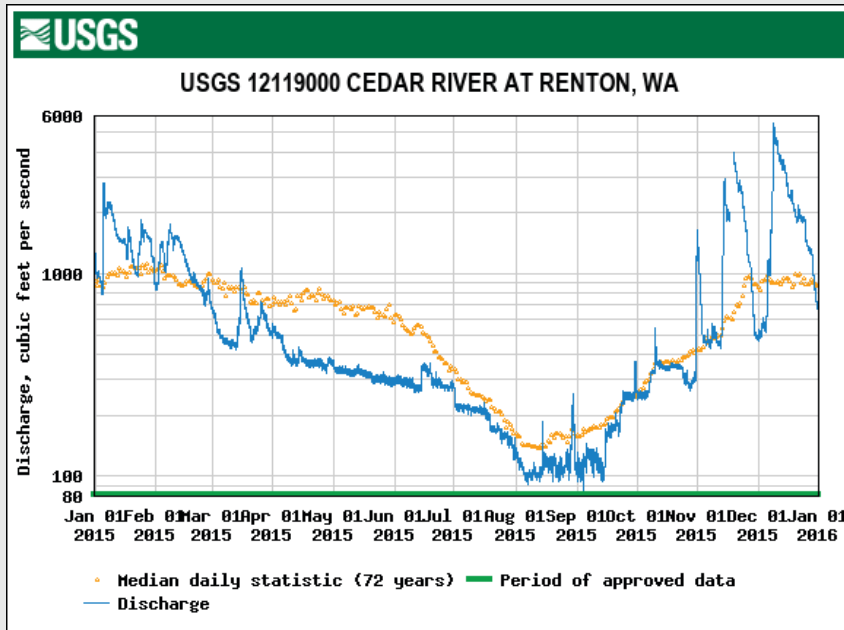


Figure 3.4: Cedar River flows into Lake Washington in 2015 (24)

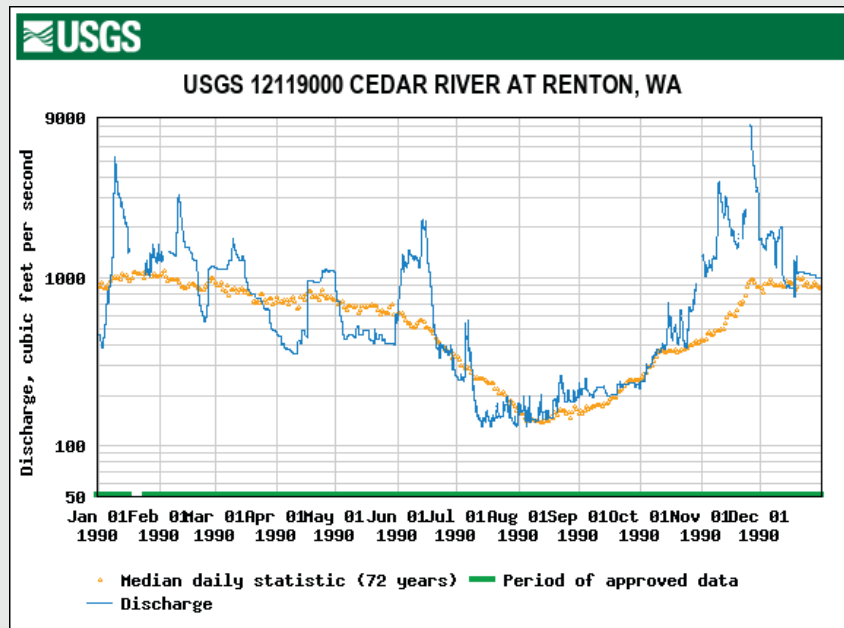
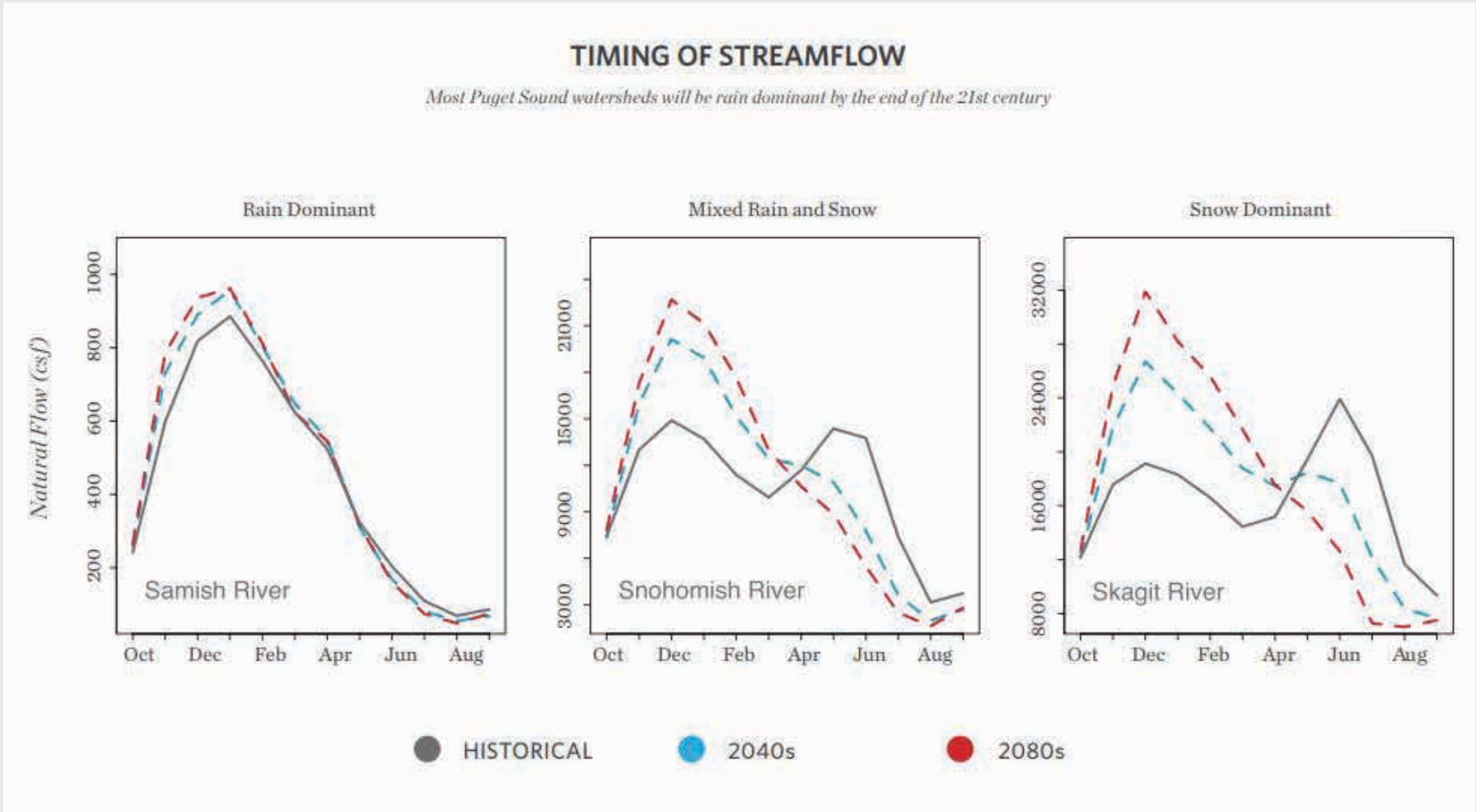


Figure 3.5: Cedar River flows into Lake Washington in 1990, the year both instream flow agreements are based on. (24)



**Figure 3.6:** Projected changes in the timing of streamflow compared to historical averages. The Cedar River is a currently a mixed rain and snow watershed. Streamflows are expected to change in similar ways to the Snohomish River (24)

### Uncertainty & Climate Modeling

Climate models on a continental and global scale are becoming increasingly capable of predicting broad impacts of climate change. However, climate adaptation in

geographically smaller areas requires a much more detailed analysis than climate models, usually global or continental in scale, are meant to provide. While extending the use of current climate models is important for planning adaptations and anticipating scenarios, these applications were not the

original intent of climate models, and so may only provide an approximation of future conditions [15]. Climate models are exceptionally complex and require accurate statistical inputs from areas such as land surface area and usage, vegetation, soil moisture, sea ice, atmospheric conditions, as well as unknown variables such as population, aerosols, and natural disasters. Many of these variables would be unknowable even with perfect data collection and statistical analysis and point to continuing uncertainty in climate and weather predictions even as climate models become more robust.

All models reveal inherent uncertainty, even the most widely used studies such as those from the Intergovernmental Panel on Climate Change (IPCC). Following the Fifth Assessment Report of the IPCC, the United Nations ratified the Paris Agreement in 2016 that targets limiting global mean temperature increase to 1.5 °C above pre-industrial levels [16]. However, there are several interpretations about how to determine when/if we reach the target temperature that include natural variability, time frame from which to draw averages, land versus sea versus whole globe warming, and regional temperature [17,18]. Thus, the target maximum increase in overall global temperature and emissions do not have consensus among the scientific community and is also difficult to measure.

Models may yield different results when given different input information, such as when to define the pre-industrial era [19]. The IPCC has identified risks for the specific thresholds associated with warming of 1.5 °C and 2 °C, which are often accepted as definitive. However, using different datasets, a 2018 study showed that many of these effects occur at different

levels of warming, showing that effects may occur even when warming approaches these thresholds [17]. The extent to which we experience effects of climate change is a dynamic process and that the temperatures where we expect certain effects are flexible.

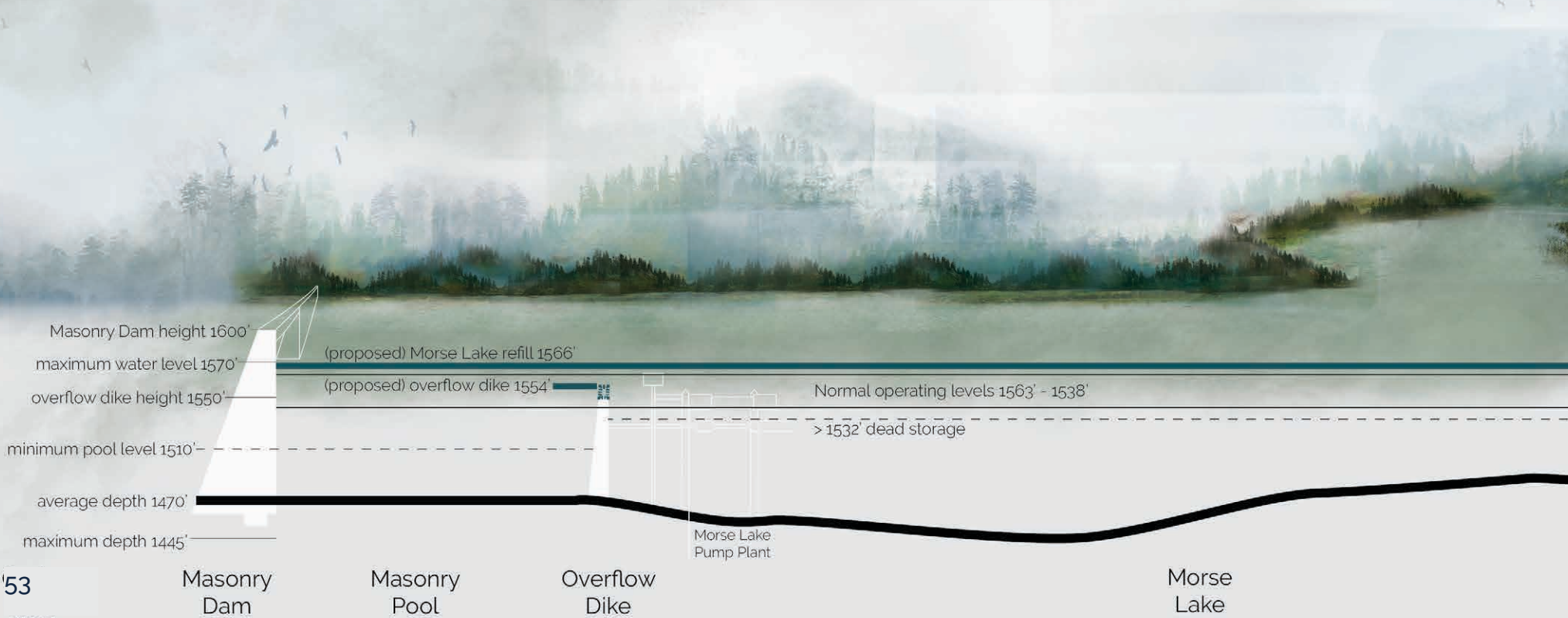
On a regional scale, temperature predictions are expected to be generally accurate, but precipitation cannot yet be as accurately modeled and vary from model to model [14]. Predicting precipitation is difficult for a number of reasons. Three of these outlined by Climate Impacts Research Consortium (CIRC) are that greenhouse gas emissions do not correlate as directly to precipitation and weather as temperature does, precipitation is more complex to model, and precipitation and annual cycles have natural variability which is generally becoming more varied and less predictable under the effects of climate change. CIRC recognizes that Global Climate Models (or regionalized models) are often not run enough times to accurately predict patterns and that significant debate on how to model precipitation scenarios is ongoing [6,8,13]

Given that uncertainties are inherent to climate modeling, understanding that significant gaps in knowledge and available data still exist, especially for conditions like extreme events, is an important reminder [20]. Climate scientists uncover more knowledge about the consequences of climate change each year but are compelled to work with the approximations available in order to prepare for the changes and challenges ahead.

# UTILITY RESPONSE TO CLIMATE CHANGE

Seattle Public Utilities acknowledges that the full scope of effects of climate change are unknowable. In essence, the new norm we face is the uncertain and unexpected [21]. SPU studies climate change scenarios and predictions in partnership with regional climate organizations as part of the water system plans, which are released every six years. Since at least 2007, SPU has repeatedly stated that no new sources of water are needed through 2060 because of the high reliability of the water system [21–23]. The assumptions and ways in which these projections are calculated are important in planning. Some of these assumptions are well developed and some are not; a discussion of these assumptions is offered here.

**Figure 3.7:** (below) A visualization of the headwaters of the Cedar River at Chester Morse Reservoir with current and proposed refill levels (data from 3, 25, 26)



## Supply

The analysis of water system reliability was developed in-depth in 2013 and bases the 98% reliability standard off the *current* firm yield. In the 2019 Water System Plan, estimates for climate induced reduction in supply availability were not plainly included, though can be inferred to some degree. In visual documents and much of the written communication, firm yield is displayed as a constant 172 mgd, though it will decline as a result of climate impacts [6,12,24]. The adaptations SPU outlines claim to return the firm yield to 172 mgd, but rely on a myriad of assumptions and have not been fully studied for safety and reliability [22].

The current firm yield is developed by compiling historical data since water year 1929 of the amount of water that can reliably be supplied each day over a yearly average, given system constraints and utilizing adaptations [25,26]. SPU and the Climate Impacts Group estimated in 2007 that firm yield will decline between six and twenty-one percent by 2050. In one-third of the scenarios, current adaptation techniques were not sufficient to prevent significant water restrictions before 2050 [21]. In the absence additional action, these projects mean that significant water use restrictions and shortages are likely to occur with increasing regularity.

Based on these projections, SPU introduced three additional suggested adaptation measures: refill of Chester Morse Lake to 1,566 feet instead of 1,563 feet that adds an additional 6,000 acre feet of water (nearly 2 billion gallons), lower drawdown of the Tolt reservoir to 1,690 feet rather than 1,710 feet which adds 7,500 acre ft of water (about 2.5 billion gallons), and Overflow Dike crest to 1,554 feet rather

**Figure 3.8:** SPU-proposed climate adaptations and assumptions in models (data from 3, 25, 26)



than current 1,550 feet which adds 6,500 acre feet (about 2 billion gallons) [19]. These adaptations aim to restore water supply availability to current levels through 2075 *if* forecasted demand is accurate and *if* infrastructure and other adaptations perform as expected. Combined, these adaptations represent a combined loss for 20,000 acre feet of water or 6.5 billion gallons no longer available due to the effects of climate change. This is the equivalent amount  $\frac{1}{3}$  of the land area in Washington covered by 1 inch of water or about 15% of the current amount of water used in all of SPU's service area per year. Adaptations appeal as low cost options, but have not yet been fully studied for their safety, reliability, environmental, and other consequences [19].

Both higher refill at Chester Morse and further drawdown at the South Fork of the Tolt can be achieved using existing infrastructure without modifying water rights because they are a modification of current water management techniques. However, there is little information provided about environmental impacts other than compliance of *current* environmental flows. Depending on the severity of impacts, instream flow agreements including the 2006 Muckleshoot agreement,<sup>1</sup> may need to be renegotiated. Furthermore, there is no available research about structural demands. The Overflow Dike crest would require modifications including additional height and modifications to the Cedar River Habitat Conservation Plan implying adverse environmental effects [28]. It also assumes consistent use of emergency supplies: dead storage in Chester Morse Lake would be accessed via the Chester Morse Lake Pumping Plant and use of the Seattle

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<sup>1</sup> The 2006 Muckleshoot agreement can be altered through mutual agreement if need dictates [27].

Well Fields to meet demand, which may also have adverse effects when used consistently [24,29]. In combination, there adaptations may still leave Seattle in a state of perpetual shortage and reliance on emergency supplies.

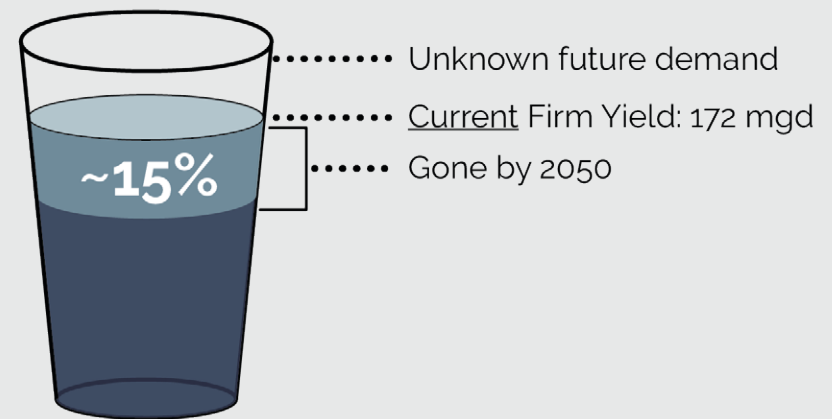
The effects of such extensive modifications have not been fully studied, so the scope of their consequences is still unknown. SPU identifies several areas for further investigation including effects of degraded water quality, which is known to decrease available supply, is detrimental to organisms, and requires more intensive treatment where the water can be used. SPU currently does not have the infrastructure necessary for this more intensive treatment because the water currently requires almost no treatment to meet potable water standards. While SPU engages in active forest management in both watersheds, the effects of forest fires were not considered. The effectiveness of these adaptations also assumes that an only slightly modified precipitation cycle over the course of the year and is not equipped to deal with extended drought or delay of fall rains, which may occur as extremes become commonplace [19].

## Demand

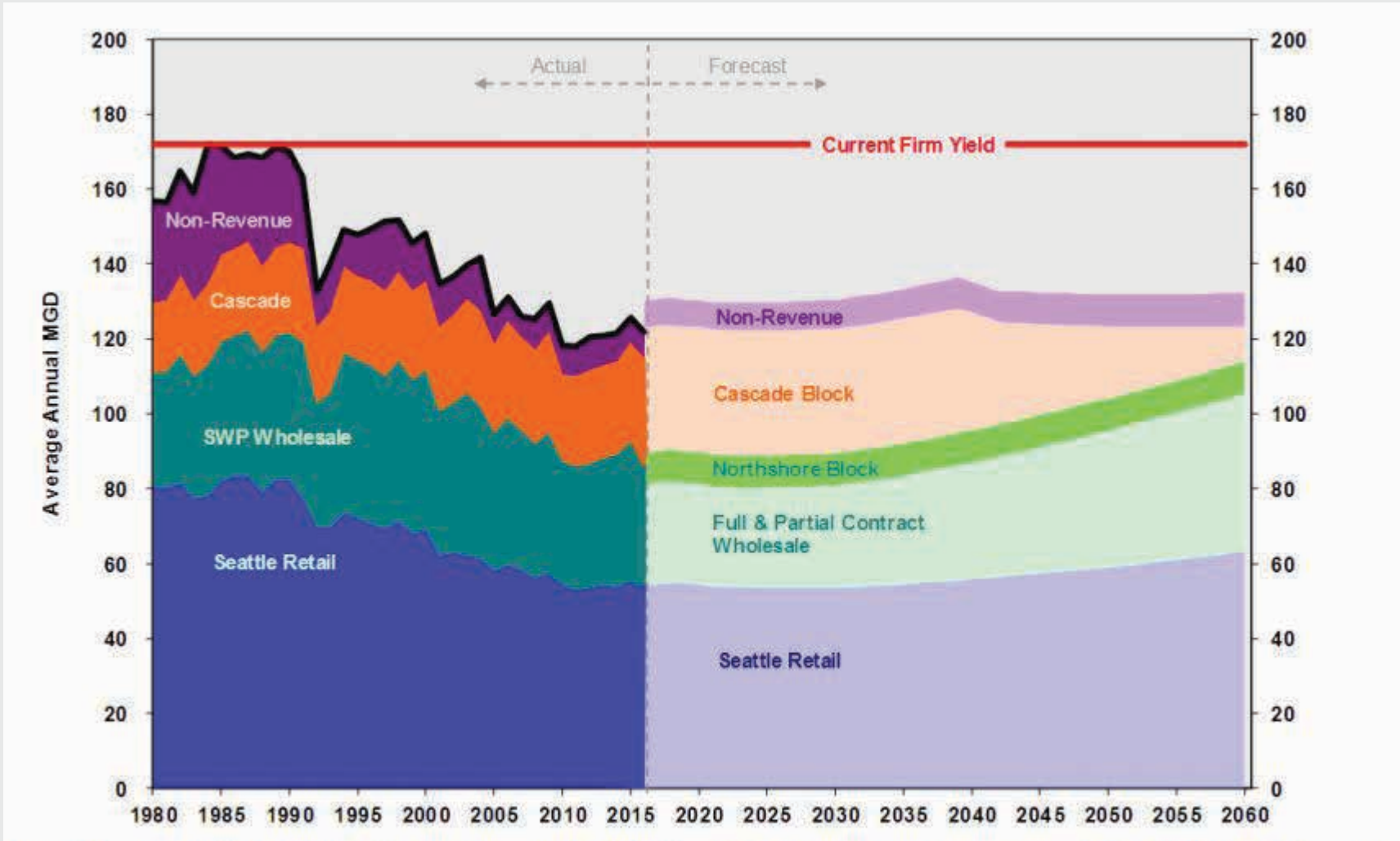
SPU does extensive demand forecasting that is released with each water supply report every five years. The forecasted demand has declined over the last three reports and water usage has remained relatively flat despite increasing population. SPU attributes this to water conservation efforts including efficient appliances and fixing leaks, though better understanding of demand forecasting is also a factor. Water demand depends on rainfall during the season, population size and growth, water use habits, groundwater availability, agricultural and industrial usage, and many other factors making it very complex to predict [6]. Overall, water demand tends to be lower in the winter, with peak demand occurring during the hot summer months for irrigation, cooling, recreation, electricity, and hygiene purposes [12].

SPU calculates water demand using a Variable Flow Factor model which takes income, price, and water conservation into account for single-family residential, multi-family residential, and non-residential customers. This approach is also used to see how rate structure affects demand and overall consumption, as well as how price might incentivize conservation [24]. This pricing structure is an effective tool to curb elastic demand but can harm customers with lower incomes and ability to pay for the increases in a city where water is already very expensive.

The Cascade Block, a primary SPU block contract customer, is currently developing its own water source at Lake Tapps. The decrease in water demanded by the Cascade Block contributes substantially to the stabilization of expected demand. SPU will continue to provide 33.3 mgd (fixed) through



**Figure 3.9:** Projection of proportion of water supply that will be lost due to the effects of climate change by 2050 (data from 3, 25, 26)



Note: Forecast demand is higher than actual demand in 2016 because the forecast includes all block contract amounts, whereas the actual demand by Cascade and Northshore has been less than their block contract amounts.

Figure 3.10: SPU forecasted water demand through 2060 broken down by customer group (3)

2039, when the contract will decrease the amount provided through 2064 when the Cascade Water Alliance will receive 5.3 mgd (fixed). Not incidentally, 2039 is also the year water demand is expected to peak at 136 mgd, and declines to 132 mgd in 2060 in correlation with expected declining block contract demands [19].<sup>2</sup> The Cascade Water Alliance has not addressed possible climate impacts at Lake Tapps, including water quality and quantity issues. These effects could have a variety of possible impacts on the Cascade Water Alliance's plan to draw from Lake Tapps, including necessitating continued water purchases from SPU [30].

Population size is one of the primary indicators of water demand but is difficult to accurately predict. SPU estimates population growth using Puget Sound Regional Council's UrbanSim model. This model uses small area estimates program data from the Washington State Office of Financial Management [24,31]. These estimates are based on 2010 census blocks and employment data and are extrapolated based on observed trends [32]. They do not necessarily account for how external events can change population growth over time (e.g. financial crisis, natural disaster, etc.), but do provide reasonable assumptions for growth if other factors are held constant. These estimates predict an eighteen percent growth rate in the SPU service area through 2040. SPU continues the growth rate beyond 2040 using the average growth rate from 2030 to 2040, but acknowledges uncertainty in population growth beyond 2040, and does not examine the possibility of climate refugees [22]. Though highly speculative, the population

<sup>2</sup> Cascade Water Alliance lacks a comprehensive plan for climate change beyond basic water efficiency goals. Current agreements and plans do not account for increased wildfire risk or decreased available supply [30]

model assumes that Seattle will continue to grow quickly.

SPU acknowledges both discrete and continuous uncertainty in the demand forecast. Discrete uncertainties are one-time events that can substantially affect demand such as the loss or gain of a contract. Continuous uncertainties include variables such as the rate of growth, for which SPU uses the mean value. The effects of climate change are not fully incorporated into demand modeling, though increasing variability of weather is assumed. Speculation over whether technologies efficiencies will increase over time, increases in urban agriculture, and other such effects of climate change are considered beyond SPU's scope, but may have significant impacts on water demand [22].

