BLUE GREEN SYSTEMS TYPOLOGY STUDY

CITY OF VANCOUVER INTEGRATED SEWER + DRAINAGE PLANNING | SEPTEMBER 2024

CITY OF VANCOUVER

Executive Summary

BLUE GREEN SYSTEMS TYPOLOGY STUDY

City of Vancouver, Integrated Sewer + Drainage Planning
September 2024

"The overall vision for Blue Green Systems is to achieve, in the not too distant future, a network of streets, parks, and open spaces that will be redesigned into leafy green landscaped spaces, which prioritize people and communities, walking, cycling, with room for the urban forest and biodiversity to grow to its potential; and where ephemeral raingardens flourish and deliver on their water management potential–these corridors are wet when it's pouring with rain and dry but healthy even at the end of our long warm Vancouver summer. Large open spaces serve as nature-rich and recreational places most of the year, and temporarily flood during intense rain events in order to limit the catastrophic impacts of extreme storms on people, property and the environment."

From 2019 General Manager's Integrated Blue Green Systems Planning report to Vancouver City Council

Background

In Vancouver's pre-colonial past, rainwater moved freely through the landscape—water soaked into the soil to recharge groundwater, pooled in wetlands, and nourished a system of creeks and streams. Indigenous peoples in the area, including Musqueam, Squamish, and Tsleil-Waututh, shared a special relationship with these same lands and waters. The ensuing 150+ years of colonization and urbanization in Vancouver's most recent history disrupted hydrological and ecological relationships by piping streams, filling in wetlands, paving over landscapes, and disconnecting people from healthy water. The impacts of urbanization in Vancouver led to increased inland flooding, poor water quality, lost wildlife and pollinator habitat, and other ecosystem and cultural impacts.

Blue Green Systems Typology Study Overview

Over the past several years, the City of Vancouver (City) has been working to rethink the way that water interacts with and moves through the urban environment. In 2019, The City adopted the Rain City Strategy to integrate Green Rainwater Infrastructure (GRI) as a suite of tools for managing stormwater. As other large-scale initiatives build on this work, such as the Broadway Plan, the Healthy Waters Plan, and the Vancouver Plan, the need for larger-scale systems implementation of GRI is driven by the need to service growth, adapt a system with aging infrastructure, eliminate Combined Sewer Overflows, and create more resilient and livable neighbourhoods in the City.

A key element of these plans and studies is the City's vision to create Blue Green Systems, which have been conceived as a network of park-like streets and open spaces throughout the City that will manage rainwater and floodwater, promote active transportation, connect people to parks and nature, and provide habitat for wildlife and pollinators. These Blue Green Systems have the potential to be transformational in the City's response to existing water management issues, climate change impacts, and livability pressures.

This Blue Green Systems Typology Study, led by the City of Vancouver Integrated Sewer and Drainage Planning team, includes an introduction to the City's vision for Blue Green Systems; an overview of precedent research exploring international examples of integrated planning and design for urban watershed health; a framework to conceptualize nine unique Blue Green System typologies; a demonstration of each typology to further define and visualize the application of each typology; and a summary of key policy, design, and implementation considerations as the City strives to advance their vision for Blue Green Systems.

Three fundamental principles define the City's comprehensive vision for Blue Green Systems:

1. Blue Green Systems are **an act of restoration** and work to restore natural systems lost through urbanization by re-imprinting them on the City's existing urban fabric as **spaces for water, wildlife, and people**.
2. Blue Green Systems are **multidimensional** and are focused on restoring multiple intertwined systems through three core objectives: **hydrological (Blue), ecological (Green), and social relational (Connect).**
3. Blue Green Systems represent connected networks that achieve their full potential when the Blue, Green, and Connect objectives are **envisioned as a system at a watershed scale.**

These three fundamental principles, along with the scale of their component parts and their expected performance (i.e., managing a 10-year storm), help distinguish Blue Green Systems from typical GRI. They are more than just a "green street."

Precedent Research

The Study began with extensive, global precedent research to learn about potentially comparable projects across a wide swath of geographies with a range of visions, drivers, and objectives. Over two dozen potential precedent projects were identified and preliminarily researched. Fourteen precedents were determined to have sufficient information available and to be at least partially analogous to the City's Blue Green Systems; findings from these 14 precedents were documented and analyzed further for key takeaways. Summary pages of each precedent are included in Appendix A. Four primary themes emerged from the global precedent research. These precedent projects often:

1. Rely on a **suite of green rainwater infrastructure technologies** working in tandem.
2. Envision **district-scale rainwater management** techniques.
3. Embed **flood storage and flood conveyance** in the public realm.
4. Use a **city-scale or district-scale plan to guide design** and implementation of built projects.

Typology Framework

Blue Green Systems are intended to restore natural hydrologic functions (Blue), natural ecological processes (Green), and connections of people with nature (Connect). **Nine key natural watershed processes serve as inspiration for envisioning Blue Green Systems as part of the urban watershed:** *conveyance, ephemeral flow, perennial flow, storage, flood storage, infiltration, hyporheic exchange, evapotranspiration, and treatment.* The proposed Blue Green System typology framework considers two fundamental principles that shape how water moves through and interacts with a landscape in a natural watershed:

1. How ***much*** water there is, and
2. How much ***space*** there is for water.

These principles become the Blue Green System **"watershed context"** and **"site context"**.

In natural systems, the watershed context is categorized into three zones (see Table 1). In the Upland Zone, rainfall and snowmelt begin to collect into ephemeral channels at the headwaters of the watershed. In the Transition Zone, small streams begin to converge into larger channels that flow continuously as they wind through the watershed. In the Lowland Zone, streams converge into large river channels with wide floodplains that store and slow water as it continues towards the ocean. These zones are similar in traditional urban watersheds, where water is

directed from the Upland Zone to the Lowland Zone. The key difference is that water is primarily conveyed in pipe networks within increasing larger diameter pipes.

In natural systems, the site context depends on the surrounding environmental conditions, such as geology, topography, and soil types (see Table 2). These conditions determine how much space is available for the water to flow. In Confined Valleys, the water channel strictly follows a direct, linear path. In Open Sloped Valleys, there is space for channels to meander into adjacent riparian areas. In Broad Floodplain Valleys, there is the most space for water to widen out and form floodplains that let water soak into the surrounding landscape. In urban conditions, the site context is determined by underground utility infrastructure, zoning, urban development, existing vegetation, and transportation needs, among many other site characteristics.

When the watershed context and site context are considered together, **nine typologies emerge to represent points along the continuum of how Blue Green Systems could be expressed in urban environments** (see Table 3). The following nine typologies are named to **create an identity for distinct Blue Green Systems** within an urban watershed:

1. *Upland Rainway*, inspired by an Ephemeral Creek
2. *Upland Blueway,* inspired by a Vernal Pool
3. *Upland Wet Meadow,* inspired by an Ephemeral Wetland
4. *Seasonal Rainway,* inspired by a Narrow Stream
5. *Seasonal Blueway,* inspired by a Meandering Stream
6. *Seasonal Wetland,* inspired by a Stream + Floodplain Wetland
7. *Perennial Rainway,* inspired by a Confined River
8. *Perennial Blueway,* inspired by a River + Wetland Bench
9. *Perennial Wetland,* inspired by a Tidal Marsh

Typology Definition and Demonstration

The Blue Green System typologies are further defined in detail to identify watershed and site characteristics, primary rainwater management mechanisms, and potential components that help achieve the Blue, Green, and Connect objectives. A conceptual design is developed for each typology at a hypothetical site to show how the typology definition may be expressed under real-world conditions. The **illustrative demonstration concepts are intended to inspire and spark conversation** about the potential for Blue Green Systems in Vancouver (see Table 4).

Conclusion: Putting Blue Green Systems Together

The typology framework and resultant typologies represent a starting place for the City to continue to develop and refine their vision for Blue Green Systems. As the vision leads to the planning and implementation of future projects, the typologies will help **guide conversations** with City partners, developers, and community members about the systems-scale nature of Blue Green Systems; the potential for urban watershed restoration and climate change adaptation; and the opportunities and challenges that arise as the City works to achieve their vision.

Blue Green Systems will likely utilize a suite of common green rainwater infrastructure components, such as bioretention planters, permeable hardscapes, linear bioswales, floodable spaces, subsurface storage and treatment, structural soil cells, and many others, as the backbone for designing vibrant public spaces that enhance and protect urban ecologies and create places for communities to move, play, and connect. Many of these common GRI components have not been used at a systems scale like this before. One outcome of this study is the identification of **policy and design standard considerations** that require near-term adaptation or refinement to achieve the desired integrated outcomes of the City's Blue Green Systems vision.

The Blue Green Systems Typology Study builds off the foundational work the City has led to envision healthy, resilient urban watersheds, ecosystems, and communities. As the City begins to implement the Rain City Strategy and their other holistic visions for Vancouver's future, the Blue Green Systems Typology Study provides a **framework for the City to take their next steps** in planning, implementing, and designing a network of park-like streets and open spaces to celebrate water, ecology, movement, people, and culture all together.

Table 1. Summary of Watershed Context Characteristics

Watershed Context	Relative Flow Volume	Flow Type	Flow Connectivity
Upland Zone	Low	Ephemeral	Discontinuous
Transition Zone	Mod	Intermittent to perennial	Connected
Lowland Zone	High	Perennial	Continuous

Table 2. Summary of Site Context Characteristics

Site Context	Space for Water	Adjacent Capacity	Blue Green System
Narrow ROW*	Confined, least space	None	Upland Zone
Expanded ROW*	Extended, moderate space	Mod	Transition Zone
Expanded ROW* + Open Space	Unconfined, greatest space	High	Lowland Zone

*ROW: right of way

Table 3. City of Vancouver Blue Green Systems Typology Framework

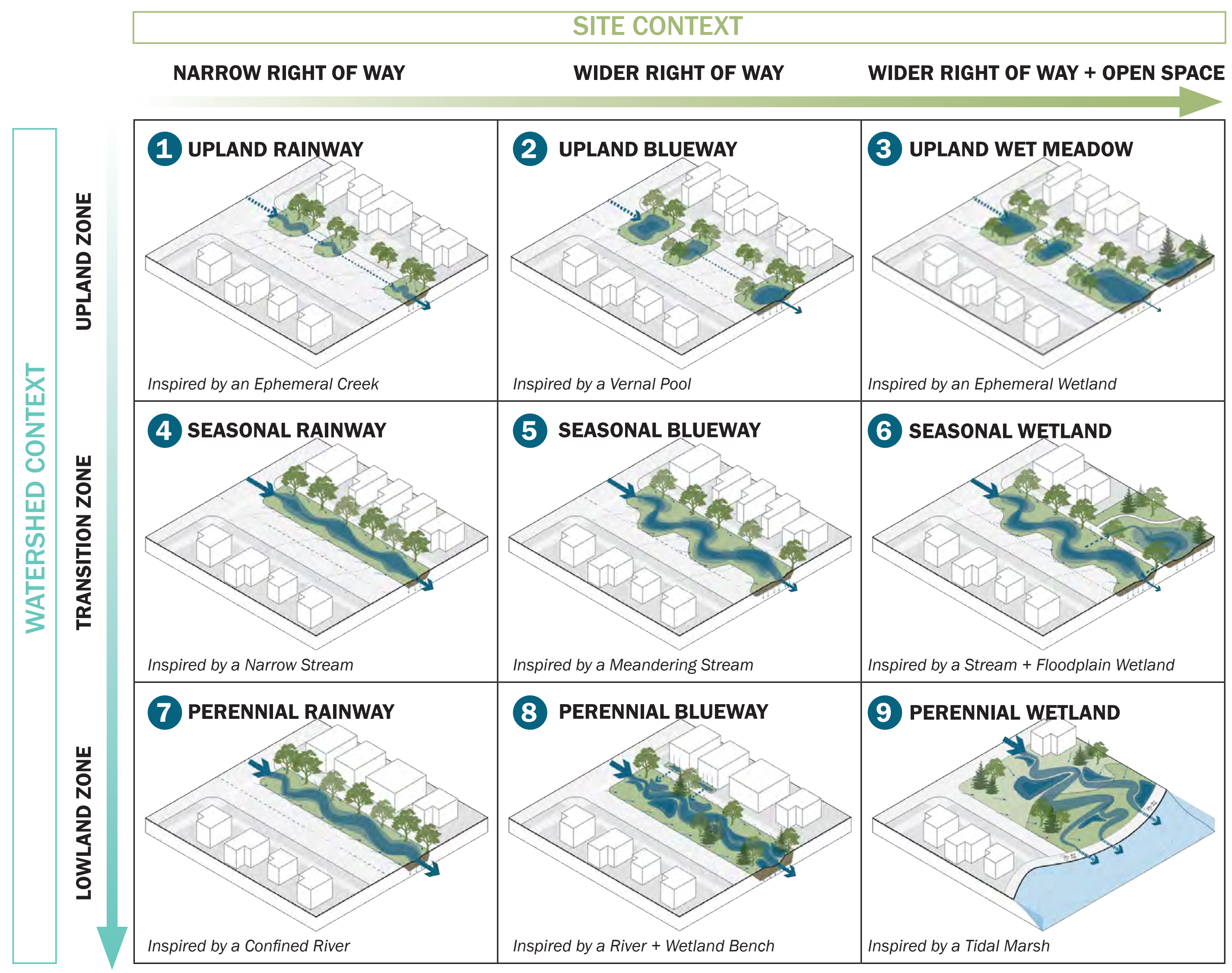
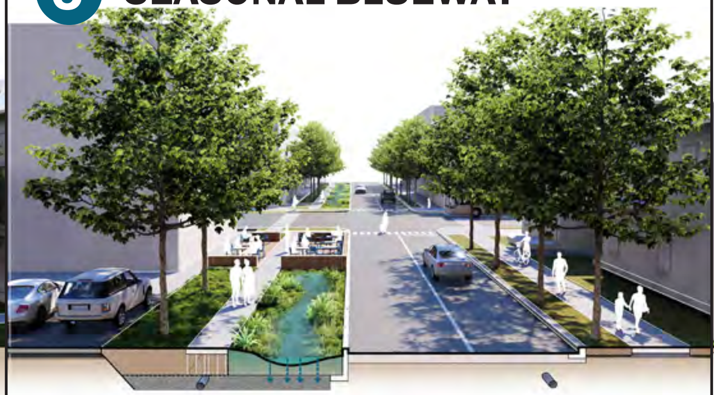


Table 4. City of Vancouver Blue Green Systems Typology Illustrative Demonstration Concepts

WATERSHED CONTEXT / SITE CONTEXT	NARROW RIGHT OF WAY	WIDER RIGHT OF WAY	WIDER RIGHT OF WAY + OPEN SPACE
UPLAND ZONE	**1 UPLAND RAINWAY**  *Inspired by an Ephemeral Creek*	**2 UPLAND BLUEWAY**  *Inspired by a Vernal Pool*	**3 UPLAND WET MEADOW**  *Inspired by an Ephemeral Wetland*
TRANSITION ZONE	**4 SEASONAL RAINWAY**  *Inspired by a Narrow Stream*	**5 SEASONAL BLUEWAY**  *Inspired by a Meandering Stream*	**6 SEASONAL WETLAND**  *Inspired by a Stream + Floodplain Wetland*
LOWLAND ZONE	**7 PERENNIAL RAINWAY**  *Inspired by a Confined River*	**8 PERENNIAL BLUEWAY**  *Inspired by a River + Wetland Bench*	**9 PERENNIAL WETLAND**  *Inspired by a Tidal Marsh*

Introduction

St. George's Rainway under construction, City of Vancouver

Table of Contents

COMMON ACRONYMS

BGS Blue Green System

CSO Combined Sewer Overflow

GRI Green Rainwater Infrastructure

ROW Right of Way

DEFINITIONS

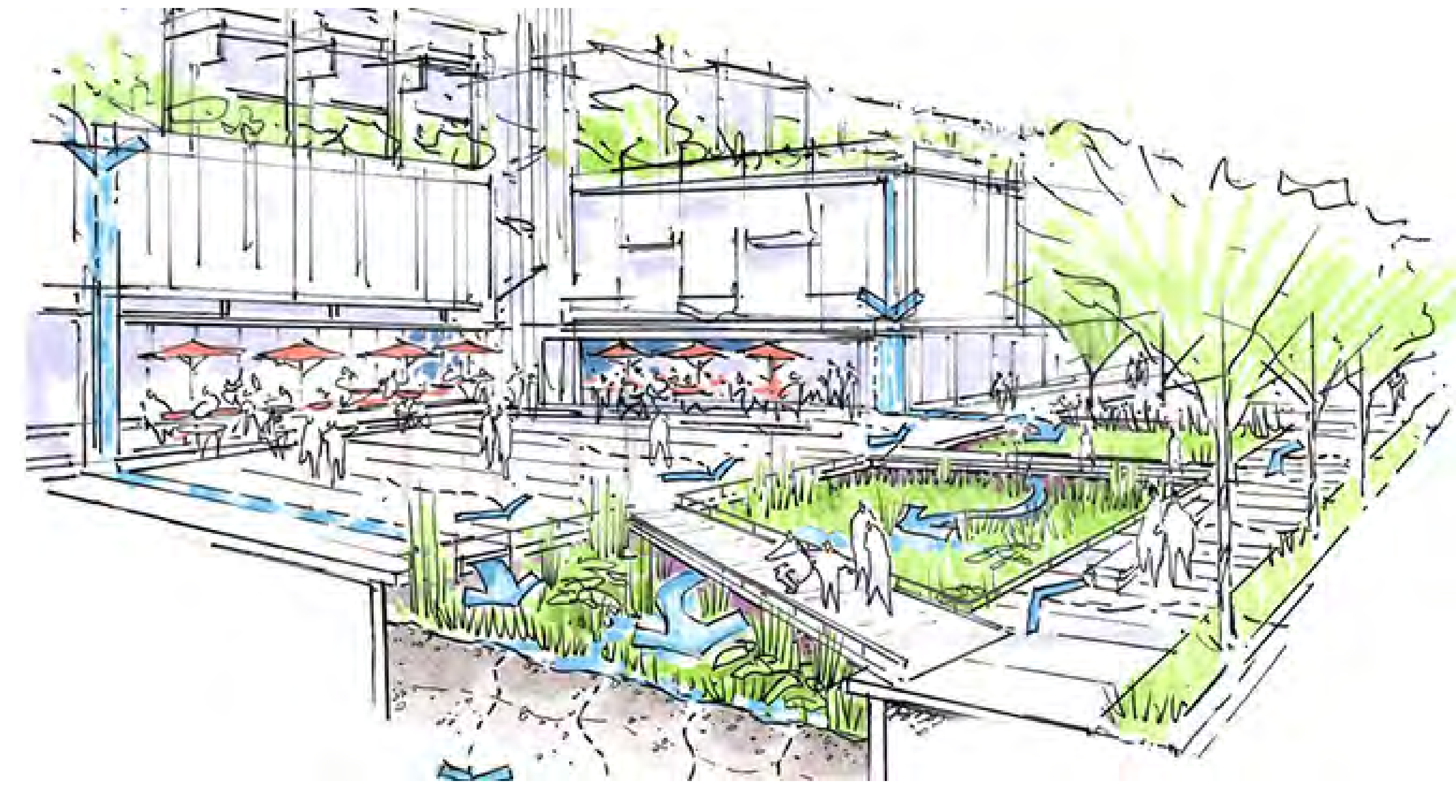
Right of Way

Publicly-owned land associated with the transportation corridor, inclusive of the roadway, sidewalk, and any vegetated or other space between private parcel boundaries.

ACKNOWLEDGMENTS

The City of Vancouver humbly acknowledges that the lands to which the Blue Green Systems Typology Study applies are the unceded territories of the Musqueam, Squamish, and Tsleil-Waututh Nations.

These Nations have called this place home since time immemorial and their ongoing, enduring stewardship of these lands and waters ensures prosperity for future generations. The work to envision Blue Green Systems in Vancouver as a means of restoring urban watershed and ecological health recognizes the lives, cultures, languages, and Peoples of this land and their important role and relationship in the past, present, and future health of these shared waters.



Blue Green System vision illustration from Rain City Strategy. Photo Credit: City of Vancouver

The Blue Green Systems Typology Study authors would like to thank the many City of Vancouver departments and Consultant partners who contributed their time, expertise, and insights to the visioning of these typologies.

Core City Team

CITY OF VANCOUVER

Cameron Owen, Integrated Sewer and Drainage Planning
Tabinda Shah, Integrated Sewer and Drainage Planning
Amir Taleghani, Integrated Sewer and Drainage Planning
Angela Steward, Integrated Sewer and Drainage Planning
Nick Mead-Fox, Green Infrastructure Implementation
Heidi Horlacher, Green Infrastructure Implementation
Sherwood Plant, Transportation
Alisha Merchant, Transportation
Emily Ding, Transportation

Blue Green Systems Typology Workshop Participants, June 2023

Consultant Team

HERRERA Science + Planning + Design

Brian Busiek, PE, Herrera
Erynne van Zee, Herrera
Shannon Gray, PE, Herrera
Kate Forester, PLA, Herrera
Julianne Chechanover, PE, Herrera
Nicole Trolio, Herrera
Rachel Johnson, Herrera
Alice Lancaster, PE, Herrera

MITHŪN

Laura Durgerian, PLA, Mithun
Zoe Kasperzyk, Mithun
Debra Guenther, PLA, Mithun

Introduction

LOOKING BACK

In Vancouver's pre-colonial past, rainwater and snowmelt moved freely through the landscape via natural hydrologic processes. These waters soaked into the soil to recharge groundwater; pooled on the surface in wetlands; and traveled across the landscape in connected systems of creeks and streams. These water bodies were largely in equilibrium with the landscape – characterized by an intricate, balanced exchange of water, sediment, nutrients, and energy flowing between land and waters. Indigenous peoples in the area, including Musqueam, Squamish, and Tsleil-Waututh, shared a special relationship with these same lands and waters - harvesting fish and shellfish, performing cultural and spiritual ceremonies, and using streams and rivers for navigation and transportation.

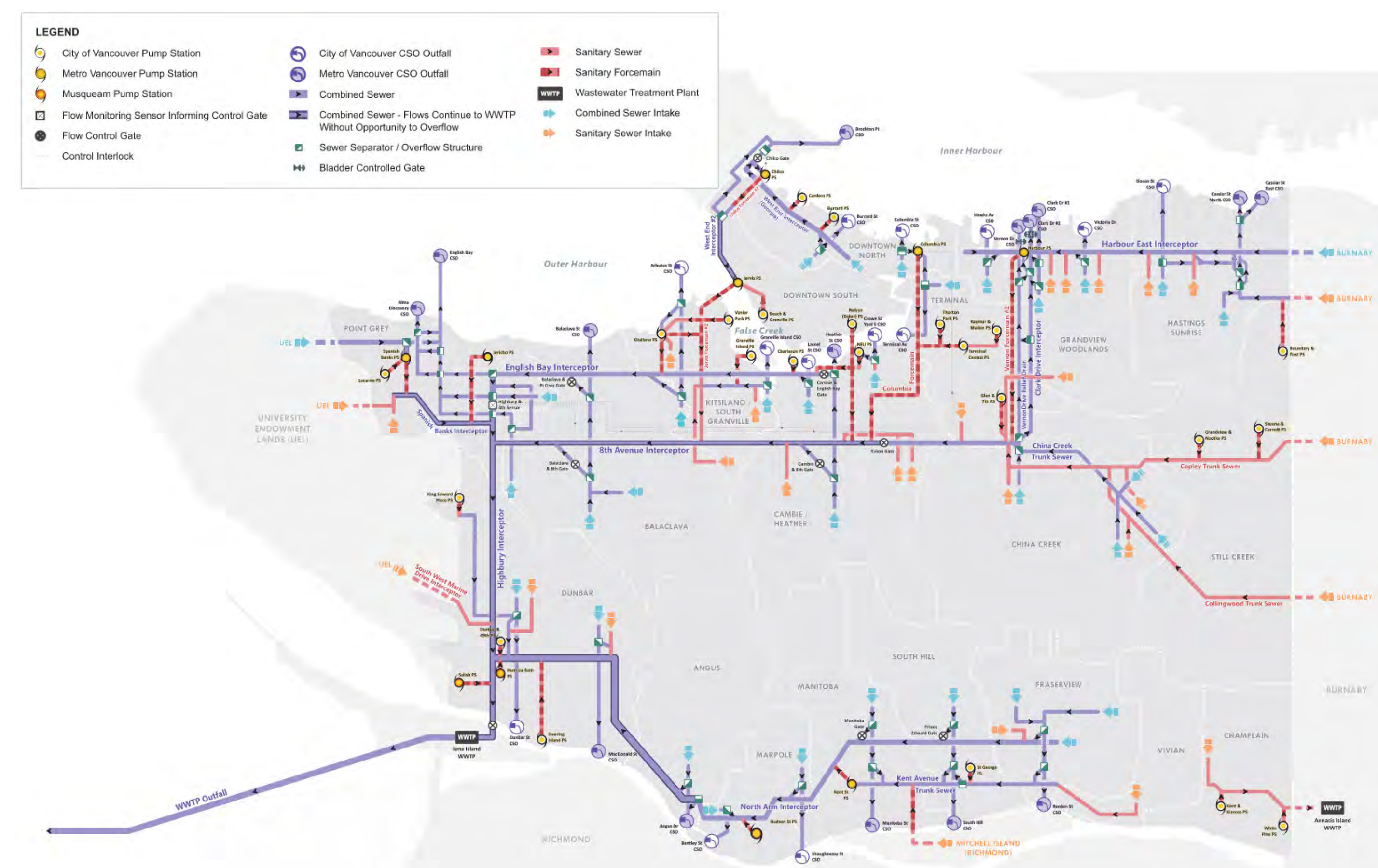
In the ensuing 150+ years of colonization and city-building, natural hydrology was slowly lost. Creeks and streams were diverted and pushed underground into pipes, wetlands and shorelines were filled in, native absorbent landscape was hardened, and people were disconnected from land and water. The equilibrium between land, water, and people was thrown out of balance. The resulting urbanization of these lands and waters yielded increased inland flooding, poor water quality, lost wildlife and pollinator habitat, and other diminished ecosystem functions.