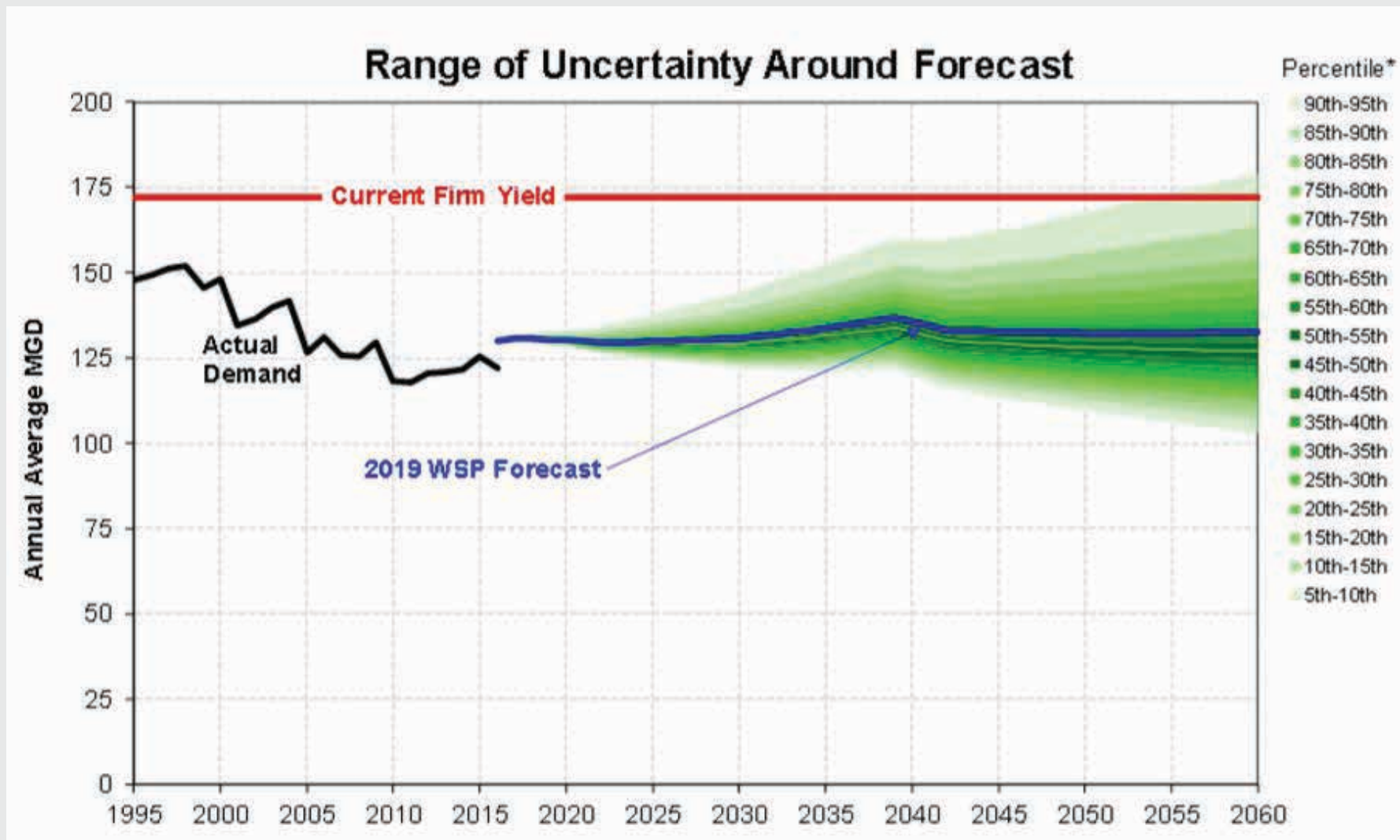
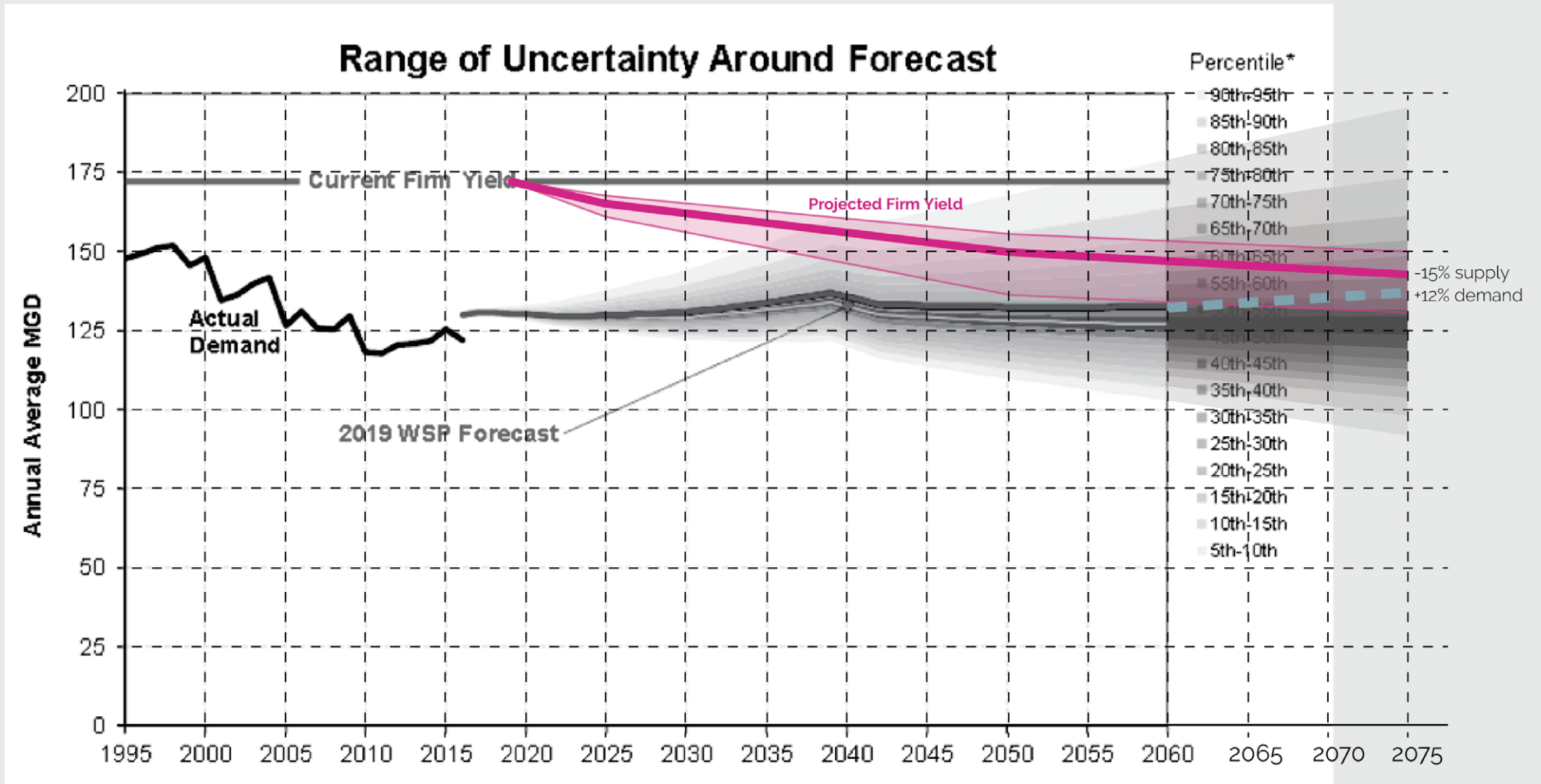


Figure 3.11: SPU forecasted demand with current firm yield through 2060 from the 2019 Water System Plan (3)



**Figure 3.12:** SPU forecasted demand with predicted decrease in firm yield through 2075. Demand lines were extended from the previous graph. The blue line indicated a 12% increase in water demand predicted by Climate Impacts Group and the Seattle Office of Sustainability and the Environment (adapted from 3, 23, 25, 27)

## Adaptations

Seattle Public Utilities currently has two main strategies for keeping water demand in check. The first is the Water Use Efficiency Program (2019-2028), under the Saving Water Partnership. The second strategy is the Water Shortage Contingency Plan, which will be activated in times of water shortage resulting from drought, systems failures, or disasters. The Water Shortage Contingency Plan has four stages: advisory, voluntary, mandatory, and emergency and was last activated during the 2015 drought at advisory stage [19].

The Water Use Efficiency Program aims to keep use under 105 mgd even with increasing population growth based on the successes of the 2013-2018 program. This amount is usually more than people actually use on average. Estimates for water conservation are based on accruing benefits of water efficient appliances over time, with water efficiency standards become stricter in the future. It is expected that appliances will be replaced relatively often: aerators every 5 years, shower heads every 10 years, washing machines every 12 years, and toilets every 30 years [22]. The estimated amount of infrastructure and appliances still needing improvement is not shown and could provide substantial benefit or could give diminishing marginal returns.

SPU outlines their Water Use Efficiency project as a way for the utility to increase adaptability and resilience. It suggests an opportunity to expand consumer water management strategies beyond current legal efficiency targets as new strategies develop [19], however it currently seems to be focused on water-efficient appliances. SPU relies on water use efficiency improvements to keep demand in check

based on recommendations from other agencies including the Department of Ecology [4] and Climate Impacts Group [2]. These programs go beyond what is legally required in the state of Washington. However, they rely on customers to make efficiency improvements, rather than the utility. Though water efficiency is important, even the most efficient appliances require some water. If population and water demand increase and potable water is still used for all functions, a new source of water will be needed.

## Case Study: North Seattle Reclaimed Water Project

SPU outlines several possible new sources of water including water for non-potable use. The main exploration of non-potable water use was of Brightwater Treatment Plant's ability to recycle 21 mgd of wastewater for irrigation in the Sammamish River Valley and Northern King County. Brightwater Treatment Plant was the only part of the North Seattle Reclaimed Water Project that was implemented and would have supplied recycled water to much of North Seattle. The project failed to move forward because of high costs, limited customer base (only very large water users were considered), low demand among those users, and limited environmental benefit (.05% nutrient load from all King County treatment plants) [33].

The centralized infrastructure project as proposed would have cost \$109 million and included a pipeline circling from Brightwater to University of Washington to Ballard and back to Brightwater. It was not implemented because SPU leadership believed that lower-cost alternatives could provide the same benefit. The recommended actions in North Seattle are to install natural or green drainage systems, improve the quality of water coming from treatment plants, switch irrigators supplying their own water to Seattle municipal supply, ramp up existing water-savings campaigns, and reducing the minimum drawdown level for the Tolt reservoir to increase available supply [33].

The failed North Seattle Reclaimed Water Project reflects at least some desire to more effectively utilize water resources so that potable water can be conserved for actual consumption. However, it only examined specific water uses

who use large quantities of water for non-potable use: self-supplied well users, cemeteries, play fields, and several uses at the University of Washington including Drumheller fountain. While these users represent a portion of possible users, they were spread out over a large area because King County Wastewater Treatment Division only wishes to sell reclaimed water to a specific subset of water users [33]. This assessment also did not speculate about future water use laws including toilet flushing on a broad scale using reclaimed water. These issues are avenues for exploration in the Georgetown site examined here and could be applied at the neighborhood scale in the future.

## Other Possible Water Sources

Other possible sources to supplement current supplies are identified. The Snoqualmie Aquifer is a possible source, which could plug into the existing Tolt Pipeline infrastructure. As previously stated, the relationships between climate change and groundwater are not fully understood and pose several additional problems. While groundwater recharge rates are slow and aquifers can easily be over pumped resulting in decline of the groundwater table, subsidence, saltwater intrusion, soil salinization, regulations including water rights, costs, pollution and water quality, factors associated with required treatment, percolation potential, and land use [29,34,35].

Desalination of water from Puget Sound could be a useful tool for providing water. Indeed, many coastal cities experiencing water shortages use desalination to provide water, but this process has several significant drawbacks. Desalination is energy and cost intensive though new technologies have made improvements. Estuarine water is easier to desalinate than saltier water, but discharge of the salts back into Puget Sound could alter salinity and other factors of ecological importance [36,37]but it is costly and energy intensive and further strains the environment with brine disposal and greenhouse gas (GHG). There are three primary categories of desalination: membrane technologies, thermal distillation, and chemical applications, each with advantages and disadvantages [38]. The complexity of factors to weigh, including the availability of simpler and cheaper alternatives make desalination less desirable in the near future.

Other alternatives to tapping new sources involve modifying existing infrastructure: aggressive drawdown at both

Chester Morse and Tolt Reservoirs, drawdown at Lake Youngs, developing the North Fork Tolt Diversion plan from the mid-twentieth century, interties between existing system elements, and building a new dam at the Overflow Dike location [19].

Finally, the use of distributed systems has the ability to preserve potable water through graywater and rainwater systems. SPU's current major initiative in this area is the RainWise program, which reimburses homeowners in specific CSO basins for the cost of rain barrels, rain gardens, and other rain harvesting equipment that are intended to be used for irrigation [22]. With its commitment to green infrastructure, this initiative has potential to grow as most current installations are on single-family residential properties and can be leveraged to greater benefit.

Collectively these initiatives are working toward a more efficient use of water throughout the system. Decreasing water waste is an important piece of sustainable water use. However, all uses still depend on the same water sources that are under increasing stress from climate-related threats. The magnitude of effects is uncertain, so greater flexibility that manifests as a range of options to address water-related contingencies can be a more reliable strategy than a single solution.

As SPU looks toward long-term adaptations and expansion in the scope of green stormwater infrastructure, other adaptation models are available as a reference. One such model is Water Sensitive Urban Design, that focuses on water reuse as a way to offset potable water demand and environmental impacts. Increasing the choice of water inputs beyond potable and nonpotable provides the utility and customer with more options in times of shortage and provides additional tools to manage flooding.

## End Notes

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# CHAPTER 4

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# WATER MANAGEMENT STRATEGIES

Low Impact Development & Green Infrastructure

Water Sensitive Urban Design

New Urban Hydrology & Overlap with LID

Values & Goals of WSUD

Water Reuse & the Fit-for-purpose Model

Integrated Water Management

Melbourne, Australia

*One Water* & Future Thinking in the US

Framework

# WATER MANAGEMENT STRATEGIES

## Low Impact Development (LID) & Green Stormwater Infrastructure (GSI)

Low Impact Development emerged in the 1990s as an alternative or complement to stormwater Best Management Practices (BMPs). It can be primarily characterized as site-scale stormwater catchment of runoff. There is wide acceptance in US cities of the detrimental impacts increased stormwater runoff has on urban rivers and streams [1]. To combat these negative environmental impacts, BMPs, LID, and Green (Stormwater) Infrastructure (GI/GSI) have been widely adopted in the United States.

BMPs focus on large precipitation events, where LID practices try to treat and detain water long enough to mimic predevelopment streamflow cycles during precipitation events. LID focuses primarily on managing stormwater to more closely mimic a natural hydrological cycle and provide climate change adaptation cobenefits like groundwater infiltration and pollinator support. LID seeks to examine the impacts of urbanization on urban waterways through retrofits and more comprehensive site planning strategies [2]. LID is a widely adopted and often required practice in the United States and LID practices are often incorporated into city codes.

Considered synonymous with LID, Green Infrastructure (GI) is a set of strategies to increase infiltration in urban areas and detain peak loads of stormwater [1]. The US EPA categorizes downspout disconnection, rainwater harvesting, rain gardens, planter boxes, bioswales, permeable pavement, green streets, green roofs, urban canopy, and land conservation as Green Infrastructure [3]. These techniques provide ways to simultaneously provide multiple benefits to communities while reducing and treating stormwater. GI provides a way to develop



Figure 4.1: LID in Eastlake, Seattle at 199 Blaine. Designed by SvR, (28)

Figure 4.2: Residential RainWise raingarden in Ballard, Seattle. Designed by Monsoon Rain Gardens (29)

strategies for more comprehensive water management in the United States.

While LID has become common, the existing knowledge base on changes in the quality and quantity of stormwater flows are still being understood and studied [2]. Strategies for LID in urban areas are now part of stormwater management in many cities, at least at the small scale. LID may be written into policies to the extent that it is not even recognized as a defined philosophy. However, developing a critical mass of GI high enough to decrease stormwater volume and increase quality remains a challenge in many places, often due to funding and water rights.

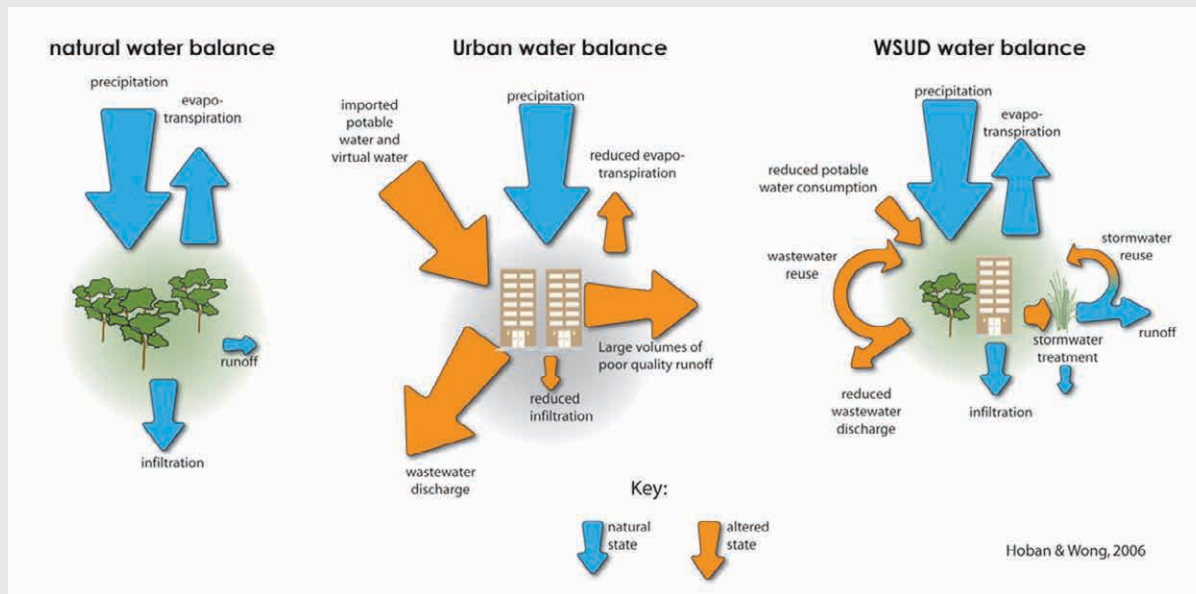
LID as a water management strategy is now thirty years old and has not changed significantly since it was introduced. Those who work with water systems have a great deal more knowledge about the relationship between water and the urban and natural environments because of LID. However, residents remain separated from the water systems they rely on, so the average person rarely sees any of the components of a water system. Gradual reintegration of visible water infrastructure into our built systems moves urban areas toward resiliency and broader understanding of the value of natural resources [4].

On January 14, 2019, H.R. 7279 became law, allowing green stormwater infrastructure (GSI) to qualify for subsidies under the Clean Water Act. The bipartisan and unamended bill calls on the EPA to actively promote the use of GSI, and creates an office to do so [5]. This law shows the widespread acceptance of GSI for water quality and stormwater treatment which gives potential to the idea that GSI can be expanded and adapted to meet future needs.

Seattle's Green Stormwater Infrastructure (GSI) strategy was announced in July of 2015 as a way to control CSOs and pollution from runoff [6–8]. Projects to date focus primarily on swales, rain gardens, and rainwater harvesting for outdoor irrigation as stormwater management strategies [8,9]. These projects are generally small in scale or are pilot initiatives. While these projects are gaining popularity for their aesthetic and function value, there is significant room to expand GSI to enable more cohesive runoff management.

Many municipalities identify LID, GSI, and GI as tools for reducing runoff and nonpoint source pollution. Cities often provide incentives for LID for retrofits or new development, but few water reuse projects currently exist in the United States. Reuse projects are generally limited to places currently experiencing severe water scarcity. There is potential to expand the capacity of green infrastructure and develop best practices for water reuse in the US.

As the twin drivers of climate change and increasing water demand are felt with greater intensity, cities must develop more resilient and creative ways to meet water demand. There is already extensive discussion on the merits and demerits of alternatives, but stormwater collection and reuse have been identified in many communities as the most accessible source of water. Despite this, there are still several challenges to be overcome including policy, cost, public acceptance, and reliable water quality.



**Figure 4.3:** Diagram of natural versus urban hydrology. WSUD modifies urban hydrology to better mimic the natural water cycle (30)

## Water Sensitive Urban Design

Water Sensitive Urban Design (WSUD) is an Australian urban development practice that has evolved over the last three decades. It began as a stormwater management strategy and evolving into an integrated, holistic urban design approach. While Low Impact Development (LID) in North America and WSUD are frequently considered equivalents, and there are many overlapping viewpoints, WSUD offers a richer and more developed framework that rose out of the necessity of prolonged, climate-induced drought. WSUD gives a possible roadmap for the maturation of LID, possible pitfalls to avoid, and an increasing amount of data to draw from.

First conceptualized in Perth, Australia in the early 1990s, WSUD was developed to capitalize on all water resources, it focuses on stormwater management and water reuse to help relieve strain on far-removed, large water supply systems

and urban waterways. Focus shifts from conveying water to receiving bodies with alacrity to managing the watershed as a system. WSUD shares LID goals of protecting local water bodies through decentralized, biomimetic design, but provides the additional, more actionable goals of reducing effluent discharge and potable water demand through water reuse [10]. WSUD relies on “fit-for-purpose” (the concept that water can have varying levels of quality depending on use) water use, and expands normalized human usage to recycled, storm, and gray waters. It argues that potable water use for all purposes is not sustainable and using nonpotable waters for other purposes helps reduce environmental strain while providing for human use. WSUD aims to manage natural hydrology, potable water, wastewater, and stormwater as one system, requires coordination between stakeholders and public acceptance [11,12].

## New Urban Hydrology & Overlap with LID

Like LID, WSUD recognizes that increasing urbanization degrades natural hydrology. Urban development requires large volumes of water from surrounding water bodies to use in municipal water systems. Water is removed from the system for human use but later discharged (often at inferior quality) and joins polluted runoff in receiving waters. Runoff drastically increases in volume and decreases in quality as a consequence of greater impermeable surface area and human alterations. Collectively these factors result in hydromodification from human-driven change in the hydrologic cycle.

Hydromodification has multiple detrimental impacts on receiving waterways including erosion, sedimentation, increased turbidity, high nutrient load, pollution, and so on. The extensive use of shoreline hardening, paving, streamflow modification, and soil compaction in urban areas results in much lower infiltration potential while the decrease in vegetation causes a decrease in evapotranspiration. The result is a sudden inflow of urban runoff into nearby water bodies that can cause flooding, erosion, and public safety risks, but also harms the natural environment. Stormwater runoff, in combination with effluent (and sometimes sewer overflows in areas with combined sewer systems) and sediment, degrades water quality when it discharges to local receiving water bodies where it has deleterious effects on wildlife, feeds toxic algal blooms, and modifying local water conditions [10,13].

In addition to driving hydromodification, urban development in floodplains further increases peak flows and localized flooding as water drains into nearby water bodies and is not absorbed into the floodplain. Localized flooding harms

urban infrastructure and can impede transit of people and goods, increase landslide risk, and damage water infrastructure [14]. Overall, the gradual modification of the urban environment has changed the natural hydrology to the extent that it can no longer function as a resource.

To better mimic natural hydrology, WSUD engages in similar stormwater management practices as LID. WSUD engages with site-specific through urban scale designs through water source control, treatment, and site design to provide multiple benefits including aesthetic and amenity spaces which help increase value. In the *Australian Runoff Quality* manual, effective water management is seen as integral to sustainable development and is meant to be incorporated across scales [10]. The deterioration of water quality is a direct result of current water management practices, showing that a finer-grained management strategy is needed in managing the urban water cycle [10,13].

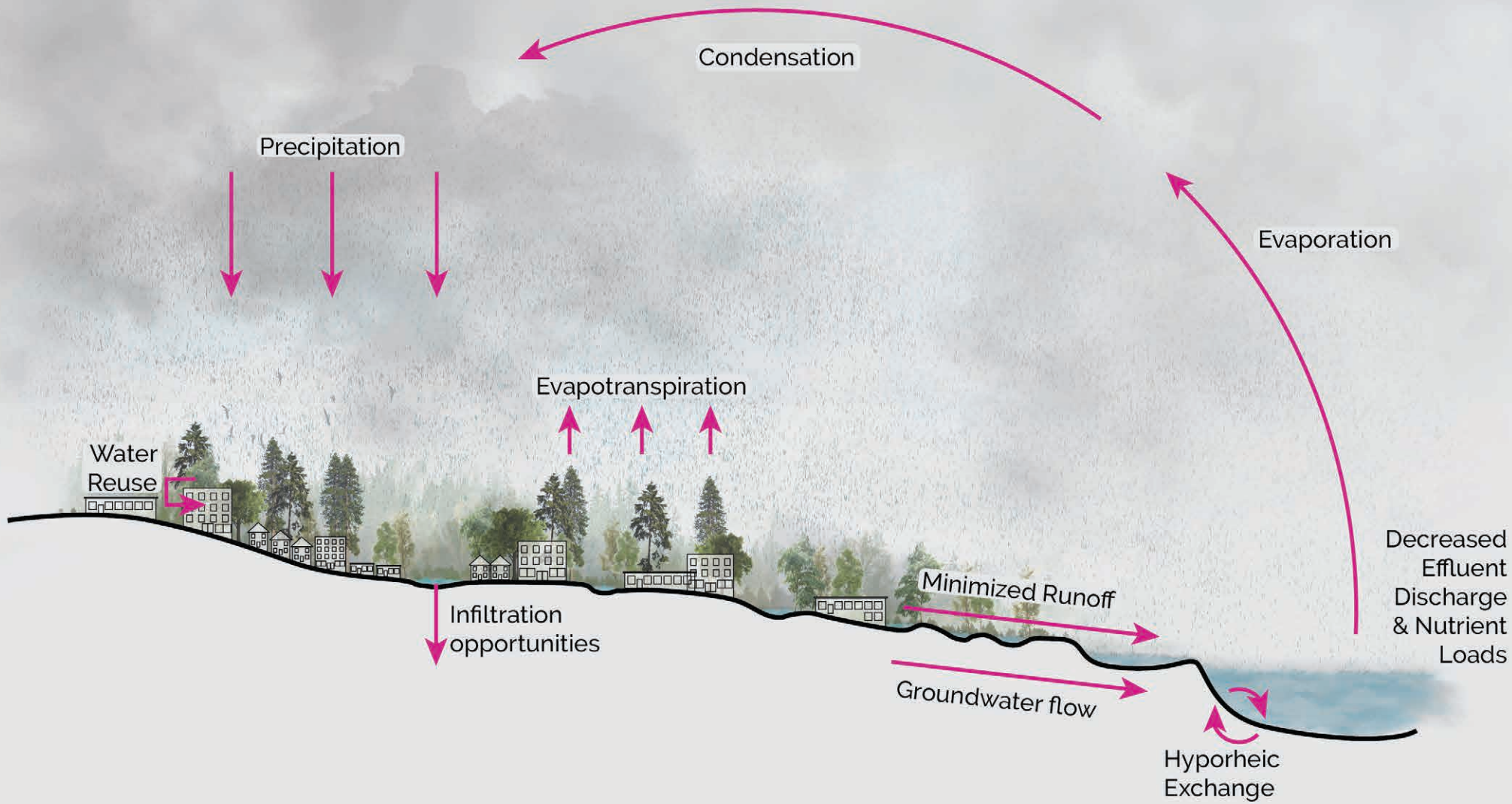


Figure 4.4: Urban hydrology that mimics natural hydrology using WSUD

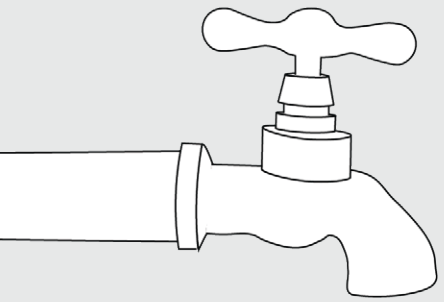


Figure 4.5: Basic goals of WSUD (adapted from page 13, 31)

Healthy Waterways

Decreased potable water demand

Decreased effluent discharge

### Values & Goals of Water Sensitive Urban Design

WSUD principles address the challenges associated with increasing urbanization and climate change and ask everyone to use water more sustainably. WSUD developed principals of water reuse that move beyond LID during a severe drought. During the drought, Australian cities were forced to find new water sources on short notice. WSUD practices evolved to address water shortages and encouraged cities to explore water reuse. WSUD as a philosophy focuses on integrated water management practices and ecological health. To improve ecological and hydrological health, WSUD focuses on mimicking natural hydrology, reducing effluent discharge, and reducing potable water demand [10,12,13,15].

By focusing on these primary goals, WSUD begins to approach stormwater as both an obstacle and a resource with the ability to relieve demand pressures and effluent and nutrient loads through reuse. Using similar practices to LID, WSUD offers several suggestions for overall water system management by using stormwater. WSUD also seeks to detain and slow stormwater to reduce peak flows and better mimic natural hydrology; uses green infrastructure like swales and raingardens to filter and treat runoff; choses native plants and materials that use water efficiently; uses green infrastructure to filter and treat runoff; and endeavors to protect water bodies' cultural, recreations, and environmental value [13,15].

WSUD also focuses on water reuse at several scales as a way to reduce effluent and reduce water demand. Small scale strategies are particularly effective as they are generally more cost effective and easier to implement. These strategies include capturing and reusing rainwater as an alternative water source in nonpotable applications to conserve potable water, graywater reuse, and small-scale for wastewater or graywater treatment for reuse in individual buildings. Larger-scale reuse strategy focuses on reclaimed water through sewer mining, runoff harvesting at the neighborhood [10,13,16]

## Water Reuse & the Fit-for-purpose Model

Potable demand and effluent reduction can be achieved through the “Fit-for-purpose” reuse model, which can reduce potable water demand by 65% in the long term. This model focuses on water reclaimed from wastewater, rain, or graywater for nonpotable uses like irrigation, toilets, cooling, and laundry. These relatively clean water sources are not potable but are of sufficient quality to protect public health. Part of determining how to best reduce discharges and potable water demand is understanding the breakdown of uses potable water goes to in each city or sub-area between households, commercial, industrial, and other uses. From there, each category can be broken down into end uses [10].

Treated wastewater, called reclaimed water in the United States, is a highly underutilized resource for reuse, but is recognized under WSUD principles. Wastewater can be recycled for any use, including potable, with modern treatment techniques. However, treating to a slightly lower quality for nonpotable uses is often more attainable and cost-effective, while maintaining excellent public health protections. These technologies exist from the small, single building scale to large, centralized systems, however are rarely utilized in the United States [10].

Wastewater treatment has historically been focused on protecting public health and has more recently added the objective of protecting waterways from pollutants. The extent of treatment to which wastewater must be subject to varies by state, locality, and even from facility to facility. Differing regulations make the quality of effluent highly. In addition to variable quality wastewater discharges, poor stormwater quality inflows degrade waterways. Together, these inflows can cause flooding, erosion, high turbidity, increase in total

suspended solids (TSS) including sediment and litter, nutrient loading including nitrogen and phosphorus, toxic materials, and introduction of high oxygen-consuming species. Stormwater quality and quantity control have the most obvious overlaps with accepted LID practices, but perhaps evolves stormwater quality treatment techniques by identifying and designing for target pollutants to best protect receiving waters [17,18].

To apply the fit-for-purpose model, Australian regulatory bodies move beyond the simplified water classification system used in the United States (potable water and non-potable water), and instead have ranged guidelines based on what application water will be used for. There is an ongoing debate about the suitability of roof runoff in hot-water uses like showers, kitchen tap, and dishwashing applications. As public knowledge and water quality technologies gain sophistication, non-potable water may become suitable for some uses with human contact [19,20]. Overall water reuse makes efficient use of already existing resources while distributing both responsibility and risk surrounding public health, giving both water utilities and customers options in how they manage and use water [21].

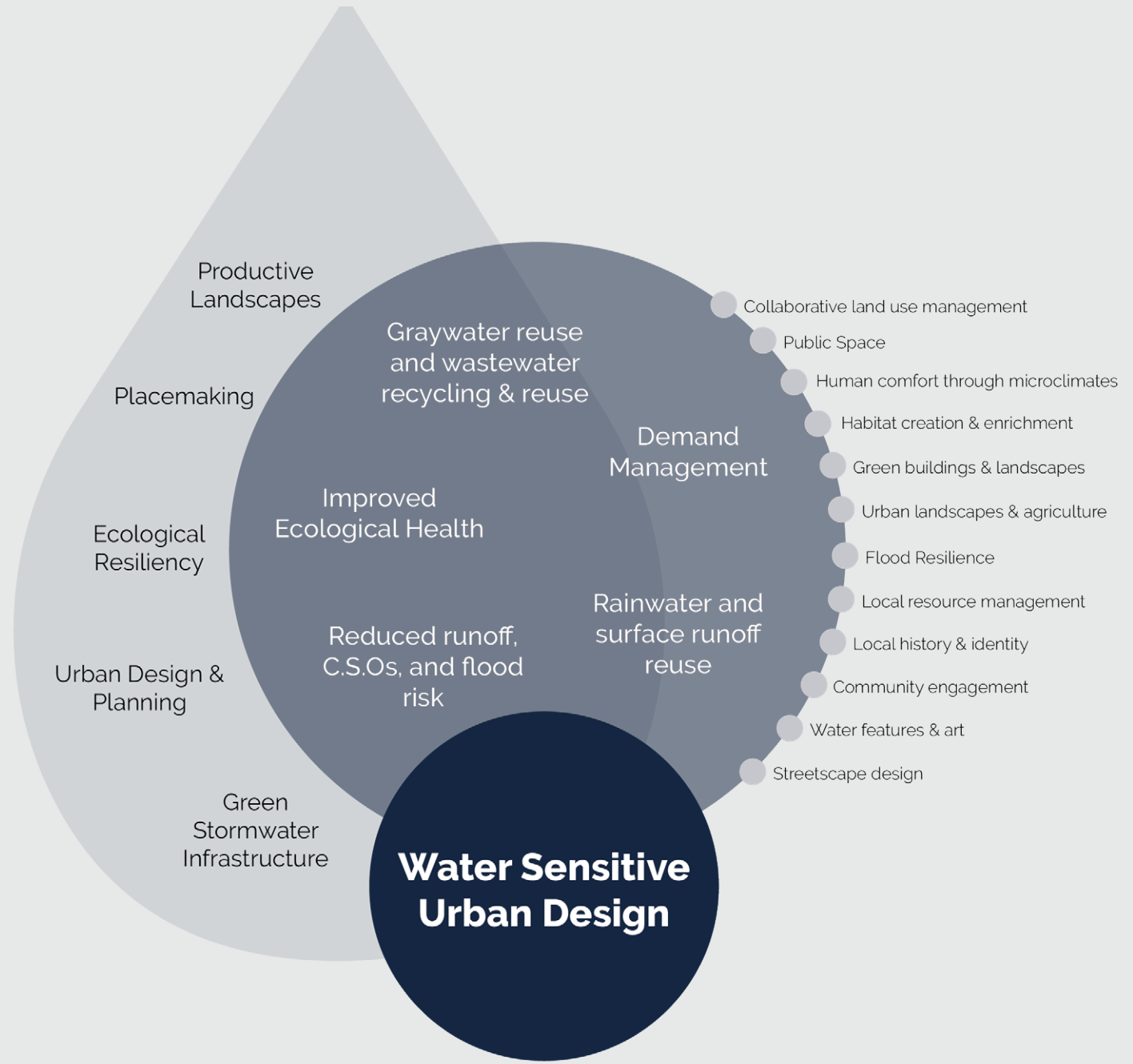


Figure 4.6: Components and factors in WSUD (adapted from page 13, 31)

## Integrated Water Management

In many places, the infrastructure and management, workforce, and policies governing wastewater, runoff, and potable water have been separated, which led to differing practices and philosophies across disciplines. In keeping with the identified trend of institutional resistance to change, water managing entities often do not see integrated management and service as necessary to technological advancements. Concerns often focus on infrastructure improvements, but management practices remain fragmented or at odds with the others. While integrating management and service practices potentially requires a lot of coordination, benefits in efficiency, costs, and effectiveness help provide incentive to integrate [7].

Adopting new technologies and comprehensive urban systems requires stakeholders at various levels to change their values and practices at a range of scales. Integration and normalization of new practices evolves over time as it has and is in Melbourne despite barriers in social, governmental, economic, and technical barriers.

For municipalities trying to pursue sustainable water management, many of these barriers are at socio-political or institutional levels. In analyzing Melbourne's progress through 2006, Brown, Clarke, and Wong, leading researchers in WSUD in Melbourne, refer to multiple institutional barriers that impede the transition to sustainable water management. The barriers Brown et.al discuss have been identified as generally transferable to water-managing entities worldwide [22].

The biggest impediment, overall institutional resistance, is both institutional and social because it requires citizens, institutions, and officials to see new practices and accessible,

necessary, and advantageous. There may be resistance from practitioners or citizens when the new technologies needed are not fully understood or accepted, which can compound with infrastructure "entrapment." Entrapment in existing infrastructures is likely to be a part of generalized resistance because, as defined by Brown et. al., existing infrastructure is a physical representation of societal values embedded through history and administration and can be difficult to remove oneself from. Additional barriers mentioned include lack of coordination, siloed departments, lack of trust between stakeholders, structural impediment, lack of political will, and incomplete or lacking incentives. These infrastructures reinforce the accepted status quo and build on a cumulative history and extensive investment, which makes resistance part of the progression toward sustainable practices [12,18,23,24].

There is still significant debate on how to operate, finance, and regulate decentralized infrastructures. Some scholars advocate for governments to manage decentralized systems through advanced sensing technology while others believe a co-managing arrangement with communities is essential in motivating people to use a new resource [25]. In the US, some government management may be necessary to protect public health and municipal systems from litigation. Some government management of this kind has been implemented in Melbourne, as water utilities have tried to achieve greater integration. Melbourne can provide insight into the relationships between government management of water, user acceptance, and forced change by climate-induced water stressors.

Table 1.1 Matrix of 'Fit-for-purpose' domestic water usage (Ecological Engineering 2003)

SOURCE	Garden	Kitchen		Laundry		Toilet	Bathroom	
		Cold	Hot	Cold	Hot		Cold	Hot
Potable	3	1	2	1	2	3	1	2
Wastewater								
Treated Black	1	4	4	4	4	1	4	4
Greywater	2	4	4	4	4	2	4	4
Stormwater								
Roof	2	2	1	1	1	2	2	1
Non-roof	2	4	4	4	4	2	4	4

1. Preferred use; 2. Compatible use; 3. Non-preferred use; 4. Not compatible

Figure 4.7: A survey on public perceptions of acceptable used by water source from the Australian Runoff Quality Manual (p. 1-3, 87)

### Case Study: WSUD in Melbourne

The city of Melbourne, in Victoria, Australia illustrates adoption of water sensitive practices over a short time period. Of the cities that are adopting WSUD, Melbourne is the most studied city with some similar or transferable environmental, governmental, and societal conditions to American cities [26]. Melbourne also has some worldwide transferability as all cities struggle with increasing populations, aging infrastructure, waterway degradation, and the effects of climate change, but have less complex water rights than typical American cities [12].

The story of WSUD begins with the worldwide environmentalism movement of the 1960s and 1970s that started the ongoing recognition process that the landscape is more than just a resource to be exploited. The period marked

a change from building larger, more expensive dams for water supply and flood control to managing water more effectively by developing best management practices [21]. Melburnians began to study Port Phillip Bay, on which the city sits, as it experienced increasingly toxic algal blooms and deteriorating water quality. The very first environmental review of Port Phillip Bay (1968-1973) by the Commonwealth Scientific and Industrial Research Organization showed that both treated wastewater discharge and stormwater (Melbourne uses separated sewers) were primary sources of nitrogen and other pollutants. In contradiction, the organization concluded the bay was in relatively good health despite the study's limited scope [27]. During this time, movement toward adding recreational amenity through interventions became popular and in the 1980s, focus turned to restoring urban streams through both municipal regulation and grassroots activism [12,15]



Figure 4.7: Map of Melbourne Water supply system and geography (32)

The stormwater management component of WSUD took off in the early 1990s and local and regional governments began to recognize that water pollution went beyond the scope of the Best Management Practices used to control point-source pollution. Though stormwater did not fall under any specific jurisdictions, governments did not want to take on responsibility for it. However, the third major environmental study on Port Phillip Bay (1992-1996) made it a necessity. Initially, the study was meant to examine whether the bay could continue to sustain discharge of treated effluent sewage. While effluent was again established as a threat to the bay, the study inadvertently proved significance and pervasiveness of stormwater pollutants on waterway health and catalyzed policy changes. Significantly, Melbourne set an ambitious goal to reduce nitrogen discharge by 1,000 tonnes, relative to 1993 levels, by 2006, with half the reduction expected from treated wastewater and half from stormwater. To achieve the nitrogen-load reduction goal, the contributory drainage scheme was developed that allowed catchments and developments to comprehensively model and mitigate pollutants based on the load from the region [12,27].

Following the 1990-1991 recession, much of the Victorian government downsized through privatization. The Melbourne Water Board, which had previously overseen drainage, sewage, and potable water regulation and service disaggregated into a wholesale water company, a drainage and wastewater authority, an environmental and waterways agency (Melbourne Water Corporation), and three retail water supply companies. The Melbourne Water Board went from an integrated water company to fragmented bodies. The disintegration of an organizational management structure and the resulting confusion arrested some of the momentum that stormwater

management had had leading up to this point [12,28].

Despite the organizational challenges of a disaggregated company, stormwater policy and research continued forward in universities and the new companies. Policymakers and industry professionals from the Victoria Stormwater Committee and Melbourne Water adapted and stimulated scientific knowledge that wetlands had the potential to reduce nitrogen loads by 20% at the regional scale and implemented the 80:45:45 rule. The 80:45:45 rule requires that new developments have to either retain 80% of total suspended solids, 45% total nitrogen, and 45% total phosphorus or construct a stormwater treatment wetland amounting to at least 1% of the total land area for all developments. The development industry also began to recognize that green stormwater treatment technologies could lead to increased market value. Adoption by developers is seen as a primary factor in bringing WSUD into the mainstream [12].

In 1997, following the 80:45:45 rule and the Port Phillip Bay Environmental Study, the National Heritage Trust project was launched to help meet the 2006 target for reduced nitrogen loads. It funded ten regional wetlands and a sub-catchment demonstration project to evaluate the feasibility of small, decentralized, street level treatment [12]. While water management professional considered government policy to be a major impediment to broad adoption of WSUD, limited buy-in through pilot projects can help overcome social and institutional barriers to some extent [29]. Pilot projects like these can help overcome barriers to adopt decentralized water reuse technologies in greenfields and existing developments [30], but may struggle to overcome momentum of traditional water management techniques [29].



**Figure 4.8:** Dry stormwater storage pond at Queen Victoria Gardens in east Melbourne (33)

**Figure 4.9:** Wet stormwater storage pond at Queen Victoria Gardens in east Melbourne. The water in the ponds is used to irrigate the park during the dry season (33).

One of the developments selected for the decentralized demonstration project was Lynbrook Estate and was a joint venture between the Melbourne Water group and a local developer. Initially the developer was skeptical about the cost and effectiveness of swale and wetland feasibility in managing floods. The Melbourne Water group financially underwrote the project and promised to replace it with traditional drainage infrastructure if it did not perform. Fortunately, the green infrastructure hydraulically performed better than traditional infrastructure for runoff quality and quantity during a five-year storm [12]. In added benefits, surveyed residents perceived the swales and wetlands as being more aesthetically pleasing, and the developer noted a 20-30% increase in developments using WSUD [12,29].

By the early 2000s, most of Australia was experiencing water security stress from the worst drought on record (1996-2010<sup>1</sup>), made worse by exponential population growth. WSUD developed rapidly through collaboration with Australian universities, consultants, developers, and most water utilities. WSUD developed into an urban design framework to support dwindling water supplies through comprehensive water cycle management, rather than just stormwater management [11].

Governments tried a range of approaches to reduce water demand including incentives like funding decentralized infrastructures such as rain barrels and restrictions including requiring all workplaces to develop water conservation strategies. Governments were anxious to find reliable water sources for their growing populations and began investing

in short, medium, and long-term solutions. Work focused primarily in the areas of desalination, wastewater recycling, and stormwater harvesting [21].

Desalination was seriously suggested as a medium to long term option to increase supply for the first time in 2002 but was not seen as necessary and was not initially pursued. As the drought continued, a significant drop in reservoir levels in 2006 (49% to 29%), and the Victorian government began aggressively pursuing a 150GL desalination plant (amounting to one-third of Melbourne's typical annual water demand) without consulting the wider water sector or community. The desalination plant project was announced in 2007 as a Public-Private Partnership. It was met with skepticism because of the lack of community engagement and partially because many doubted the wisdom in pursuing an expensive desalination plant at the expense of alternative technologies. The plant was completed in 2012, though public discontent continues and the plant has never been used [18].

In 2001, the Victorian government set a target to recycle 20% of wastewater by 2010 to reduce pollutant loads on local waterways including Port Phillip Bay. Recycled water was to be used as a supply for non-drinking purposes, but also served to expand water classifications beyond potable and sewage. The major water treatment plants were upgraded to treat to a Class A recycled water level (suitable for use in non-potable settings and for irrigation of food crops) primarily as an environmental protection measure but had the secondary benefit of producing viable recycled water. By 2005, farmers experiencing water shortages from the ongoing drought, were using recycled water to cultivate crops.[20]

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<sup>1</sup> Different sources claim different years for the drought and several years of extensive flooding that followed encompassing 1996-2010.



Figure 4.10: South East Water's reclaimed water supply progress for the 2016-2017 water year. South East Water is one of Melbourne's (disaggregated) utility providers. (34)

During the same period, public health and environmental regulations were being written by the Melbourne Water, the Victorian government, and other agencies to allow new developments to be laid with a "third pipe system" that supplies recycled or graywater for non-potable uses. Wastewater utilities developed infrastructure to distribute water and by 2006, new greenfield developments were supplied to customers for the first time. Demand for graywater increased, with the public being largely supportive of using recycled water (with occasional concerns about color and odor). Due to perceptions of lower quality, residents were not willing to pay the same price for potable and nonpotable water even though they cost the same to supply. Water recycling generally occurs at the medium to small scale, with medium scale developments having a third pipe systems and some small scale developments having on-site wastewater recycling [18].

Stormwater reuse generally works on the medium or small scale and serves to decrease stormwater discharges into receiving water bodies, just as wastewater recycling decreases discharges from treatment facilities. Both provide sources of non-potable water that can be used for irrigation, toilet flushing, and laundry. Stormwater was first understood for its impacts on Port Phillip Bay and other local water bodies, but the extended period of drought showed its potential as an additional source of water. State initiatives for using stormwater did not take off until post 2005 when the Facility for Advancing Biofiltration and the National Urban Water Governance Programme were formed and able to prove that stormwater could be treated to a reliable level for non-potable uses despite variable water quality inputs. And yet, stormwater harvesting has the least well-developed institutional framework and usage of the three

major strategies because it required the largest adjustments in terms of values, infrastructures, and relatively low level of symbiosis with traditional water supply approaches [18].

On the national scale, Australia uses the National Water Quality Management Strategy (NWQMS) and associated assessments that determine the targeted goals on an individual catchment basis. Individual properties then receive assignments on priority target objectives to work toward overall watershed health. This finer grained approach allows the government to regulate pollutants and water quality more comprehensively [12].

While trying to achieve institutional change their water industry, Melbourne has encountered numerous institutional, financial, political, and social barriers to new water management practices. While some of Melbourne's decisions are still contentious, the relatively quick rate of acceptance of water reuse and water conservation efforts shows how the value of water can shift. The pressure water shortages exerted may have encouraged faster acceptance among stakeholders. Since climate-induced water shortages will continue, the Melbourne model provides inspiration and insight for potential water management practices and their integration in the United States.

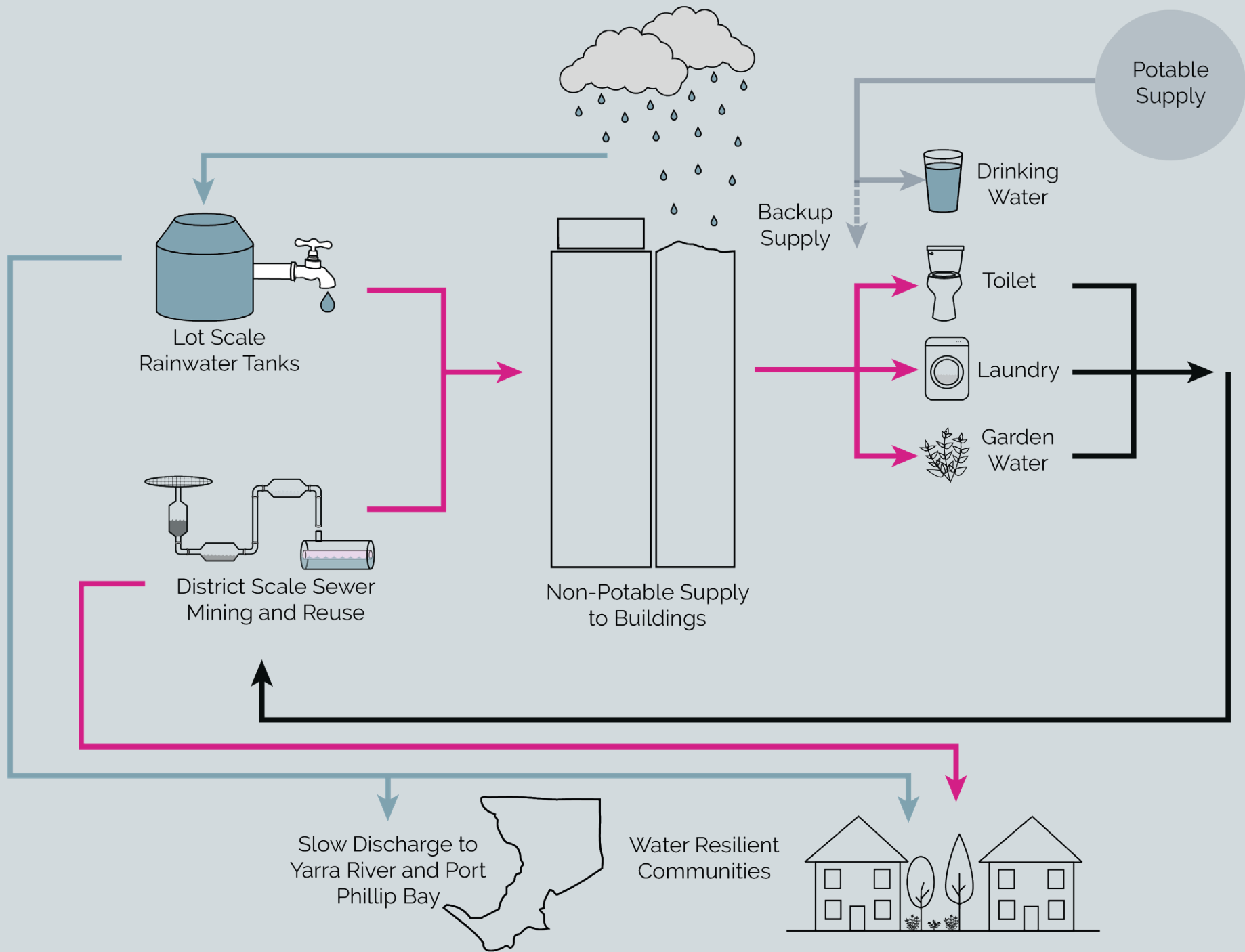


Figure 4.11: Water reuse system in Fishermen's Bend, Melbourne. Diagram adapted from Southeast Water's Fishermen's Bend Project. (35)

## ***One Water* and Future Thinking in the US**

WSUD has great similarity with the concept of *One Water*, which is gaining traction in North America. *One Water* focuses on managing all types of water as a single resource including drinking water, natural water, sewage, graywater, and so on. In this philosophy, all water belongs to the hydrologic system, so it has come to be known as *One Water*. The Water Research Foundation described *One Water* as follows: "*One Water* is an integrated planning and implementation approach to managing finite water resources for long-term resilience and reliability, meeting both community and ecosystem needs" (p.2) [31]. *One Water* focuses on combining management for sewage and drinking water are generally managed as separate utilities [32]. *One Water* is becoming more popular in the United States as more municipalities adopt *One Water* practices. Some cities currently working toward *One Water* are Philadelphia, Los Angeles, San Francisco, Orange County, and Denver [31].

While Seattle is briefly mentioned in the *Blueprint for One Water*, no official documents released by SPU associate with the *One Water* philosophy, though a classmate's experience at SPU indicates consideration [31,33]. Much of the conversation is about achieving multiple benefits by making better use of existing or proposed infrastructure. The Drainage and Wastewater line of business has expanded their scope of responsibility to at least partly include flooding, in-water habitat, landslide prevention, floodplain opportunities, fish passage, groundwater investigation, and other climate-related impacts, though water reuse is still largely missing from the plan [33,34].

## Design Framework

The theoretical framework for this thesis comes from the integration of WSUD philosophies, influences of grassroots activism, and practical tools for change. The first article examines how water sensitive cities regard water and categorical transformations institutions can strive for to become more water sensitive. This perspective provides a robust framework for the institutional level but does not address citizen capacity for change or actionable tools.

As human impacts on the environment are better understood, water management and impact mitigation strategies are becoming increasingly complex. Institutions often cannot fully control these impacts and are beginning to recognize that individuals and groups outside the water management sector can amplify climate mitigation and adaptation initiatives through their behaviors. To be successful, institutional perspectives on water should parallel social values and actions, which are explored via grassroots action and socio-regulatory tool sets.

## Design Framework: The Water Sensitive City

Brown, Keath, and Wong, prominent scholars in WSUD at Monash University, provide useful insight on the transformation to a Water Sensitive City using three institutional categories and six typologies to describe a city's relationship with water. These categories provide a dynamic framework that incorporates the changing goals of water management over time [22].

The three institutional development categories Brown et al. argue for a movement toward water sensitivity, where more conscious use of water and changing relationships with water occur through:

- **Cognitive change** - the dominant pattern of thinking and skill sets
- **Normative change** - values and areas of focus
- **Regulative change** - laws, systems, rules, and organizations

These types of change recognize the technological, temporal, and cultural nature of transitions. Institutional changes have a self-reinforcing nature, accelerating when different systems support each other. The Brown et al. water city typologies are "The Water Supply City," "The Sewered City," "The Drained City," "The Waterways City," "The Water Cycle City," and "The Water Sensitive City." These purposefully broad categories are a continuum that can be applied to different cities. Cities can move between categories through progression, regression, or skipping through phases [22].