TO LOOK FORWARD

Over the past several years, the City of Vancouver (City) has been working to rethink the way that water interacts with and moves through the urban environment. This reconsideration has been driven by a confluence of challenges, including population growth, aging infrastructure, and climate change, along with a renewed civic interest in improving livability and revitalizing natural, social, and cultural aspects of city life.

In 2019, The City adopted the Rain City Strategy to integrate Green Rainwater Infrastructure (GRI) as a suite of tools for managing stormwater. As other large-scale initiatives build on this work, such as the Broadway Plan, the Healthy Waters Plan, and the Vancouver Plan, the need for larger-scale systems implementation of GRI is driven by the need to service growth, adapt a system with aging infrastructure, eliminate Combined Service Overflows, and create more resilient and livable neighbourhoods in the City.

A key element of these plans and studies is the City's vision to create Blue Green Systems (BGS), which are conceived as a network of park-like streets and open spaces throughout the City that will manage rainwater and floodwater, support active transportation, connect people to parks and nature, and provide habitat for wildlife and pollinators. These Blue Green Systems have the potential to be transformational in the City's response to existing water management issues, such as combined sewer overflows (CSOs) and water quality; extreme rains, droughts, and sea level rise associated with climate change; and development, mobility, and livability pressures.



The historic map of streams circa 1880-1920 from Sharon Proctor's 'Vancouver's Old Streams' (1978) at top right shows a network of natural hydrology across Vancouver. In contrast, the map below shows present-day Vancouver's drainage, sanitary, and combined sewer network. Many of the historic stream are now piped in the sewer network.

Introduction

BLUE GREEN SYSTEMS NETWORK

Vancouver's conceptual Blue Green Systems alignment (2024) shows a vision for urban watershed restoration that parallels the historic watersheds.

Introduction

STUDY PURPOSE

To date, the City has conceptualized Blue Green Systems by utilizing interdisciplinary planning efforts and local-scale rainwater modeling. These efforts led to a preliminary proposed network of Blue Green Systems at the city-scale. To help advance planning for these systems, the City is conducting this Blue Green Systems Typology Study. This study will help inspire, inform, and guide the City in realizing its vision for Blue Green Systems. This study will also help anticipate and navigate the many challenges to implementation. The Blue Green Systems Study will provide a starting point for conversation between developers and City staff to contemplate the expression of Blue Green Systems on specific sections of City streets.

STUDY AT-A-GLANCE

The study is organized and structured as follows:

Background – This section describes the City's vision for Blue Green Systems and some of the key principles that define them.

Precedent Research – This section summarizes research of related projects around the globe and provides an understanding of how other cities have approached planning, design, and implementation. The Appendix includes detailed documentation of the precedents.

Typology Framework – This section presents a framework for broadly conceptualizing Blue Green Systems and introduces a set of nine distinct typology types that respond to specific site and watershed contexts.

Typology Definition and Demonstration – This section further defines the nine distinct typologies by describing general characteristics, design criteria, and performance. The typologies are further supported by a demonstration concept that helps visualize how they each could look, function, and feel in a hypothetical real-world application.

Conclusion – The study concludes with a summary of key characteristics and components for each typology and a discussion of planning, siting, design, and implementation considerations.

Photo credit: Herrera Environmental Consultants

Traditional Green Rainwater Infrastructure

Traditional green rainwater infrastructure often addresses localized rainwater runoff through small-scale design, such as a single-curb bioretention retrofit at the end of a block.

Photo credit: Herrera Environmental Consultants

Blue Green Infrastructure

Blue Green Infrastructure addresses urban rainwater management and watershed restoration at a neighborhood or city scale and simultaneously bolsters urban ecology, multi-modal transportation, and community amenities.

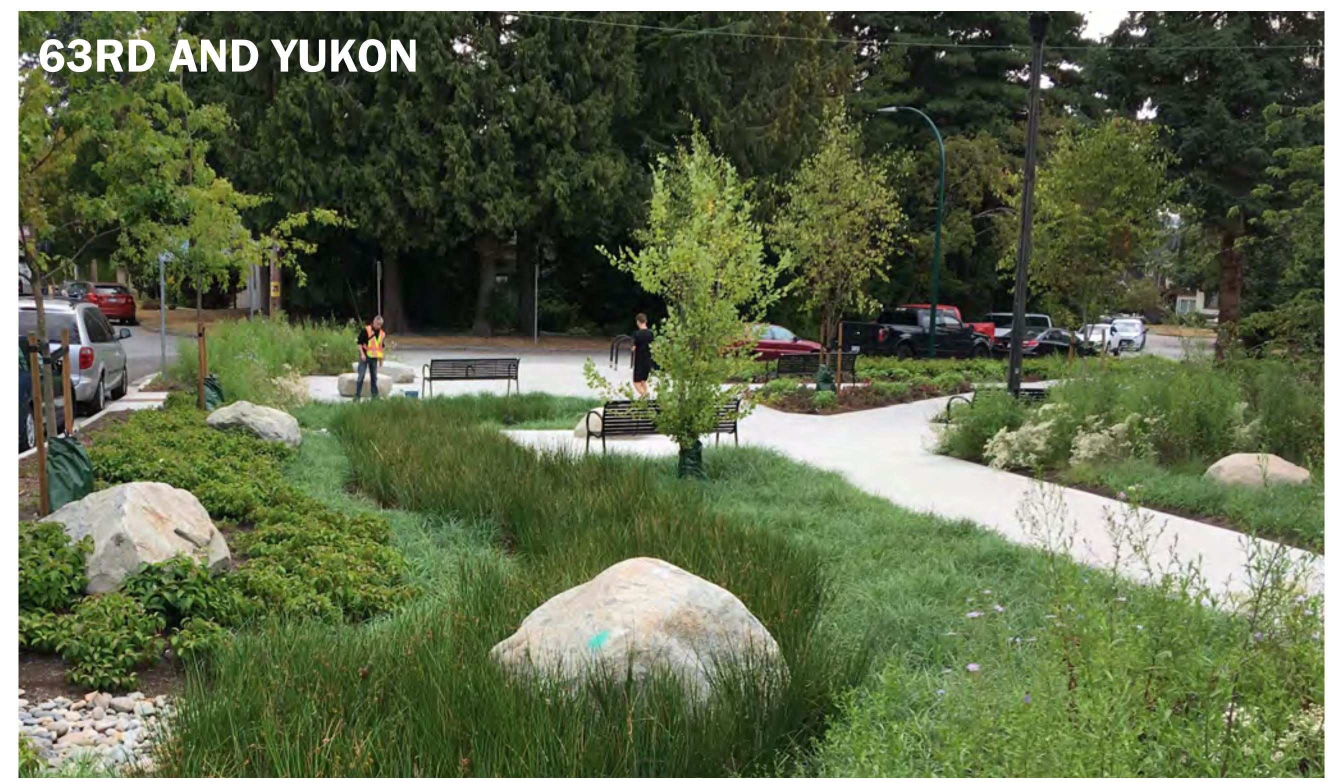
Introduction

VANCOUVER'S FIRST BLUE GREEN SYSTEM PROJECTS

Richards Street between Cordova and Pacific Street is part of the first installment of a citywide blue-green system. The rainwater tree trenches between Dunsmuir and Pacific capture and clean urban runoff while also contributing to the growth of urban forest.

As part of the Grandview Woodland Community Plan, this bioswale captures close to 3,000 sq. meters of rainwater to prevent 3.8 million liters of annual runoff from entering the sewer. As a result, the sewer system has capacity for increased housing density, a key objective of the Community Plan.

The permanent closure of Prince Edward Street led to a new All Ages and Abilities cycling path to promote active transportation and connect the growing community of Sunset Park. A bioswale helps improve water quality to the Fraser River, reduce flooding during extreme storms, and provide habitat for bees, butterflies, and birds.



Within the Marpole Community Plan, 63rd Ave and Yukon St were identified as an opportunity to increase access to green space, enhance rainwater management, and improve neighborhood amenities. A historic stream runs underground near the GRI asset. The design of the plaza evokes the image of fallen trees across a creek. The soils and plantings were selected to clean pollutants in urban runoff with predominantly native species. The plaza contains seating, bicycle racks, trees, and a drinking water fountain.

Background

Sunset Park, City of Vancouver

Background

BLUE GREEN SYSTEMS VISION

"The "blue" in blue green systems refers to integrated water management and green rainwater infrastructure services provided as an inherent component of the blue green system...The "green" in blue green system refers to the value of and the services provided by elements of terrestrial vegetation and biodiversity including trees or urban forest as well as other layers of plants, soils and biota present within the system...Together, blue green systems support both place-making and functional, enjoyable infrastructure that encourages walking and cycling transportation modes."

From 2019 General Manager's Integrated Blue Green Systems Planning report to Vancouver City Council

Many cities across North America and beyond are working to simultaneously improve multiple facets of their communities from the health of their watersheds to the health of their people. The precedent research shows a number of projects around the globe have been implemented to make cities and neighbourhoods more climate and flood resilient, improve water quality, enhance community experiences, and restore habitats at district scales. Many of these precedents are innovative and creative, and there is much to learn from them. But few approach the magnitude and ambition of Vancouver's Blue Green Systems. Three fundamental principles define and set apart Vancouver's comprehensive vision for Blue Green Systems:

1. Blue Green Systems are acts of restoration.
2. Blue Green Systems are multidimensional.
3. Blue Green Systems are systems.

These three fundamental principles along with the scale of their component parts and their expected performance (i.e., managing a 10-year storm) help distinguish Blue Green Systems from typical GRI. They are more than just a "green street".

1 Blue Green Systems are an act of restoration.

Blue Green Systems work to restore natural hydrologic and ecological systems and functions lost through urbanization and to re-imprint them on the City's existing urban fabric as flow paths for water. Parks and open spaces become sponges. Processes that occur in natural systems are reintroduced but with an urban twist that acknowledges the practical constraints present in the City. On the continuum of fully urban to fully natural, Blue Green Systems seek to blend the best of both.

Natural—Urban Systems Continuum

Natural Systems
Unaltered natural systems — including forests, streams, meadows, wetlands, and coastal marshes — provide ecosystem services including clean water and air, carbon sequestration, temperature regulation, and food and habitat for wildlife.

Blue Green Systems
A network of streets, parks, and open spaces that use GRI and other nature-based solutions to manage water, increase habitat connectivity, enhance access to nature, reconnect people with water, and improve climate resiliency by restoring watershed functions using natural systems as a guide.

Urban Systems
A matrix of roads, buildings, and underground pipes make up conventional systems that support people working and living in an urban environment.

Background

2 **Blue Green Systems are multidimensional.**
Blue Green Systems meet the overall goals of restoring natural hydrologic and ecological functions and reconnecting people to and within the environment. In the context of Blue Green Systems typology planning, these intertwined parts and functions are distilled into three elements — ***Blue, Green, and Connect.***

BLUE

Represents restored hydrologic functions and the interaction of water with the landscape. Blue components of Blue Green Systems include a wide variety of distributed and connected GRI facilities (e.g., bioretention planters, bioswales, tree trenches, permeable pavement, etc.) as well as district-scale techniques (e.g., constructed wetlands, open channels, creek-daylighting, floodable spaces, etc.). These components replicate natural hydrologic processes to slow water down, remove pollutants, and hold it within the landscape. Blue features will be designed and built acknowledging critical watershed and site contexts and constraints. Their design emphasis will address site-specific needs now (e.g., peak flow reduction for areas with combined sewers or water quality treatment for areas with separated sewers) but they will meet multiple blue objectives and be adaptable knowing that conditions change over time (e.g., sewers will ultimately be separated, neighbourhoods redevelop, climate is changing).

Objectives
- **Peak flow reduction**
- **Volume reduction**
- **Water quality improvement**
- **Flood management**
- **Sea level rise adaptation**
- **Groundwater recharge**

GREEN

Represents the restored or enhanced ecological functions of Blue Green Systems that were previously provided by the abundant forests, streams, meadows, wetlands, and coastal marshes in Vancouver's pre-colonial past. Green functions include filtering water, purifying air, sequestering carbon, regulating temperatures, and providing food and habitat for wildlife and pollinators. Such functions are provided by a rich diversity of native and climate-adapted trees, grasses, and other plants, as well as natural habitat structures like wood, rock, and carbon-rich soil. Linking these features through Blue Green Systems and nearby ecological corridors also serves to provide important habitat connectivity to allow wildlife to move freely to access nearby food, water, shelter, and breeding habitat.

Objectives
- **Urban forest enhancement**
- **Terrestrial and aquatic wildlife habitat enhancement**
- **Pollinator habitat enhancement**
- **Habitat connectivity**

CONNECT

Represents a restoration or enhancement of the connections and relationships of people with water and the environment. These connections with nature help promote physical and mental well-being and foster a sense of community. Blue Green Systems also represent an opportunity to highlight local First Nations' past and current connections to land and water through materials, design features, educational displays, and partnerships. Further, many of the Blue Green Systems will overlay with existing transportation routes and will thus be critical tools for the promotion of active transportation modes like walking and cycling, which also enhance physical well being.

Objectives
- **Park connectivity**
- **Environmental education and stewardship**
- **Cultural connections**
- **Active mobility improvements**

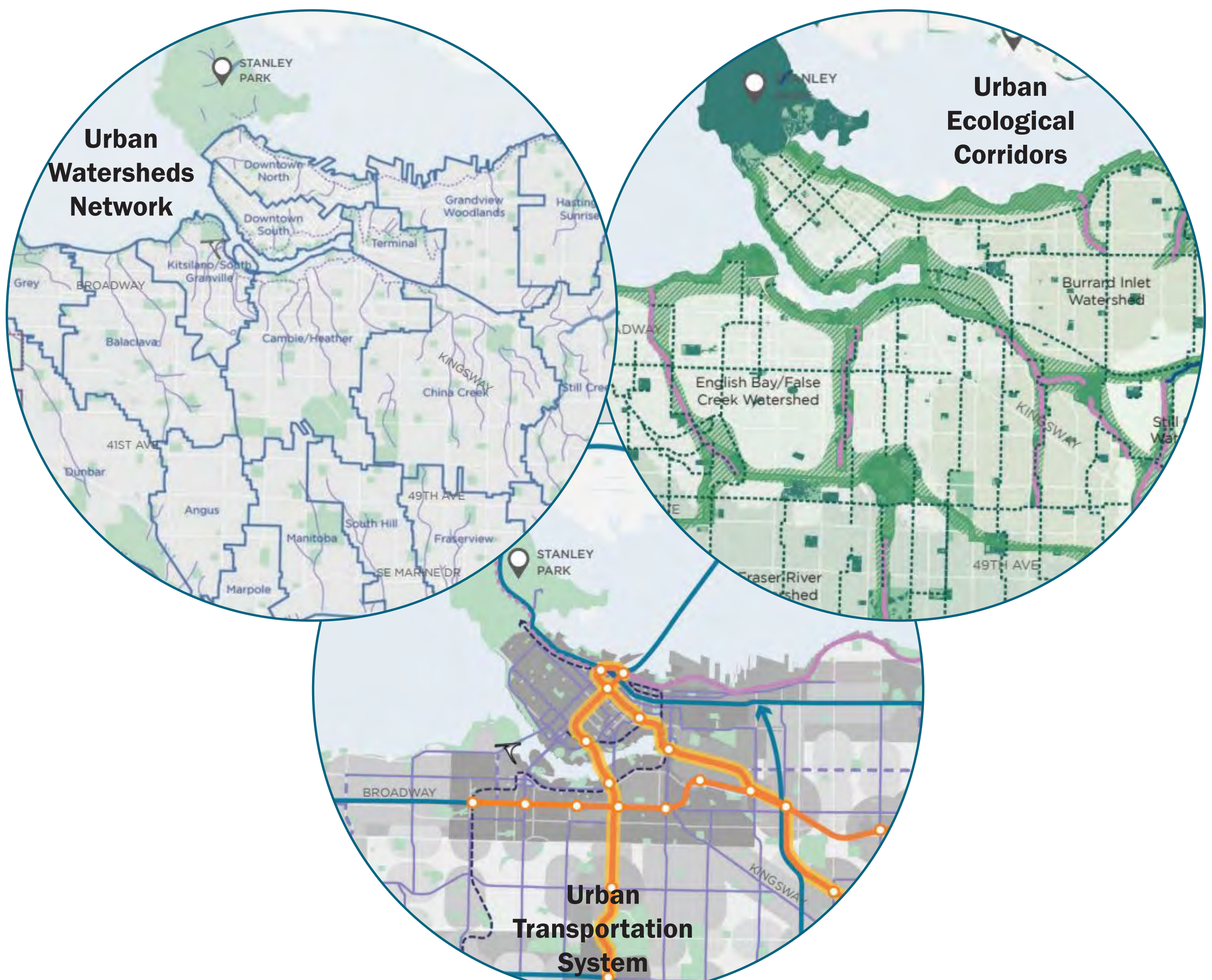
39th Avenue Open Channel Greenway, Denver, CO, U.S. Photo Credit: City of Denver

Background

3 Blue Green Systems are systems.

Only when elements of Blue Green Systems are connected and envisioned as a system at a watershed scale can they achieve their full potential and the Blue, Green, and Connect objectives. “Systems” is clearly part of the name, but the interconnectedness that Blue Green Systems represent is critically important. Within a natural hydrologic system, the movement of water across the landscape relies on a connected network of wetlands, lakes, and channels linked to each other via surface and subsurface flows. The connections and linkages are what allows the system to achieve its overall purpose of moving water from upland to lowland. When natural hydrologic systems are disrupted there are predictable upstream and downstream impacts. The same interconnectedness is a requirement for most systems to function correctly including piped urban drainage, transportation, habitat, and hydrological networks. The interconnected nature of Blue Green Systems is a what makes them more than just a typical “green street.”

System Examples from Vancouver Plan (2022)



21st Street Green / Complete Street Improvements, Paso Robles, CA, U.S.
Photo Credit: Top - SvR Design Company, Bottom - Cannon Engineering Consultants

Background

BARRIERS AND CHALLENGES

The City of Vancouver and many other municipalities globally are striving to design and implement blue green infrastructure to address climate change impacts, urban watershed restoration, and multi-benefit infrastructure goals. The City's first Blue Green System pilot projects, as well as global precedents discussed in the following Precedent section, prove that designing and implementing blue green infrastructure is possible. However, designing this infrastructure as a system and at a city scale is challenging. There are a number of technical and regulatory obstacles to this type of multi-benefit infrastructure being more commonly implemented.

The following is an overview of planning, technical, and regulatory challenges that can be overcome through a combination of site selection, policy change, technical standard development, and creative design. These opportunities to overcome barriers are discussed in more detail in the **Conclusion** section.

Planning Considerations:

Complex urban systems and long-range planning impact the feasible timeframe for implementing Blue Green Systems at a city-scale. Multi-partner collaboration with Transportation, Parks, Community Development, and other City agencies is key.

Siting Considerations:

Designing Blue Green Systems will be uniquely challenging at each site that hosts a Blue Green System. The Blue Green Systems Typology Study will guide the planning and conceptual design; however, each component to the City's Blue Green System network will need to respond to site-specific conditions that may impact feasibility, space available for rainwater management or community amenities, and the realities of urban infrastructure. Site-specific conditions include, but are not limited to:

- Streetlights and electrical lines
- Traffic signals
- Transportation networks
- Fire and Emergency access, including hydrants and road widths
- Water service connections
- BC Hydro ducts
- Water valves
- Above-ground electrical lines
- Urban tree canopy preservation
- Urban tree setbacks
- Critical environmental areas, including wetlands, steep slopes, and in-fill areas

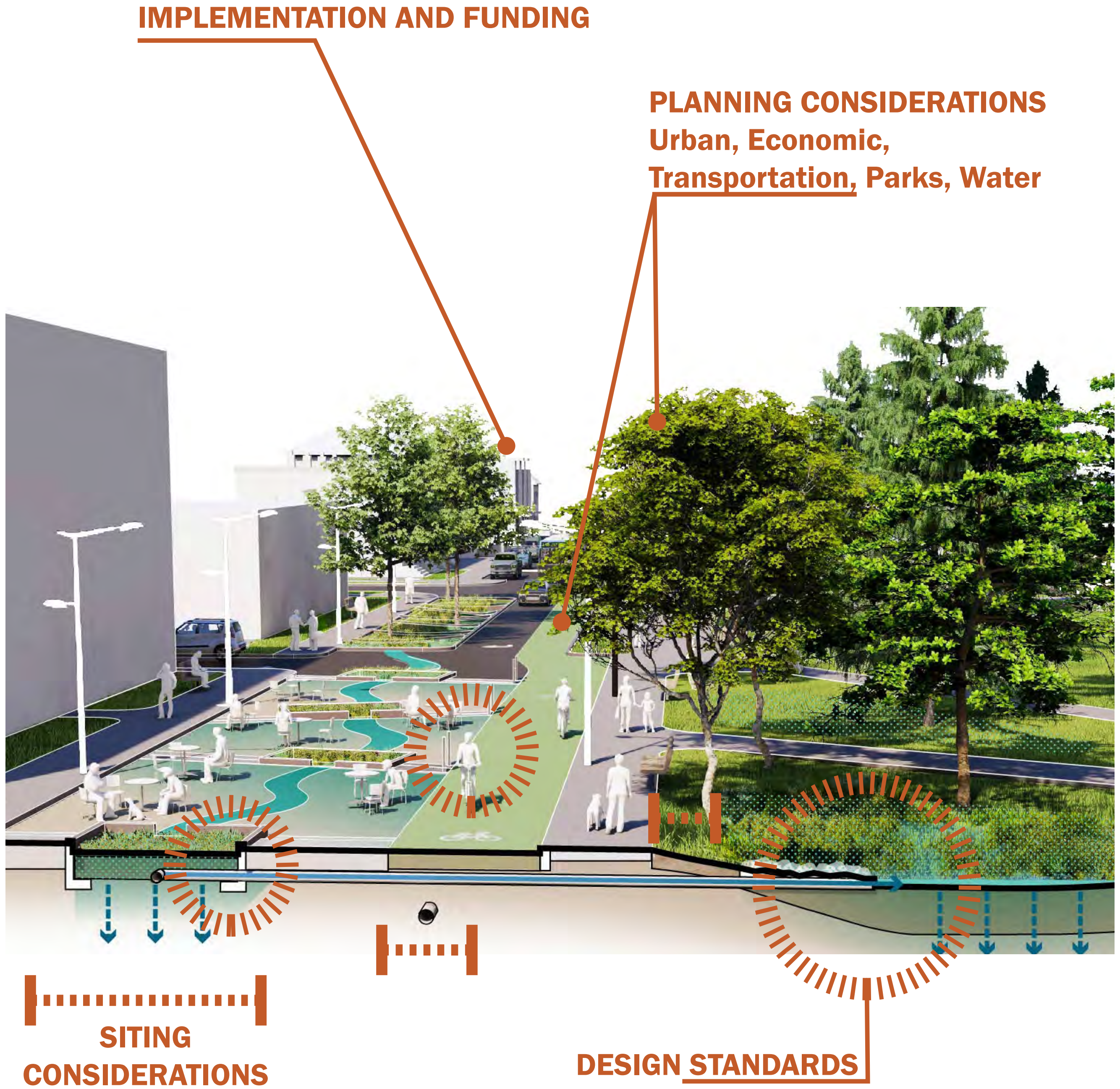
Design Considerations:

Many existing design standards used by the City do not account for integrated Blue Green System designs. This will create challenges, as many designers do not have standards to turn to. The design of Blue Green Systems provides an opportunity to craft new design standards and bylaws to encourage the implementation of these systems at a city-scale, including but not limited to:

- Design standards for larger GRI facilities
- Design standards for conditions where rainwater management, transportation, and/or urban ecology are integrated
- Ponding depth standards to account for more extreme storms due to climate change
- New performance standards for Blue Green Systems

Implementation and Funding Considerations:

The implementation of Blue Green Systems across Vancouver may challenge funding sources, public funding allowances for integrated design projects, and sustained momentum to implement a system that is cohesive and connected. There are opportunities to create implementation policies and unique public-private partnerships to ameliorate these challenges.



Precedent Research

63rd and Yukon blue green system, City of Vancouver

Precedent Research

One of the first steps of this study was to perform precedent research to compile examples of similar projects from other international cities. The goal of this research is to inspire the City's planning and to provide an understanding of how other cities have approached planning, design, and implementation of similar projects.

The Blue Green Systems precedent research was intentionally broad to capture a range of global geographies, visions, drivers and objectives, site conditions, and design approaches. While many of the precedent projects reviewed are not complete analogs for the City of Vancouver's Blue Green Systems, all have features, functions, and/or conditions that were deemed to be informative for the City's planning efforts.