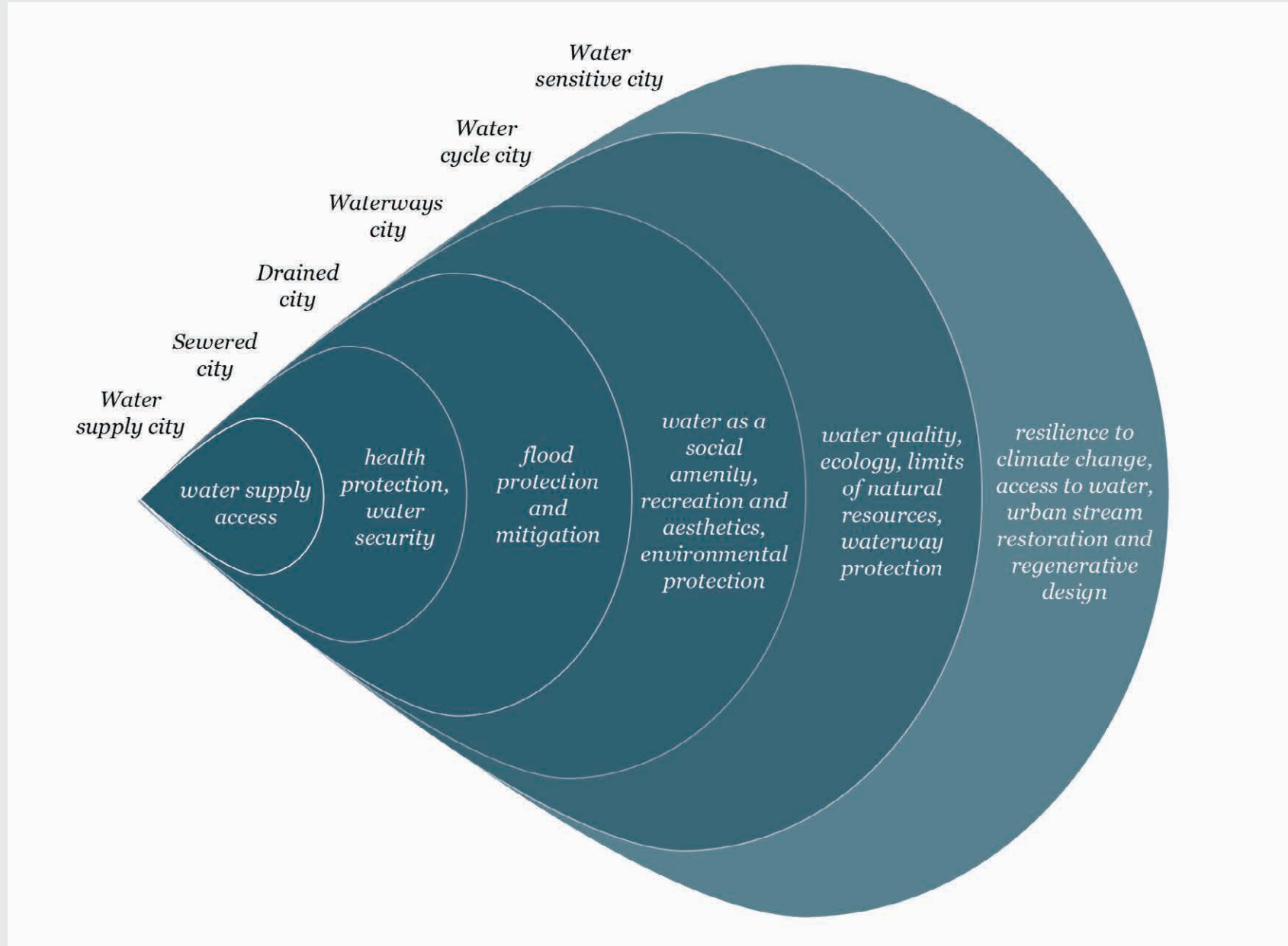


Figure 4.12: City typologies and social values on the Water Supply City to the Water Sensitive City (36)

The **Water Supply City** has a centralized water supply. It is an early form of the social contract between governments and residents and is underlied by the belief that an endless supply of clean water should be available to all. Typically, accessibility of water is achieved by subsidizing water provision through taxation or other public financing option to allow equal access between the rich and poor [22]. Seattle achieved its status as a Water Supply City in 1901 when the first Cedar River water arrived in the city. The belief that limitless water should be available to all still persists in Seattle.

**The Sewered City** is considered as much of a technological advance as it is a public health advance. Sewage systems initially discharged untreated sewage away from cities into water bodies to prevent contamination of drinking water supplies and is credited with a major factor in the decline of waterborne illness. Sewers can be separated or combined and provide varying levels of treatment throughout the world. They are generally operated and subsidized in a similar fashion to centralized water supplies and may operate as the same or separate organizations [22]. Sewers have long been used in Seattle where open trench sewers predate the centralized water system. Centralized subsurface sewers were installed through the end of the nineteenth and first several decades of the twentieth century in Seattle [35].

**The Drained City** better controls flooding from runoff and stormwater by directing it to the nearest water body. Typically runoff in areas with separated sewer systems does not receive treatment before being discharged. In Australia, the Drained City evolved with the popularity of suburban development, followed by regular flooding due to changing hydrological conditions [22]. Seattle's separated sewers still

fulfill this role in the local context. Few combined sewer systems exist in Australia, and it can be argued that events like combined sewer overflows are included in either the Drained City or the Sewered City.

**The Waterways City** is the first classification to give value to environmental services and environmental health. Categorized in Australia as part of the 1960s-1970s environmental movement, the Waterways City is concerned with point and nonpoint source pollution controls, industrial pollution, effluent damage, including widespread stormwater quality management. The authors do not feel that anywhere in Australia has achieved this state yet. Though stormwater controls are partially institutionalized, responsibility for funding, maintenance, and accountability are still debated [22]. Similarly, Seattle encourages stormwater management, but lacks widespread application of stormwater infrastructure that maintains environmental health.

**The Water Cycle City** recognizes limits on ecosystems exploitation; natural water bodies can provide finite amounts of water and handle limited amounts of effluent and other pollutants. This state focuses on using fit-for-purpose water sources that are most appropriate for each use while diversifying and sharing (perceived or actual) risk among water users. While much of Australia uses the fit-for-purpose method to some extent, the role of centralized versus decentralized infrastructure is still widely debated. Many adaptations at higher levels of government approved centralized technologies while lower levels of government and associated organizations challenged the centralized approach to water infrastructure and successfully implemented decentralized technologies [22]. While Seattle allows rainwater to be used for irrigation,

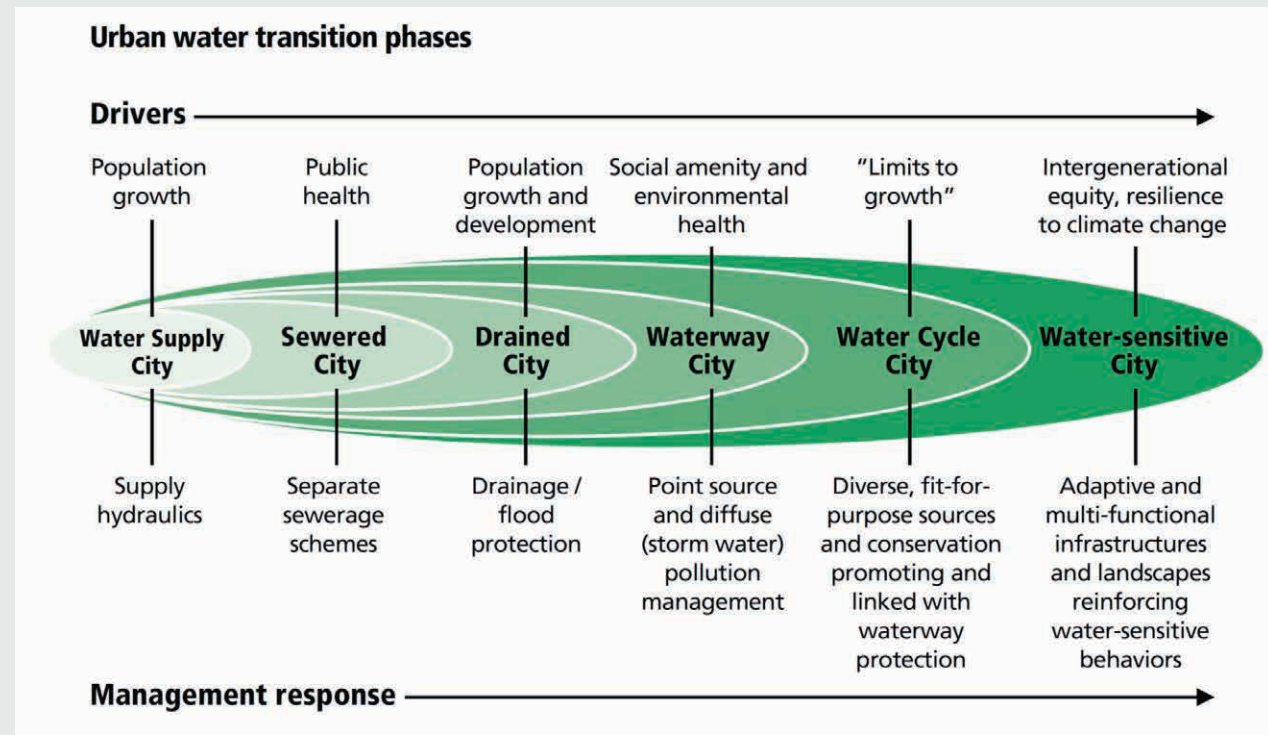


Figure 4.13: Drivers and management responses for progression from a Water Supply City to a Water Sensitive City (37)

using other nonpotable sources is still difficult or illegal due to regulative and normative barriers.

**The Water Sensitive City** is the ideal sustainable city. It balances access to water and sanitation with environmental health and restoration while building resiliency. There are no current examples of a Water Sensitive City today. If they existed, sustainable water management would involve innovation in water management techniques among water sector professionals. These techniques and technologies would give the Water Sensitive City a diverse set of flexible tools to respond to any water challenges [22].

These broad categorizations of institutional change and city typologies show a progression in top-down management of water using WSUD. However, water reuse schemes require sharing risk and responsibility with stakeholders. Stakeholder

buy-in means that water users need to obtain information on water reuse, accept responsibility for mitigating any associated risks, and commit to reusing water. Public perceptions and values can be shifted from the top down, but for water management to be truly integrated and responsibilities shared, citizens should also contribute and drive value shifts [22].

The failure to share responsibility can lead to underutilization of nonpotable water sources as well as discontent and disenfranchisement. This lack of shared knowledge and responsibility is part of what led to discontent over Melbourne's desalination plant and can be mitigated through greater public involvement in water management processes [22].

## Design Framework: Public Involvement & Social Learning

As institutions that manage water attempt to bridge regulatory, administrative, and cultural barriers in order to integrate, they participate in social learning which results in normative change in instructional attitudes about water management. These changes must also occur among non-water management individuals within the public to facilitate adoption of new water source, practices, beliefs, and behaviors. This collective social learning prepares people to share water management risks and responsibilities across scales and helps bridge administrative and cultural boundaries. Changes in resource management will struggle to fully coalesce unless cultural values coevolve with institutional ethos. Acknowledging that public participation in water management is important requires movement away from top-down, technical water management strategies of the last few centuries.

Water management techniques have and continue to focus primarily on large-scale, engineered solutions to ensure quality and quantity of available water in a way that overlooks the importance of societal and individual behaviors. In the 2007 article "The importance of social learning and culture for sustainable water management," European scholars Pahl-Wostl et al. discuss the importance of social learning for successful integrated water management [36].

Growing challenges in climate adaptation and resource allocation cannot be fully met using traditional water infrastructure. Two major aspects of resource allocation have often been excluded from traditional top-down water resource management: public understanding of the limitations of available water resources and customizable water services

that allow individuals to meet their own water needs and preferences. Pahl-Wostl et al. call attention to social learning as a way to encourage greater public participation in water management which must also be recognized and validated by institutions as a productive water management strategy [36].

Pahl-Wostl et al. define social learning in a water management context as, "the growing capacity of social entities to perform common tasks related with a river basin," (p. 485) that can change social structure through reciprocal interaction [36]. Community members who are learning together adapt their perspectives and behaviors and influence other community members to do likewise. Increased awareness surrounding water management helps community members engage with utilities while also having the potential to catalyze grassroots action.

## **Design Framework: Public Involvement & Grassroots Environmental Change**

Grassroots initiatives provide a way to engage in social learning and influence change at the neighborhood and local levels. According to the 2009 article "Building capacity for low-carbon communities: the role of grassroots initiatives," communities can affect environmental change by changing social values and behaviors toward sustainability [37]. Low-carbon case studies are relevant to water resource management in the sphere of sustainability and climate change adaptation. Carbon reduction strategies and initiatives are well-recognized and relatively more developed than water strategies because of their direct influence on climate change and rising temperatures. Carbon reduction efforts make useful examples in exploring the impacts community-based efforts may have as concerns over water are realized. The grassroots low-carbon projects Middlemiss and Parrish explore capitalize on grassroots initiatives for sustainable action within communities [37].

Middlemiss and Parrish outline multiple sustainable initiatives run by grassroots volunteers that proactively address environmental challenges with limited or no institutional recognition. Despite the authors' initial view that community groups were not in a position to affect changes, they had to conclude that the communities they examined were able to leverage their resources and position to expand their capacities for change. These communities can frame initiatives and draw on community resources in ways institutions cannot, which guides social learning and values within the community [37].

Potential challenges in community-led sustainability initiatives can arise from assuming community willingness

to adopt institutional perspectives and disproportionate advantage being given to wealthier, whiter communities. Viewing community groups as an extension of government and policy is problematic in its hierarchical view of power structures. Community activists often exist in opposition to injustices perpetuated by both social norms and institutions.

Activist groups also have differing levels of power in their ability to engage in social learning and to affect change within their group or community. Communities with more resources generally have better capacity to address ecological impacts in personal, infrastructural (including governmental), organizational (within the community), and cultural ability to accept and enable changes [37]. While communities with capacity for change in all of these categories may be better positioned to affect community projects and local policy change, any capacities for sustainable action can translate to community impact.

## Design Framework: Tools for Change

The rapid advance of the effects of climate change and the need for widespread adoption of sustainable water management practices necessitates change among institutions and the public. Grassroots and institutional proponents both need tools that allow flexibility and agency in water management. To allow for differentiation in how goals are met, Schuster provides a gradient of socio-political tools that range from full citizen control to government mandate [38]. While these tools are situated in a historical preservation lens in Schuster's 1997 book [38], they create practical categories for moving toward integrated water management and water sensitive cities.

To explore how change can come to pass across organizations and scales, Schuster outlines the following types of change [38]:

1. Community ownership and operation
2. Education and information
3. Incentives and disincentives
4. Property and development rights
5. Regulation and policy

These tools provide a more tangible way forward than trying to actualize Brown et al.'s cognitive, normative, and regulative change. While Brown et al.'s groups are useful for categorizing overall attitudes toward water, Schuster's categories give tools for groups and individuals to take action [22,38].

To move Seattle toward becoming a Water Sensitive City, changes are needed in the way people and the utility think about, use, and value water. These changes begin with the understanding that climate change will change our precipitation, ecology, and hydrology and that the water supply will change as a result. To achieve integrated water management, both water users and water providers have to evolve in their perspectives and habits.

As values shift, expected and common practices in water management should follow. However, the complexity of regulation, institutional structures, and uneven value shifts can act as barriers to improving practices. Grassroots movements and community action encourage lawmakers and utilities to provide safe, legal options for water reuse. Rather than causing contention, these two actors may be able to collaborate on pilot projects while exchanging information necessary to better cooperate in the future.

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**PART 2**

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**DESIGNING SYSTEMS IN  
GEORGETOWN**

# CHAPTER 5

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# GEORGETOWN

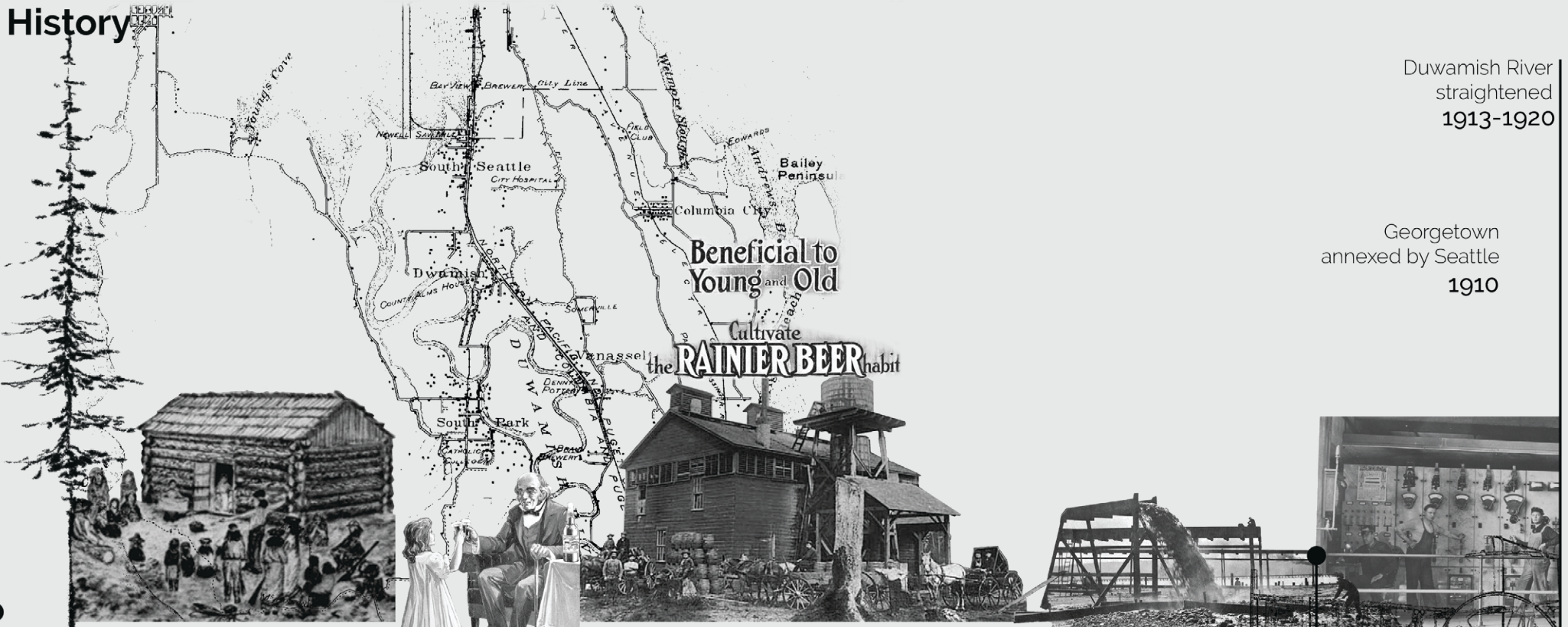
History

Demographics

Land Use

Existing Conditions

# History



Duwamish River  
straightened  
1913-1920

Georgetown  
annexed by Seattle  
1910

Earliest archaeological  
record of Dkhw'Duw'Absh  
(Duwamish) people  
c. 600 A.D.

Georgetown  
developed into a  
redlight district  
1870s

Last Ice Age created  
the Duwamish River  
Valley  
c. 10,000 B.C.E.

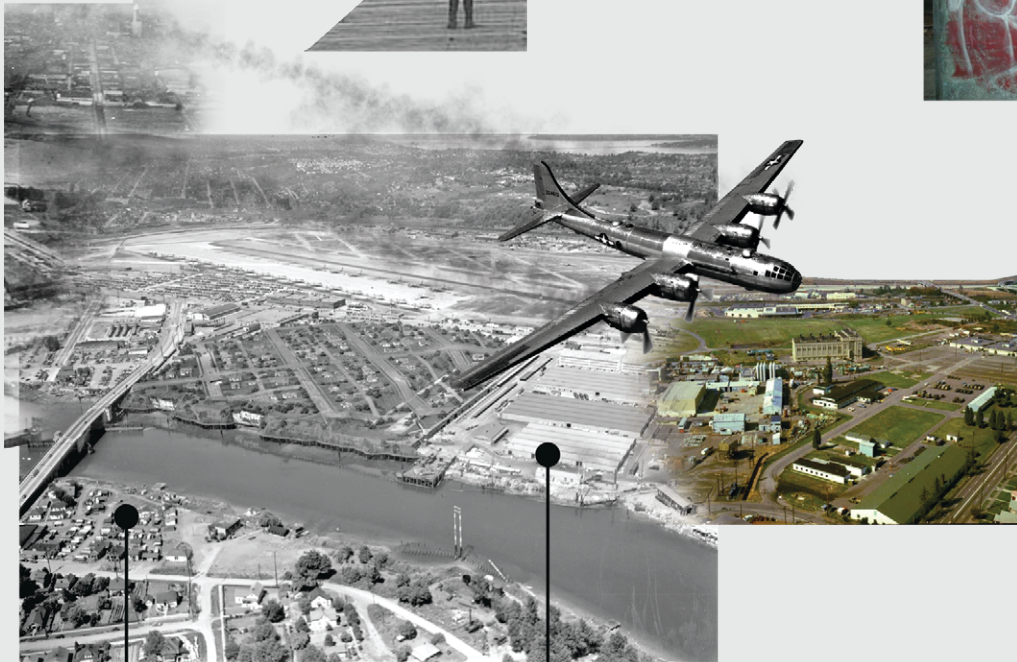
Settlers Collins, Holgate, Maple,  
and Van Asselt arrived & made  
contact with the Qelquaquby  
(Proud People) of the  
Duwamish  
1851

Bayview Brewing (later  
Rainier) established  
&  
Last Duwamish longhouses  
burnt by colonists  
1893



Georgetown electric  
steam plant opened  
1906

Figure 5.1: A timeline of the history of Georgetown (original images 38-49)



Boeing established  
**1916**

Boeing plant is famously disguised during WWII  
**1940s**

Call to phase out residential zoning to make room for more industry  
**1956**

Georgetown arts community emerged  
**1997**

Superfund cleanup began  
**2013**

Lower Duwamish Waterway declared a Superfund site  
**2001**

Resilient Georgetown pilot explores climate adaptation  
**2030s**

# GEORGETOWN

Georgetown is a neighborhood that has been identified by multiple groups within and outside the city for lacking infrastructure and resources for its residents and workforce. Many projects and opportunities have been identified by private and city groups, but little of the desired change has been delivered.



Figure 5.2: Duwamish River in 1926 (46)

## History

The land that is now the neighborhood of Georgetown is a result of the last ice age c. 10,000 B.C.E. when glaciers carved out the Duwamish River Valley [1]. The first archaeological record of the Dkhw'Duw'Absh (Duwamish) people is from 600 A.D., who had developed a rich culture (then known as Qelqaquby or Proud People) by the time European colonists arrived in 185. This encounter ultimately led to conflicts and native people were pushed onto reservations. The last of the traditional longhouses, which were central to tribal culture, were burnt in 1893 and were not rebuilt on the banks of the Duwamish until 2009 [2,3]. Once the native peoples were forced out, settlers built homes, bars, farms, and other businesses that produced goods for trade.

The colonial settlement, named for developer and resident Julius Horton's son George [4], soon grew into a town. Georgetown was then on the outskirts of quickly growing Seattle soon became a red-light district boasting many distilleries (including Rainier Brewing est. 1893), brothels, and gambling establishments [4]. It ultimately voted to be annexed by the City of Seattle in 1910 in exchange for a sewer system [1]. The City of Seattle set about straightening the Duwamish River in 1913 and industrializing the neighborhood and gradually disincentivizing residential housing to try to make more space for industry [1,3]. One of these companies was Boeing, established 1916, which expanded substantially during the interwar period. The Boeing Plant just south of Georgetown was famously disguised as a suburban neighborhood during World War II to hide it from Japanese bombers. Following the war, industries and city officials called for phasing out residential zoning entirely [1]. Some of the effects can be seen in the

extremely wide streets in the neighborhood that were all built for freight. While many residents left, a small community remains in Georgetown, despite its lack of infrastructure (including schools, sidewalks, grocery stores, crosswalks, and so on). Georgetown began to be seen as a haven for the arts beginning in the 1990s and its strange and beautiful exhibits remain one of the primary draws to the neighborhood even as gentrification sets in [1].

Beginning with the passage of the Clean Water Act in 1972, the extensive pollution in the Duwamish River began to come to light. Efforts by the City of Seattle, the Port of Seattle, and others to clean up the waterway began in the 1970s and continue to present day despite ongoing pollution from industry. The Lower Duwamish Waterway was finally declared a Superfund site in 2001, though cleanup did not begin until 2013 [1]. The cleanup primarily focuses on traditional types of remediation (capping, topsoil removal, and dredging). The EPA works with local industries to clean up their sites. Unfortunately, little recognition has been given to direct industrial wastewater discharges to the river, groundwater contamination, and the mobile nature of polluted sediments.

Since sediments and groundwater are both mobile contaminants, they move pollutants around the neighborhood and continue to have negative impacts. Groundwater contamination is expensive, difficult, and invasive to clean up. Failing to clean up contamination in groundwater allows it to migrate from the initial pollution source where pollutants bind to soils as they move, though complete groundwater remediation is not always possible [5]. Eventually the groundwater would reach the Duwamish River and the Puget Sound where it would enter surface water through hyporheic exchange [6]. Polluted groundwater can

also cause problems for self-supplied water users (who use wells to draw water for industrial purposes) [7]. Contaminated water may be toxic or not of sufficient quality for use.

Contaminated groundwater can also cause problems for GSI. Generally, water infiltration in areas with already contaminated soil and/or groundwater is not recommended because it can mobilize contaminants. Contaminants can move from toxic soils on the surface to groundwater and spread to surrounding areas [8,9], like the plume of contamination leftover from a toxic landfill site and several other industrial sources [10].

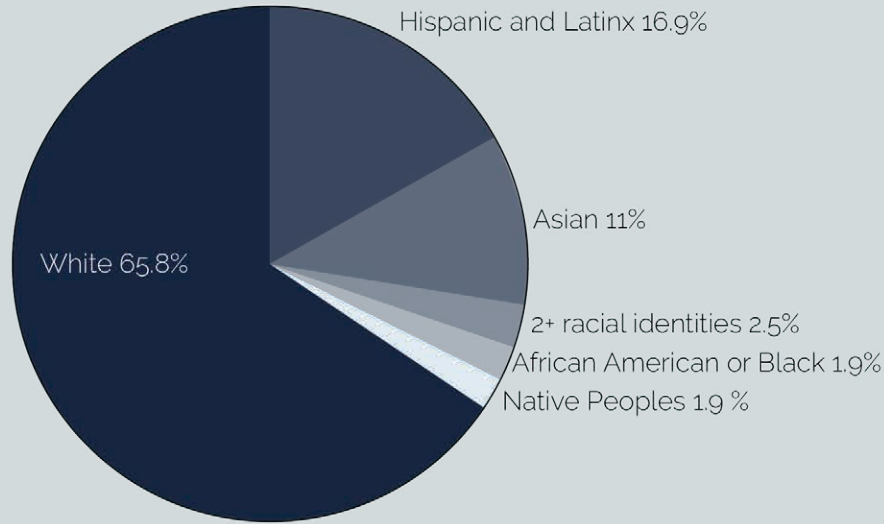


Figure 5.3: Duwamish River in 2007 (50)

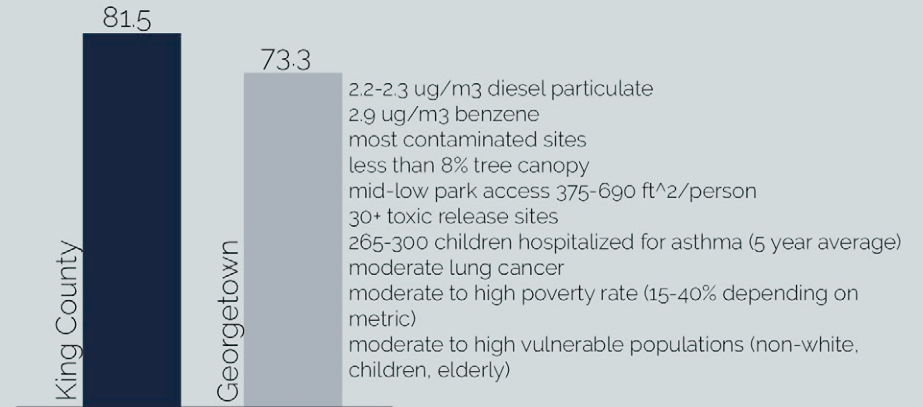
# Georgetown Demographics

Figure 5.4: Demographics in Georgetown (data from 51)

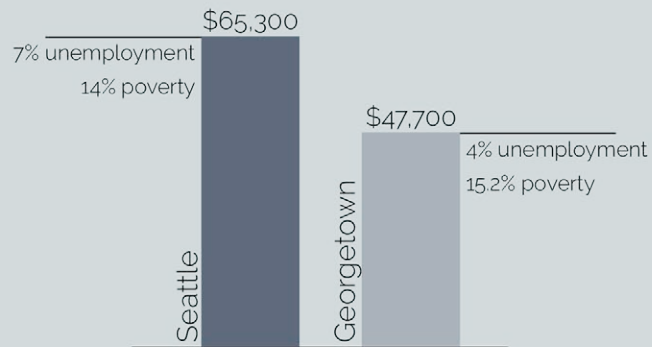
## Race



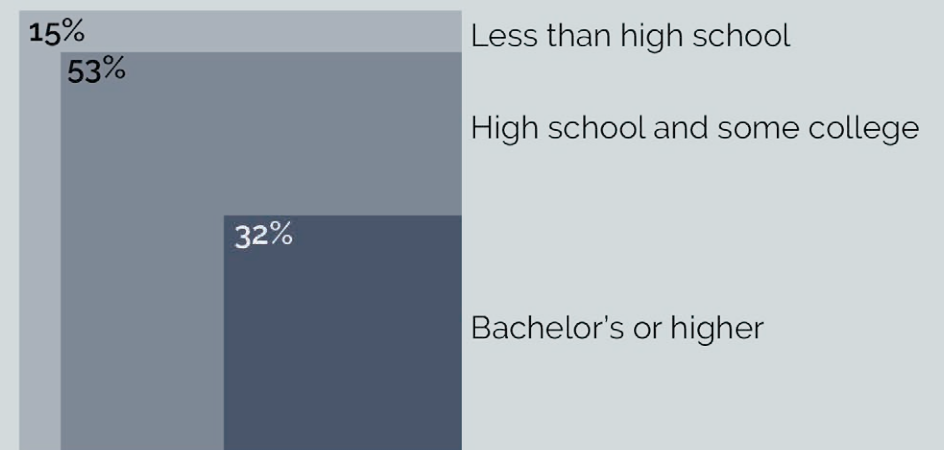
## Life Expectancy



## Income



## Education



## Demographics

Georgetown is a predominately industrialized area on the Lower Duwamish Waterway boasting 30,000 workers during the day but only 1,500 residents [11]. It suffers from the legacy of a century of industrialization with many unaddressed or under addressed brownfield sites in addition to the Lower Duwamish Superfund site. The contamination still in Georgetown has led to poorer health for Georgetown residents which is present along racial lines, socioeconomic class, and educational attainment [12].