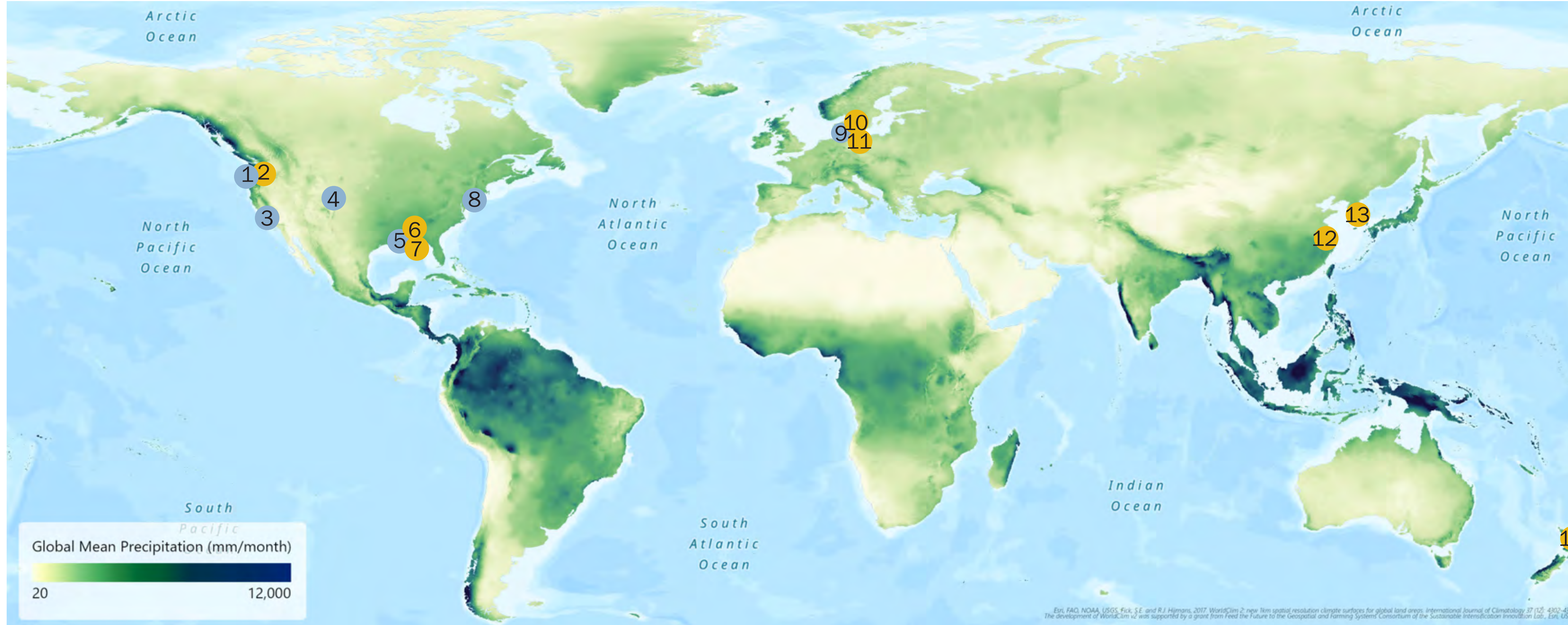
Over two dozen potential precedent projects were initially identified and researched. Of these, 14 precedents were determined to have sufficient information available and to be at least partially analogous to the City's Blue Green Systems. These precedent projects represent a range of implementation stages from planning to fully constructed.

Each of the 14 precedent projects are briefly summarized in the following pages including a summary matrix that provides an at-a-glance comparison of key information for each precedent.

Appendix: Precedent Research includes more detailed information on each of the case studies.

NOTES:

Precedents marked with (X) had more extensive information available for deeper research, and have typically two to three pages of information. Precedents marked with (X) have one page of summary information.



MAP NO.	PRECEDENT NAME	LOCATION	PAGE NO.	FLOOD CONVEYANCE	FLOOD STORAGE	FLOW CONTROL	WATER QUALITY	GROUNDWATER RECHARGE	OTHER
1	SWALE ON YALE	SEATTLE, WA, U.S.	P. 149				■		
2	VENEMA CREEK NATURAL DRAINAGE		P. 153			■	■		
3	21ST STREET GREEN/COMPLETE STREET IMPROVEMENTS	PASO ROBLES, CA, U.S.	P. 155		■			■	
4	39TH AVE OPEN CHANNEL GREENWAY	DENVER, CO, U.S.	P. 159	■	■				
5	BLUE AND GREEN CORRIDORS	NEW ORLEANS, LA, U.S.	P. 163	■	■			■	
6	CHURCHILL TECHNOLOGY PARK		P. 167		■	■			
7	LAKEVIEW/CITY PARK HAZARD MITIGATION		P. 169		■	■			
8	SOUTH JAMAICA HOUSING CLOUDBURST PLAN	QUEENS, NY, U.S.	P. 171		■	■			
9	THE SOUL OF NØRREBRO	COPENHAGEN, DENMARK	P. 175		■		■		
10	COPENHAGEN CLOUDBURST FORMULA		P. 181	■	■				
11	LINDEVANGS PARK		P. 183	■	■				
12	KUNSHAN CONSTRUCTED WETLANDS	KUNSHAN, CHINA	P. 185			■	■		
13	CHEONGGYECHEON STREAM RESTORATION	SEOUL, SOUTH KOREA	P. 187	■					
14	DALDY STREET LINEAR PARK	AUCKLAND, NEW ZEALAND	P. 189				■		■

Precedent Research

Each of the 14 precedent projects are briefly summarized in Table 5 on the next two pages, which provide a comparison of key information for each precedent. A more detailed summary is provided in the Appendix, where each precedent receives a one-page summary spread with important project identification, objective, and status details, as well as available contextual information (e.g., land use, topography, soil conditions, etc.) and design details (e.g., sizing and performance considerations, dimensions, etc.). Six of the precedent projects had more extensive information available. For those precedents, deeper research was conducted, and additional images and other key information are provided beyond the one-page summary. During subsequent stages of this study, these precedents were consulted to help inspire and inform development of Blue Green System typology demonstrations. They will also hopefully serve as inspiration for the City's further planning and design of real world Blue Green Systems.

Table 5: Precedent Research Summary

Project Name	1 Swale on Yale	2 Venema Creek	3 21st St Im-provements	4 39th Ave Greenway	5 Blue + Green Corridors	6 Churchill Tech Park	7 Lakeview / City Park	8 South Jamai-ca Housing	9 The Soul of Norrebro	10 Copenhagen Cloudburst	11 Lindevangs Park	12 Kunshan Wetlands	13 Cheong-gyecheon Stream	14 Daldy Street Linear Park
Location of Project	Seattle, Washington, United States	Seattle, Washington, United States	Paso Robles, California, United States	Denver, Colo-rado, United States	New Orleans, Louisiana, US	Avondale, Louisiana, United States (Greater New Orleans)	New Orleans, Louisiana, United States	Queens, New York, United States	Copenhagen, Denmark	Copenhagen, Denmark	Frederiksberg, Denmark (Greater Copenhagen)	Kunshan, China	Seoul, Korea	Auckland, New Zealand
Owner	Seattle Public Utilities	Seattle Public Utilities	City of Paso Robles	City of Denver	City of New Orleans, Resilience and Sustainability	Jefferson Parish Econom-ic Development Commission (JEDCO)	Sewerage and Water Board of New Orleans	New York City Housing Author-ity (NYCHA)	The City of Copenhagen	Municipality of Copenhagen	Frederiksberg Municipality, Frederiksberg Supply	Kunshan City Construction, Investment, and Develop-ment Company	Seoul Metropolitan Government	Waterfront Auckland Development Agency
Primary Goals	Water quality, regulatory	Water quality, flow control	Flood storage, groundwater recharge	Flood convey-ance, flood storage	Flood conveyance, flood storage, groundwater recharge	Flood storage, flow control	Flood storage, flow control	Flood storage, CSO flow control	Flood storage, water quality	Flood storage, flood convey-ance	Flood storage, flood convey-ance	Water quality, flow control, aesthetics	Flood convey-ance	Water quality, urban develop-ment
Secondary Goals	Flood conveyance	Groundwater recharge, habitat	Water quality	Active mobil-ity, habitat, community amenities	Cultural, economic, public health	Flood convey-ance, active mobility	Shoreline erosion, water quality, habitat, groundwater recharge	Urban nature	Habitat, urban nature	Water quality, urban nature	Urban nature	Biodiversity	Biodiversity, greenspace, urban heat, air quality, economic	Greenspace, biodiversity, active mobility
Primary Driver(s)	Regulatory	Water quality, treatment	Aging infra-structure, drought, climate resilience	Flood risk, water quality, transit, outdoor recreation	Climate resilience	Climate resilience	Climate resilience, hurricanes	Climate resilience, CSO reduction	climate resil-ience, social cohesion, innovation	Climate resilience	Climate resilience	Water quality	Flood risk, economic development	Redevel-op-ment, climate resilience, sea level rise
Location of Project	Street ROW	Street ROW (local)	Street ROW (arterial)	Street ROW	Street ROW (arterial, collector), public parcels	Private development	Public parcel	Public housing	Public parcels, street ROW	Street ROW, public parcels	Public parcel	Public	Street ROW (former highway)	Street ROW
Rainfall	100 cm/yr	100 cm/yr	36 cm/yr	20 - 38 cm/yr	152 cm/yr	162 cm/yr	163 cm/yr	102 - 132 cm/ yr	75 cm/yr	74 cm/yr	74 cm/yr	130 cm/yr	137 cm/yr	112 cm/yr
Land Use	Mixed use	Low density residential	Low density residential	Mixed use, residential	Residential	Mixed use	Mixed use, residential	Mixed use	Neighbourhood	Mixed use, commercial	Mixed use, residential	Commercial - arts plaza	Transportation, mixed use	Mixed use
Topography	1-2% slope	Gradual slope	Unknown	Flat	Flat, more than 50% of City below sea level	Flat, below/at sea level	Unknown	Flat, 0 to 3%	Unknown	Primarily flat	Flat	Flat	Unknown	Flat
Soils	Non-infiltrating	11 m of glacial till, suitable for UIC well	Unknown	Remediated ar-senic and lead on residential parcels	Alluvial depos-its covered with peat (low infiltrating)	Low infiltration	Weak organic soils	Sandy, medium permeability	Unknown	Unknown	Unknown	Unknown	Unknown	Reclaimed land, marine mud, industrial contamination
Groundwater	Unknown	20 - 45 m	Unknown	Low	High	High	Shallow	Low water table	Unknown	Unknown	Unknown	Unknown	High (river)	1 - 1.5 m

Precedent Research

Table 5: Precedent Research Summary, Continued

Project Name	1 Swale on Yale	2 Venema Creek	3 21st St Im-provements	4 39th Ave Greenway	5 Blue + Green Corridors	6 Churchill Tech Park	7 Lakeview / City Park	8 South Jamaica Housing	9 The Soul of Norrebro	10 Copenhagen CloudBurst	11 Lindevangs Park	12 Kunshan Wetlands	13 Cheonggyecheon Stream	14 Daldy Street Linear Park
Utilities	Unknown	Unknown	Moved overhead utilities underground, replaced aging sewer pipes.	Unknown	Unknown	Primarily proposed new utilities	Subsurface	N/A	Unknown	N/A - Master Plan	Unknown	Unknown	Unknown	Unknown
Type	Retrofit	Retrofit	Retrofit	Retrofit	Retrofit (major boulevards)	New development	Retrofit	Retrofit	Retrofit	Retrofit (Master Plan)	Retrofit	New development	Restoration	Rebuild
Runoff Source	Public, Private	Public	Public	Public, Private	Public, Private	Private	Public, Private	Public, Private	Public, Private	Public, Private (city-scale)	Public	Public, Private	Public, Private	Public, Private
Contributing Area (Total)	193 hectares	35 hectares	500 hectares	2600 hectares (Montclair Basin)	Unknown	57 hectares	14-square blocks	Unknown	8.5 hectares	10 km^2	5.4 hectares	Unknown	Unknown	32 hectares
Point of Downstream Discharge	Lake Union	Venema Creek	Salinas River	Globeville Landing Park outfall - South Platte River	Lake Pontchartrain	Levee south of the site	Lake Pontchartrain	Unknown	Peblinge Lake	Copenhagen Harbour, Øresund Strait	Unknown	Local stream	Han River	Waitemata Harbour
Design Criteria	712 m^3/yr, max 0.23 m^3/x flow into swale, up to 20.3 cm deep water.	Unknown	5-year storm 5 mm/hr	100-year storm, 76 m^3/s	Unknown	10-year storm, 60-min time of concentration, 87 mm/hr rainfall.	~650,000 m^3 of stormwater volume, 100-year storm	10-year storm event, Block 5 (580 m^3), Block 7 (610 m^3)	10-year, and 100-year rain events. 18,000 cubic meter, 24-hour retention	100-year storm, one sewer overflow per 10 years.	100-year storm	5-day wetland recirculation, 30-day wetland turnover time	200-year storm, 118 mm/hr	100-year storm surge, 2100 sea level rise
Length	4 blocks (335 m)	5 blocks	5 blocks	1.6 km	Unknown	Unknown	Unknown	N/A	N/A	N/A	N/A	N/A	5.8 km long	N/A
Width of All Elements	5.5 m bioswale, 8.2 m street, 18.3 m ROW	Unknown	25 m ROW, 4 m sidewalk, 1 m pervious pavers, 3 m bike lanes, 7 m vehicle lanes, 5 m median channel, 3 m bioretention	varies	Up to 22 m wide, 3 m deep.	Unknown	Unknown	N/A	N/A	N/A	Total area of 21000 m^2	1000 m^2 total wetland area, 300 mm avg water depth.	Total area 40.5 hectares	N/A
Description of Design Elements	Non-infiltrating bioswale, commercial storefronts	Natural drainage system (bioretention), native plantings including street trees, biofiltration, deep underground injection control (UIC) well	Pervious pavers, bioretention, structural soil cells with trees, natural channel with energy dissipation, infiltration trench, reduction in impervious surfaces	4.9 hectares multi-use trails, amphitheater, playgrounds, open conveyance channel, underground trash vaults, sidewalks and safe connections to transit stations.	Meandering waterway (retention basin) alongside roads, bike lanes and transit, and parks	Naturalized drainage canal, roadside rain gardens, trees, bioswales, detention ponds	Stormwater lagoons/detention basins, constructed wetlands, bioswales, native plantings, trees, stormwater treatment devices to remove trash, debris, sediment	Pervious pavers, rain gardens, trees, underground retention tanks	Floodable park, floodable street, biofiltration prior to discharge	Toolbox of 8 types of projects: park, plaza, street, green street, urban canal, urban creek, retention boulevard, boulevard with bioretention, floodable space, retention basins	Rain gardens, vegetated long basin, detention basin, outdoor theater, sunken public square	Series of 3 inter-connected stormwater wetland cells, includes recirculation and landscape pool, built into art center plaza	Highway removal, stream daylight, ecosystem restoration, connection to regional subways	Lined bioretention systems, primary storm sewer conveyance system, roof water raingardens, street water raingardens, 'water play' park facility

PRECEDENT TAKEAWAYS

The precedent research at the beginning of the project process provided valuable insights for the City to consider in the development of Blue Green System typologies. The following key takeaways informed the development of the typology framework, concepts, and demonstration sites throughout this project.

1 Suite of GRI and Nature-Based Tools

Across the 14 precedents researched during this stage of the Blue Green System study, the majority of them utilized a suite of GRI and nature-based tools to achieve the water, ecological, and community-focused goals unique to each specific precedent. Rainwater management policy varies widely between countries, state, even city; however, many precedents used a common set of GRI and nature-based tools, including:

- Bioretention
- Permeable pavement
- Constructed or natural wetlands
- Planted conveyance channels
- Creek daylighting
- Structural soil cells
- Native and climate-adapted plant ecosystems
- Tree canopy preservation and expansion for urban heat mitigation
- Floodable, multi-use spaces
- Innovative and emerging technologies, such as deep infiltration wells

2 District-Scale Treatment Facilities

As cities compete for space for housing, jobs, community spaces, and climate change adaptation, among many other urban pressures, space for managing urban water becomes increasingly difficult. Many precedents utilized a district-scale treatment facility approach where rainwater from larger portions of urban watersheds are conveyed to larger, centralized facilities for storage, treatment, and later conveyance to receiving water bodies. These district-scale treatment facilities not only address urban water management challenges at a larger scale, but often were paired with other community and ecological benefits such as community centers, stream restoration, or urban tree canopy expansion. Precedents with examples of district-scale treatment approaches include:

- The Swale on Yale (Seattle, Washington)
- 39th Avenue Greenway (Denver, Colorado)
- The Soul of Nørrebro design competition (Copenhagen, Denmark)

3 Flood Storage and Conveyance

Many precedent projects included a combination of flood storage and flood conveyance strategies embedded within the urban public realm. Multi-benefit projects envision central parks as locations to store floodwaters during large storms or linear bicycle networks as floodable streets to convey water to treatment or receiving water bodies once storms have passed.

Platte to Park Hill + 39th Avenue Greenway
Photo Credit: Livable Cities Studio

4 City-Scale Guiding Plan

Of the 14 precedents researched, many of the precedents that had been completed through construction were originally part of a larger, city-scale guiding plan or vision for multi-benefit, regional green infrastructure. The guiding plans provided overarching goals, metrics, and visions to help drive project funding, design, and implementation. Precedents that had been constructed or were in the process of construction with city-scale guiding plans include:

- 39th Avenue Greenway (Denver, Colorado)
- Blue and Green Corridors (New Orleans, Louisiana)
- South Jamaica Housing Cloudburst Plan (Queens, New York)
- Copenhagen Cloudburst Formula (Copenhagen, Denmark)

Typology Framework

Sunset Park, City of Vancouver

Typology Framework

NATURAL SYSTEMS AS THE ULTIMATE PRECEDENT

Given that Blue Green Systems are intended to restore natural hydrologic functions (Blue), natural ecological processes (Green), and connections of people with nature (Connect), it makes sense that natural systems are the ultimate Blue Green System precedent.

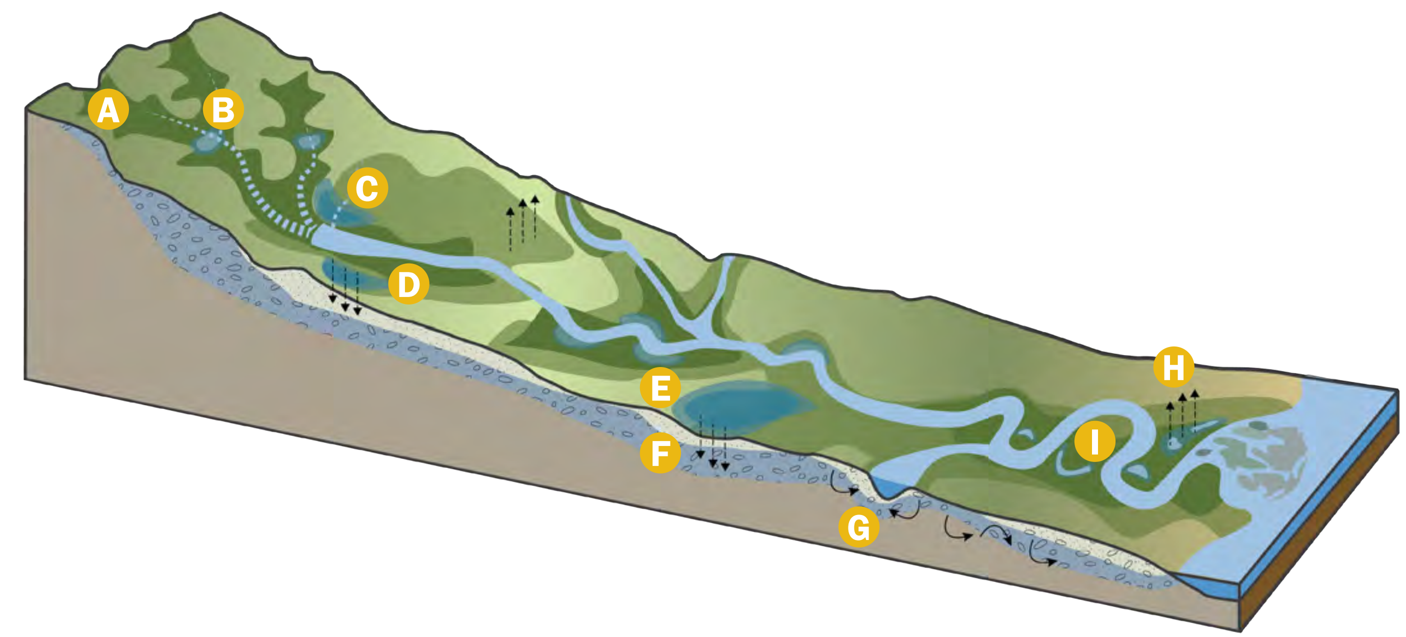
Natural systems represent complex interactions between hydrological, ecological, biological, and sociological processes. Each of these processes influences the others, but in the simplest term, in natural systems, water leads the way. Vegetation communities, people, and wildlife almost always follow the water. For this reason, the Blue aspect of Blue Green Systems is the primary scaffolding in the development of the Blue Green System typology framework. The Blue framework takes its inspiration from the way water interacts with a natural watershed.

THE STORY OF WATER

Imagine the natural hydrologic system in a hypothetical undeveloped watershed. Water winds through the landscape and simultaneously shapes and is shaped by the landscape. In the upper reaches of the watershed, runoff accumulates and flows faintly at first, traveling in ephemeral channels and pooling in natural depressions. As water moves down the watershed, flows from multiple ephemeral streams converge and begin to flow perennially in defined channels with greater volume and power. The shape and course of water's movement is influenced by surrounding geography and topography. Where the landscape is steeper and geology limits the path forward, water may flow turbulently in confined channels. Where the landscape is flatter and there is room for water to spread out, water will slow down. In these less confined settings, streams and rivers will meander and establish floodplains. Along the way, surface water will feed and be fed by subsurface groundwater. Larger natural depressions will fill up with surface water and groundwater to form wetlands and lakes. At the bottom of the watershed, water will meet the next downstream receiving water body and continue on its journey to the ocean.

KEY NATURAL HYDROLOGIC PROCESSES

This story of the way water interacts with its watershed is directed by several fundamental hydrological processes:



A **Conveyance:** Water moves via gravity along flow paths and channels;

B **Ephemeral flow:** In upper sections of the watershed, water may move seasonally;

C **Perennial flow:** In lower sections, water may move continuously;

D **Storage:** Water pools in natural depressions to form ponds, lakes, and wetlands. These too may be seasonal, permanent, or in response to floods;

E **Flood storage:** Water pools in natural depressions in response to floods;

F **Infiltration:** Water soaks into the ground, nourishes plants, and recharges groundwater;

G **Hyporheic exchange:** Water in streams and rivers moves in and out of the subsurface and interacts with groundwater;

H **Evapotranspiration:** Linked processes where water evaporates from the surface **(evaporation)** and is taken up by plants and trees and released to the air **(transpiration)**.

I **Treatment:** Water is cleaned via settling and filtration through soil and plant communities.

A classic definition for traditional green rainwater infrastructure (GRI) is that it includes distributed facilities that "mimic natural hydrology." The hydrological processes that GRI facilities attempt to replicate typically include infiltration, evapotranspiration, storage, and treatment. But as noted above, natural water systems do so much more and at a much larger scale.

Like GRI, Blue Green Systems are inspired by natural water systems and mimic natural hydrologic processes, but they ***do so with a connected systems perspective of the way water moves through the landscape***.

Typology Framework

TYPOLOGY FRAMEWORK OVERVIEW

In the realm of urban planning, a typology represents a group of urban design forms (e.g., buildings, roads, etc.) that possess common essential characteristics. The intent behind the creation of typologies for Blue Green Systems is to help the City plan for these systems by understanding the variability in how they look, feel, and perform based on essential characteristics.

To aid the typology development process, a unifying framework was needed for thinking about and broadly conceptualizing these systems. But what are the essential Blue Green System characteristics to build such a framework? There are a multitude of considerations, including individual Blue, Green, and Connect objectives as well as a range of site conditions or characteristics that could be encountered. Creating a framework and associated typologies with these long lists of potential objectives and characteristics (as well as the many others not noted) would be extremely complicated given the numerous permutations that could be arranged. This calls for a more simplified approach.

Primary Objectives

Rainwater management
- Peak flow reduction
- Volume reduction
- Water quality improvement

Flood management

Sea level rise adaptation

Groundwater recharge

Urban forest enhancement

Terrestrial and aquatic wildlife habitat enhancement

Pollinator habitat enhancement

Habitat connectivity

Park connectivity

Environmental education and stewardship

Cultural connections

Active mobility improvement

Site Characteristics

- Project type (e.g., retrofit or reconstruction)
- Slope (e.g., steep or flat topography)
- Groundwater elevation (e.g., shallow or deep)
- Soils (e.g. well-drained or impermeable)
- Road type (e.g. arterial or local)
- Non-roadway space (e.g. wide or narrow)
- Zoning type (e.g., commercial, residential)
- Utility congestion (e.g. high or low)
- Adjacent space (e.g., park, development, none)
- Sewer system (e.g., combined or separated)
- Hydrologic historic (e.g. historic stream, floodplain)
- Existing tree canopy (e.g., missing or full)
- Community demographics (e.g., race or ethnicity, age, income)

CONTEXT IS EVERYTHING

The proposed essential characteristics for the Blue Green System typology framework are the same two fundamental principles that shape how water moves across the landscape in a natural system:

How much water there is
and
How much space there is for water.

These principles can be described as the **"watershed context"** and the **"site context."**

Sunset Park, City of Vancouver

Typology Framework

WATERSHED CONTEXT

Natural Systems

In natural systems, your location in a watershed provides an important understanding of the amount and character of water that flows past. The watershed context can be loosely categorized into three zones distinguished primarily by flow volume.