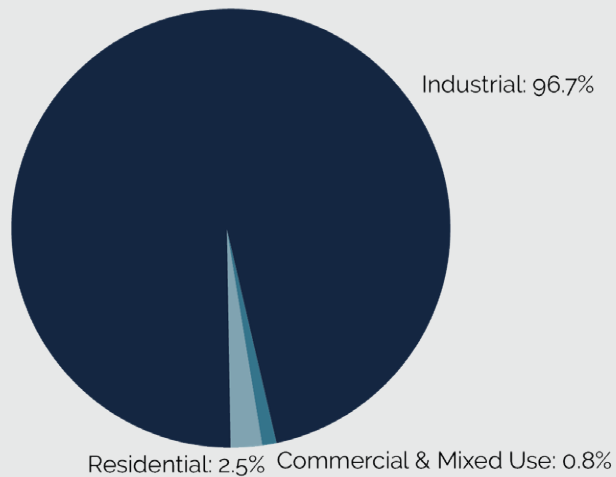
This toxic environment has led to a gap in life expectancy. Georgetown residents live an average of 73.3 years, nearly a decade less than the average King County resident (81.5) largely attributed to the effects of pollution and limited resources. While much of the neighborhood is white, significant minority concentrations are present with 14+ languages spoken at home. Income and educational attainment lag behind the rest of Seattle in Georgetown. Residents are more likely to live on lower incomes and are generally less educated than residents of other parts of King County [6].

The industrial nature of the neighborhood has made it unattractive to many. Now it is one of the last affordable places to live in Seattle and is home to many vulnerable populations (including immigrants, non-white communities, children, elderly, etc.). These populations are most susceptible to health effects of living with industry. Contamination continues to perpetuate gaps in health, wealth, education, and overall well being.

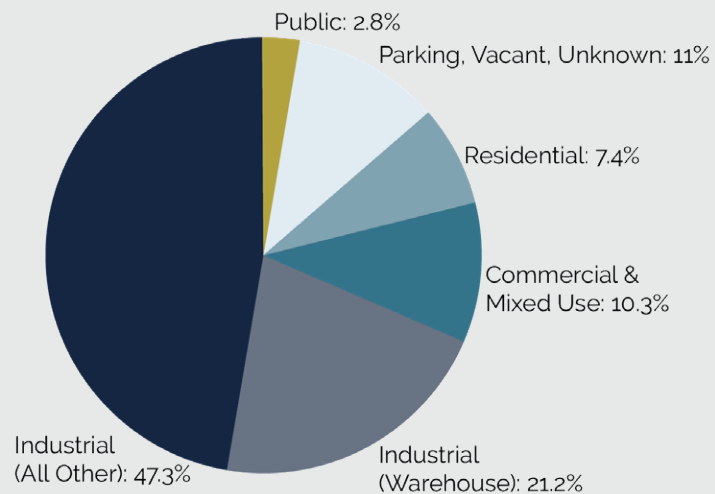


**Figure 5.5:** Land use patterns in Georgetown. There are a large number of single family residential parcels compared to other uses but they take up a small proportion of land area (data from 52)

0 .075 .15 .3 .45 .6 Miles

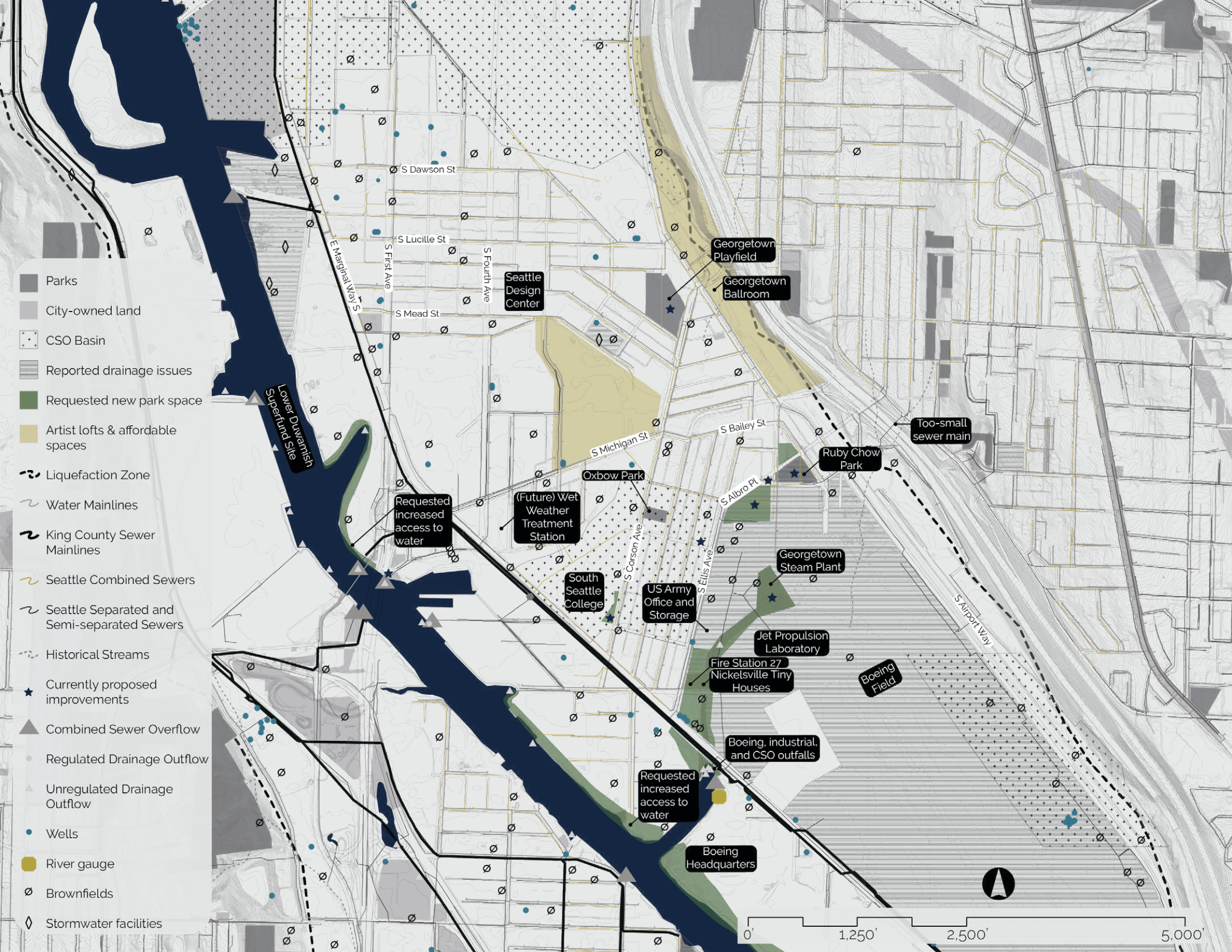


**Figure 5.6:** (Top) water use by sector and (bottom) land use by percentage area (data from 3, 9, 25, 52-58)



## Land Use

Much of the land area in Georgetown is used by warehouses and industries (68.5%). Many of these parcels are underutilized, unutilized, or are used for storage. The remaining active uses (residential, mixed use, and commercial) make up only 20.5% of land use, though parcels tend to be more clustered and numerous. The remaining 11% is land documented to be vacant or is used for parking. The substantial amount of underutilized land both on private property and in the right of way present significant opportunities to provide services that have been lacking from the neighborhood including sidewalks, trees, parks, designated parking, bicycle infrastructure, transit stops, and so on. Many of these suggestions have significant overlap or potential synergies with water and utility infrastructure [13].



- Parks
- City-owned land
- CSO Basin
- Reported drainage issues
- Requested new park space
- Artist lofts & affordable spaces
- Liquefaction Zone
- Water Mainlines
- King County Sewer Mainlines
- Seattle Combined Sewers
- Seattle Separated and Semi-separated Sewers
- Historical Streams
- Currently proposed improvements
- Combined Sewer Overflow
- Regulated Drainage Outflow
- Unregulated Drainage Outflow
- Wells
- River gauge
- Brownfields
- Stormwater facilities

0' 1,250' 2,500' 5,000'



## Existing Conditions

In addition, to the extensive problems with pollution, Georgetown faces additional challenges. It is one of the lowest-lying neighborhoods in Seattle with little slope, with most areas having a slope under 1%. This results in incomplete drainage and constant standing water. Multiple properties struggle with flooding, which interferes with the operation of several industrial sites including those on the property of Boeing Field. Many residential parcels, even new development, are at a lower elevation than the adjacent streets, causing vulnerability to flooding in the future.

In addition to its vulnerability to flooding, Georgetown joined Seattle to get access to the Seattle Sewer System [4]. Because of its ad hoc industrial development, the neighborhood boasts separated, semi-separated, and

combined sewer systems in different areas, making wastewater planning challenging and complicated. Multiple combined sewer outfalls sit on the Lower Duwamish as the King County mainline to West Point Treatment Plant runs along East Marginal Way South. As the city continues to try to meet the 2025 EPA mandate (2030 for King County outfalls) that combined sewers may overflow an average of once per year [14], keeping stormwater and runoff out of the combined system is extremely important. That mandate does not include the separated and semi-separated discharges that also present substantial opportunities for improvements.

The sewer systems in Georgetown share capacity with Beacon Hill sewers and as both neighborhoods grow, existing capacity will not be sufficient. Of particular concern is the combined sewer main that runs down South Albion Place between Beacon Hill and Georgetown. In 2015, the Urban Land Institute recommended that the main be replaced, a parallel relief sewer added, or GSI included to relieve the capacity problem [15]. This particular main provides an opportunity to relieve pressure on the sewer, which is a significant contributor to combined sewer overflows on the Duwamish River.

In Georgetown there are many pollutants present in stormwater, soil, and the Duwamish River. Industrial stormwater throughout the world is the most polluted of urban runoff and presents challenges for green infrastructure, waterways that often receive it without treatment, and for traditional water treatment techniques. These pollutants can pose issues for the establishment and long-term survival of many plant species. Plant selection and breeding will be important in the long-term performance and success for any green infrastructure in Georgetown. Strategies that should be considered include

**Figure 5.7:** (opposite) Georgetown analysis map focused on community-identified improvements, water infrastructure, and existing conditions (data from 4, 52, 59-63)

Site Photos



Figure 5.8: "The future is water under the bridge and over"



Figure 5.9: standing water on the railroad tracks near the Duwamish River



Figure 5.10: standing water with visible contamination



Figure 5.11: visible heavy metals in puddles

Site Photos



Figure 5.12: poor drainage conditions



Figure 5.13: underutilized parking at the US Army offices at Boeing Field



Figure 5.14: current sidewalk and roadway conditions along S Airport Way



Figure 5.15: existing conditions at proposed electroflocculation site adjacent to Boeing Field

selection for evergreen plants, hardiness, phytoremediative capability, endophytic communities, and climate resilience to drought and flooding.

The Lower Duwamish Waterway was designated as a Superfund site in 2001 by the US EPA. The area has been widely studied and several different phases for remediation have been introduced. The final cleanup eligible for federal funds was released by the EPA in 2013 [16], though additional efforts are being undertaken by the Washington State Department of Ecology and the Lower Duwamish Waterway Group. These smaller scale remediation efforts focus on controlling point and nonpoint sources of pollution, innovative remediation methods, and cleaning up individual brownfield sites along the waterway [17,18]. Though extensive, these cleanup efforts do not fully address the contamination in Georgetown. Specific areas of concern include groundwater, air quality, and ongoing contamination [19].

In addition to major concerns over water and pollution, Georgetown is also vulnerable to earthquakes. Almost the entirety of Georgetown sits in a floodplain, and despite infill, subsurface sediments are extremely vulnerable to liquefaction during an earthquake. The 700+ page study from 2018 between the US EPA and SPU has been widely criticized for its lack of transparency [20–22]. As a result of public pressure, more of the study has been released, though specific information about Georgetown is still classified [23]. Georgetown lies in the Seattle Fault zone and given the age of much of its water infrastructure, can be assumed to have moderate to high vulnerability and is likely to need retrofits. These retrofits could present an opportunity to lay additional pipes at decreased cost.

Georgetown lacks green space and even street trees in most of the neighborhood due to its industrial history. Among the myriad of benefits vegetation provides, plants are a helpful tool for stormwater quantity and quality, air quality, and soil and groundwater remediation. This would be particularly helpful in mitigating the poor air quality thought to be one of the primary causes of asthma and lower life expectancy [12]. Sources disagree on the amount of canopy cover in Georgetown. Estimates range from 2.4% [24] to 11.6% [25] to 23% [1], but any of these falls far short of the goal of the City of Seattle's 30% canopy by 2037. Open space is currently 40% lower than the 2037 goal [1]. The lack of access to green space and trees provide an opportunity to add amenities while managing water.

Overall, Georgetown is challenged by the needs of an industrial area with quality of life for its residents. The layers of contamination that have built up over years of industrial production make water quality in the Duwamish River and in stormwater runoff a pervasive problem across the neighborhood. There are many opportunities to test the effectiveness of both gray and green infrastructure while providing a cleaner environment.

In addition to cleaning up residual contamination, better stormwater management illuminates an opportunity for water reuse, especially in industrial settings. The vast majority of water use in Georgetown is by industry. Some of these needs can be met by harvesting rainwater and minimizing stormwater runoff, which leads to other water reuse opportunities depending on the quality required.

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# CHAPTER 6

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## SMALL SCALE

Rainwater: Indoor Reuse

Rainwater: Industrial Reuse

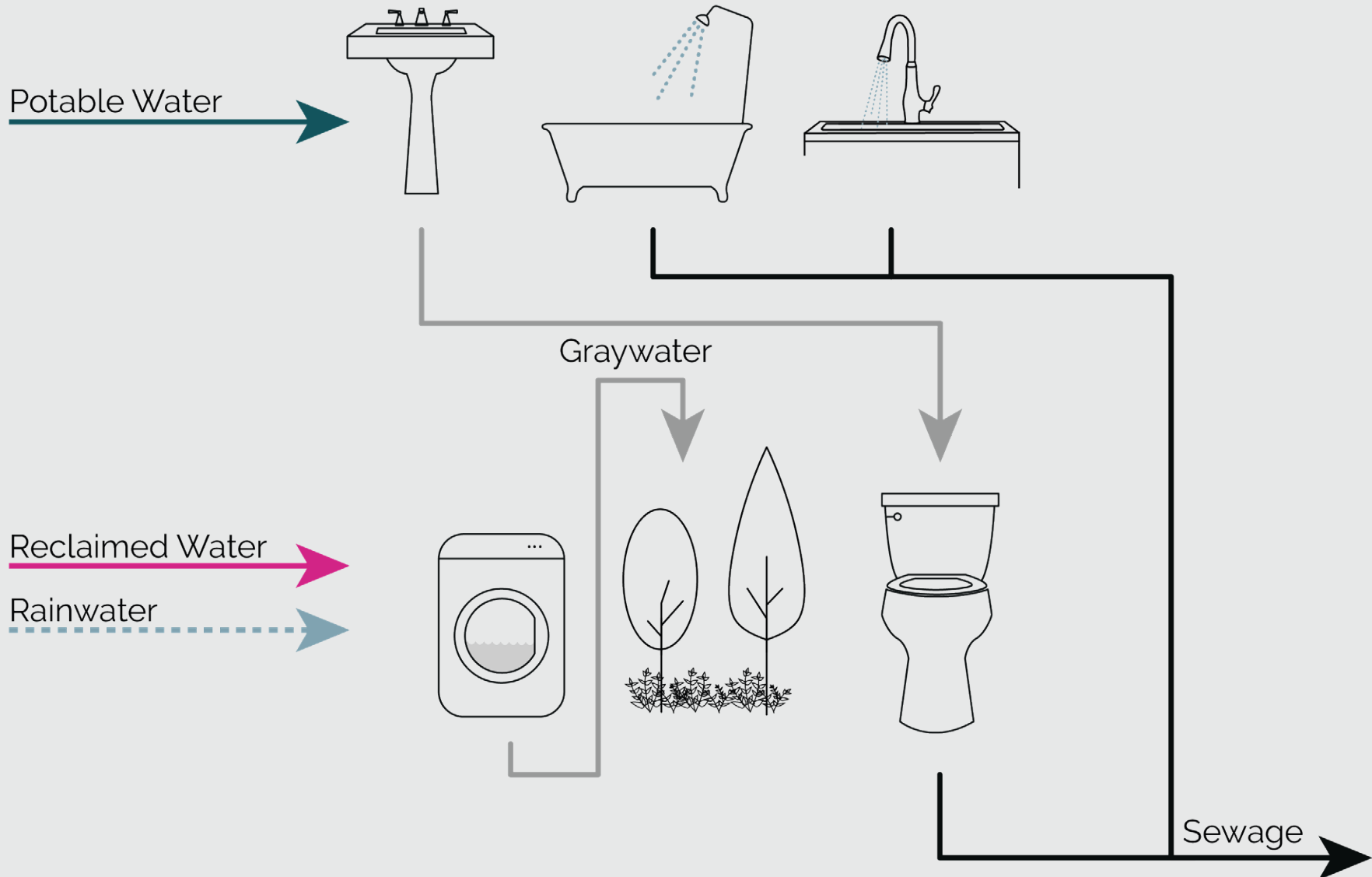
Graywater: Laundry to Landscape

Graywater: Toilets

Barriers & Opportunities for Reclaimed Water

# Water Type Inputs & Outputs of Household Use

**Figure 6.1:** proposed household water uses. Potable water should be used for cooking, drinking, showers, and sinks while nonpotable sources should be used for irrigation, laundry, and toilet flushing.



Current regulations make implementing water reuse most attainable at the small scale, classified here as a single land parcel. There are different levels of attainability for different land use types. Overall, interventions at the single-parcel scale have the fewest legal hurdles and the most tangible benefits for water customers, providing accessible ways to save on utilities and to act sustainably.

Graywater and rainwater reuse have good approachability for individuals to become familiar with possible issues and adjust to the idea of multiple sources of water. The costs for installation can be minimal in many cases or can be built into new construction easily. Graywater and rainwater reuse are also dependent on the amount of water an individual has space to store and require regular maintenance to ensure sanitation and safety.

Rainwater reuse is currently the most widely employed method of water reuse through SPU's RainWise program. Rainwise reimburses homeowners for part or all of the costs of rain barrels, rain gardens, infiltration areas, and such with a focus on outdoor irrigation and on-site stormwater management. So far the program has focused primarily on single-family homes in specific CSO basins amounting to less than a quarter of overall land area (of which Georgetown is not part of) as a way to lower the strain on existing sewer infrastructure [1]. The program is financially constrained but has been expanding as funding becomes available and successes prove its worth. Indoor rainwater reuse and industrial rainwater harvesting are two opportunities to expand RainWise or create similar programs.

However, rainwater alone generally cannot meet all non-potable water needs. Graywater reuse and reclaimed water present additional opportunities for decreasing potable water

## SMALL SCALE

use. Graywater reuse can be applied at the household level with graywater toilets, as well as households and businesses with both laundry and irrigated landscaping. Reclaimed water has potential for non-potable water use, especially for large users.



Figure 6.2: proposed household water harvesting and graywater systems

### Rainwater: Indoor Reuse

For much of the year, enough rain falls in the Seattle area that most gardens do not require additional irrigation. If rainwater is being used wholly for summer irrigation, large quantities of rain are still flowing into the sewer system and surrounding water bodies because storage capacity is always limited. In the months where Seattle receives the most rain (October to March), it is generally not being used [2]. However, if this water were put to use during the fall, winter, and spring for toilet flushing and doing laundry, it would significantly reduce the amount of potable water households need.

If rainwater were used for all toilet flushing and laundry from October to April, most households would still receive more rain than they could use (600-2,000 gallons) even when harvesting from a small area (500 square feet). Storing rainwater in May would provide significant reserve for outdoor summer use, which would continue through August or September.

Water use in September would likely be part outdoor, part indoor use.

Indoor rainwater reuse is legal in the State of Washington and in King County. It seems to be encouraged by the state [3,4], but not by the county. Permits for rainwater reuse are not available online and must be completed in-person, at one of two county offices, during business hours, and may require additional documentation that cannot be accessed in advance [5-7][4,17]. There are no additional lists available of commonly required permits, the associated costs, maintenance instructions, or resources provided. The general public is not likely to know indoor reuse is an option or may become frustrated by the implementation process. This lack of transparency leads many people to install their own rainwater systems without permits or inspections and other ad hoc interventions such as disconnecting sink drains.

The biggest risk with any non-potable system is cross contamination with the potable supply. This risk could easily



**Figure 6.3:** Common 50 gallon rain barrel that can be set up for indoor or outdoor rainwater use (64)

be mitigated if the city, county, or state provided some basic guides on how to approach water reuse indoors. Additionally, plumbers and other contractors who install water reuse systems have to pay to take a course to legally install any kind of water reuse systems in King County [6]. While this is meant to ensure public health standards, it also deters contractors from offering this service because it requires additional study and cost. Greater transparency of risks, permits, costs, and other requirements would help determined water reusers install systems safely. Additional support through RainWise or other GSI programs could encourage more people to adopt rainwater reuse.

If homeowners can get the current permit, it allows one rainwater line to connect to three faucets, which can generally cover toilets and perhaps the washing machine depending on the size of house and household. Depending on the efficiency of appliances, household size, and rainwater storage capacity,

rainwater alone can replace between a quarter and half of indoor water use, just by using rainwater for toilet flushing and laundry [6].

With rainwater harvesting, indoor or outdoor, Seattle Public Utilities offers credits for installing on-site stormwater management. Installation credit can come through RainWise grants if the property is in an eligible basin, or from King County's Green Stormwater Infrastructure Mini Grant [8]. Residents, businesses, and public properties can also get a percentage of their utility bill credited (up to 50%) from the Seattle Department of Construction and Inspections (SDCI) [9–11]. Discount percentage depends on parcel size, building size, impervious surface area, combined or uncombined sewer district, size of pipes, and type of intervention installed (i.e. rainwater harvesting, or deep infiltration gets a higher discount rate than peak flow management).

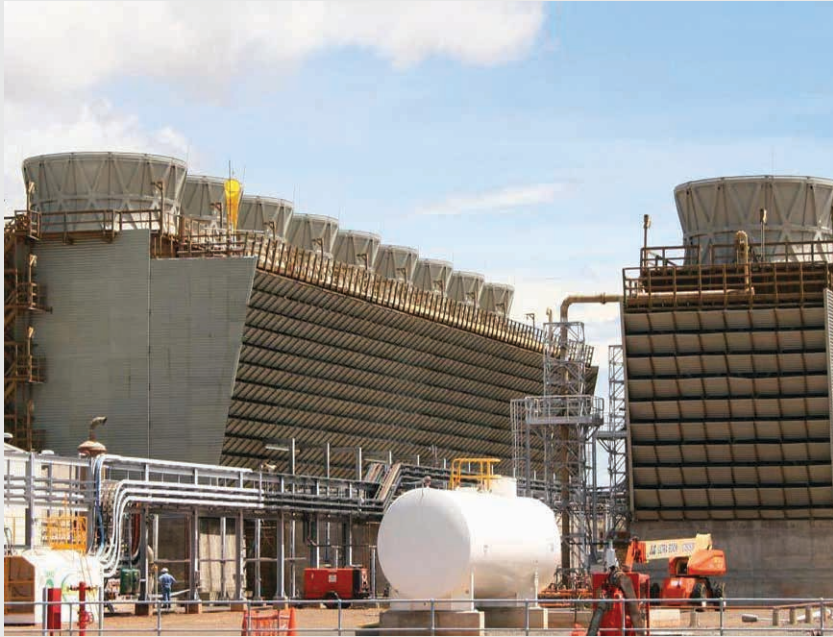


Figure 6.4: Industrial cooling towers do not need to use potable water (65)



Figure 6.5: Industrial power washing can generally use nonpotable water (66)

### Rainwater: Industrial Reuse

While many industrial applications use large amounts of water, larger storage and purification tools for rainwater exist, but have not been widely adopted or encouraged. For large industrial water users, cisterns of 500+ gallons are often buried on the property. These large cisterns are compatible with different filtration, chlorination, UV treatment, etc. functions depending on the necessary water quality required for the end use. Depending on individual site requirements, this water could be used for manufacturing, dust control, washing, cooling, toilet flushing, water treatment, irrigation, or other production. The accompanying utility credits are appealing for industrial businesses who typically pay a very high water bill and could benefit from commercial rainwater harvesting credits and utility discounts from the SDCI.

Industrial reuse is especially applicable in neighborhoods like Georgetown, where the majority of land and water use are industrial. While feasible and with great potential, retrofitting existing infrastructure may be prohibitively expensive depending on existing setup. On parcels where the existing system is simple and consistent quality is not needed, rainwater reuse could be an excellent option.