- **Upland Zone:** At the headwaters, rainfall and snowmelt begin to collect in seasonal depressions or ephemeral channels, which are typically shallow, narrow, and sometimes discontinuous. The amount of flow in this zone is relatively low.
- **Transition Zone:** As water flows further through the watershed, multiple flows from the upland zone converge into streams that can accommodate increasingly larger flows. Streams may flow for longer extended periods (intermittent flow) or continuously (perennial flow) in channels with typically wider, deeper paths. The amount of flow in this zone is relatively moderate.
- **Lowland Zone:** Water from these many streams and sources converge into increasingly larger river channels that flow continuously. Many will have wide floodplains that allow the water to spread out as the river flows towards an ocean. The amount of flow in this zone is relatively high.

Urban Systems

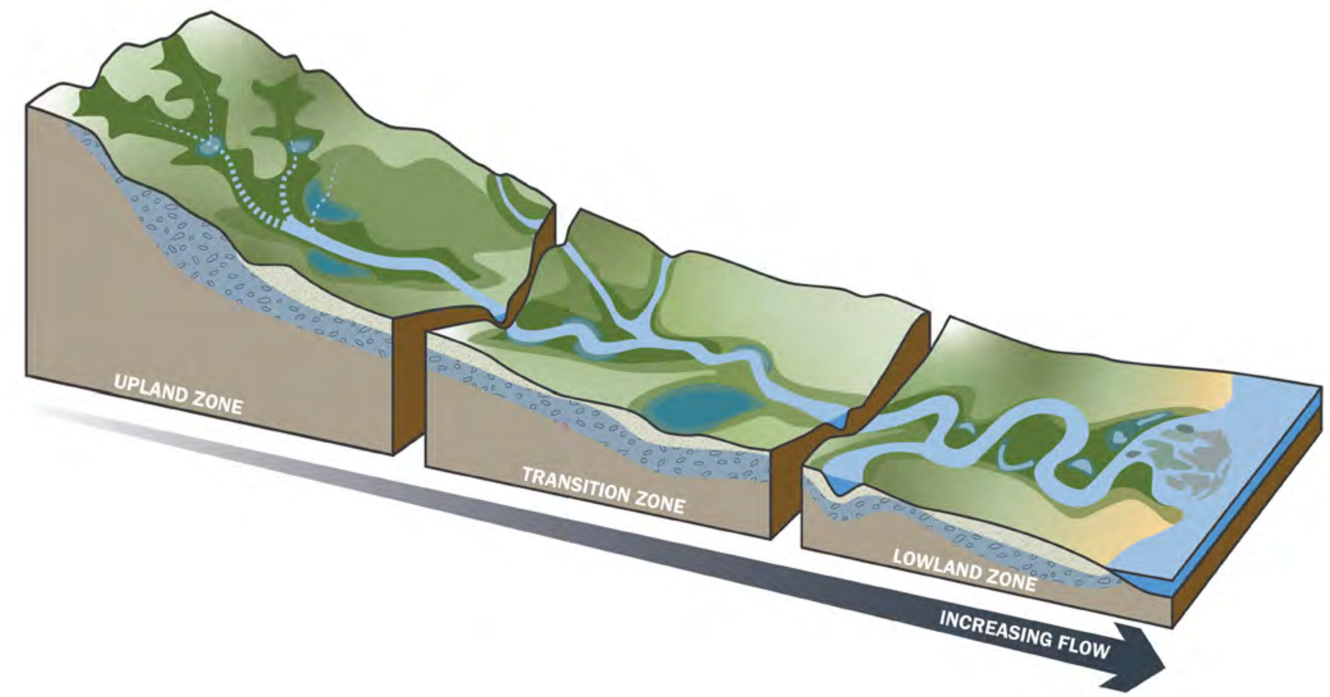
This same idea of watershed context applies in built-out, urban watersheds as well – flows increase from the top of the watershed to the bottom. The key difference is that natural hydrologic processes have been disrupted by hardening the landscape with impervious surfaces and moving water flows into pipes below ground.

In urban systems, your location in the watershed is largely revealed by the diameter of the pipes beneath your feet and the size of the floods that occur when they are overwhelmed.

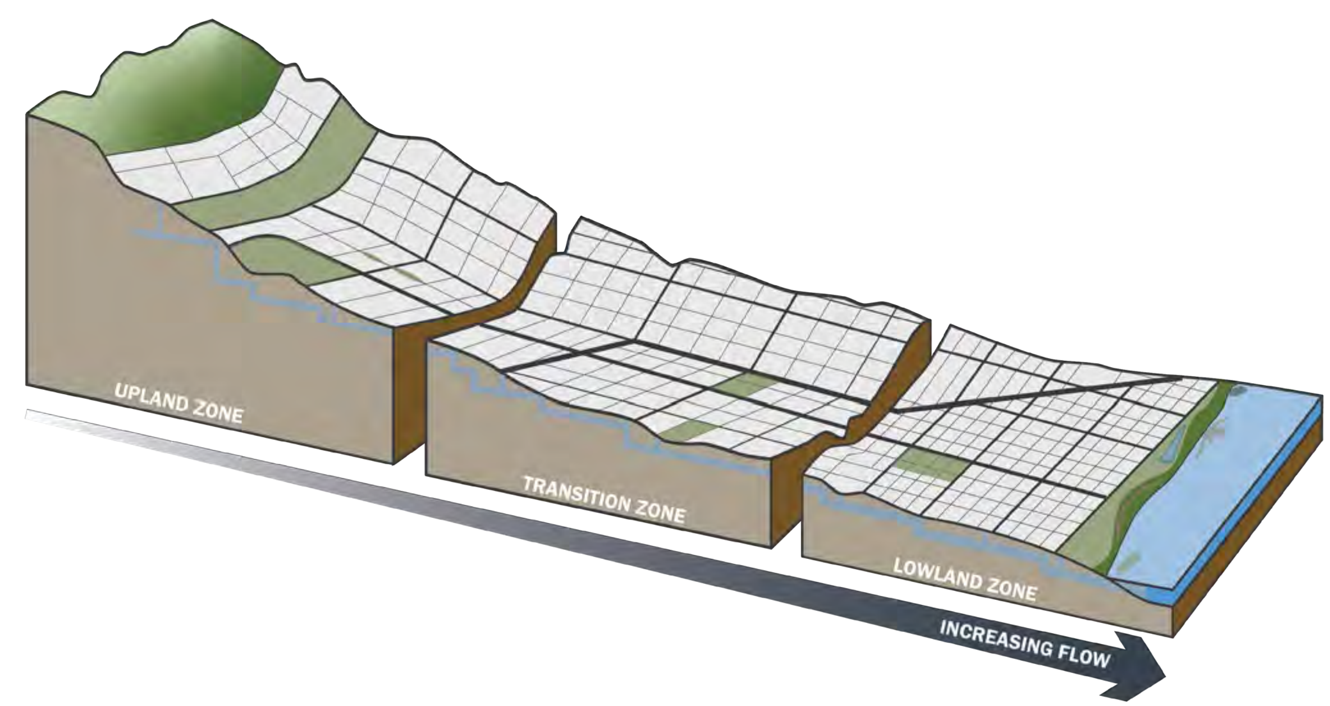
Table 6: Watershed Context Characteristics

	Relative Flow Volume	Flow Type	Flow Connectivity
Upland Zone	Low	Ephemeral	Discontinuous water bodies
Transition Zone	Moderate	Intermittent to perennial	Connected water bodies
Lowland Zone	High	Perennial	Continuous water bodies

WATERSHED CONTEXT | NATURAL SYSTEMS



WATERSHED CONTEXT | URBAN SYSTEMS



Typology Framework

SITE CONTEXT

Natural Systems

In natural systems, the space available for water to flow is directly tied to the surrounding environment (e.g., geology, topography, soils) and the character of the valley it flows through. This site context can be described using three valley types found in natural systems.

- **Confined Valley:** Typically V-shaped, the flow channel strictly follows the narrow valley bottom through the landscape. Channels are more likely to flow in a direct, linear path.
- **Open Sloped Valley:** Typically U-shaped, the space for water on the valley bottom is slightly greater, which allows for channels to meander and for flows to extend into adjacent riparian areas.
- **Broad Floodplain Valley:** In these broad valleys, the space for water is even greater, which allows channels to widen and meander even more. They are surrounded by fully formed floodplains that slow and spread-out water and hold it on the landscape in wetlands and depressions

Urban Systems

The space for water is a critical consideration in urban systems. In addition to geology and topography, numerous other urban conditions (e.g., development, transportation, parking, utilities, etc.) have significant influence on the space available for water to flow.

This fierce competition for space is one of the reasons that water has historically been pushed underground into pipes. These pipe networks though are also subject to capacity constraints with many pipes conveying both rainwater and sanitary sewage, which contribute to combined sewer overflows. Other older pipes are often undersized and ill-equipped to handle flows from more intense precipitation due to climate change. The City's approach to rainwater management services calls for public right of ways to go beyond spaces for cars and provide a more integrated approach to service delivery.

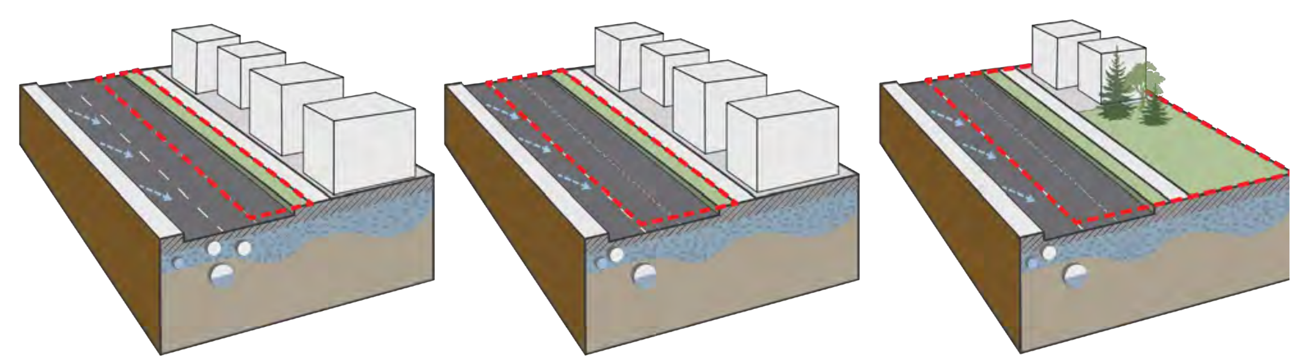
Table 7: Site Context Characteristics

	Space for Water	Channel Form	Adjacent Capacity
Confined Valley (Narrow Right of Way)	Confined, least space	Straight, narrow channels	None
Open Sloped Valley (Expanded Right of Way)	Expanded, moderate space	Slightly meandering channels	Moderate
Broad Floodplain Valley (Expanded Right of Way + Open Space)	Unconfined, greatest space	Fully meandering channel	High

SITE CONTEXT | NATURAL SYSTEMS

CONFINED VALLEY — OPEN SLOPED VALLEY — BROAD FLOODPLAIN VALLEY

SITE CONTEXT | URBAN SYSTEMS



NARROW RIGHT OF WAY — EXPANDED RIGHT OF WAY — EXPANDED RIGHT OF WAY + OPEN SPACE

Typology Framework

PUTTING THE FRAMEWORK TOGETHER

When you interlace the two essential typology characteristics – watershed context and site context, the typology framework begins to take form. Each combination of watershed and site contexts represents a potential Blue Green System typology. There are nine typologies in the matrix to the right. While these nine typologies will aid in highlighting the differences in Blue Green Systems across watershed and site contexts, these contexts represent a continuum of flows and space availability that may be encountered. ***As the contexts rest on a continuum, so too do the Blue Green Systems and the ways that they can be expressed in an urban environment.***

Table 8: Typology Framework Characteristics Summary

WATERSHED CONTEXT (INCREASING FLOW ↓)		SITE CONTEXT (INCREASING SPACE AVAILABILITY →): CONFINED VALLEY (NARROW ROW)	OPEN SLOPED VALLEY (EXPANDED ROW)	BROAD FLOODPLAIN VALLEY (EXPANDED ROW + OPEN SPACE)
UPLAND ZONE		**1 UPLAND RAINWAY**	**2 UPLAND BLUEWAY**	**3 UPLAND WET MEADOW**
	Flow volume	Low	Low	Low
	Flow Type	Ephemeral	Ephemeral	Ephemeral
	Flow Connectivity	Discontinuous water bodies	Discontinuous water bodies	Discontinuous water bodies
	Space for Water	Confined, least space	Extended, moderate space	Unconfined, greatest space
	Channel Form	Straight, narrow channels	Slightly meandering channels	Fully meandering channels
	Adjacent Capacity	None	Moderate	High
TRANSITION ZONE		**4 SEASONAL RAINWAY**	**5 SEASONAL BLUEWAY**	**6 SEASONAL WETLAND**
	Flow volume	Moderate	Moderate	Moderate
	Flow Type	Intermittent to perennial	Intermittent to perennial	Intermittent to perennial
	Flow Connectivity	Connected water bodies	Connected water bodies	Connected water bodies
	Space for Water	Confined, least space	Extended, moderate space	Unconfined, greatest space
	Channel Form	Straight, narrow channels	Slightly meandering channels	Fully meandering channels
	Adjacent Capacity	None	None	High
LOWLAND ZONE		**7 PERENNIAL RAINWAY**	**8 PERENNIAL BLUEWAY**	**9 PERENNIAL WETLAND**
	Flow volume	High	High	High
	Flow Type	Perennial	Perennial	Perennial
	Flow Connectivity	Continuous water bodies	Continuous water bodies	Continuous water bodies
	Space for Water	Confined, least space	Extended, moderate space	Unconfined, greatest space
	Channel Form	Straight, narrow channels	Slightly meandering channels	Fully meandering channels
	Adjacent Capacity	None	None	High

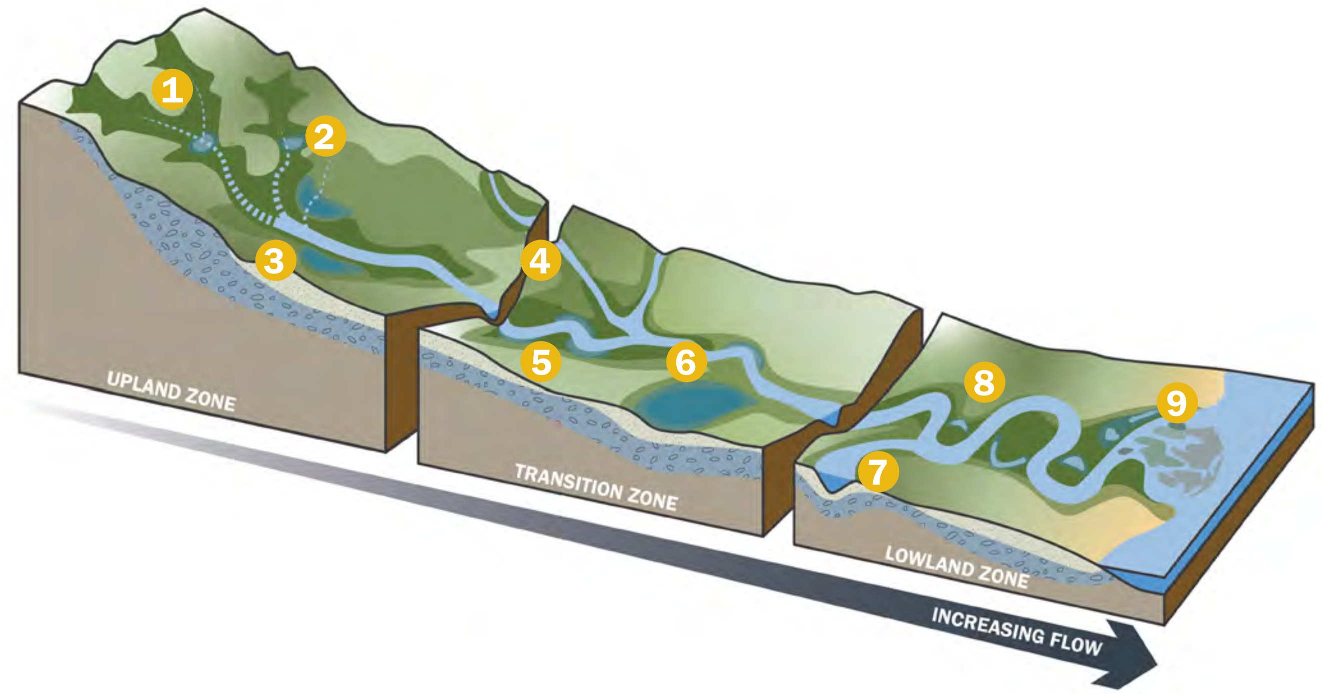
Typology Framework

BLUE GREEN SYSTEMS

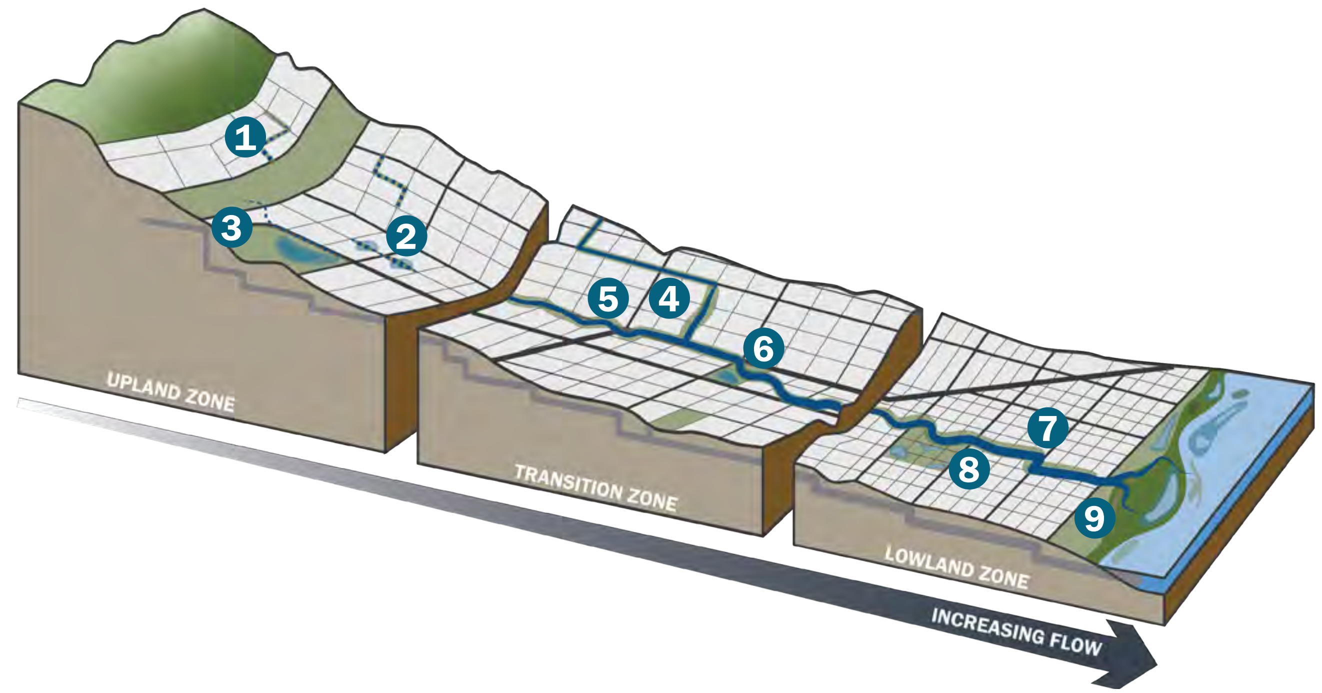
Each of these nine typologies has a natural system analog that reflects the watershed and site contexts within a healthy fully functioning watershed. These natural system serve as an inspiration for the Blue Green System typologies. By inspiring the typologies, fundamental characteristics of each analog are imprinted on the Blue Green System while acknowledging the real-world constraints found in an urban environment.

Natural System Inspiration	*Blue Green System Typologies*
1 **Ephemeral Creek:** Found in the upper reaches of watersheds where runoff flows briefly following rainfall or snowmelt. Some have very faint flow paths, others have a more defined channel.	1 ***Upland Rainway***
2 **Vernal Pool:** A shallow, seasonal pool that accumulates rainwater or snowmelt during the wet season.	2 ***Upland Blueway***
3 **Ephemeral Wetland:** Seasonally wet areas that retain water from accumulated snowmelt, rainwater, and/or shallow groundwater in lowlying areas.	3 ***Upland Wet Meadow***
4 **Narrow Stream:** A stream channel that flows through a confined area where there is limited room for meandering and spreading, but typically contribute to infiltration and groundwater recharge.	4 ***Seasonal Rainway***
5 **Meandering Stream:** A stream channel that follows a curved path and typically is in flatter, wider topography that allows for stream migration.	5 ***Seasonal Blueway***
6 **Stream + Floodplain Wetland:** A meandering stream that migrates in wide valleys and erodes flat areas to create a floodplain that holds water during large storms as it slowly infiltrates into groundwater.	6 ***Seasonal Wetland***
7 **Confined River:** Streams merge into larger river channels in valleys with geologic and topographic features that restrict meandering and floodplains.	7 ***Perennial Rainway***
8 **River + Wetland Bench:** Rivers in partially confined valleys form shallow pockets on the inside of their meanders that hold water during floods and contribute to groundwater recharge.	8 ***Perennial Blueway***
9 **Tidal Marsh:** An open wetland found in the lowlands where streams and rivers from upland and transition zones flow into tidally influenced marine and estuarine water bodies.	9 ***Perennial Wetland***

NATURAL SYSTEM INSPIRATION



BLUE GREEN SYSTEMS TYPOLOGIES



Typology Framework

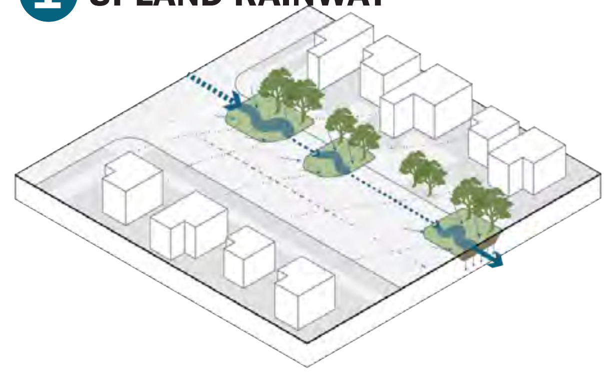
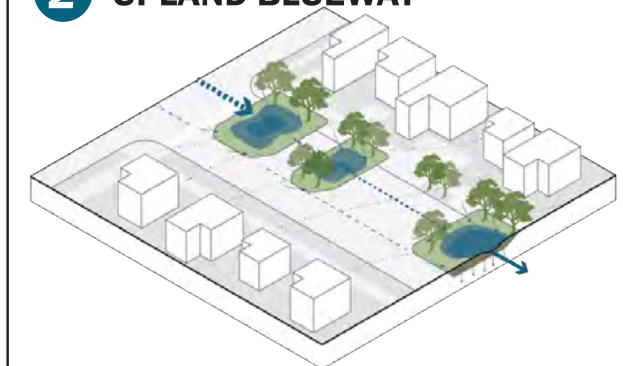
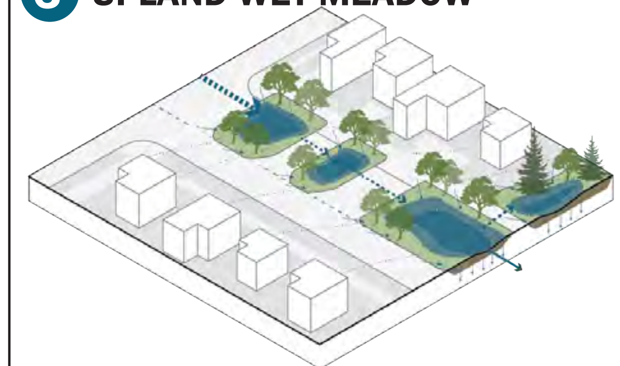
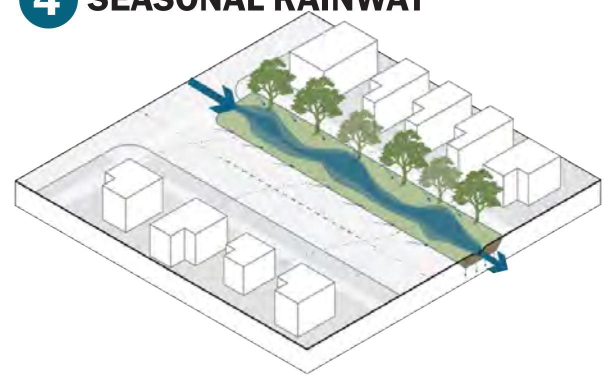
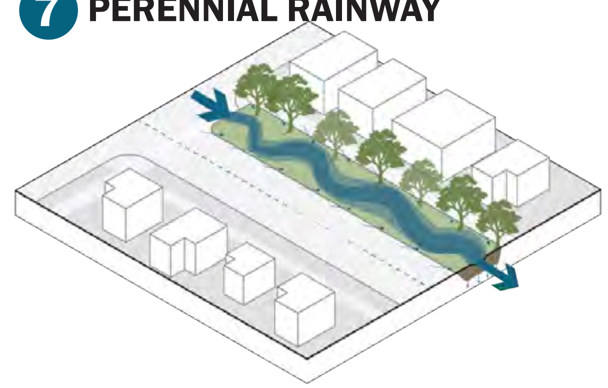
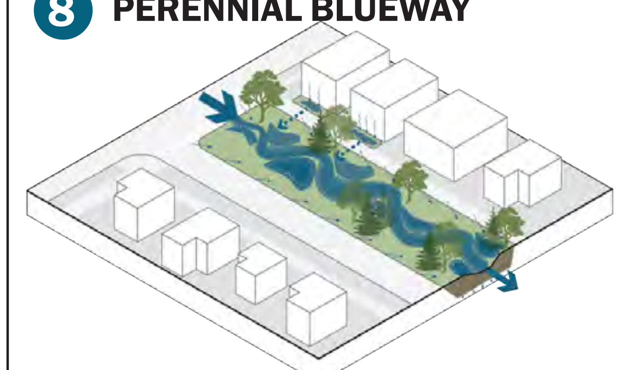
BLUE GREEN SYSTEMS TYPOLOGIES

These nine Blue Green Systems Typologies are defined and explored further in the next section, including application to a hypothetical demonstration site to show how the typology definition could work under real-world conditions.

Table 9: Blue Green Systems Typologies Summary

SITE CONTEXT — *INCREASING SPACE AVAILABILITY*

WATERSHED CONTEXT — *INCREASING FLOW*

	NARROW RIGHT OF WAY	WIDER RIGHT OF WAY	WIDER RIGHT OF WAY + OPEN SPACE
UPLAND ZONE	**1 UPLAND RAINWAY**  *Inspired by an Ephemeral Creek*	**2 UPLAND BLUEWAY**  *Inspired by a Vernal Pool*	**3 UPLAND WET MEADOW**  *Inspired by an Ephemeral Wetland*
TRANSITION ZONE	**4 SEASONAL RAINWAY**  *Inspired by a Narrow Stream*	**5 SEASONAL BLUEWAY**  *Inspired by a Meandering Stream*	**6 SEASONAL WETLAND**  *Inspired by a Stream + Floodplain Wetland*
LOWLAND ZONE	**7 PERENNIAL RAINWAY**  *Inspired by a Confined River*	**8 PERENNIAL BLUEWAY**  *Inspired by a River + Wetland Bench*	**9 PERENNIAL WETLAND**  *Inspired by a Tidal Marsh*

Typology Definition and Demonstration

Site tour of Woodland and 2nd bioswale, City of Vancouver

Typology Definition + Demonstration

The following section describes each typology in detail, including general typology definition information such as where the typology is located in the framework, the natural system inspiration, and overview information about the primary mechanisms and characteristics.

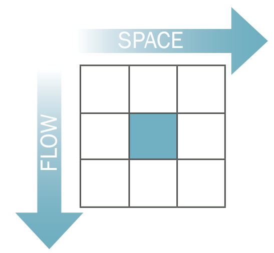
Each typology is then applied to a hypothetical demonstration site to show how the typology definition may work under real-world conditions. Demonstration objectives and site information provide examples for how an illustrative concept could be developed. The conceptual hydrologic design criteria is to manage a 10-year return period rainfall event.

The typology definition and demonstration is further described on the right with thumbnail graphics that show up throughout this section.

TABLE OF CONTENTS

TYPOLOGY DEFINITION

Typology Key

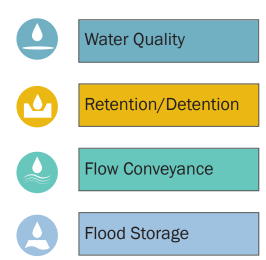


The Typology Key in the top right corner indicates the typology being described. The colored box shows where the typology is situated in the site and watershed contexts, which drives the available space and the anticipated flow associated with each typology.

Natural System Inspiration

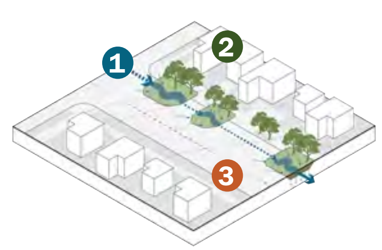
The Natural Systems Inspiration on the top left orients you to which watershed zone the typology inspiration draws from. The star indicates where the specific typology inspiration is shown on the graphic.

Typology At-A-Glance



The Typology At-A-Glance provides overview information on the primary mechanisms that the Blue Green System typology uses to manage rainwater. Additionally, the Characteristics and Potential Components include an overview of how runoff is managed and what typical GRI components may be included.

General Typology Concept



The General Typology Concept shows the typical space and flow characteristics of the Blue Green System typology when applied to a site. Numbers indicate further description, classified by Blue, Green, and Connect.

TYPOLOGY DEMONSTRATION

NOTE: The demonstration site concept are for conceptual illustration of Blue Green Systems planning. The illustrations show how Blue Green Systems could address water, ecological, and community needs to aid in communicating the potential impact and benefit of Blue Green Systems. These are not proposed design. Any resemblance to recognizable locations does not imply plans nor concepts for future design projects.

All potential park GRI features would be determined and developed by Park Board. All transportation amenities would be determined by City of Vancouver Transportation and subject to transportation network compatibility, thorough review and analysis across all Transportation branches, and utilize approved best practices guidelines.

Demonstration Site Overview

The Demonstration Site Overview contains example objectives and context for Blue, Green, and Connect considerations. An example site plan and cross section highlight how site context informs Blue Green System concepts.

Demonstration Site Concept

The Demonstration Site Concept shows an illustration for how the Blue Green System typology may be adapted to a site or project. Arrows illustrate how water would flow through the concept. These Demonstration Site Concepts are planning illustrations only, and are not proposed designs.

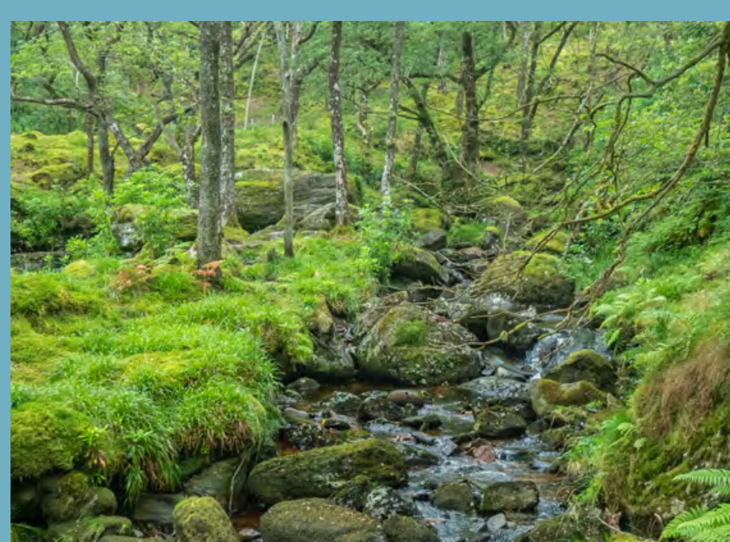
Demonstration Site Section Perspective

The Demonstration Site Section Perspective is an illustration showing in 3D how the Blue Green System typology may be adapted to a site or project. Arrows illustrate how water flows. The 3D angle gives readers a better sense of the ecological and community benefits of Blue Green Systems in addition to the water management benefits

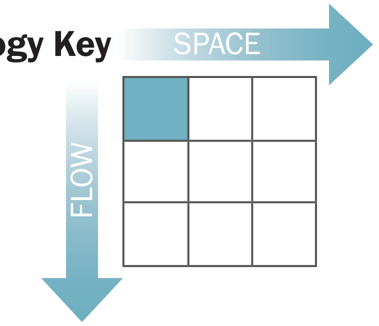
Typology 1: Upland Rainway

INSPIRED BY AN EPHEMERAL CREEK

In natural systems, an ephemeral creek is dry during the summer and extended periods without rainfall but can flow continuously during consistent winter rainfall. Rainwater flowing in an ephemeral creek may infiltrate and recharge groundwater instead of moving downstream. The urban analog for this typology features narrow, distributed and discontinuous GRI that manages local runoff in a narrow section of the right of way.



Typology Key



TYPOLOGY DESCRIPTION

Blue

1. Discontinuous, linked or unlinked via piped connections
2. Recharges groundwater through infiltration, or temporarily stores water.
3. All runoff from contributing catchment is retained. No downstream flows except in extreme events.
4. GRI is sized to capture all runoff flows for a 10-year event.

Green

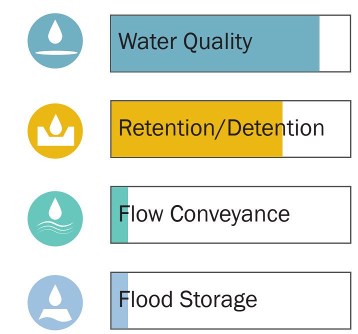
5. Native vegetation and native soils
6. Drought-resistant trees for habitat, shade
7. Floodable grassland

Connect

8. No encroachment into traffic lanes.
9. Extends into parking lane to calm traffic in neighbourhoods

TYPOLOGY AT-A-GLANCE

Primary Mechanisms



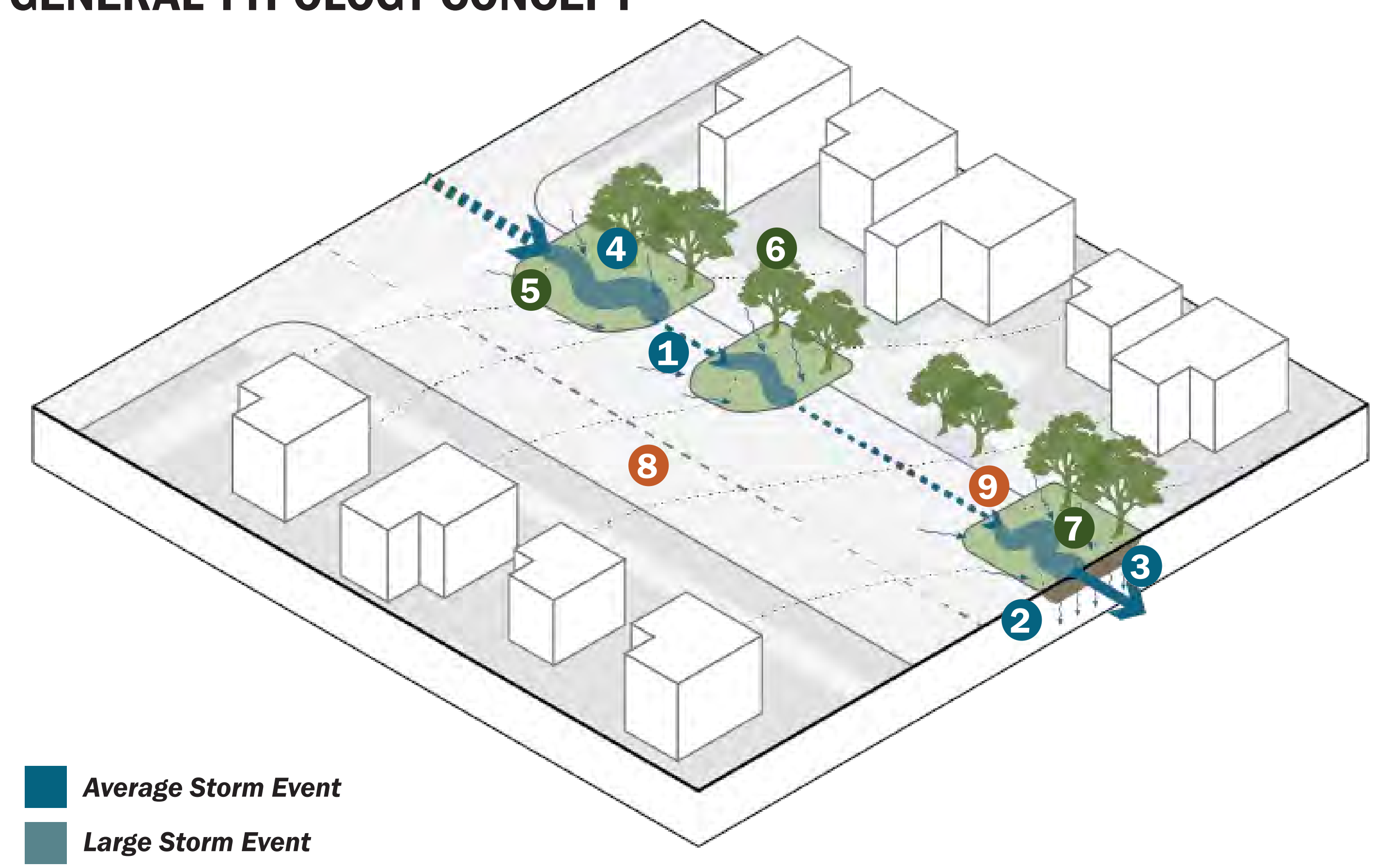
Characteristics

- Manages local runoff + minimal to no upstream flow
- Utilizes discontinuous distributed facilities
- Uses narrow road cross sections within ROW

Potential Components

- Bioretention planters/ bump-outs
- Tree trenches
- Permeable paving

GENERAL TYPOLOGY CONCEPT



Typology 1: Upland Rainway

TYPOLOGY DEMONSTRATION SITE

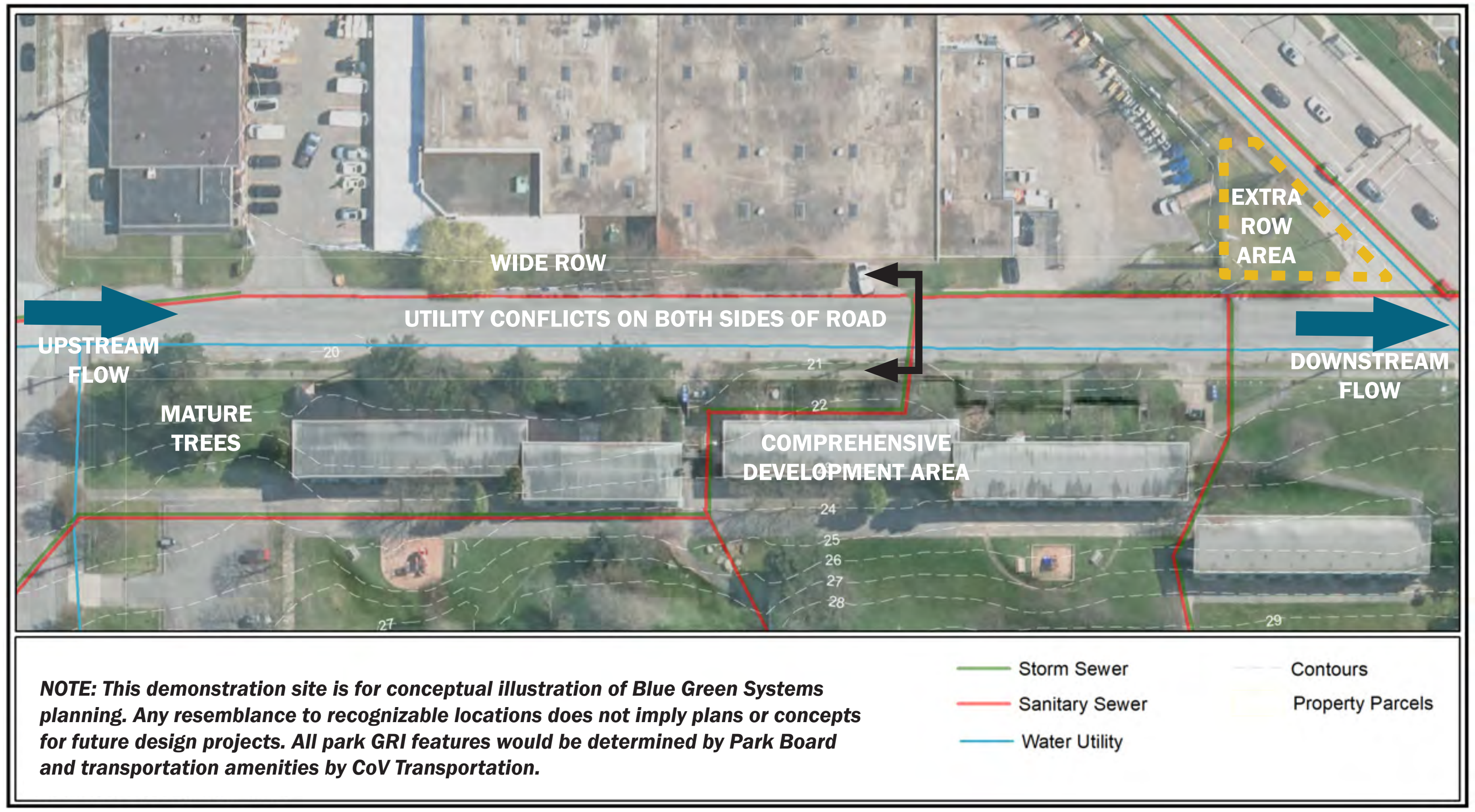
The Typology 1: Upland Rainway demonstration site is in a highly commercial neighbourhood adjacent to several major highways. The contributing area is highly impervious but limited to a few blocks in size. The area is served by separated sewer pipes, so this demonstration project can focus on water quality treatment. Subsurface utilities on both sides of the street constrain the space available for the Blue Green System; however, the over-sized street ROW with wide shoulders offer opportunities. Although a local street, there is a desire to maintain existing vehicular lanes and accommodate future bike connections.

What is happening in the Extra ROW Area? Occasionally opportunities like the Extra ROW Area at the right corner may be present. Although outside the typical typology conditions, this area may help expand the Blue Green System footprint.

DEMONSTRATION SITE OBJECTIVES AND CONTEXT

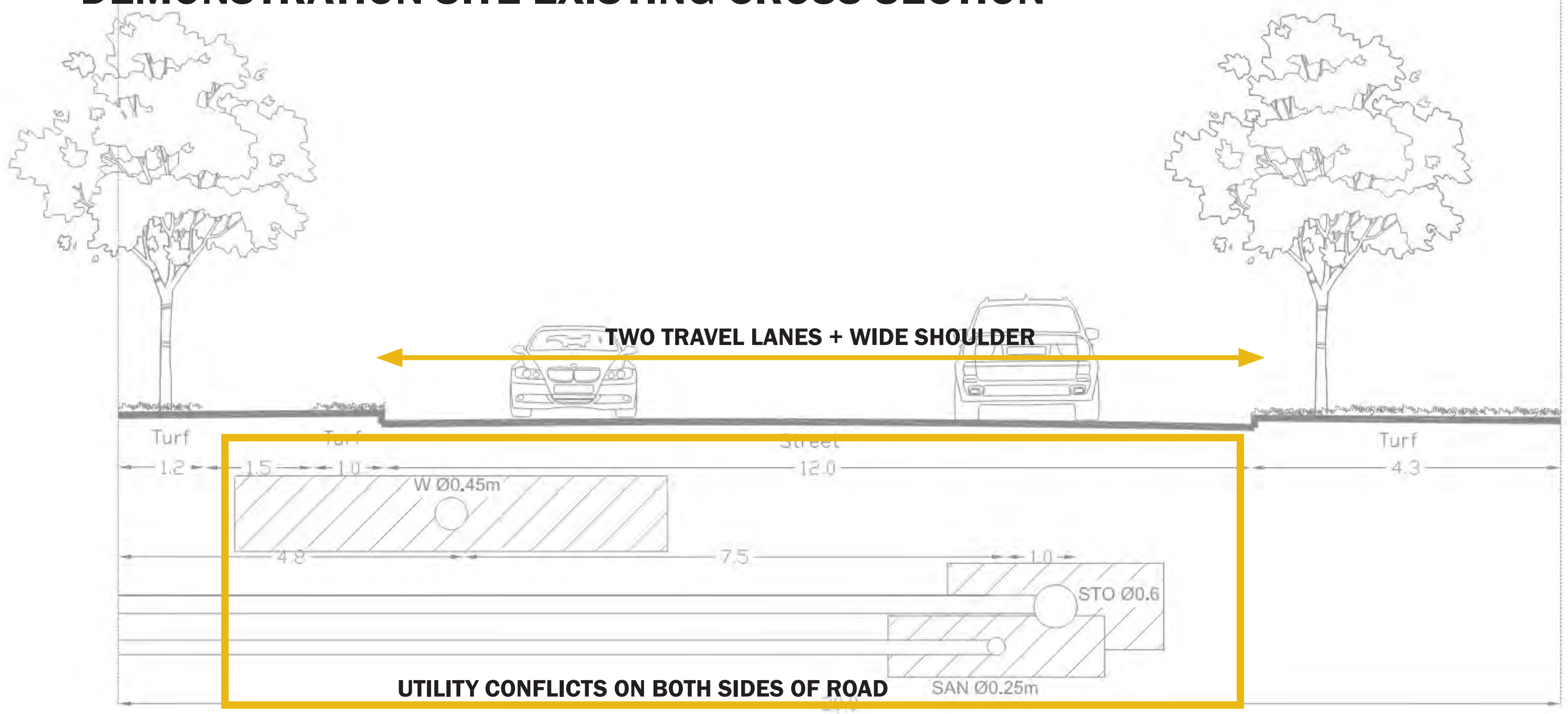
	Blue	Green	Connect
Objectives	• **Water quality improvement** • Volume reduction • Groundwater recharge	• **Habitat connectivity** • Pollinator habitat enhancement	• **Active mobility improvement**
Neighbourhood Context	• Highly urbanized and impervious development	• Habitat corridor • Nearby community and regional parks	• Regional bike route networks • Local road near highway
Site Context	• High infiltrating soils • Flat road (<1%) with steep slope adjacent • High utility congestion	• Habitat corridor • High tree canopy density	• Proposed bikeway connection nearby • Future Rapid Transit Station nearby • Commercial and comprehensive development

DEMONSTRATION SITE PLAN



NOTE: This demonstration site is for conceptual illustration of Blue Green Systems planning. Any resemblance to recognizable locations does not imply plans or concepts for future design projects. All park GRI features would be determined by Park Board and transportation amenities by CoV Transportation.

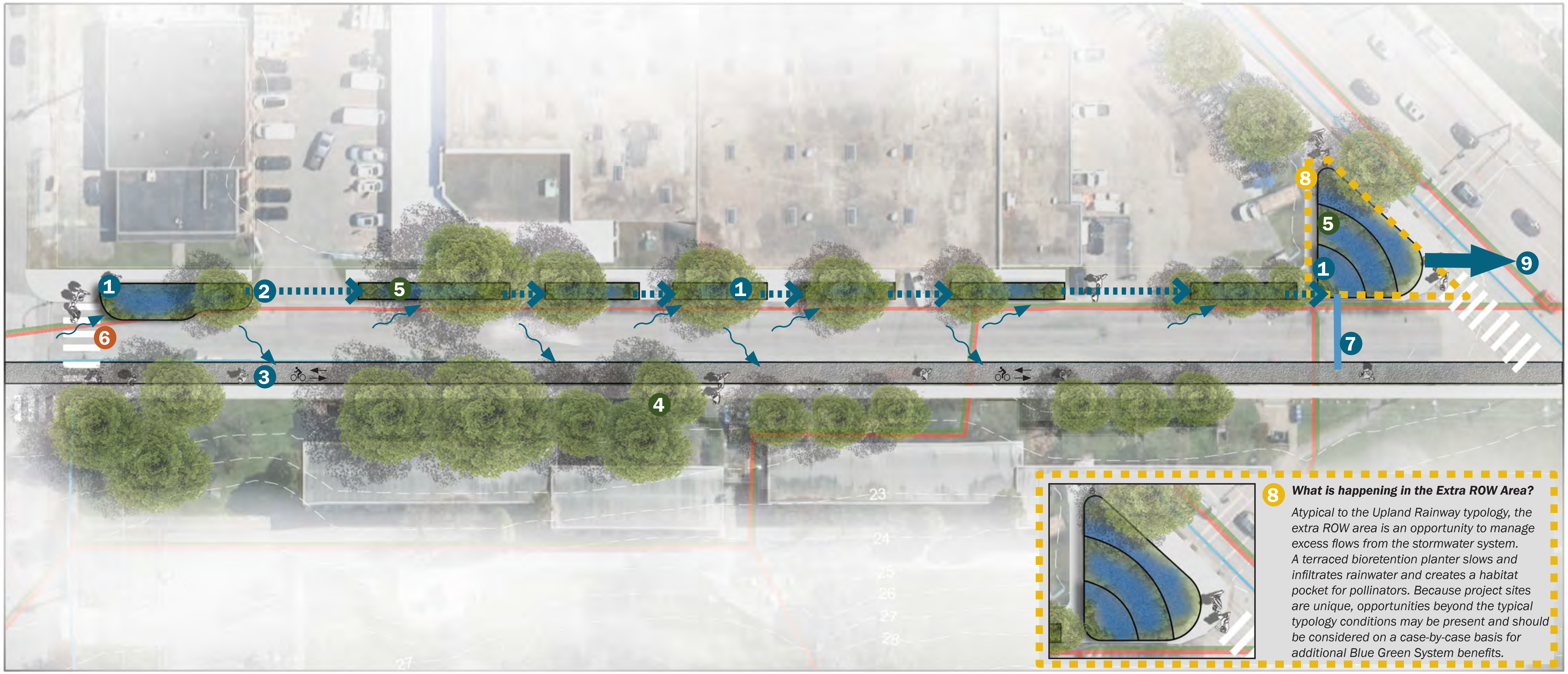
DEMONSTRATION SITE EXISTING CROSS SECTION



Typology 1: Upland Rainway

Typology 1: Upland Rainway is the closest in character to a typical green street, which employs discontinuous facilities to manage road runoff. For this demonstration site, a set of four infiltrating bioretention planters with high flow piped connections are installed within existing vegetated areas on the north side of the street to capture runoff from the crowned roadway. Runoff flowing to the south side of the street is collected within a permeable bike lane with a bottom liner to avoid infiltration above a water utility. The liner is sloped to the north to direct accumulated flow to a linear sump away from the water utility. At the end of the block, a bioretention planter promotes infiltration.