## Graywater: Laundry to Landscape

Graywater can be used to water gardens through subsurface irrigation systems drawn from laundry, sinks, or showers. Traditional surface irrigation systems are also possible, but less preferable because, though health risks are low, there is more potential for human contact with graywater. Laundry graywater tends to be of more consistent quality, already has a pump as part of the system, is easier and cheaper to install, and offers a more contained system, which is why it is chosen for irrigation.

A major concern with laundry to landscape irrigation is toxicity to plants from detergent. However, many liquid, biodegradable detergents that avoid salts, bleach, boron, and ingredients that significantly change pH are compatible with laundry to landscape systems. Many such products are now easily available and should not pose a barrier to installation of a graywater irrigation system.

Laundry to landscape is also appealing because it has potential to be used any place that does laundry and is not limited to residential use the way other systems may be. Laundromats or other businesses with irrigable features have potential to partly or fully reuse laundry water through irrigation depending on the amount of water surrounding plants require. Additionally, regular irrigation with graywater can potentially help offset the 30% of water that is used outside in Seattle.

Legality of graywater irrigation systems is unclear. Chapter 246-274 WAC, Graywater reuse for subsurface irrigation was passed in 2010 and permits the use of graywater for subsurface irrigation [12]. In contrast, WAC 51-56-1500, which contains amendments to the state plumbing

and building codes from 2015 expressly prohibit the reuse of graywater for irrigation [13].



Figure 6.6: graywater toilet designed by Za Bor Architects (67)

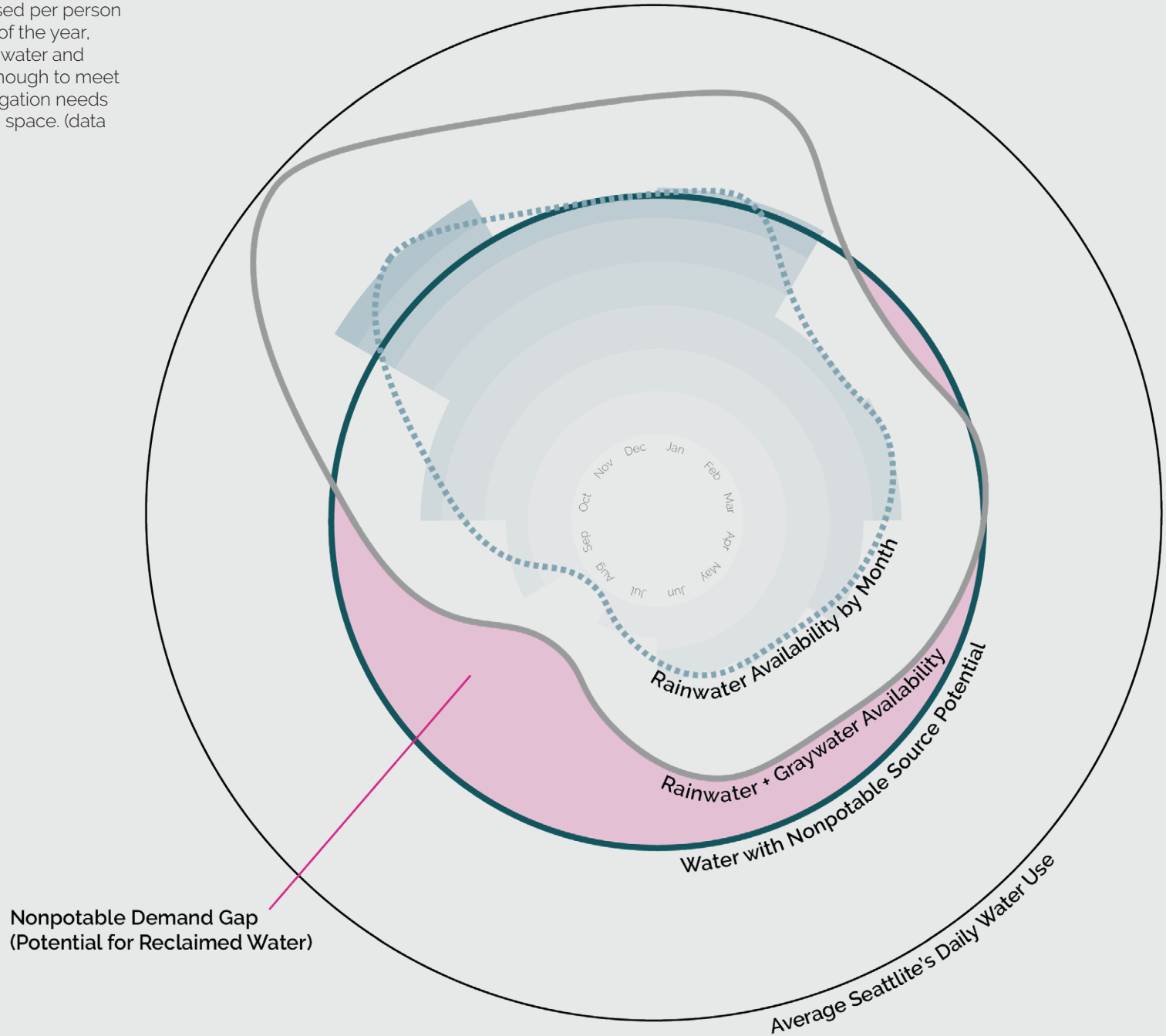


Figure 6.7: graywater toilet (68)

## Graywater: Toilets

A standard toilet in Japan is a combination of bathroom sink and toilet where the sink water is used to flush the toilet. The toilet reservoir empties every 24 hours to prevent bacterial growth and are available in a variety of designs. This precedent shows that graywater toilets do not have to pose a public health risk. Additional basic filtration could be easily added through coarse filters or other built-in/ low maintenance sanitation measures like drip chlorination. Graywater toilets should be used in residential settings where people are using their own water, which will be easier to accept and provide much lower health risks than in public settings. They could be included in the Saving Water Partnership with funds installation of low-flow toilets among other efficient appliances to help offset costs on both the consumer and water management sides.

**Figure 6.8:** Potential for nonpotable water use in Seattle homes assuming 96 gallons of water used per person per day. During most of the year, a combination of graywater and rainwater would be enough to meet toilet, laundry, and irrigation needs with sufficient storage space. (data from 3, 9, 18, 69)



## Barriers & Opportunities for Water Reuse

Graywater is currently subject to many restrictions in Washington. It must meet or exceed class A reclaimed water standards through traditional wastewater treatment processes (oxidation, coagulation, filtration, and disinfection), making it technically legal but nearly impossible to use because of the large area and energy footprint required to use activated sludge treatment [12].

King County makes no official statements on graywater reuse but refers to a 2009 document from the Washington State Department of Health that prohibits graywater from being used in toilets, or indeed for anything other than subsurface irrigation, and also limits storage capacity and duration to 24 hours. The document concedes that graywater from sinks and showers harbor the fewest pathogens, but does not allow reuse [14].

The primary reason for the prohibition of graywater reuse is the public health precaution, because human contact with toilet water may occur. However, the number of pathogens already in a residential toilet bowl<sup>1</sup> far exceeds those in bathroom graywater (158 -  $3.2 \times 10^3$  total coliforms) samples

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1 Few measurements of bacteria in toilet bowls exist because most studies focus on toilet seats. Most studies referring to toilet bowls cite a 1975 study [15] where toilet bowls were cleaned before sampling ( $\log_{10} \times 8.25$  total bacteria). Other estimates were 34,000 total bacteria in a toilet bowl in a study done by a company specializing in antibacterial coatings on products [16], and an estimate of 3.2 million bacteria per cubic inch by WebMD [17].

by orders of magnitude.<sup>2</sup> It is also of note that this resolution cites a single study from 1996. Significant advancements have since been made in compact, affordable, basic treatment and represent potential for improving graywater quality [18]. There are many possible precautions that can be used with graywater to alleviate public health risks: elimination or limitation of human contact and treatment before use [19].

While some believe graywater constitutes a health risk, others feel the risk is no greater than exposure to normal toilet water since graywater use in homes has never been traced to illness or public health impacts [19]. Another concern is likely litigation and legal consequences because the use of nonpotable water places more responsibility on the user. Providing clean water to toilets diminishes risk of fault should illness occur as a result of already-existing viruses and bacteria.

While much of Georgetown is now industrial, its status as an urban village under the Seattle 2035 plan anticipates residential growth [20]. Future developments provide an opportunity to build with water reuse systems included. Industrial sites may opt for graywater irrigation from laundry or sinks for future green infrastructure.

For much of the year, a combination of rainwater and graywater would be sufficient to replace potable water use for toilets, irrigation, and washing machines. In the drier summer months, when streamflows are lowest and demand is highest, there is not enough rain to fully offset these uses, even with a

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2 The coliforms cited by King County Public Health (158 -  $3.2 \times 10^3$  total coliforms for sinks and showers) does not match the number in the referenced article (MPN 500 -  $2.4 \times 10^7$  average total coliforms for all bathroom sources)

large storage capacity. This gap represents an opportunity to use reclaimed water in and outside of homes, especially during the summer months.

Reclaimed water has particular potential for large water users that do not have stringent water quality requirements (surpassing Class A reclaimed water). Some uses of interest are industrial, toilet flushing, laundry, water features, irrigation, dust control, fire suppression, power washing, and other cleaning.

Much of Georgetown and surrounding neighborhoods are industrial, providing a relatively compact area where reclaimed water could be distributed for nonpotable use.

## End Notes

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# CHAPTER 7

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## RIGHT OF WAY

# **TEMPORARY INTERVENTIONS // LEAPFROGGING THE RIGHT OF WAY**

Directing Water

Soaking up Water

Reclaiming Carleton Avenue

Future Development

# **PERMANENT INTERVENTIONS**

Swales

Swale Islands

River Street Water Quality Channel

## TEMPORARY INTERVENTIONS








The right of way (ROW) scale section is separated into two different pieces, a temporary and permanent stage. The temporary stage is associated with the Leapfrog the Right of Way grant from the Bullitt Center with UW faculty, students, private practitioners, city representatives, and members of the Georgetown neighborhood.

Leapfrog the ROW's Georgetown project is to build a pedestrian and bicycle path (hereafter referred to as the "Connector") that connects the major neighborhood hubs in a way that current infrastructure does not. Temporary installations along the Connector can provide wayfinding and include art that sheds light on a variety of community issues, showcases artist work, labels areas, celebrates history, advertises local businesses, and so on.

My part in this project has been suggesting water quality fixes that could be deployed along the Connector to help manage existing drainage problems. Unusually for Seattle, nearly all of the neighborhood is under 2% slope, which is not conducive to efficient drainage. The roads in Georgetown are industrial, cracked, and heavily used. Uneven roads in combination with a lack of sidewalks makes drainage even more difficult. To better tailor solutions to specific areas during the temporary phase, areas of >1% are identified with pink arrows. Interventions focus along the proposed Connector and include strategies for directing water, soaking up water, and reclaiming the street for multi-modal use. These suggestions are still hypothetical though there is potential for implementation as the project progresses this summer.

**Figure 7.1:** proposed temporary water quality interventions around the Georgetown Connector (data from 4, 52, 54, 59, 61, 70)

**Community-Identified Sites for Interventions**

-  Historical Duwamish River Channel
-  (Proposed) Artist lofts & affordable spaces
-  Slope est. >1% (directional)
-  Rain garden & swale opportunity sites
-  Community-proposed Connector route
-  Proposed Connector inter-ties
-  Brownfields

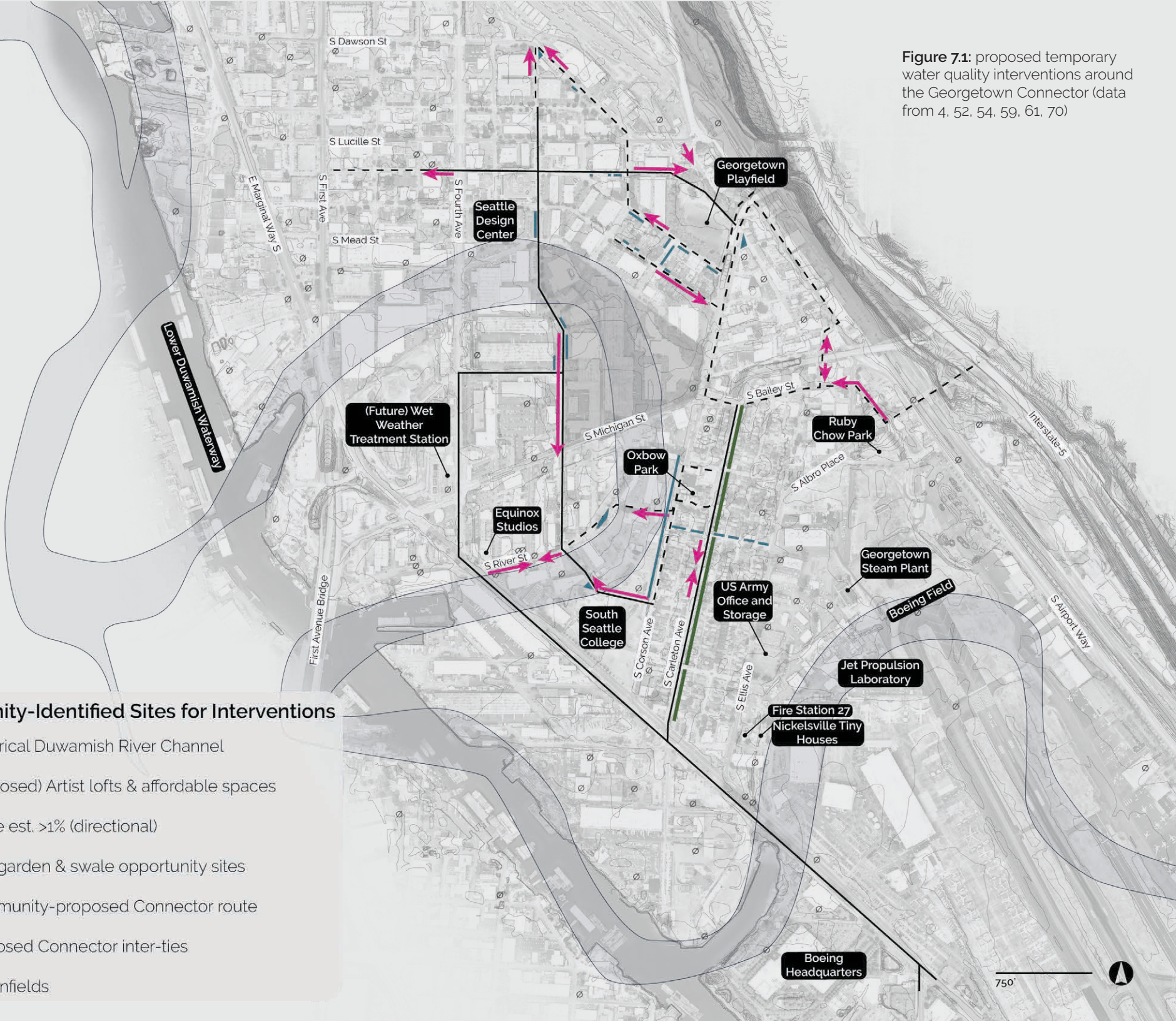




Figure 7.2: example of a brick runnel directing water into planting space (71)



Figure 7.3: example of a how a lay flat hose can be manipulated to direct water (72)

## Directing Water

Temporary interventions for directing water still require some materials and modifications to the existing streetscape to make water drain. One approach is to use DIY runnels that can be formed using reclaimed materials including bricks, small concrete pieces, large-diameter gravel (too large to slip into the sewer grates), reclaimed materials, or other available materials. These runnels can direct water along the connector to existing drains where there is sufficient slope.

Many of the existing downspouts pour out directly onto streets and sidewalks and struggle to flow to existing sewers, exacerbating flooding and adding to standing water. These downspouts can be attached to flexible hose pipes (also called a lay flat hose) and directed into sewers, runnels, and plantings. Flexible hoses offer a good alternative to traditional tube pipes because they can be driven over, manipulated into a variety of shapes, and do not freeze.

Finally, in places where curbs already exist, curb cuts can help water move into permeable, planted areas. While DIY curb cuts are not sanctioned by the city, they offer a fast and cheap alternative to relaying entire curbs. Many people in Georgetown have experience with hand tools and heavy machinery and could make the necessary cuts with concrete saws or hole saws. These holes will allow runoff to be filtered by planting strips and the water to infiltrate into existing permeable spaces. As time and funding allows, planting strips should be redesigned with proper grading, soil, and plantings to accommodate industrial runoff.



**Figure 7.4:** creating a curb cut in an existing curb using a hole saw (73)



**Figure 7.5:** a purposefully poured curb cut that directs water into plantings (74)

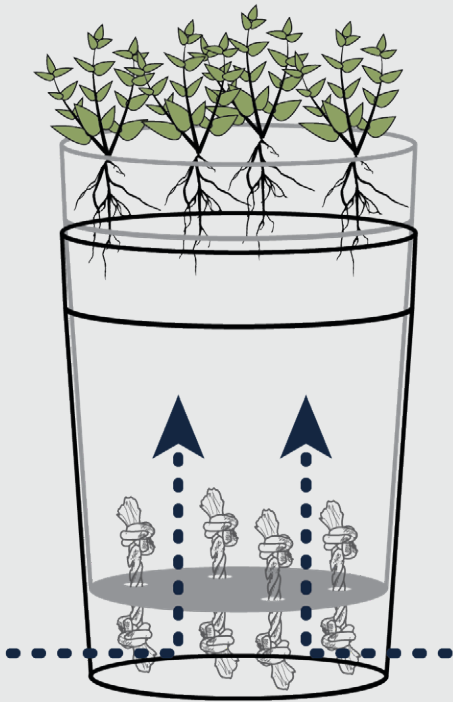


Figure 7.6: an example water-wicking planter using five gallon buckets



Figure 7.7: a self-watering planter made from styrofoam cooler. The design could be made into a wicking planter by removing the bottom on the outside container (75)



**Figure 7.8:** sketch of wicking planters as parking space dividers in standing water

## Soaking up Water

In areas where standing water is a reoccurring problem, permeable, water-wicking planters can be constructed. Based on self-water planter designs, wicking planters can be constructed simply using wood, metal, barrels, insulating foam, or other available stacking containers. The inner container has holes drilled in the bottom and a spongy material threaded through. Made long enough to touch the ground when the inner planter is stacked inside the second, bottomless planter, the spongy wicking medium soaks up water for the plants roots inside.

These wicking planters can take the place of some of the concrete dividers currently being used to deter RV parking.

Wicking planters can stand on their own, provide wayfinding, or be indicators of pocket parks and public amenities.



Figure 7.9: a small parklet with seating and plantings in Auckland, New Zealand (76)



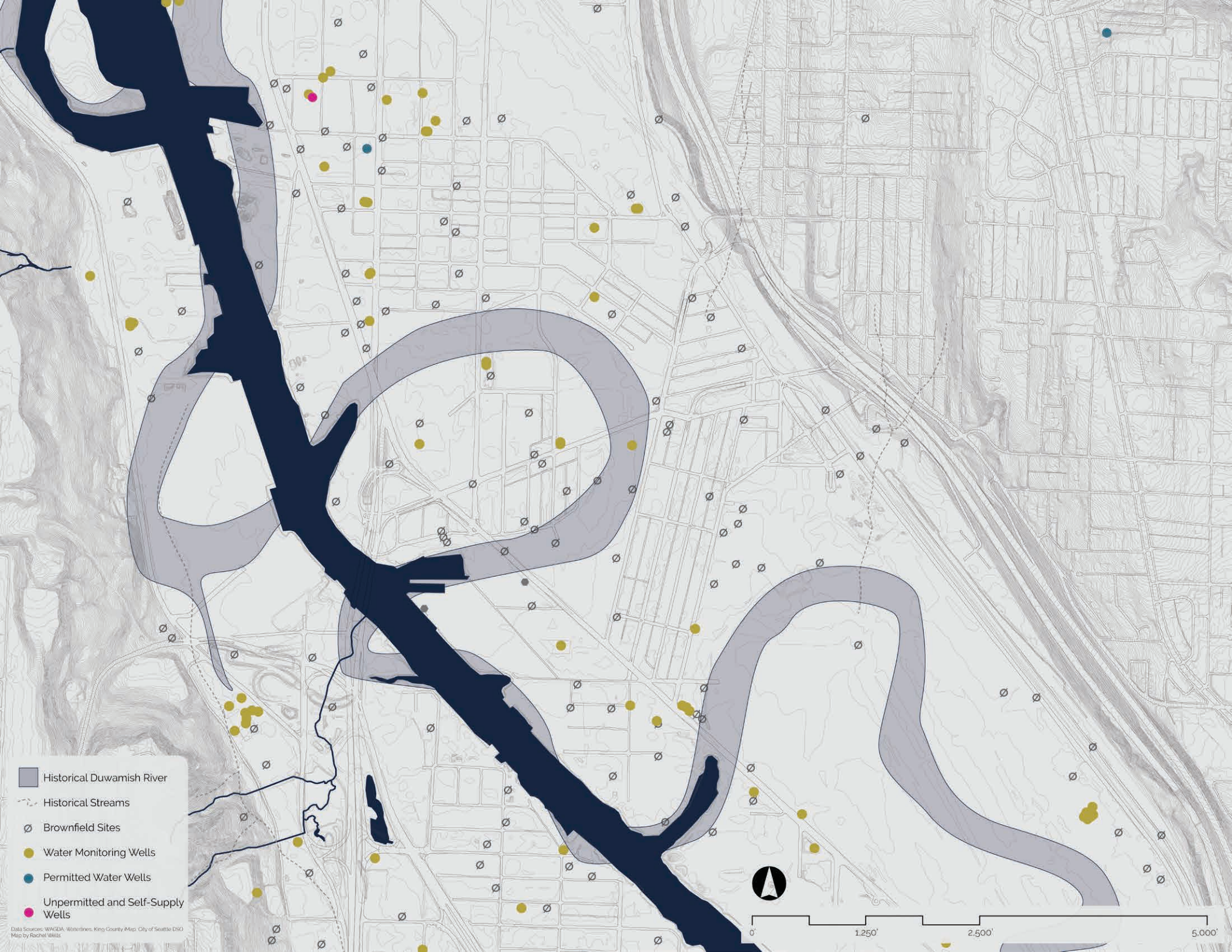
Figure 7.10 roadway pocket park with paint, planters, and seating in Seattle (77):

## Reclaiming Carleton Avenue

Carleton Avenue was once supposed to be a freeway entrance for I-5. It is now a residential street approximately 100 feet wide, but with small planting strips. The south side of the street (does not have overhead power lines) can be taken over and occupied using combinations of street paint, pavement removal, planters, bicycles, seating, and so on. These interventions will act as traffic calming cues and can eventually be made permanent.

Reclaiming Carleton Avenue would likely be through the City's Festival Streets Program or guerrilla activity. It would require the homeowners on the street to agree that they wanted to occupy the street, as well as extensive coordination on timing and types of interventions.





- Historical Duwamish River
- Historical Streams
- Brownfield Sites
- Water Monitoring Wells
- Permitted Water Wells
- Unpermitted and Self-Supply Wells

Data Sources: WAGDA, Waterlines, King County IMap, City of Seattle DBO  
Map by Rachel Wells



## Future Development

In addition to coordinating the above water quality interventions, outreach events, and creating the Connector, there are several additional projects developing in conjunction with the Leapfrogging the Right of Way project. One concern about the Lower Duwamish Superfund cleanup is the minimal groundwater remediation planned in Georgetown. To call attention to this oversight, water wells will be identified. These flags or markers might share additional information like the suspected types of pollutants or the companies responsible for contamination, if known.

**Figure 7.11:** water monitoring wells, self-supply wells, and permitted wells in Georgetown for further investigation on groundwater contamination (data from 4, 59, 70, 78)

# PERMANENT INTERVENTIONS

In the second phase of right of way interventions, a series of swales and swale-like interventions can permanently receive and treat stormwater, which will help mitigate much of the flooding the neighborhood is already experiencing. These suggestions make permanent and formalize the DIY interventions from Phase 1 but fulfill the same and similar functions.

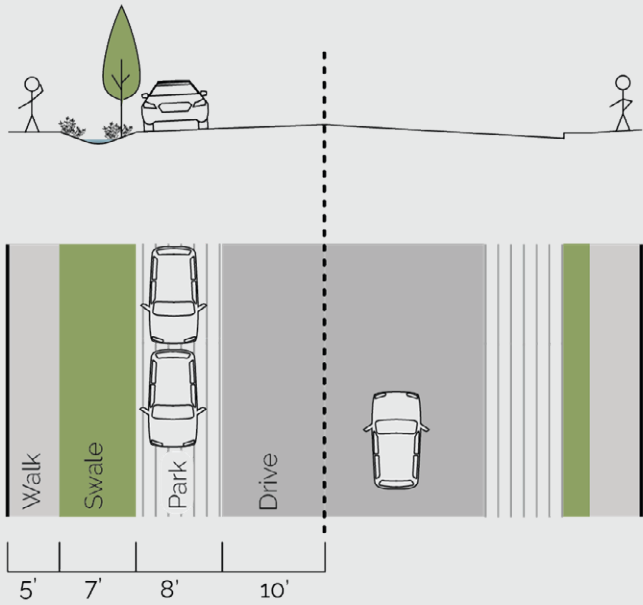


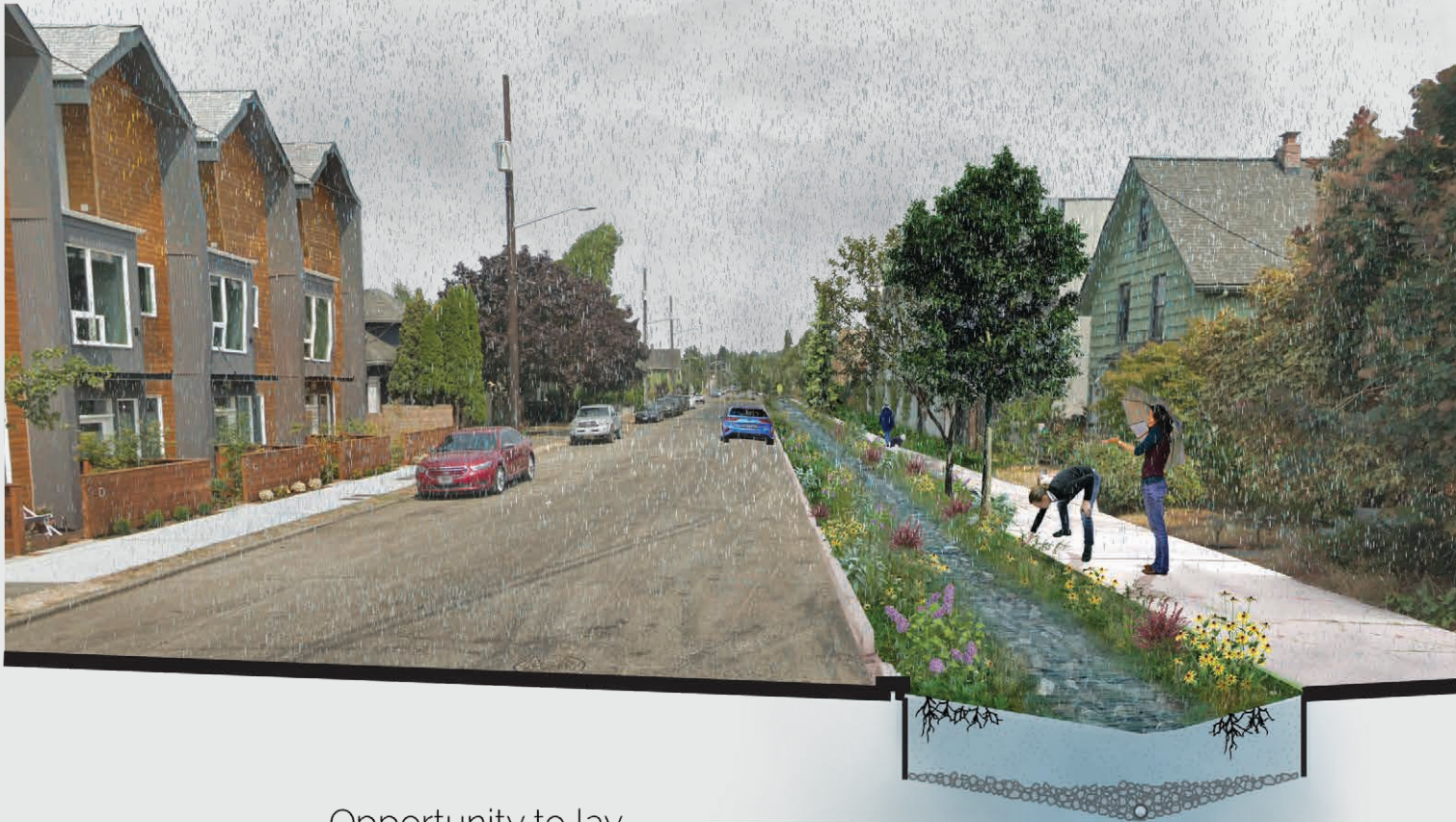
Figure 7.12: before (right) and after (left) proposed swale additions on Carleton Avenue

## Swales

Untreated runoff is the largest non-point source of pollution affecting the Duwamish River. Using LID and GSI practices that the City of Seattle has endorsed, runoff can be captured and treated. While water discharges from green infrastructure will not be potable standard, careful design and maintenance allows swales to filter many harmful elements, sediments, and pathogens to keep them out of waterways.