DEMONSTRATION SITE CONCEPT



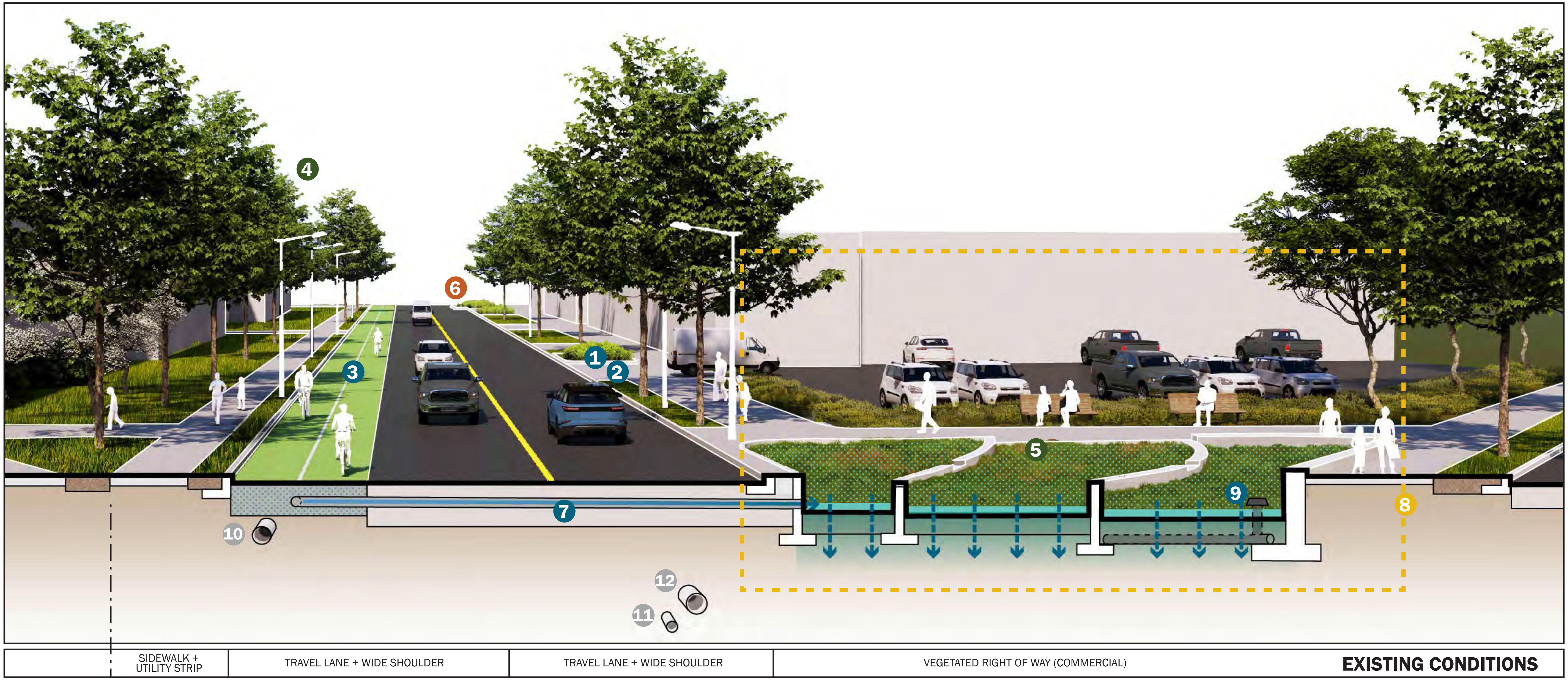
NOTE: This demonstration site is for conceptual illustration of Blue Green Systems planning. Any resemblance to recognizable locations does not imply plans or concepts for future design projects. All park GRI features would be determined by Park Board and transportation amenities by CoV Transportation.

- RUNOFF
- PIPED CONNECTION
- PIPED HIGH-FLOW CONNECTION
- FLOW TO DOWNSTREAM BGS

1. INFILTRATING BIORETENTION
2. PIPED HIGH-FLOW CONNECTION
3. BIKE LANE WITH LINED PERMEABLE PAVEMENT FACILITY
4. ADJACENT EXISTING TREE CANOPY
5. EXPANDED NATIVE POLLINATOR HABITAT
6. CROSSWALK BUMPOUTS TO SLOW TRAFFIC
7. PIPED CONNECTION FROM PERMEABLE PAVEMENT TO BIORETENTION
8. EXTRA ROW AREA PROVIDES OPPORTUNITY FOR BGS FOOTPRINT EXPANSION - SEE INSET
9. OVERFLOW CONNECTION TO DOWNSTREAM BGS

Typology 1: Upland Rainway

DEMONSTRATION SITE PERSPECTIVE



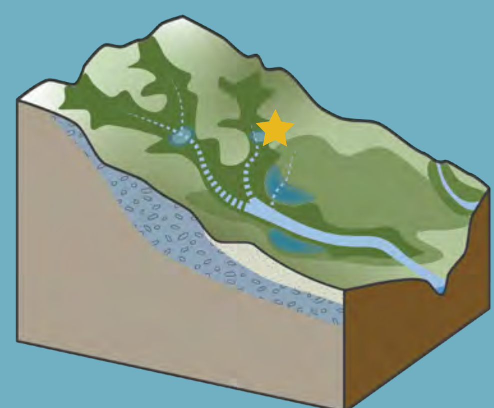
NOTE: This demonstration site is for conceptual illustration of Blue Green Systems planning. Any resemblance to recognizable locations does not imply plans or concepts for future design projects. All park GRI features would be determined by Park Board and transportation amenities by CoV Transportation.

1. INFILTRATING BIORETENTION
2. PIPED HIGH-FLOW CONNECTION
3. BIKE LANE WITH LINED PERMEABLE PAVEMENT FACILITY
4. ADJACENT EXISTING TREE CANOPY
5. EXPANDED NATIVE POLLINATOR HABITAT
6. CROSSWALK BUMPOUTS TO SLOW TRAFFIC
7. PIPED CONNECTION FROM PERMEABLE PAVEMENT TO BIORETENTION
8. EXTRA ROW AREA PROVIDES OPPORTUNITY FOR BGS FOOTPRINT EXPANSION - SEE INSET ON PAGE 64
9. OVERFLOW CONNECTION TO DOWNSTREAM BGS
10. EXISTING WATER UTILITY
11. EXISTING SANITARY SEWER
12. EXISTING STORM SEWER

- PIPED CONNECTION
- INFILTRATION

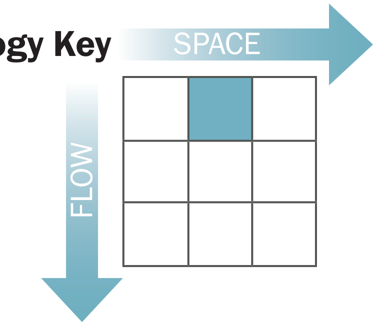
Typology 2: Upland Blueway

INSPIRED BY A VERNAL POOL



In natural systems, a vernal pool is a shallow depression that accumulates rainwater and/or snowmelt during the wet season. Rainwater in vernal pools may infiltrate and dry out seasonally, which creates important habitat for rare plants and amphibians in forested and open meadow ecosystems. The urban analog for this typology features wider, distributed, and discontinuous GRI that manages local runoff through infiltration and storage.

Typology Key



TYPOLOGY DESCRIPTION

Blue

1. Little to no flow originating from upstream BGS reaches.
2. Discontinuous, linked or unlinked via piped connections
3. Recharges groundwater through infiltration.
4. Temporary, shallow water storage.
5. GRI is sized to manage all runoff for average events on-site
6. GRI is sized to capture all runoff flows for a 10-year event and convey to downstream BGS.

Green

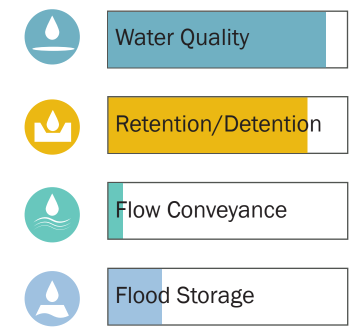
7. Native vegetation and native soils
8. Drought-resistant trees for habitat, shade.

Connect

9. Extends into a portion of traffic lanes, possible lane closures or reroute traffic.
10. Extends into parking lane and intersections to calm neighbourhood traffic.

TYPOLOGY AT-A-GLANCE

Primary Mechanisms



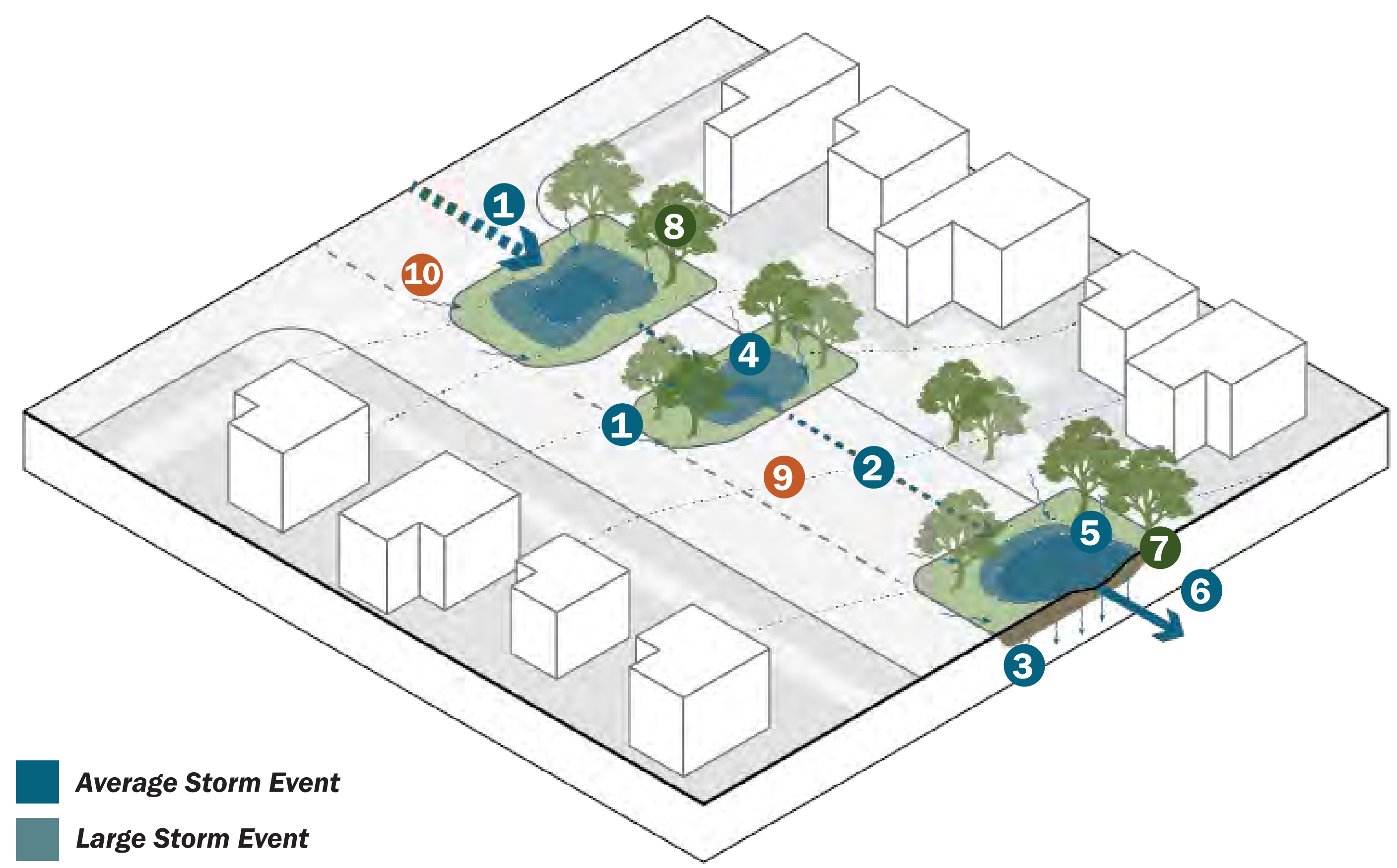
Characteristics

- Manages local + minimal upstream flow
- Utilizes discontinuous distributed facilities
- Uses larger road cross sections within ROW

Potential Components

- Oversized bioretention planters/bump-outs
- Tree trenches
- Permeable paving

GENERAL TYPOLOGY CONCEPT



Average Storm Event

Large Storm Event

Typology 2: Upland Blueway

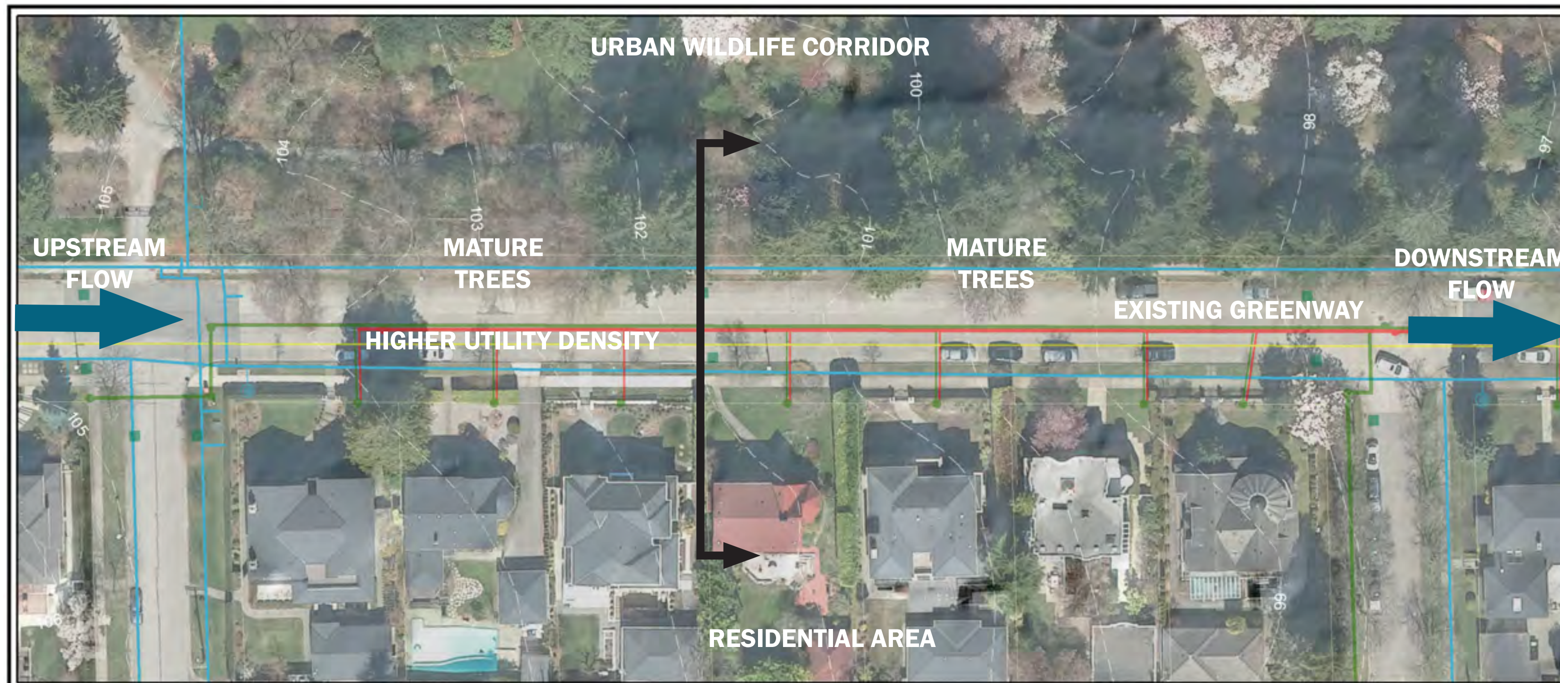
TYPOLOGY DEMONSTRATION SITE

The Typology 2: Upland Blueway demonstration site is in a residential neighourhood along a local, low-traffic greenway. The demonstration site is higher in the watershed with high-infiltration soils, small runoff volumes, and separated storm sewer pipes. Rainwater volume reduction through GRI helps mitigate the downstream sewer system from being overwhelmed in large storm events. The demonstration site is adjacent to a large, forested wildlife corridor, so the Blue Green System will play a role in preserving tree canopy and providing pollinator habitat extension. The site is along an existing greenway with low traffic, so there are opportunities to revise traffic patterns to improve pedestrian and bike experience while also making room for rainwater.

DEMONSTRATION SITE OBJECTIVES AND CONTEXT

	Blue	Green	Connect
Objectives	• **Water quality improvement** • **Volume reduction** • Peak flow reduction	• **Habitat connectivity** • Urban forest enhancement • Pollinator habitat enhancement	• **Active mobility improvement**
Neighourhood Context	• Located within the upper watershed, runoff volumes are smaller • Upland rainwater management plays important role in reducing lowland flooding	• Nearby urban wildlife corridor • High density tree canopy (20-25%)	• Regional bikeway connections • Access to regional rapid transit routes
Site Context	• High infiltration • Higher utility congestion • Separated storm sewer • Moderate slope (2-3%)	• Urban biodiversity zone • Pollinator habitat connectivity • Existing tree preservation • Nearby urban parks and open space	• Local road • Existing greenway • Single family residential • Nearby community amenities • Prominent active mobility hub with planned expansion.

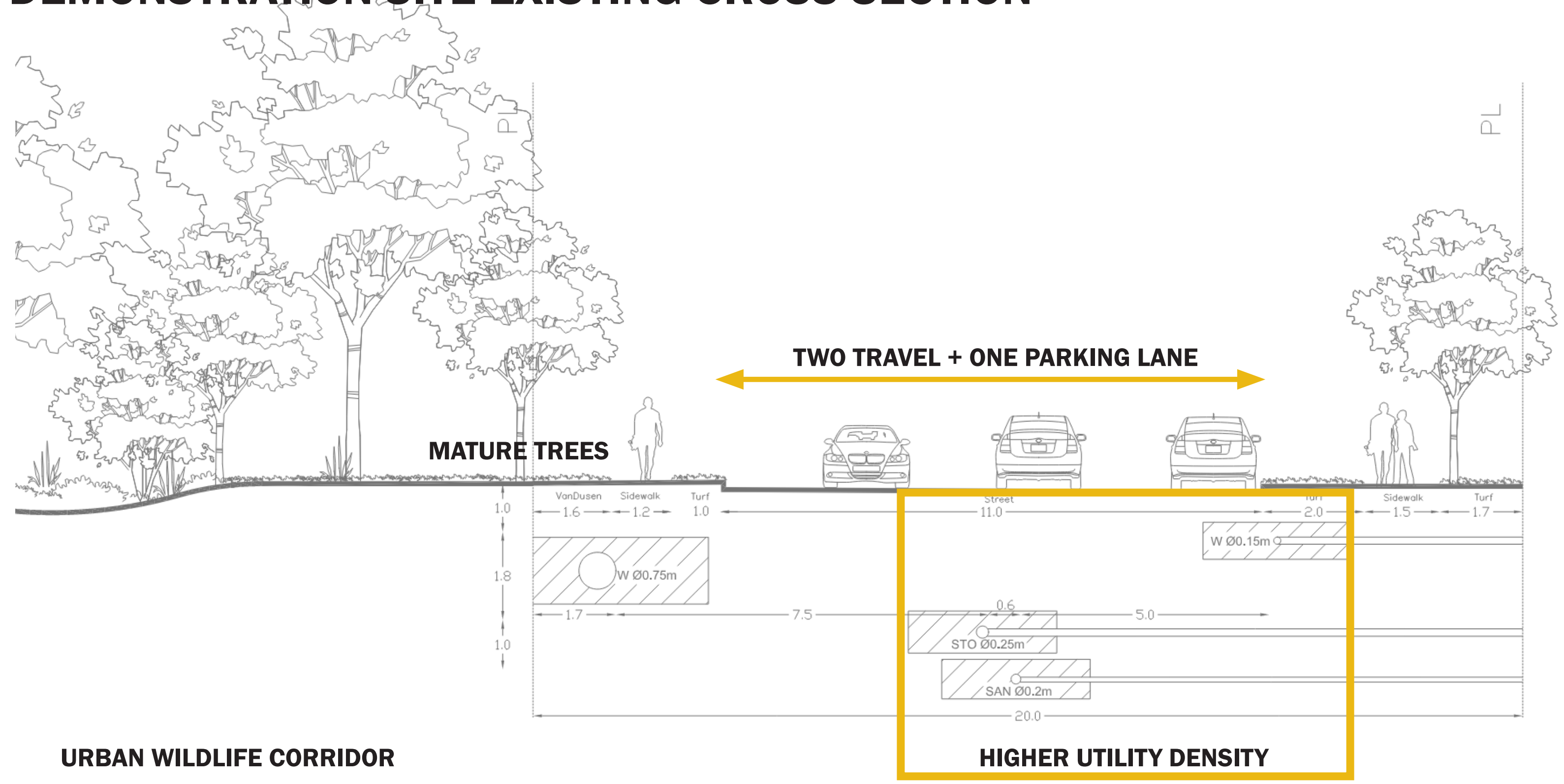
DEMONSTRATION SITE PLAN



NOTE: This demonstration site is for conceptual illustration of Blue Green Systems planning. Any resemblance to recognizable locations does not imply plans or concepts for future design projects. All park GRI features would be determined by Park Board and transportation amenities by CoV Transportation.

Sewer Catch Basins
Storm Sewer
Sanitary Sewer
Natural Gas Utility
Water Utility
Contours
Property Parcels

DEMONSTRATION SITE EXISTING CROSS SECTION



Typology 2: Upland Blueway

The Typology 2: Upland Blueway includes some typical characteristics of a green street, but prioritizes space for water through oversized bioretention. At this demonstration site, the infiltrating bioretention manages the volume of rainwater on site through storage and infiltration while creating a meandering greenway. The meandering design of the greenway prioritizes bike route safety by slowing already low traffic volumes. Residential parking is maintained by distributing parking to both sides of the road between existing mature trees. The oversized bioretention are planted with native, pollinator-friendly plants.

DEMONSTRATION SITE CONCEPT

NOTE: This demonstration site is for conceptual illustration of Blue Green Systems planning. Any resemblance to recognizable locations does not imply plans or concepts for future design projects. All park GRI features would be determined by Park Board and transportation amenities by CoV Transportation.

RUNOFF

PIPED FLOW

FLOW TO DOWNSTREAM BGS

1 INFILTRATING BIORETENTION

2 PIPED HIGH-FLOW CONNECTION

3 PRESERVED EXISTING TREE CANOPY

4 EXPANDED NATIVE POLLINATOR HABITAT

5 SHARED SLOW STREET GREENWAY (BIKE + VEHICLE)

6 FUTURE BIKEWAY CONNECTION

7 STREET PARKING

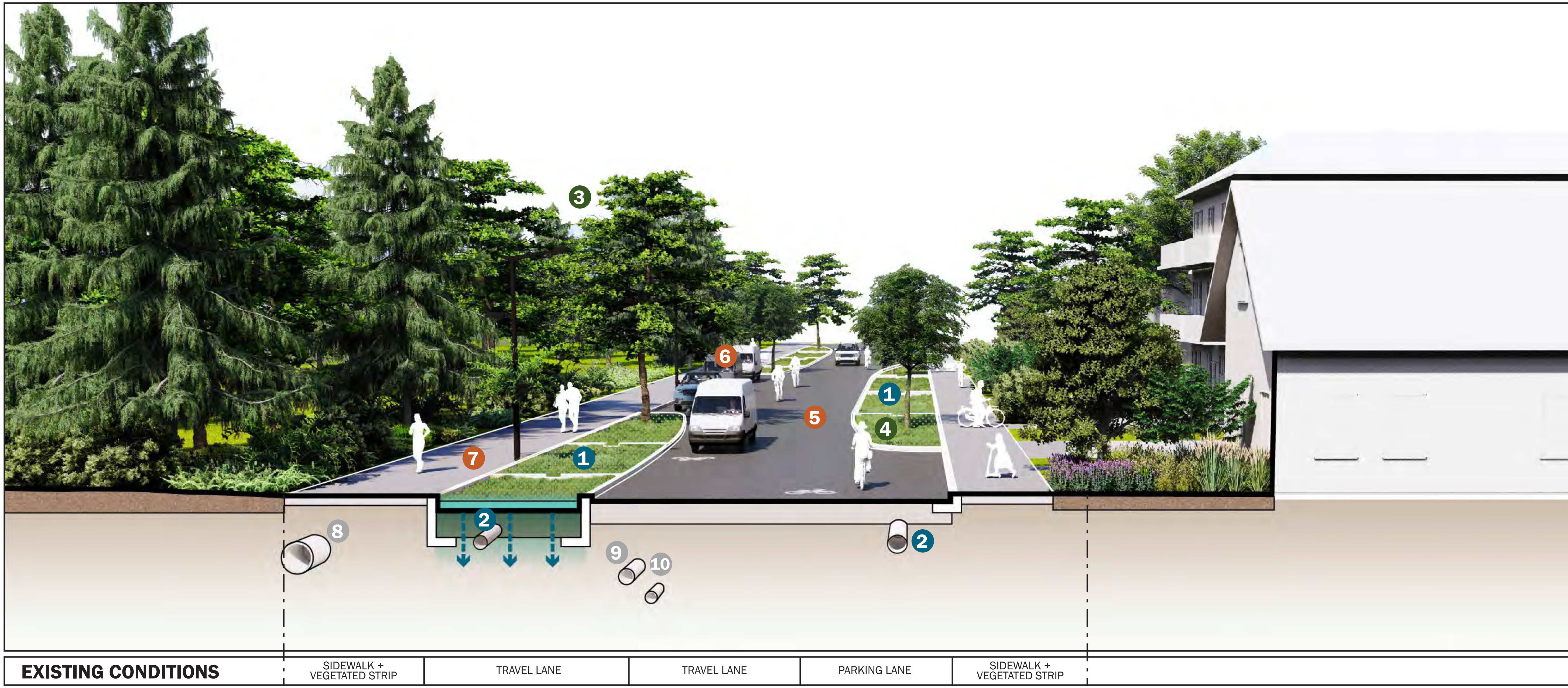
8 EXISTING PEDESTRIAN SIDEWALK

9 LINED PORTION TO PROTECT LATERALS

10 OVERFLOW CONNECTION TO DOWNSTREAM BGS

Typology 2: Upland Blueway

DEMONSTRATION SITE PERSPECTIVE

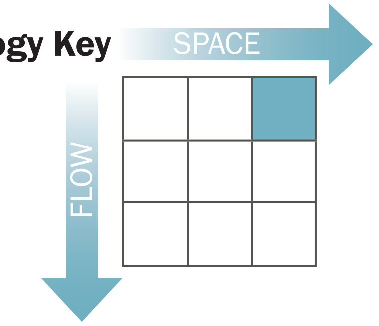


NOTE: This demonstration site is for conceptual illustration of Blue Green Systems planning. Any resemblance to recognizable locations does not imply plans or concepts for future design projects. All park GRI features would be determined by Park Board and transportation amenities by CoV Transportation.

1. INFILTRATING BIORETENTION
2. PIPED HIGH-FLOW CONNECTION
3. PRESERVED EXISTING TREE CANOPY
4. EXPANDED NATIVE POLLINATOR HABITAT
5. SHARED SLOW STREET GREENWAY (BIKE + VEHICLE)
6. STREET PARKING
7. EXISTING PEDESTRIAN SIDEWALK
8. EXISTING WATER UTILITY
9. EXISTING STORM SEWER
10. EXISTING SANITARY SEWER

↓ INFILTRATION

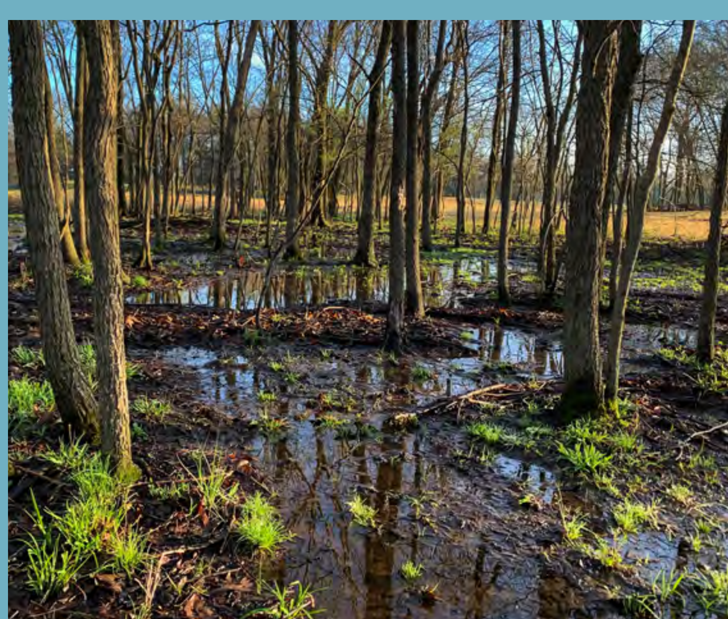
Typology Key



Typology 3: Upland Wet Meadow

INSPIRED BY AN EPHEMERAL WETLAND

In natural systems, ephemeral wetlands occur in low lying areas and retain water from accumulated snowmelt, rainwater, and/or shallow groundwater. Ephemeral wetlands can be found in isolation from or connected to nearby streams, rivers, or other wetlands and provide important habitats for wildlife and many native plant species. The urban analog for this typology features distributed, discontinuous GRI that extend into the right of way and adjacent open space to manage rainwater through storage, retention, and infiltration.



TYPOLOGY DESCRIPTION

Blue

1. Little to no flow originates from upstream BGS reaches.
2. Discontinuous, linked or unlinked via piped connections.
3. Recharges groundwater through infiltration.
4. Temporary, shallow water storage.
5. GRI is sized to manage all runoff for average events on-site. Adjacent open space remains dry.
6. GRI is sized to capture all runoff flows for a 10-year event by using adjacent open space.
7. All runoff managed on-site. Excess in large storms conveyed to downstream BGS.

Green

8. Native vegetation and soils
9. Drought-resistant trees
10. Floodable native grassland and shrub open space

Connect

11. Extends into a portion of traffic lanes, possible lane closures or reroute traffic.
12. Extends into parking lane and intersections to calm neighbourhood traffic.
13. Extends into open space to create multi-functional rainwater parks.

TYPOLOGY AT-A-GLANCE

Primary Mechanisms

- Water Quality
- Retention/Detention
- Flow Conveyance
- Flood Storage

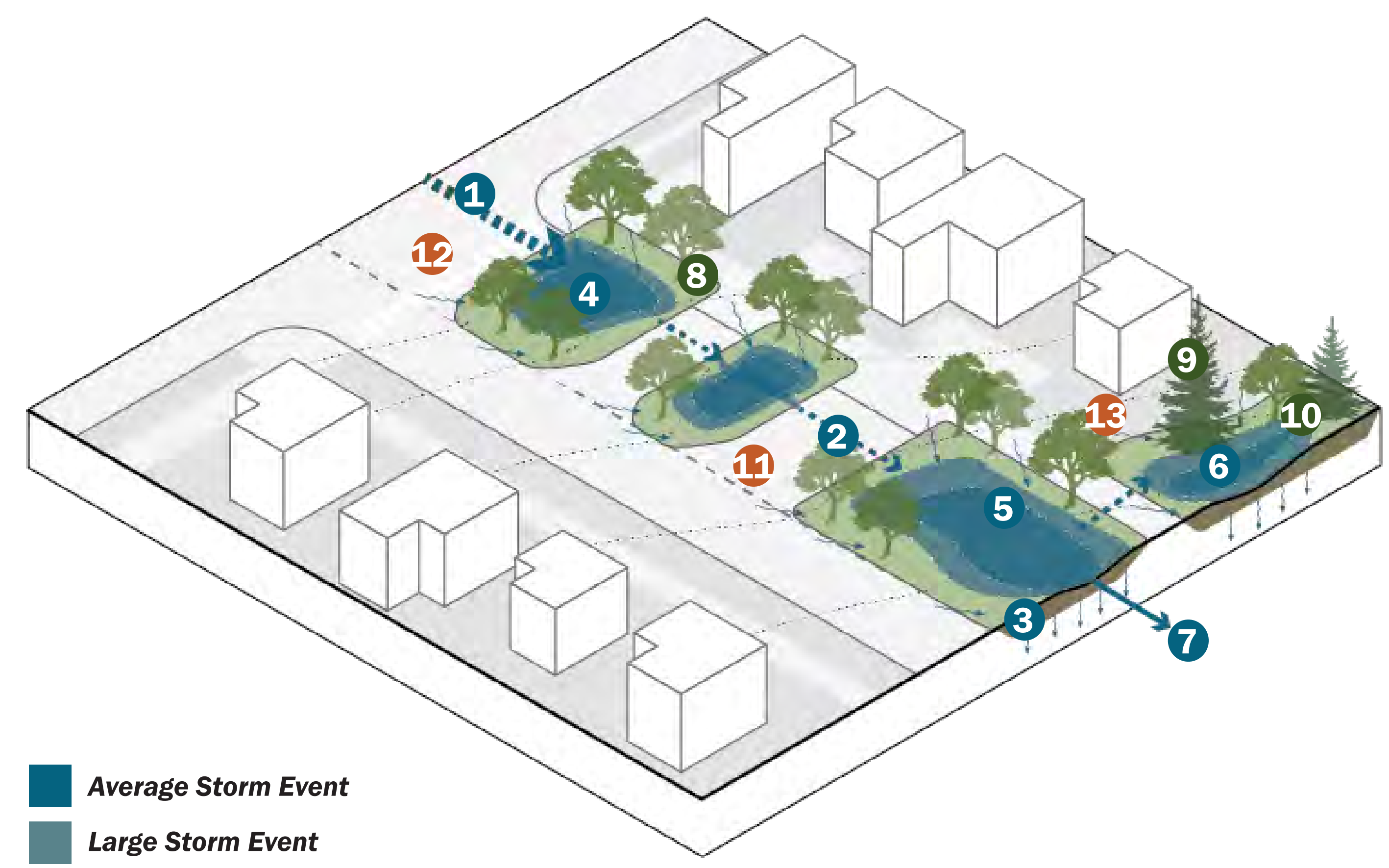
Characteristics

- Manages local + minimal upstream flow
- Utilizes discontinuous distributed facilities
- Uses larger road cross section + adjacent open space

Potential Components

- Oversized bioretention planters/bump-outs
- Tree trenches
- Permeable paving
- Constructed wetlands or surface storage

GENERAL TYPOLOGY CONCEPT



Typology 3: Upland Wet Meadow

TYPOLOGY DEMONSTRATION SITE

The Typology 3: Upland Wet Meadow demonstration site is in a residential area higher in the watershed with smaller flows. The area is served by small-capacity separated sewer pipes adjacent to an urban creek, so the demonstration project is focused on volume reduction and water quality to protect the creek. The street right of way is along a local road with nearby community amenities, including a playfield and park, so vehicular access is required but can be slowed down with the Blue Green System. The adjacent park offers opportunities to increase habitat, manage rainwater, and maintain community recreation amenities. An adjacent school and community center provide an opportunity for environmental education.

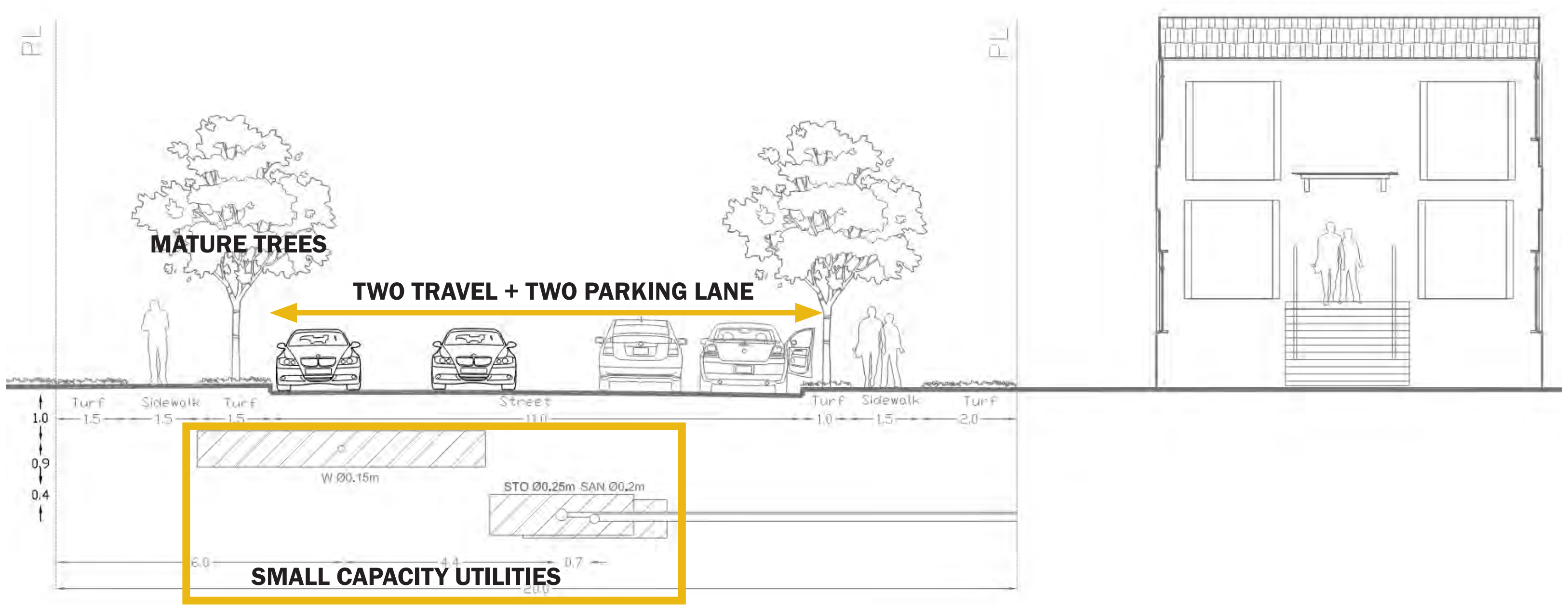
DEMONSTRATION SITE OBJECTIVES AND CONTEXT

	Blue	Green	Connect
Objectives	• **Water quality improvement** • Volume reduction	• **Habitat connectivity**	• **Active mobility improvement** • Park connectivity • Environmental education and stewardship
Neighbourhood Context	• Upper watershed • Separated stormwater sewer	• Ecological corridor along urban stream • Low canopy coverage	• Network of bike routes and bus connections
Site Context	• Higher utility congestion, small capacity • Moderate slope (3-4%) • Historic stream	• Habitat for birds, bees, pollinators • Mature trees on site, tree canopy continuity with rest of watershed • Adjacent park and playfield	• Local road • Intersects bike route • Low traffic volume, but maintain vehicle access to community amenities and for City services

DEMONSTRATION SITE PLAN

NOTE: This demonstration site is for conceptual illustration of Blue Green Systems planning. Any resemblance to recognizable locations does not imply plans or concepts for future design projects. All park GRI features would be determined by Park Board and transportation amenities by CoV Transportation.

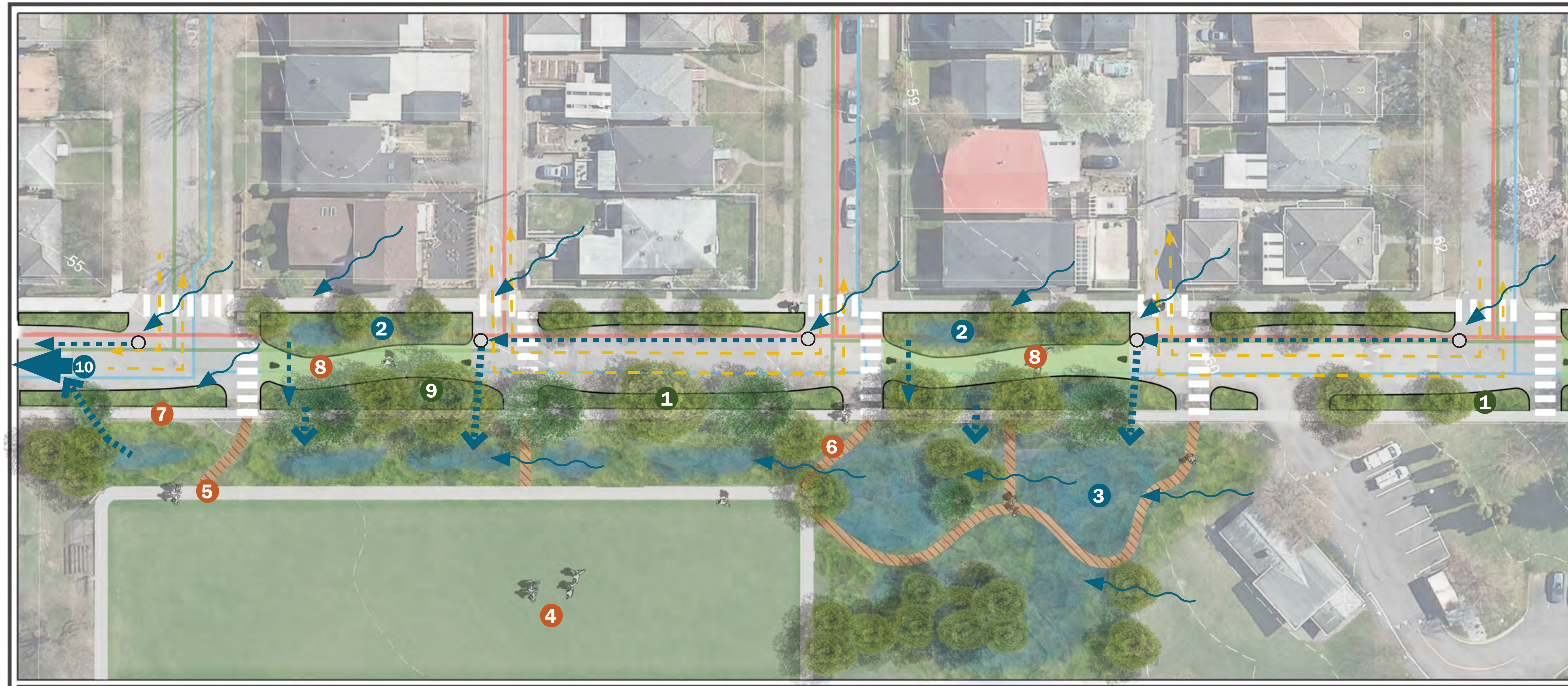
DEMONSTRATION SITE EXISTING CROSS SECTION



Typology 3: Upland Wet Meadow

The Typology 3: Upland Wet Meadow demonstration site uses the street right of way and a portion of adjacent park area to manage local runoff, enhance pollinator habitat, and create an enjoyable recreation space for the neighourhood. Along every other block, the street is closed to vehicular traffic. These street closures provide space for infiltrating bioretention to slow rainwater, protected bikeways, and expanded planting areas to enhance the tree canopy. Along the south side of the road, expanded planting areas blend with a series of wet meadows in the park that store and clean rainwater during large storms. A pedestrian boardwalk winds through the park and connects visitors to the existing playfield. At the end of the park, rainwater continues on to downstream Blue Green Systems.

DEMONSTRATION SITE CONCEPT



NOTE: This demonstration site is for conceptual illustration of Blue Green Systems planning. Any resemblance to recognizable locations does not imply plans or concepts for future design projects. All park GRI features would be determined by Park Board and transportation amenities by CoV Transportation.

- RUNOFF
- PIPED FLOW CONNECTION
- PIPED HIGH FLOW CONNECTION
- FLOW TO/FROM DOWNSTREAM / UPSTREAM BGS
- TRAFFIC CIRCULATION

1. STREET TREES
2. INFILTRATING BIORETENTION
3. WET MEADOW
4. EXISTING PLAYFIELD
5. WALKING PATH
6. BOARDWALK PATH
7. SIDEWALK
8. BIKEWAY CLOSED TO VEHICLES
9. ENHANCED TREE CANOPY
10. HIGH FLOW CONNECTION TO DOWNSTREAM BGS

Typology 3: Upland Wet Meadow

DEMONSTRATION SITE PERSPECTIVE

EXISTING CONDITIONS	PARK	SIDEWALK + VEGETATED STRIP	PARKING LANE	TRAVEL LANE	TRAVEL LANE	PARKING LANE	SIDEWALK + VEGETATED STRIP	PARCEL

NOTE: This demonstration site is for conceptual illustration of Blue Green Systems planning. Any resemblance to recognizable locations does not imply plans or concepts for future design projects. All park GRI features would be determined by Park Board and transportation amenities by CoV Transportation.

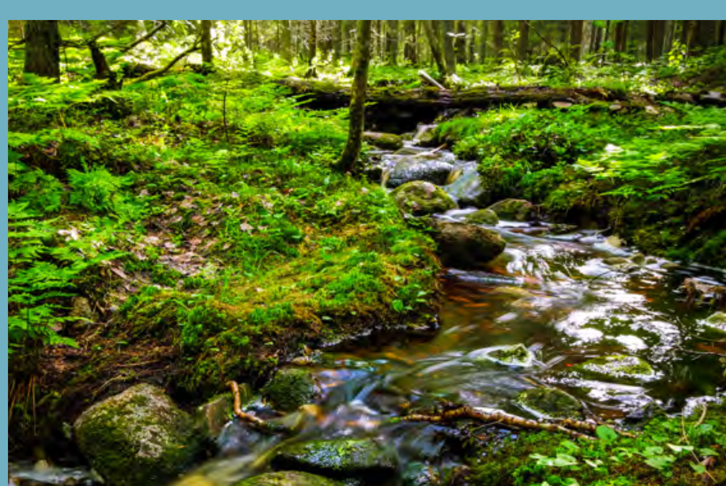
1. NATIVE POLLINATOR HABITAT
2. ALLEY LANE CLOSURE BIORETENTION
3. WET MEADOW
4. EXISTING PLAYFIELD
5. WALKING PATH
6. BOARDWALK PATH
7. BIKEWAY CLOSED TO VEHICLES
8. PRESERVED + ENHANCED TREE CANOPY
9. EXISTING WATER UTILITY
10. EXISTING STORM SEWER
11. EXISTING SANITARY SEWER

INFILTRATION

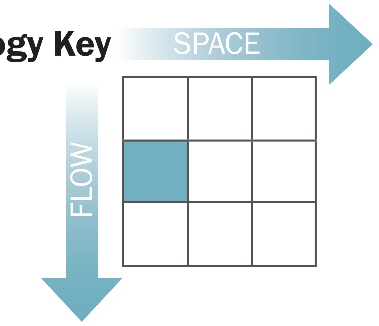
Typology 4: Seasonal Rainway

INSPIRED BY A NARROW STREAM

In natural systems, narrow streams form in confined valleys as rainfall and snow melt flow into more defined channels as the watershed transitions to lower reaches. The shape that a narrow stream takes is largely defined by the surrounding site conditions, such as geology and topography. Pooling, infiltration, and groundwater recharge occur when conditions allow. The urban analog for this typology features narrow, continuous GRI that manage local runoff and upstream flow in a narrow section of the right of way.



Typology Key



TYPOLOGY DESCRIPTION

Blue

1. Local runoff and low to moderate flows from upstream BGS.
2. Continuous or linked via piped connections
3. Retains water through infiltration, some ponding
4. GRI is sized to manage all local runoff for average events on-site. Upstream BGS flow conveyed to downstream BGS.
5. GRI is sized to capture all runoff flows for a 10-year event and convey to downstream BGS.

Green

6. Native vegetation and native soils
7. Drought-resistant trees for habitat, shade
8. Floodable vegetated channels

Connect

9. No encroachment into traffic lanes
10. Extends into parking lane to calm neighbourhood traffic

TYPOLOGY AT-A-GLANCE

Primary Mechanisms

- Water Quality
- Retention/Detention
- Flow Conveyance
- Flood Storage

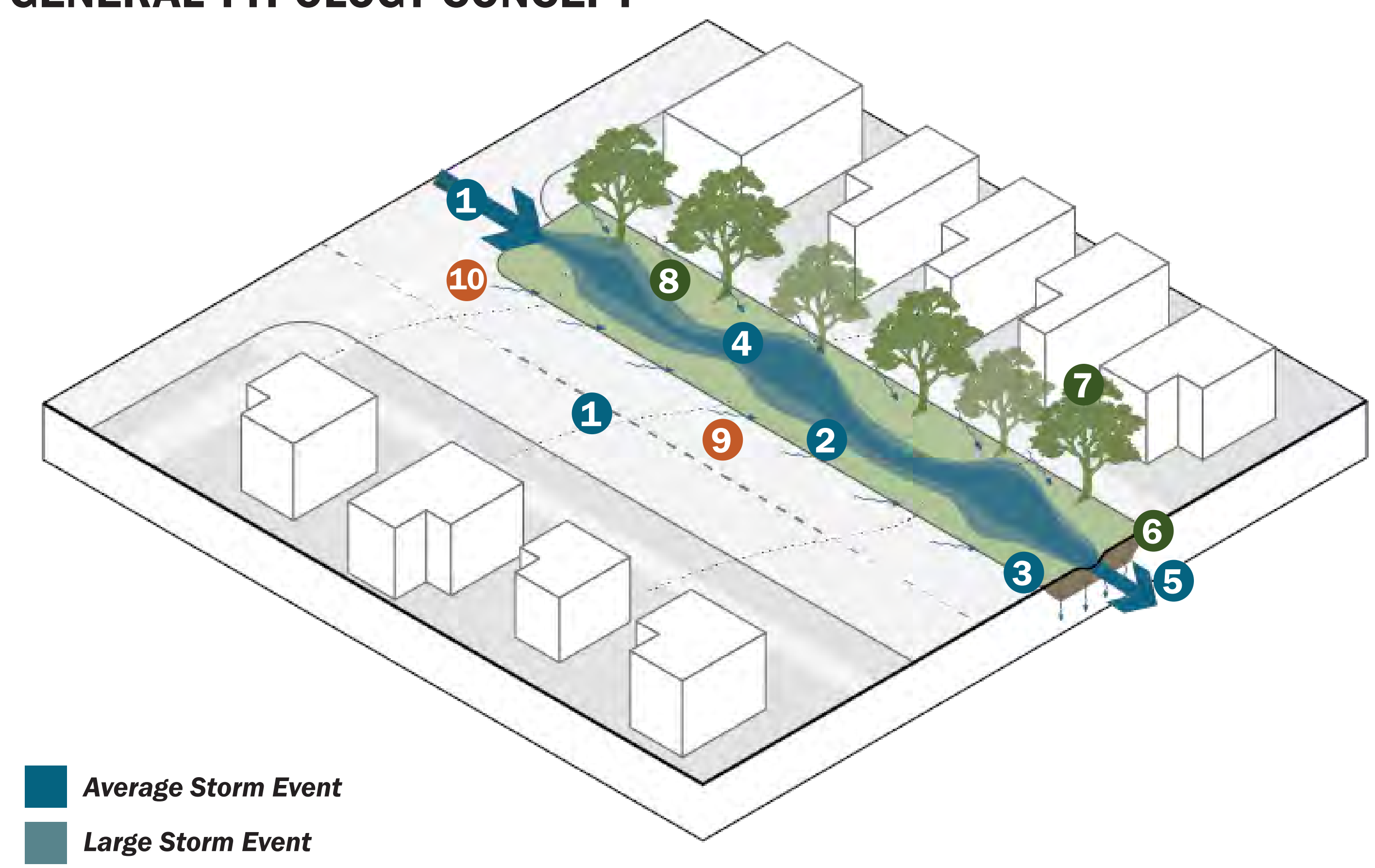
Characteristics

- Manages local runoff + upstream flow
- Utilizes continuous or linked facilities
- Uses narrow road cross sections within ROW

Potential Components

- Bioretention planters/ bump-outs
- Bioswales
- Tree trenches + potentially expanded soil volume
- Permeable paving + expanded soil volume

GENERAL TYPOLOGY CONCEPT



Typology 4: Seasonal Rainway

TYPOLOGY DEMONSTRATION SITE

The Typology 4: Seasonal Rainway demonstration site is located on a local road in a primarily single-family residential neighbourhood. The site falls within the middle transition zone of the watershed and receives local runoff from the road and surrounding residences. The area is served by partially separated sewer pipes draining approximately 12-acres of the surrounding residential neighbourhood. The demonstration project will focus on treating runoff and slowing peak flows because of the partially separated sewer area and steep road with potentially erosive runoff. The road has low utility congestion with two lanes of traffic and one parking lane on the north side. An existing greenway crosses the street at the upstream end. Existing traffic patterns and street parking must be maintained. Therefore, limited space is available for the Blue Green System within the road right of way.