In residential and commercial areas, treatment trains akin to several existing Seattle projects (Swale on Yale, SEA Streets, etc.) can be used to clean runoff. Infiltrating or non infiltrating swale types depend on the location of each swale and where its outlet lies. In-ground swales can improve water quality by creating a treatment train that plugs into stormwater sewers, wetlands, tide flats, the river, or other receiving spaces.

Along Carleton Avenue, the street the neighborhood is proposing occupying, a series of swales and pedestrian infrastructure can replace the temporary chalk, planters, and seats. Having a series of long swales offers more treatment for runoff but also provides an environment for raingardens, community requested trees, traffic calming, and a lush setting for neighborhood activities. Depending on community interest, space, success, and cost, these swales can be constructed in other parts of the neighborhood for compounding benefits.

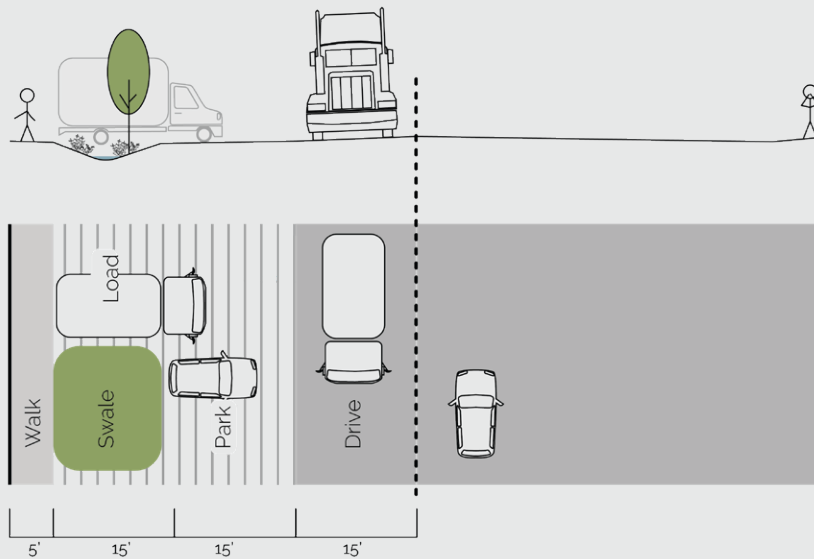


Opportunity to lay reclaimed water pipes

**Figure 7.13:** Section B. section along Carleton Avenue with proposed infiltrating swale during a rain event.

Figure 7.14: Section C. industrial swale islands with infiltrating (left) and noninfiltrating (right) examples





**Figure 7.15:** before (right) and after (left) the proposed swale islands assuming a 100' wide street

## Swale Islands

In the more industrial areas, a continuous swale is not a viable option. While there is much underutilized space, the right of way serves multiple purposes that must be preserved for commercial uses. Many companies use right of way parking to park extra vehicles, load, unload, and park. As a result, most of the industrial parts of Georgetown do not have sidewalks. Adding "swale islands" provides a buffer between pedestrians and heavy machinery while collecting stormwater while preserving industrial uses.

The swale islands have several deployable options for different conditions. Though they are intended to connect via a subsurface pipe underdrain, they can be stand-alone percolating swales if need be. Depending on the levels of

pollution in the soil, swales can be infiltrating or non infiltrating. For both infiltrating and non-infiltrating swale islands, underdrains should connect and overflow into the larger green infrastructure proposed in the neighborhood scale section.

Installing infrastructure in the right of way also provides an opportunity to lay reclaimed water pipes and perform any needed seismic upgrades to the existing systems. The feasibility and cost savings of laying pipe and performing maintenance at the same time depends on the level of access and method of laying or replacing pipe.



**Figure 7.16:** The Markey Machinery swales during planting by volunteers in 2010. Photo by Carl Simon (79)

### Case Study: Markey Machinery

Much of industrial Georgetown lacked any stormwater infrastructure in the form of pipes or swales until Markey Machinery built stormwater swales. The company was struggling with flooding, potholes in the gravel/mud road surface, and safety issues. They had originally proposed paving their lot but were required to mitigate the additional runoff that would come from a paved property. The proposed solution was over \$1 million of subsurface pipe connecting into the existing King County drainage system [1].

Markey Machinery partnered with several neighborhood groups, including the Duwamish River Cleanup Coalition and the Georgetown Riverview Restoration Project, as well as SDOT to construct several percolating industrial stormwater swales on their property. The project ran into many institutional

barriers since it is the first of its kind but was ultimately completed in 2010 for just under \$100,000. The swales provide basic treatment before the stormwater enters the Duwamish River that stormwater pipes would not have provided. Many of those involved with the Markey swales project would like to replicate them in other industrial areas because of their performance, cost, and aesthetic appeal, but the arduous approval process makes that challenging [1,2].



**Figure 7.17:** the Thornton Creek Water Quality Channel shortly after planting in 2009 (80)

### Case Study: Thornton Creek Water Quality Channel

All of Georgetown lies in the Duwamish River floodplain where the historical hydrology has been modified to the extent that stormwater struggles to find its way to the creek. Thornton Creek in North Seattle has suffered from inflows of polluted runoff, flooding, and declines in salmon populations among the consequences of hydromodification. The Thornton Creek Water Quality Channel was constructed to partially restore water quality and habitat while managing flooding in the Northgate Urban Village in north Seattle [3].

The water quality channel is located near the headwaters of the South Fork of Thornton Creek. It treats polluted runoff from nearly 700 acres of surrounding land area [3]. The design was based on traditional bioswales but modified to allow constant water and to mimic the original natural creek (which was buried in pipes during construction of Northgate

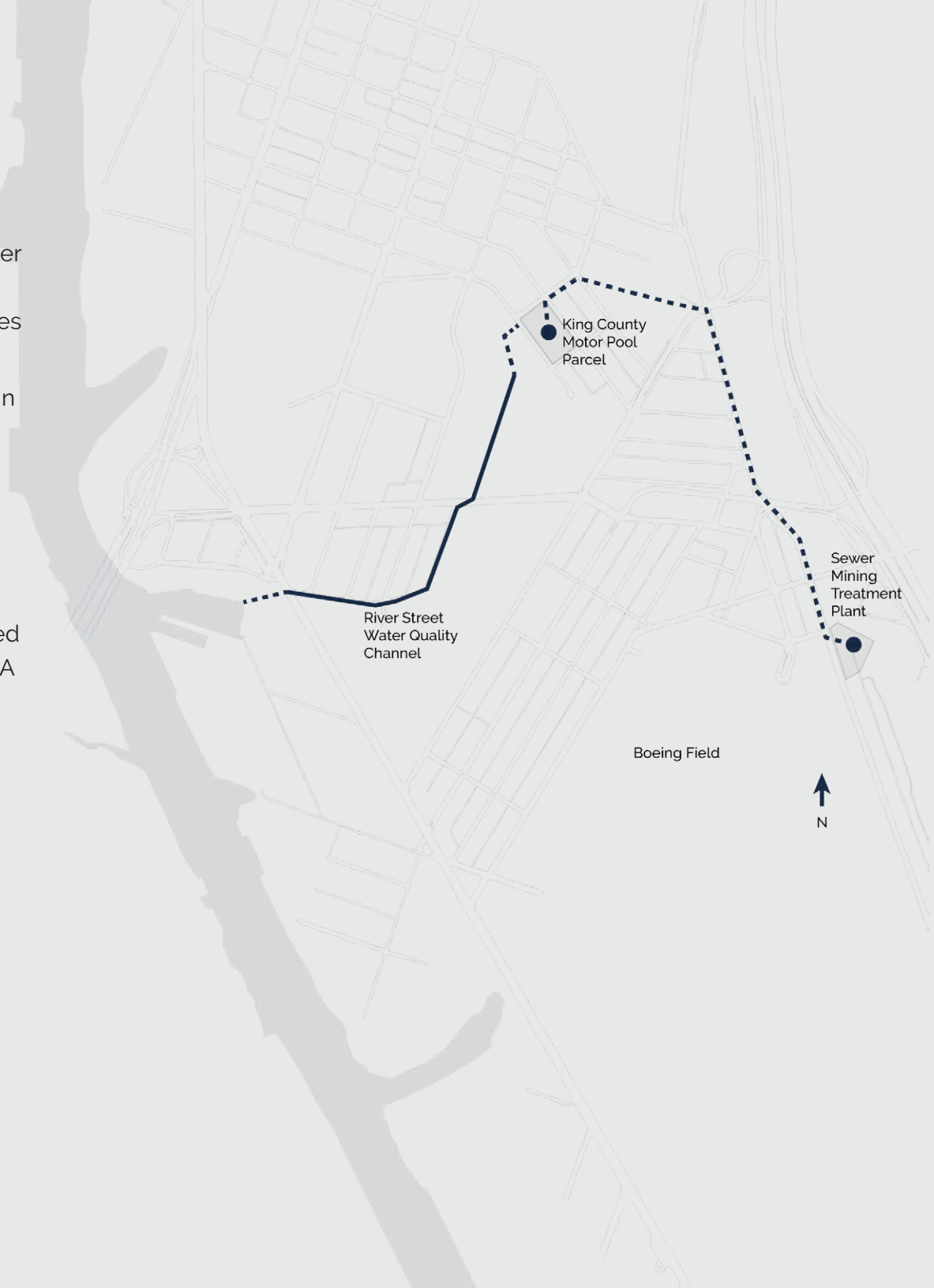
Mall in the 1950s). Since opening in 2009 in conjunction with other stream protection measures, Thornton Creek has begun to see salmon return [4]. Its success in improving water quality in an urban context demonstrates potential for biomimetic design to support natural water systems.

### River Street Water Quality Channel

The final adaptation proposed in the right of way is the River Street Water Quality Channel that functions as a discharge point for the proposed subsurface reclaimed water reservoir under the King County Motor Pool Maintenance parking lot. This channel is a place to direct runoff and swales into to prevent flooding.

As its name suggests, River Street frequently floods, in part because it follows part of the natural (pre 1921) path of the Duwamish River. It is also bordered by several industrial facilities and has combined sewers that overflow during heavy rains. The water quality channel is intended to be relatively narrow, between ten and twenty feet wide. The water quality channel can act as a semi-daylighting project for the old Duwamish River, a regular discharge for reclaimed water, and a stormwater sponge in the current right of way. A one-way shipping loop around the affected businesses will help preserve industrial and road access to accommodate the existing businesses. The road will slightly overhang the water quality channel, ensuring that the right of way can function for both water flow and traffic.

Upstream, north of Michigan Street, the water quality channel becomes shallower and more swale like, following an abandoned railroad tie for several hundred feet. This takes it nearly to King County Motor Pool Maintenance and minimizes the amount of pipe that would need to be laid.





One-way road provides freight and shipping access

**Figure 7.18:** Section A. proposed River Street Water Quality Channel with one-way shipping access

## End Notes

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4. Thornton Creek: Nature rebounds when an urban stream is restored [Internet]. The Nature Conservancy in Washington. [cited 2019 Jun 5]. Available from: <http://www.washingtonnature.org/fieldnotes/2019/5/24/thornton-creek-nature-rebounds-when-an-urban-stream-is-restored>



# CHAPTER 8

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# NEIGHBORHOOD SCALE

## Reclaimed Water Phasing & Impacts

Phase 1

Phase 2

Phase 3

Phase 4

# NEIGHBORHOOD SCALE

Many of the proposed interventions at the neighborhood scale are more centralized, utility driven solutions due to the multi-parcel and multi-agency scope. These proposals center around the creation and distribution of reclaimed water since most of Georgetown's water use is industrial and requires a greater volume than storage capacity for rainwater typically allows. The goal here is (theoretically) to replace 20% of neighborhood industrial water use with non-potable sources.

## Reclaimed Water Phasing & Impacts

Based on SPU's predictions, fifteen percent (or an average of ~9.5 billion gallons each year) of the current water supply will be lost to the effects of climate change by 2050 [1,3]. To replace the same amount by reusing water (based on current water use levels), twenty percent of all potable water use would need to be replaced. To replicate this on the small scale, the goal for this project is also to replace twenty percent of Georgetown's industrial water use (since Georgetown is primarily industrial) and ten percent of household use with non-potable water. This amount is easily attainable if people were to flush toilets with rainwater whenever it is available. However, adoption is likely to be patchy in early stages, with some reusing and conserving more, and some less, so ten percent of household use is reasonable in the short term.

Applying a twenty percent reuse rate for industrial water use and a ten percent reuse rate for households, regardless of water input type across the whole, current SPU service area reclaimed seventy-eight percent of the estimated 9.5 billion gallons lost to climate change. This adoption rate is relatively low. While it would require some significant investment to achieve this rate of reuse, many of the needed systems are already in place and achievable.

**Figure 8.1:** (opposite) proposed neighborhood scale green and reclaimed water infrastructure (data from 4, 25, 61, 81, 82)

- Perspectives:**
1. Tide Flats South (page 165)
  2. Tide Flats North (page 159)
- Sections**
- A. River Street Channel (page 152)
  - B. Carleton Ave. Swales (page 146)
  - C. Swale Islands (page 147)
  - D. Subsurface Wetland (page 164)

**Proposed Interventions**








-  Proposed Water Treatment Infrastructure
-  Historical Duwamish River (Waterlines)
-  Subsurface Treatment Train Connectors
-  Georgetown Pedestrian Connector
-  New Streets
-  Sections
-  Perspectives





Figure 8.2: Perspective 2. proposed Tide Flats North, advanced water treatment & distribution center, and consolidated shipping infrastructure (data from 3, 25, 81, 83)

## Phase 1

One such piece of infrastructure is King County Wastewater Treatment Division's Wet Weather Treatment Station. The Wet Weather Treatment Station in Georgetown is currently being constructed to treat combined sewer overflows and is planned to open in 2022. The Georgetown Wet Weather Treatment Station is located at the corner of Michigan Street and Fourth Avenue, as well as the intersection of multiple sewer mains. It is currently under construction to prevent CSOs into the Duwamish River. While the station has a capacity of 70 mgd, the station will only be in operation during overflow events under the current plan, though it has the potential to mine sewers regularly [4]. It is located less than a block away from two of SPU's largest water users with potential to use reclaimed water according the 2019 Water System Plan: Certainteed Gypsum and CalPortland. [1]. The geographic proximity, capacity, and land use suggest that the land around the First Avenue Bridge has potential to support further treatment infrastructure for reclaimed water.

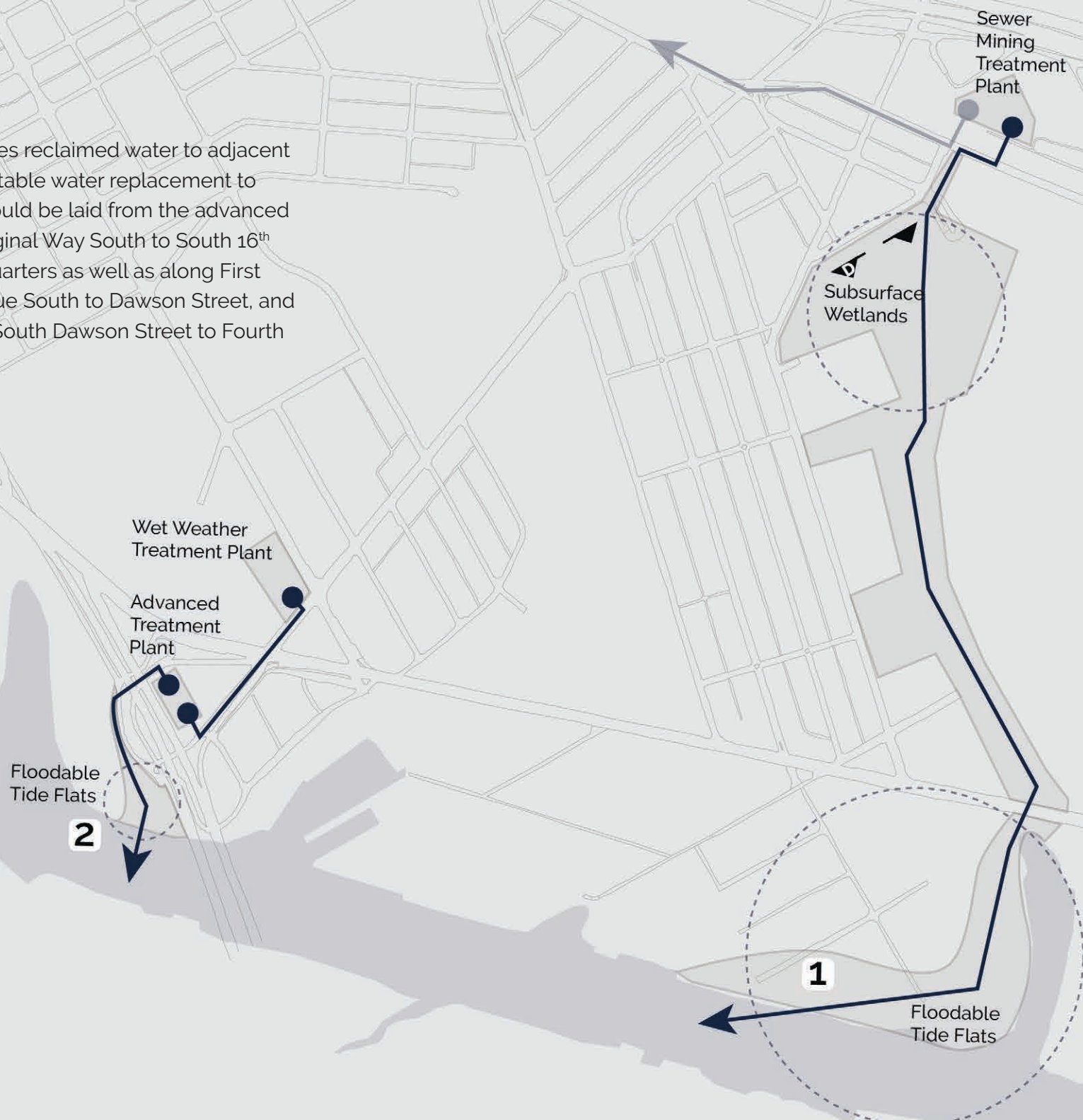
While King County Wastewater Treatment Division is not willing to sell to "small" water users [2]. In order to sell to smaller users, SPU could buy or receive the water discharged from the Georgetown Wet Weather Treatment Center. This treated wastewater could be treated at an SPU facility across the street, stored in a water tower, and distributed along East Marginal Way South between South Michigan Street and South Dawson Street. In conjunction with the SPU advanced wastewater treatment center are Tide Flats North that act as a final polishing treatment step for any discarded reclaimed water, treat runoff from the First Avenue Bridge, provide the

community-requested water access adjacent to the boat launch, and collects and treats runoff coming overland or from swales.

All water users along East Marginal Way South are industrial, so assuming that each customer replaced twenty percent of water use with reclaimed water, graywater, and rainwater, three percent of the total neighborhood water use would be replaced. While this may not seem like a significant number, the 40,125,076 gallons per year that would be saved is equivalent to approximately 800,000 fifty-gallon rain barrels that could be used by single-family homes. This first stage of reclaimed water supply retrofits and adds to existing infrastructure in a way that sets up further stages of reclaimed water use in Georgetown.

Phase 2

The second phase supplies reclaimed water to adjacent streets and raises the rate of potable water replacement to twelve percent. Water mains would be laid from the advanced treatment plant along East Marginal Way South to South 16<sup>th</sup> Avenue and the Boeing Headquarters as well as along First Avenue South and Fourth Avenue South to Dawson Street, and along South Lucille Street and South Dawson Street to Fourth Avenue South.



### Phase 3

The third phase involves the addition of a second treatment plant. The proposed site is adjacent to the strained South Albro Place sewer mainline. The treatment plant would mine from the Albro Place sewer to produce reclaimed water. However, because of its small footprint, the facility would need to use a treatment method other than activated sludge, which necessitates a large footprint and is known to attract birds. Due to perceived danger of aircraft malfunction, the Federal Aviation Administration prohibits activated sludge wastewater treatment facilities in adjacency to their facilities [2,5]. To respond to these restrictions, the proposed treatment plant will use flocculation technology to treat wastewater, and discharge into a subsurface wetland. Both of these practices need and have potential to be approved by the Federal Aviation Administration and State Laws concerning water treatment methods for reclaimed water [5,6].

The proposed treatment facility has a small site footprint that would not be compatible with traditional biological treatments used for wastewater, even if context permitted. This site will use electroflocculation in conjunction with advanced treatments (UV light, chlorination, etc.) depending on the necessary measures to exceed class A reclaimed water standards. Electroflocculation is relatively new to large-scale treatment but is currently being used in several places in North America. For example, Unity, Saskatchewan uses an electroflocculation system from one of two companies licensed to sell the technology [7,8].

Electroflocculation involves electrocuting metal nodes in the wastewater tank. These electrocuted metal ions bind to pollutants and cause them to float to the top where they can be skimmed off and disposed of. Compared to traditional methods,



Figure 8.3: before and after electroflocculation treatment (82)



Figure 8.4: electroflocculation treatment infrastructure in Unity, SK (82)

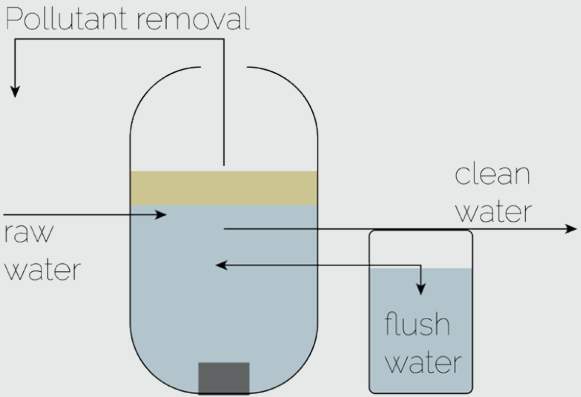
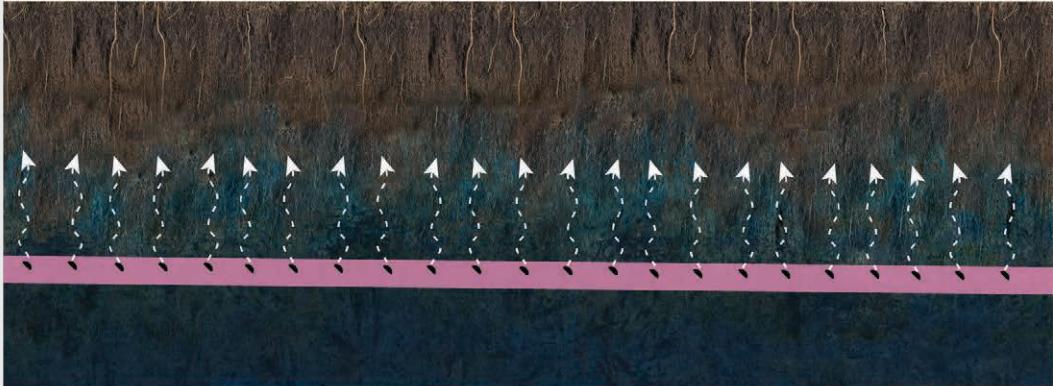
electroflocculation produces very small amounts of sludge, needs a much smaller land footprint, and has low energy demand. In a single treatment, wastewater can be treated to 97-99% of potable water standards, but performance can be increased with the use of silver ions or advanced treatment methods such as chlorination or UV treatment, which have to potential to be applied at the treatment plant and/or in the proposed reservoir [8].

The treatment plant and reservoir would have two outflows: one to supply customers, and the other to a subsurface treatment wetland, which would provide additional treatment before ultimate discharge to groundwater and the Duwamish River. Subsurface wetlands are commonly used for wastewater discharge in Washington already and are known to be both safe and reliable [9]. The proposed subsurface wetland can combine with many of the current community proposals in the area including the dog park, airplane viewing deck, and sculpture park [10].

The subsurface wetland and Boeing Stormwater Swale would receive final treatment at Tide Flats South. These tide flats would act as the final treatment stage for subsurface wetland and other runoff, would restore vulnerable habitat, and give communities access to the water that is currently lacking. The entire neighborhood of Georgetown is constructed on the tide flats of the Duwamish River Delta, which was filled in during the late 1800s and early 1900s using fill from the Denny and Beacon Hill regrades. This project would aim to reconstruct many of the functions of the original tide flats including decreased speed of water, sediment collection, softened river edge, and opportunity for shallow and intertidal life. This would give Georgetown a place to direct floodwaters, and in the

future could become a part of a sea level rise accommodation strategy.

The third phase distributes water along Michigan Avenue South, along Airport Way South, and connects into the original system along Lucille Street. This phase also adds a reclaimed water storage reservoir under the King County Motor Pool Maintenance parking lot, which would require careful monitoring and the maintenance of residual chlorine levels to prevent the growth of pathogens. Regular reservoir cleaning effluent and unneeded reclaimed water would flush regularly into the River Street Water Quality Channel. This phase reduced the Georgetown Neighborhood's potable water use by seventeen percent, and still mostly supplies to industrial users.



**Figure 8.5:** simplified electroflocculation diagram. untreated water is added to the tank, electric current is run through the nodes at the bottom causing pollutants to rise to the top (data from 82, 84)

**Figure 8.6:** Section D. subsurface wetland at Boeing Field provides flood protection and water treatment for stormwater and unneeded reclaimed water

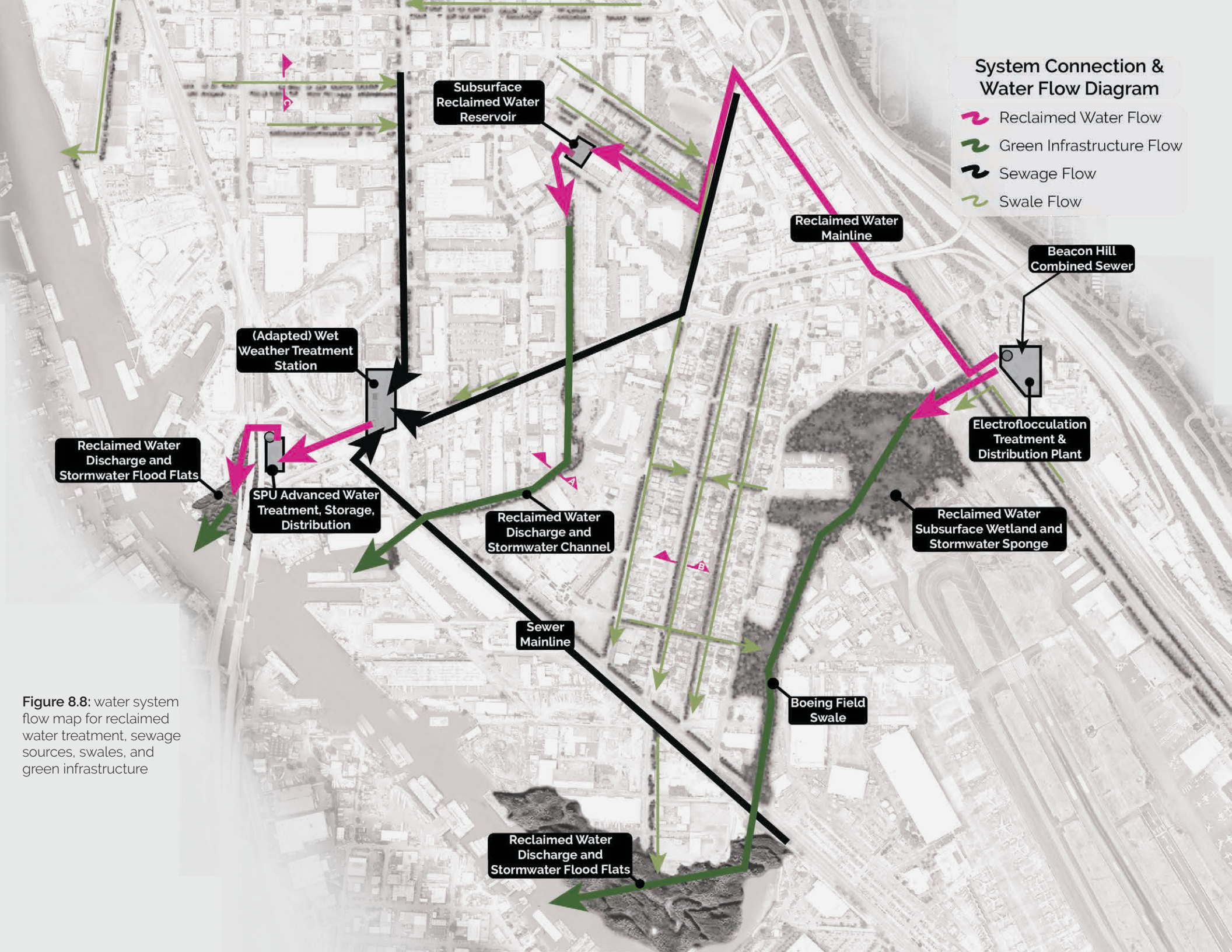


**Figure 8.7:** Perspective 1. Tide Flats South maintains industrial uses while providing partial restoration of the native Duwamish tide flats that provide treatment for runoff and act as a buffer for floods

## Phase 4

The final phase adds mains on South Orcas Street, South Ellis Street, South Corson Street, and South Sixth Avenue. Based on the current land use types, this system has the capacity to supply 98% of industrial parcels and nearly half of total parcels. This system has the potential to replace twenty percent of Georgetown's water use, which amounts to 0.6% of all water used in the SPU service area.

While 0.6% may not seem to be a significant proportion of overall water used, when 20% industrial and 10% residential reuse is applied across the entire SPU service area, 78% of the water forecasted to be lost to climate change can be replaced with nonpotable sources. The costs of laying pipes in an already-developed area are generally prohibitively expensive, however sewer retrofits for seismic retrofits and upgrades could make costs of laying reclaimed pipes more accessible with a cut-and-cover construction approach. Though costs of adding infrastructure are currently restricted, recognition of dwindling water supplies could make projects like this accessible across the region. Replacing 20% of industrial water use is attainable with minimal infrastructure investment. Regionally, with this approach towards industrial water reuse, combined with 10% water reuse in residential areas, SPU's service area could recoup nearly all of the water supply that would otherwise be lost to climate change.



**Figure 8.8:** water system flow map for reclaimed water treatment, sewage sources, swales, and green infrastructure

	Current Firm Yield	2050 Firm Yield without changes	Gallons lost in a year by 2050	
est. 15% Lost to Climate Change by 2050	172 mgd	145.75 mgd	9,581,250,000	
<b>replacing potable use by percent</b>	<b>Georgetown</b>	<b>half of Seattle</b>	<b>Seattle</b>	<b>SPU</b>
10	157,296,750	950,460,000	1,900,920,000	4,163,920,000
20	314,593,500	1,900,920,000	3,801,840,000	8,327,840,000
40	629,187,000	3,801,840,000	7,603,680,000	16,655,680,000
60	943,780,500	5,702,760,000	11,405,520,000	24,983,520,000
1 50 gal rain barrel/person	150,000	18,000,000	36,000,000	70,000,000
10% of household water use replaced	394,200	380,184,000	760,368,000	2,263,000,000
10% of industrial use replaced	152,073,600	380,184,000	760,368,000	1,810,400,000
10% industrial and business replaced	152,714,175	475,230,000	950,460,000	2,263,000,000
20% of household water use replaced	7,884,000	760,368,000	1,520,736,000	4,526,000,000
20% industrial use replaced	304,147,200	760,368,000	1,520,736,000	3,620,800,000
20% of industrial and business replaced	305,428,350	950,460,000	1,900,920,000	4,526,000,000
* multifamily water use is excluded				

**Figure 8.9:** (top) scaling potable water use from Georgetown to the full SPU service area showing that replacing 10% residential and 20% industrial uses with nonpotable water sources can replace 78% of the expected loss in water supply (data from 9, 25, 27, 55, 85-86)

**Figure 8.10:** (right) supporting infographic, see above explanation

Applied across the (current) SPU service area...

replacing  
20% of industrial use  
+  
10% of household use  
=

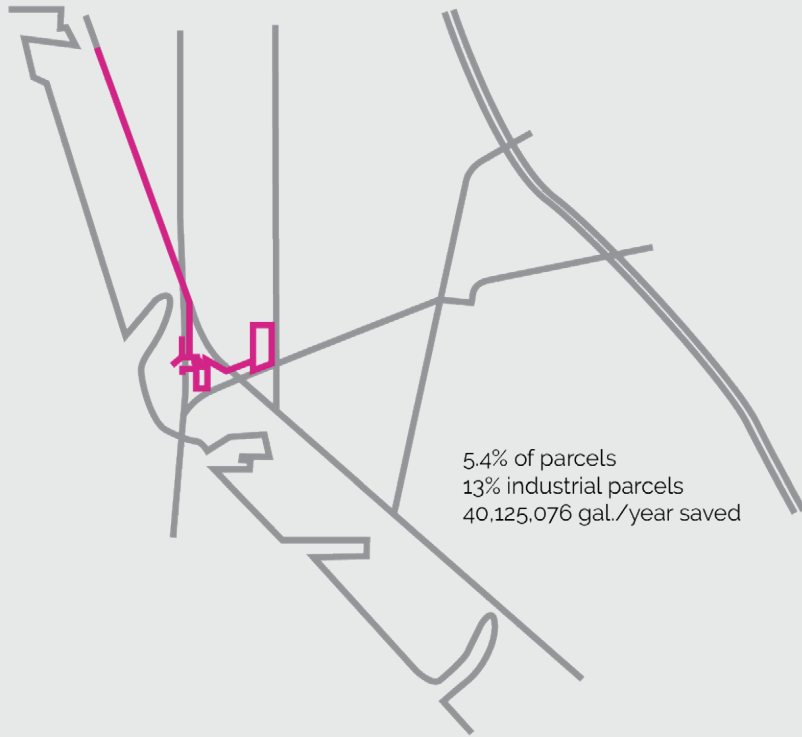
**78% of water lost to climate change replaced**

# Project Phases: 20% of Potable Water Use Replaced

Figure 8.11: reclaimed water supply phasing and estimated potable water use reductions

## Phase 1

Expanding the Georgetown Wet Weather Treatment Station  
Main from Michigan St to Dawson St on E Marginal Way S targets largest water users



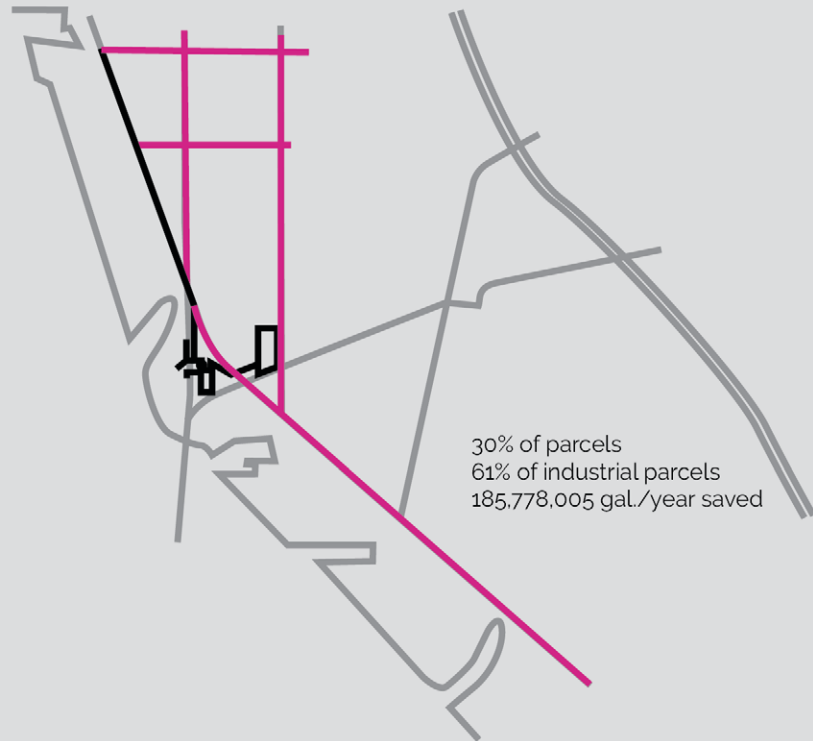
Neighborhood Potable Water Use Reduction:

**3%**

Equivalent to 800,000 rain barrels

## Phase 2



E Marginal Way S main extended to S 16th Ave  
Additional mains laid on First Ave S, Fourth Ave S, S Lucille St, and S Dawson St



Neighborhood Potable Water Use Reduction:

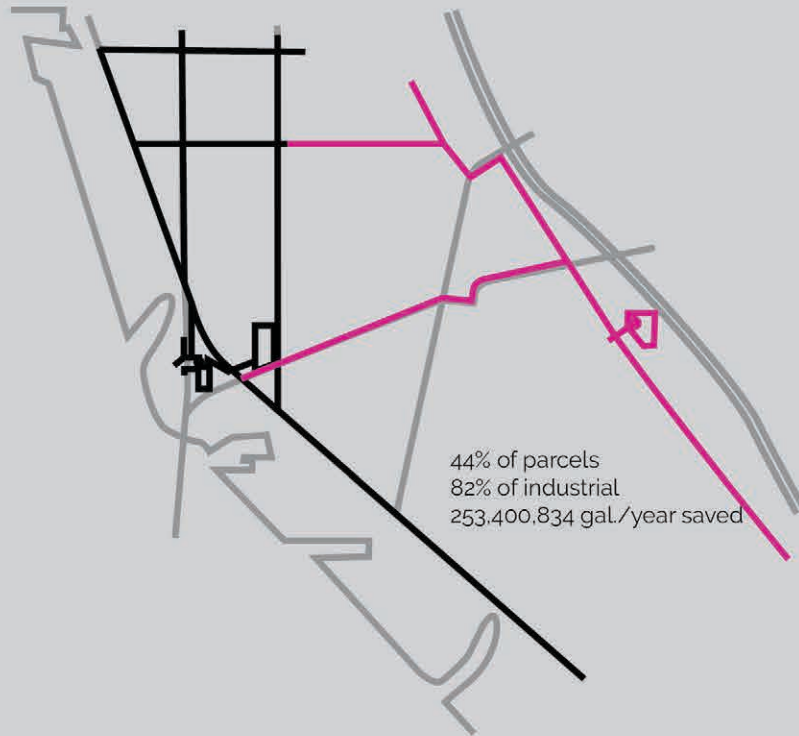
**12%**

Equivalent to 3,700,000 rain barrels

-  Arterial Roads
-  New Reclaimed Water Mains
-  Mains from previous phases

### Phase 3

Electroflocculation Plant mines from the Albro Pl sewer main  
 Mains laid on S Airport Way, S Michigan St, and S Lucille St



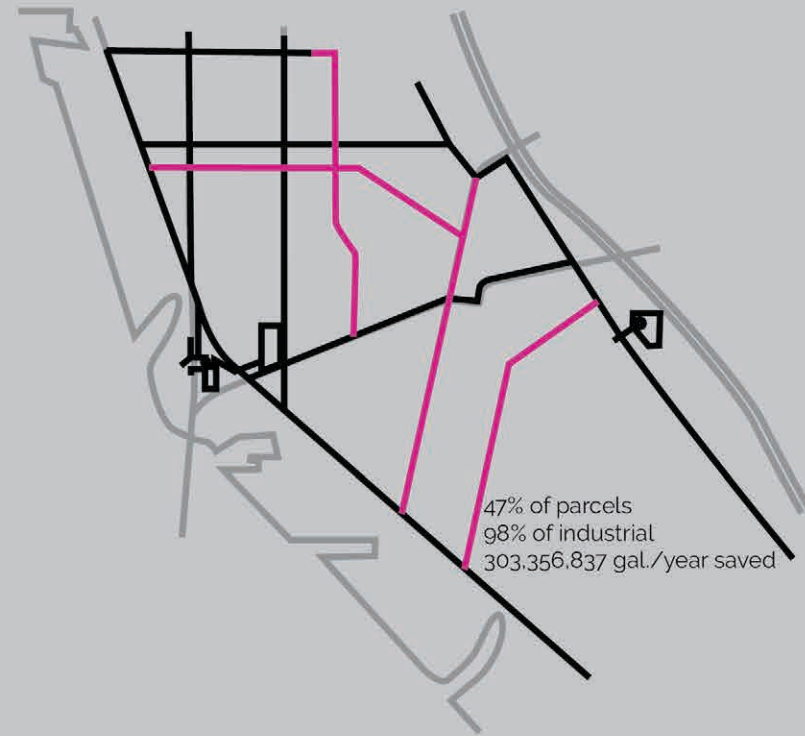
Neighborhood Potable Water Use Reduction:

**17%**

Equivalent to  
 5,060,000 rain barrels

### Phase 4

Mains laid on S Orcas St, S Ellis Ave, S Corson St, and S 6th Ave



Neighborhood Potable Water Use Reduction:

**20%**

Equivalent to 0.6% of all water  
 used in SPU service area

## End Notes

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# CHAPTER 9

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# CONCLUSIONS

Closing Thoughts

Areas for Further Exploration

Reflection

## Closing Thoughts

Climate change will disrupt every profession. As changes to our base assumptions about regional infrastructure, resources, and ecologies are upended, our built environment will have to help society adapt to its new world. Currently landscape architects and engineers mostly deal with water separately, as do ecologists, hydrologists, potable water professionals, wastewater professionals, and sometimes runoff professionals. Sometimes they work for completely separate companies or lines of business and rarely get a chance to interact. Interactions are usually around an existing project and may be fraught with conflict which does little to promote future cooperation.

Over the course of this project I have encountered professionals, professors, and several students who have said that water reuse and infrastructure falls into the scope of an engineering project. From an engineering point of view, reforestation following dam construction is a landscape or ecology project. These project aspects are part of the same system; neglecting one part makes the whole less functional. The same is true for water systems. If landscape architects truly wants to remake the profession, adding scope to give full systems consideration can solve problems of greater complexity and is a strong step toward that goal. Landscape architects can move away from dealing in incremental tools that arbitrarily divide systems.

There are many such technologies and systems in the built environment that have the opportunity to better support each other and are much more resilient as a result. The combination of green (traditionally landscape) and gray

(traditionally architectural or engineering) infrastructures is just beginning to be explored and represents great potential for more sustainable future practices

Through a combination of research and design, this thesis has explored how connecting traditionally separated water and sewer systems through water reuse can make water supplies more resilient to the effects of climate change. Water reuse capitalizes on resources already present in the city: rain, graywater, and reclaimed water. These sources are not directly influenced by climate change and can act as a reliable supply for nonpotable uses.

Both the research and design explorations reveal great complexity in Seattle's water and sewer systems. There are however many opportunities in complex systems for synergistic, stacking uses that can increase efficiency and perform additional functions. Many of the examples described in this thesis focus on efficient use of water by moving beyond the single use model of water consumption. Suggestions for water reuse are guided by existing philosophies as well as contextual information.

Water conservation is not enough to reliably ensure enough water for both people and the environment in the long term. The climate crisis affects every industry, provokes anxiety, and feeds uncertainty about the future but has not galvanized the scope of actions needed to deliver the necessary resilience. Proposals that seek to address the immensity of the climate problem seem to resonate with broad communities across scales. The speculative nature of these design proposals acknowledges the uncertainty inherent to predicting the future, but also in unsecured investment in environmentally sound

solutions and the challenges involved in cross-disciplinary solutions like integrated water management.

Existing discourse in water management practices like Water Sensitive Urban Design, Low Impact Development, One Water, and Green Stormwater Infrastructure are seeking to manage the increasing demand for water while restoring and protecting environmental systems. Collectively these philosophies promote on-site and small-scale stormwater management strategies. One Water and WSUD have developed further in promoting integrated water management and water reuse. They help address concerns about budget, management practices, and service capacity. These strategies work from the agency level and in decentralized systems to accommodate water in a way that minimizes human and environmental costs.

Decentralized infrastructures shift some of the financial and public health responsibilities to water users, which challenges common practices of utility providers in the United States. Utilities have been able to provide uninterrupted service to all with help of subsidies, this country's prosperity, and other available resources in the past. It is also easier to supply only one type of water: potable, rather than maintaining several systems. However, implementation of separated sewer systems (as opposed to only the original combined sewers) have shown that utilities have the capacity to expand perspectives on services when there is need.

The water supply side has not been challenged by capacity in the same way as wastewater service providers have in most locations and generally still provide only potable water in the United States. This history of service and public health

supports the practice of providing only potable water, but as population grows and available resources are stretched, so are traditional best practices. New practices suggest exploring water reuse in the huge quality gap between potable water and wastewater. Though there is more risk in these technologies, they present a more robust suite of options for the huge range of water uses while reclaiming volumes lost to climate change.

Addressing climate impacts pushes routine practice of any utility, activity, person, or group relying on water. Uncertainties in the magnitude and scope of climate impacts make ensuring availability of water while preventing flooding challenging endeavors. It is also difficult to create a flexible system that can adapt to inconsistent and variable conditions. Future conditions will force utilities and individuals to mind their resource use; beginning before an emergency where water runs out will make new practices more efficient, palatable, and financially responsible.

Seattle's current plans to address the effects of climate change depend on constant water demand, increasing efficiency indefinitely, and assuming residents can do without in times of shortage. SPU's current "emergency plan" relies on the people of King County to conserve water in times of shortage. In the past, every time SPU has asked people to conserve water, the people of King County have always exceeded expectations,<sup>1</sup> therefore, it seems that they expect the people of King County will continue to exceed expectations or that water shortages will not be severe. In either instance, this is not a plan, but a recognition of success in past situations. This

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<sup>1</sup> This same statement was also used by an SPU professional at my thesis review and at the International Living Futures Conference in the same week, which implies it is a commonly-understood response.

history of past behaviors may not be a good indicator of future water preservation. Future water shortages are likely to be much more severe than they have been up to this point. The decision to rely on people to not use water in times of shortage is also contrary to SPU's guiding principles, which state the customers should not have to make sacrifices to receive the highest quality of service.

While using drinking water for everything may feel like the highest level of service right now, a future where utilities ask people to conserve may become commonplace. Asking people to go without watering their lawn is a reasonable way to conserve but asking people not to shower as much or do laundry less are much more significant sacrifices that could be largely avoided. The way "the highest level of service" is viewed in Seattle is likely to look different than it does today. Using non-potable water is one way to maintain quantity of supply and conserve the quality supply for consumption.

More traditional infrastructures, like desalination, groundwater pumping, and new dams, are likely to appeal because they allow predictable quantities and quality of water for a fixed price. However, these infrastructures do not interact with other systems except to take in a resource or dispose of waste. If our ability to mitigate the environmental impacts of these technologies does not improve, these newly harnessed water sources of the future may further perpetuate ecological harm where ecosystems are already struggling to adapt to the effects of climate change. Balancing ecological impacts with human needs are not separate problems but approaches to solving the same problems from different points of view.

Climate impacts touch many different industries and specializations. Gaps in knowledge feed uncertainty, but also present an opportunity to create more flexible, dynamic systems. The additional challenge is that many of those opportunities occur between professions. In the built environments, built systems often do not interact with living systems, which do not interact with engineered systems, just as each profession struggles to communicate with others. Cross-profession collaboration provides a richer knowledge base to draw from and is likely to aid professional fulfillment as well as contributing to solving systemic problems.

To broadly implement water reuse, regulations, values, expectations, and assumptions have to be reexamined. An increase in cross-collaboration may yield cost and management synergies that could help but drinking water and drainage and wastewater teams accomplish their goals and moves SPU closer to adopting One Water practices reminiscent of WSUD.

Design offers a way to test solutions to complex problems and performs best when it can anticipate or include accurate conditions and context to the greatest possible extent. Extensive research into Seattle's water system, water management practices, and climate impacts have illuminated variable future conditions in various future climate scenarios. For example, publicly available information takes on a different context once underlying history and politics become apparent. While physical realities of drainage, contamination, and regulation complicate the ways that water can be reused, these proposals have explored contextually relevant ways to make reused water safe and available. These explorations informed

the proposed designs in a way that was intentionally logical, challenging, and speculative.

These reuse and management technologies can be implemented on a single parcel and can scale all the way up to the full SPU service area (reasonableness of doing so depends on cost and need). Implementing small-scale water conservation and reuse mechanisms gives individuals greater agency in how they use water beyond a binary “use” or “not use.” A variety of tools gives the opportunity for individual customization to meet specific needs which makes water saving and reusing technologies more economical and practical to use.

One example where individuals are pushing beyond where regulations permit is indoor rainwater reuse. Permits and costs associated with indoor rainwater reuse are quite opaque and difficult to get. As a result, three categories of possible water reusers form: people who do not know they can reuse rainwater indoors; people who know about indoor reuse but give up because of the complexity and difficulty in getting systems permitted; or people who install illegal systems by themselves. Increasing the transparency of the permitting process would help ensure that rainwater reuse systems protect public health, so wastewater and potable water do not end up mixing with rainwater somewhere that might be dangerous. Generally, illegal rainwater reuse systems are in efforts to act sustainably and use less potable water; now regulation and communication must catch up to support rainwater reuse so residents can do it safely.

Small-scale retrofit interventions are likely to happen piecemeal, and each system tailored to suit individual

household, space, or company needs. Rainwater interventions are likely to happen first in many homes, followed by graywater and reclaimed water. Conversely, reclaimed water is more likely to be adopted first among large water users if it is available at approachable price points. Adoption of rainwater, reclaimed water, or graywater systems are likely to suit some users more than others, but adoption of any, all, or a combination of systems contributes to widespread acceptance and adoption of more sustainable practices.

In the right-of-way, interconnected stormwater systems require collaboration of multiple stakeholders depending on land use and ownership while isolated systems can be realized much more quickly. Most right-of-way interventions have focus on stormwater management in this context because of the existing and expected problems with pollution and flooding from increasing rainfall. There are other potential runoff treatment and reuse applications for stormwater that may be more applicable in more arid regions, or that might be applicable in the far future depending on realized climate impacts that do not make sense in Seattle right now. There is also potential for stormwater management in the right-of-way to overlap with other uses via permeable paving, greening initiatives, buffers, etc. that will likely develop as Seattle becomes increasingly multimodal.

While reclaimed water can be realized on the small scale, the highest benefit in Georgetown (or other industrial or agricultural areas) can be achieved with a neighborhood scale reclaimed water supply. Though some industrial users reportedly provide additional treatment to the potable water they receive, there are still many opportunities for reclaimed water in Georgetown. Many of the places that use large

quantities of water in processing and cleaning do not require a potable supply. Alternatively, investigating whether additional-water-treating companies need to be supplied with potable water as opposed to class A+ reclaimed water is an interesting opportunity for future investigation.

Crossing scales of impact has cumulative effects. Implementation can happen at any scale and thereby incrementally decreases potable water demand and effluent discharge. Though impacts are cumulative and the whole system provides the greatest benefit in terms of potable water displaced, most phases are not dependent on each other for the designed system to function and thus phasing can be flexible. Flexible timescales allow water management strategies to be implemented when there is momentum, public approval, budget, permits, and other fluctuating circumstances, and this accommodates for incremental progress.

Varying levels of intensity at the scales proposed give differing levels of viability to each proposal. The persistence of legal, institutional, public acceptance, and financial barriers balanced with need will determine how, if, and when stormwater management and water reuse projects are implemented. As seen in Melbourne, increasingly extreme climate-induced occurrences galvanize investment and public acceptance, and open opportunities for rethinking accepted practices. However, Melbourne is also a cautionary tale where climate impacts were drawn out and where government agencies and the public were able to respond with sets of solutions.

Seattle's limited water storage capacity may accelerate water depletion rates if precipitation received does not meet

expectations. However, unlike Melbourne, Seattle still has the time to not be a cautionary tale. Seattle and its Georgetown neighborhood have the opportunity to demonstrate how Water Sensitive Urban Design can avert the most damaging effects of climate change, offering a sustainable supply of usable water for generations to come.

## Areas for Further Exploration

Over the course of this year-long project, I have gotten to explore water management philosophies in WSUD and *One Water* and delve deeply into SPU's climate response strategies. Over the course of these studies and associated conversations, new questions, opportunities, and areas to explore have emerged:

- Green gentrification and unregulated capitalism
- Where and how to change laws
- Sea Level Rise
- Yellow water<sup>2</sup>
- Coordinated pipe laying with other projects
- Expansions and formalization of onsite wastewater treatment systems beyond septic systems for onsite blackwater, graywater, and yellow water
- Level of knowledge the public has
- Public outreach via flyer, mailer, advertising, website, community groups
- City support through funding or code change
- Treating runoff versus sewage
- Water footprint in products

## Reflection

All of these questions, as well as the ones I set out to answer with this thesis have emphasized how important good water management is. As landscape architects we must advance concepts beyond GSI and work with larger water systems to contribute to the solutions that are necessary for our survival. The skills we develop in systems thinking give us insight we must put to better use in the fights for climate adaptation and equity.

It is important that we as a society learn to value water as a finite resource. The progression of climate change will further challenge historically accepted practices and push us to develop better ways of managing natural resources. While the threat of climate change is daunting, we as a society have the resources and ingenuity to provide enough water for all uses and all users.

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<sup>2</sup> Treatment of liquid human waste, but not solid.



Figure 9.1

## Image Source Notes

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