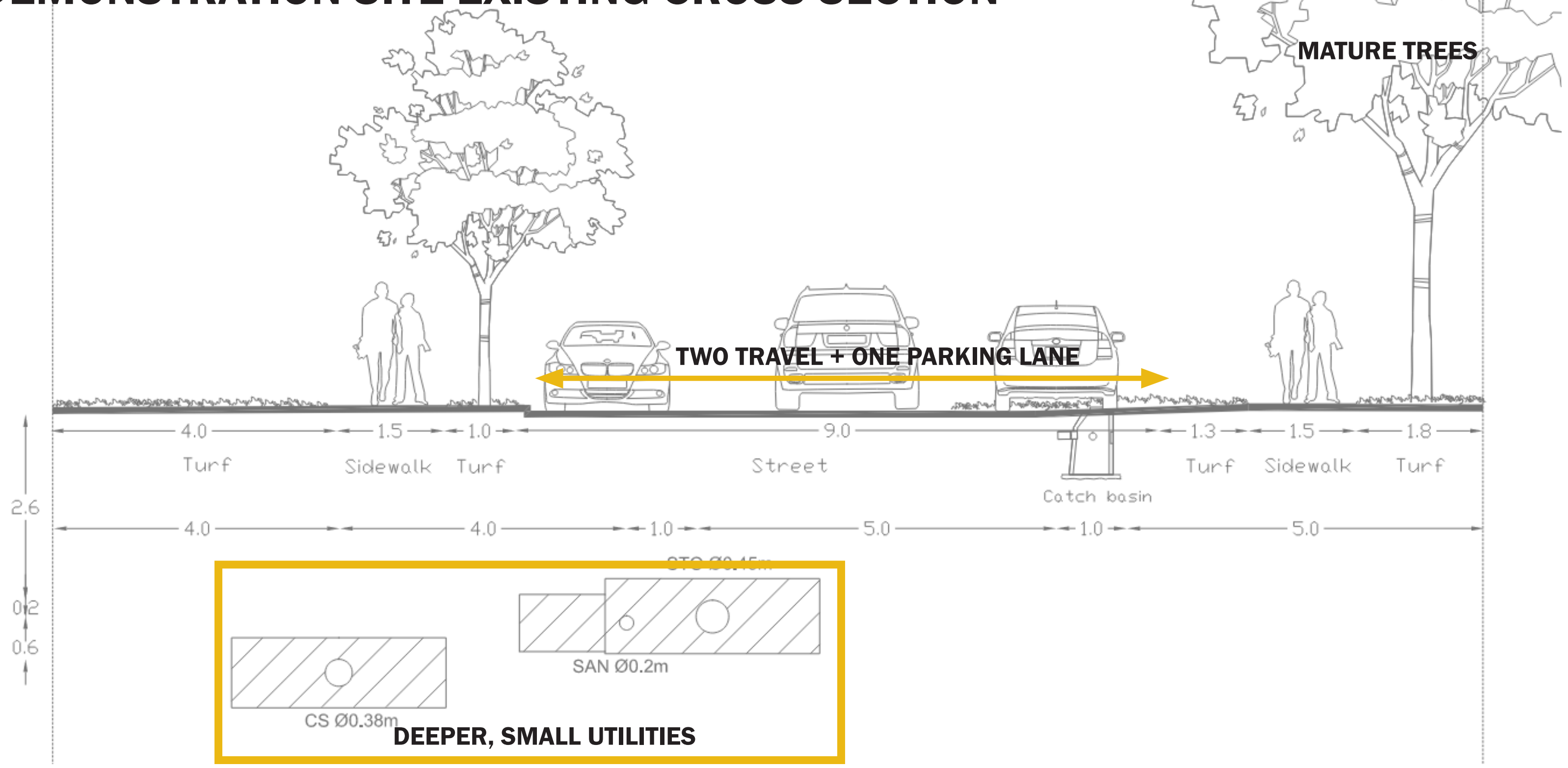
What is happening in the Extra ROW Area? Occasionally opportunities like the Extra ROW Area at the left corner may be present. Although outside the typical typology conditions, this area may help expand the Blue Green System footprint.

DEMONSTRATION SITE OBJECTIVES AND CONTEXT

	Blue	Green	Connect
Objectives	• **Peak flow reduction** • **Water quality improvement**	• Habitat connectivity • Pollinator habitat enhancement	• Active mobility improvement
Neighbourhood Context	• Located in a combined sewer with transition to separated basin • Overland flood vulnerability • Steep grades, sediment transport along road	• Largely residential with neighbourhood parks. • Moderate tree canopy coverage (15-20%) and increased urban heat effects	• Located on current neighbourhood greenways and bikeways with N/S and E/W connections.
Site Context	• High infiltration capacity • Low utility congestion • Very steep slope (8-9%)	• Prioritize pedestrian safety at greenway crossings • Moderate canopy coverage	• Local road • Single family residential

DEMONSTRATION SITE PLAN

DEMONSTRATION SITE EXISTING CROSS SECTION



Typology 4: Seasonal Rainway

The Typology 4: Seasonal Rainway demonstration site uses the limited right of way area available to manage local runoff from the neighourhood and flow conveyed via the upstream Blue Green System. Five large infiltrating bioretention facilities are installed on the same side of the street. The facilities are stepped to accommodate the steep slope of the street. A sedimentation basin is provided at the top of the street to catch sediment eroding from upstream portions of the road. The bioretention facilities are connected via subsurface pipes to provide a continuous flow path and still accommodate some parallel street parking. The most downstream bioretention facility is installed in a larger, unprogrammed ROW. This extra ROW area is converted to a pocket park to provide habitat and a neighourhood amenity while expanding the BGS footprint.

DEMONSTRATION SITE CONCEPT

NOTE: This demonstration site is for conceptual illustration of Blue Green Systems planning. Any resemblance to recognizable locations does not imply plans or concepts for future design projects. All park GRI features would be determined by Park Board and transportation amenities by CoV Transportation.

- RUNOFF
- PIPED CONNECTION
- FLOW TO/FROM DOWNSTREAM/ UPSTREAM BGS

1. SEDIMENT SETTLING BASINS
2. INFILTRATING BIORETENTION WITH WEIRS
3. PIPED CONNECTION
4. PRESERVED EXISTING TREE CANOPY
5. EXPANDED NATIVE POLLINATOR HABITAT
6. REARRANGED STREET PARKING
7. BENCHES
8. BUMPOUTS AT CROSSWALKS
9. EXTRA ROW AREA FOR BGS FOOTPRINT EXPANSION - SEE INSET
10. STORMWATER POCKET PARK
11. CONNECTION TO DOWNSTREAM BGS

Typology 4: Seasonal Rainway

DEMONSTRATION SITE PERSPECTIVE

NOTE: This demonstration site is for conceptual illustration of Blue Green Systems planning. Any resemblance to recognizable locations does not imply plans or concepts for future design projects. All park GRI features would be determined by Park Board and transportation amenities by CoV Transportation.

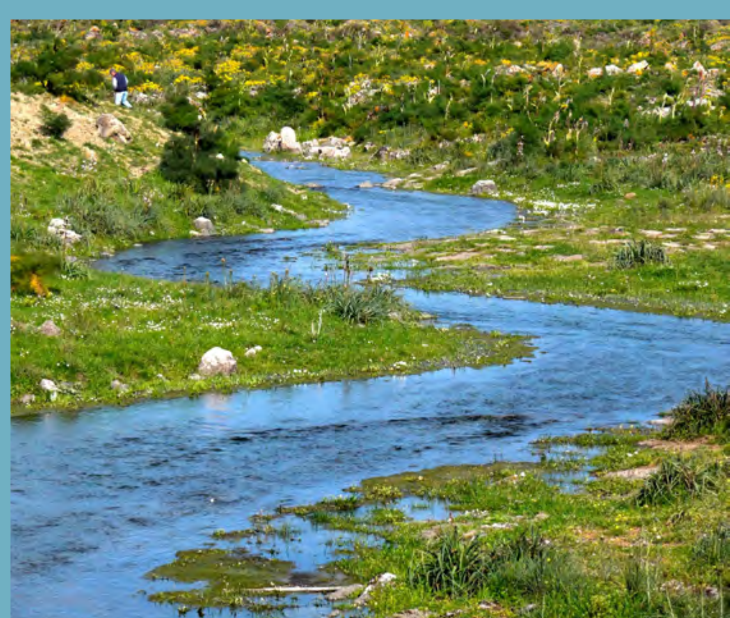
1. SEDIMENT SETTLING BASINS
2. INFILTRATING BIORETENTION
3. PIPED CONNECTION TO POCKET PARK - SEE INSET ON PAGE 88
4. PRESERVED EXISTING TREE CANOPY
5. EXPANDED NATIVE POLLINATOR HABITAT
6. REARRANGED STREET PARKING
7. BUMPOUTS AT CROSSWALKS
8. EXISTING STORM SEWER
9. EXISTING SANITARY SEWER
10. EXISTING COMBINED SEWER

↓ INFILTRATION

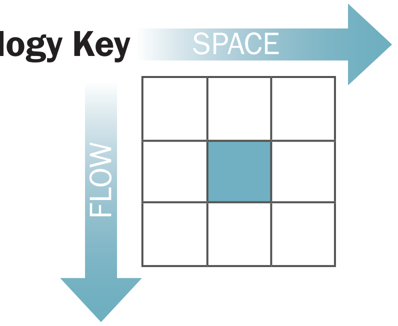
Typology 5: Seasonal Blueway

INSPIRED BY A MEANDERING STREAM

In natural systems, a meandering stream channel follows a curved path and is typically found in flatter topography where there is room for the channel to migrate from side to side. A meandering stream manages larger volumes of rainfall and snow melt that accumulate and flow from the upland zone seasonally or year-round. Rainwater flows slowly, which infiltrates and recharges groundwater. During large storms, water flows downstream within the banks of the stream. The urban analog for this typology features continuous, wider GRI within the right of way so rainwater can slowly meander.



Typology Key



TYPOLOGY DESCRIPTION

Blue

1. Low to moderate flows from upstream BGS and local runoff.
2. Continuous facilities or linked via piped connections.
3. Recharges groundwater through infiltration and/or stores water in shallow pools.
4. GRI is sized to manage all local runoff for average events on-site. Upstream BGS flow is conveyed to downstream BGS.
5. GRI sized to capture all runoff flows for a 10-year event and convey to downstream BGS.

Green

6. Native vegetation and native soils
7. Drought-resistant trees for shade, habitat
8. Floodable vegetated channels

Connect

9. Extends into a portion of traffic lanes, possible lane closures or reroute traffic.
10. Extends into parking lane and intersections to calm neighbourhood traffic.

TYPOLOGY AT-A-GLANCE

Primary Mechanisms

- Water Quality
- Retention/Detention
- Flow Conveyance
- Flood Storage

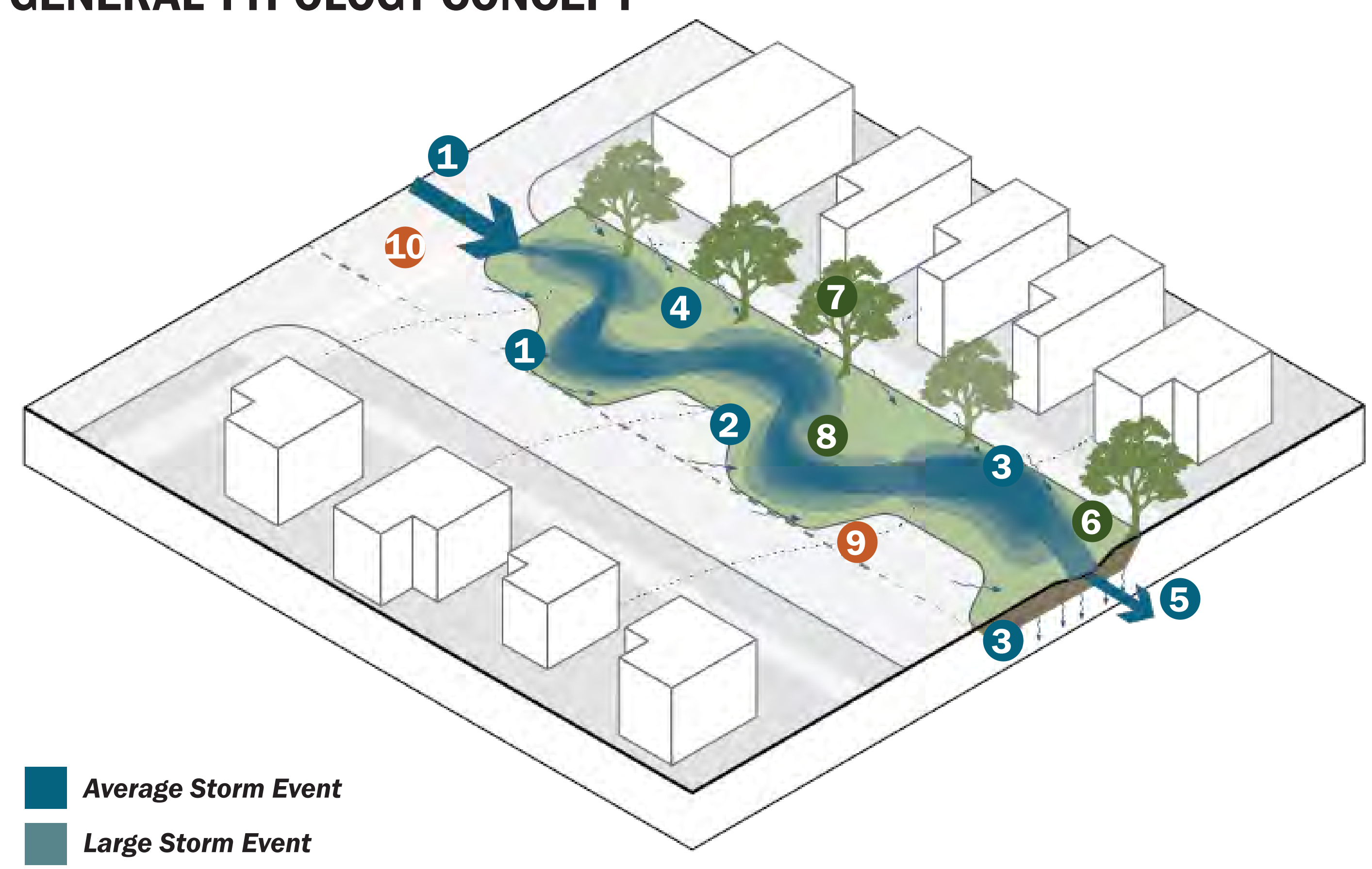
Characteristics

- Manages local + upstream flow
- Utilizes continuous or linked facilities
- Uses larger road cross sections within ROW

Potential Components

- Oversized bioretention planters/bump-outs
- Oversized bioswales
- Tree trenches + potentially expanded soil volume
- Permeable paving + expanded soil volume

GENERAL TYPOLOGY CONCEPT



Typology 5: Seasonal Blueway

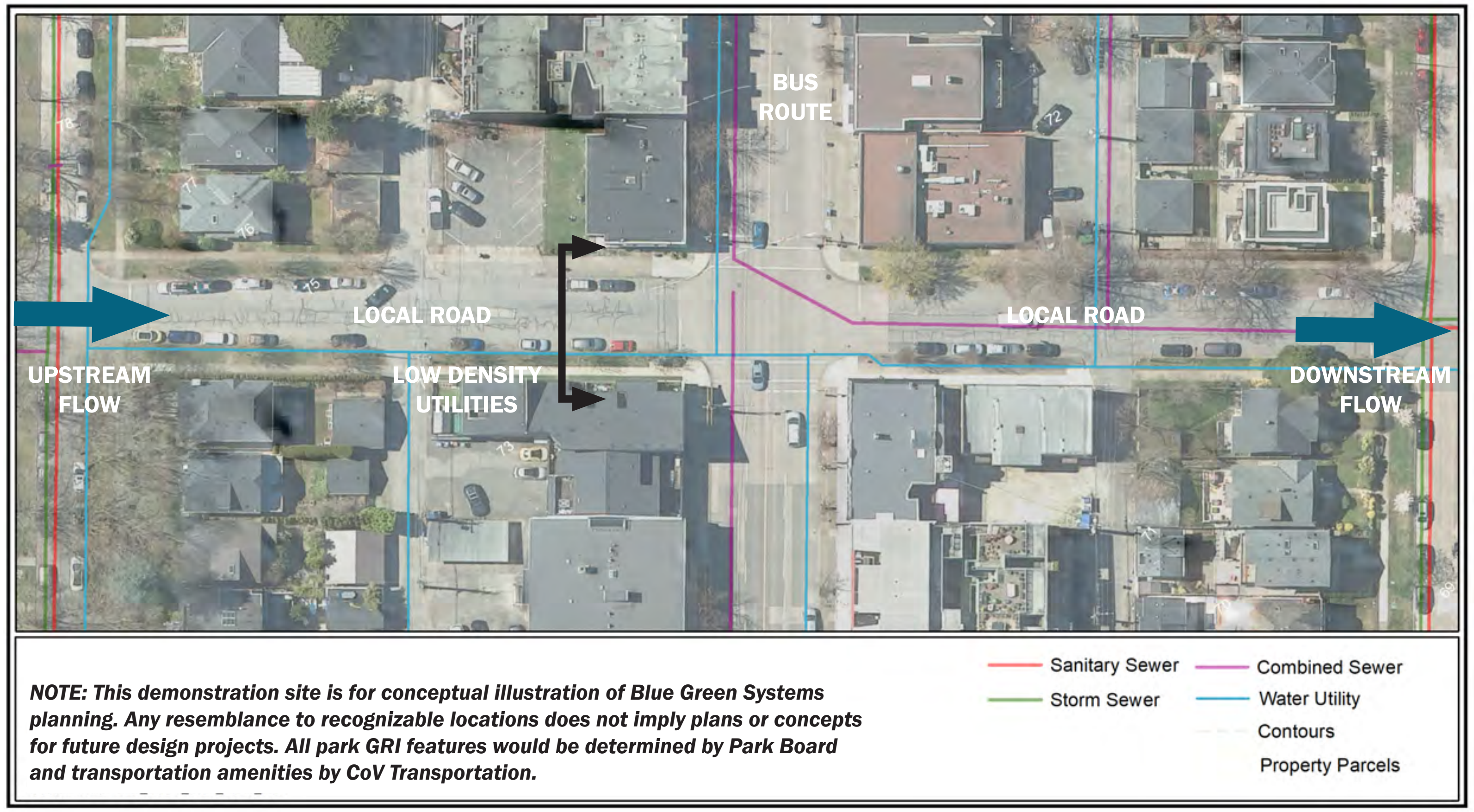
TYPOLOGY DEMONSTRATION SITE

The Typology 5: Seasonal Blueway demonstration site is in a residential area in the central watershed with moderate flows. The area is served by both a separated and combined sewer system with plans to fully separate in the near future, so the demonstration project is focused on volume reduction and peak flow reduction. The demonstration site right of way is along a local road that intersects with an arterial “complete street” with bus routes and commercial amenities. A greenway is just one block away, so people will access this demonstration site by bus, bike, car, and on foot. With low utility congestion and high soil infiltration, this demonstration site creates opportunities for surface management of rainwater and local commercial amenities.

DEMONSTRATION SITE OBJECTIVES AND CONTEXT

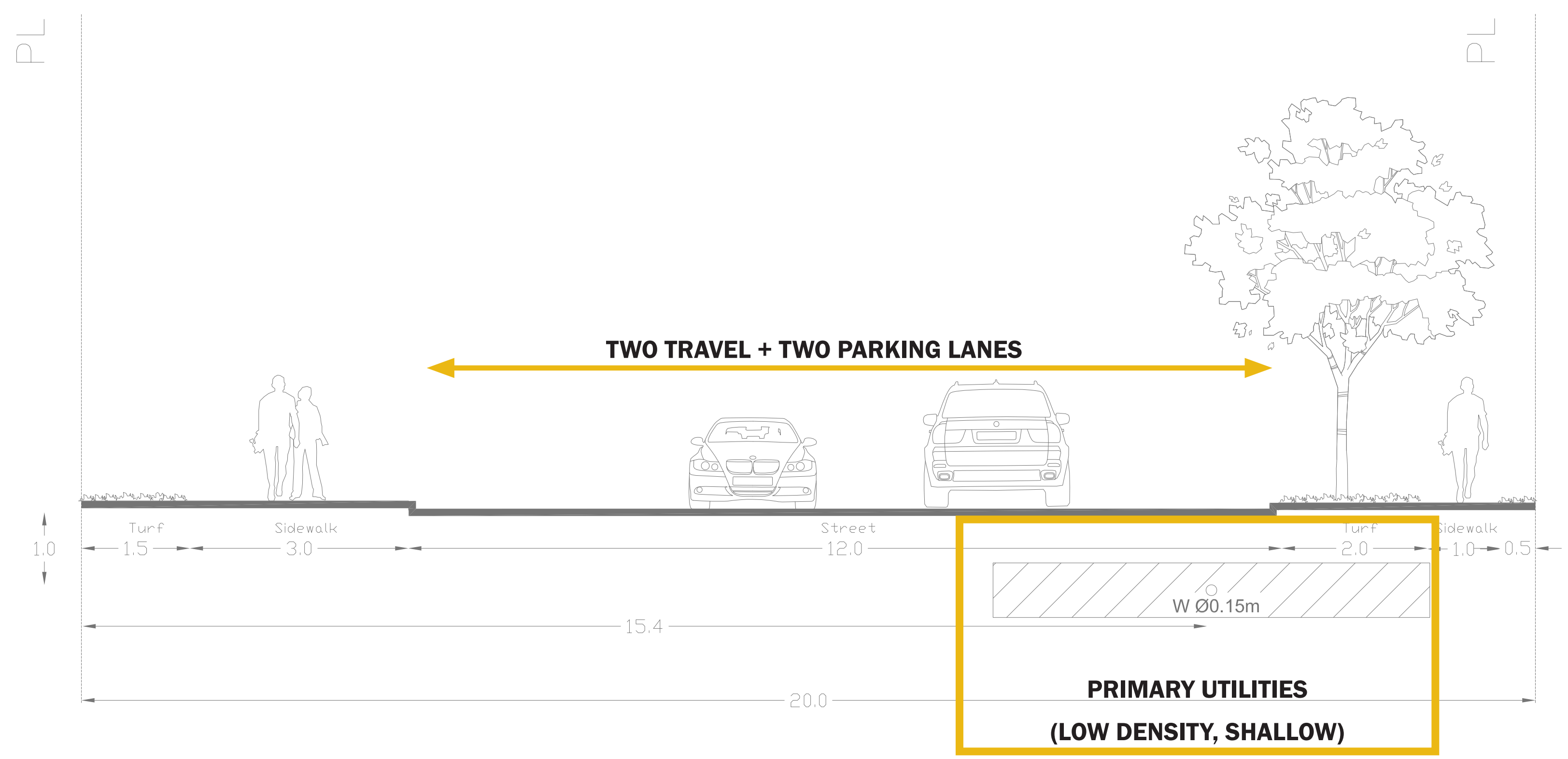
	Blue	Green	Connect
Objectives	• **Volume reduction** • Peak flow reduction • Water quality improvement	• **Habitat connectivity** • Urban forest enhancement	• Active mobility improvement • Environmental education and stewardship
Neighourhood Context	• Separated and combined sewer systems • Need to reduce rainwater volume to manage CSO events • Historical streams within urban basin	• Nearby parks and habitat preserves • High tree canopy coverage across neighourhood	• Existing nearby bikeways and greenways • Bus route along arterial road
Site Context	• High soil infiltration • Moderate slope (3-4%) • Low utility congestion • Current combined sewer system with separation plans in near future.	• Preserve and enhance existing tree canopy • Enhance urban habitat for pollinators and wildlife moving between nearby habitat corridors	• Local road with low traffic volume • Small commercial district adjacent to residential neighbourhood

DEMONSTRATION SITE PLAN



NOTE: This demonstration site is for conceptual illustration of Blue Green Systems planning. Any resemblance to recognizable locations does not imply plans or concepts for future design projects. All park GRI features would be determined by Park Board and transportation amenities by CoV Transportation.

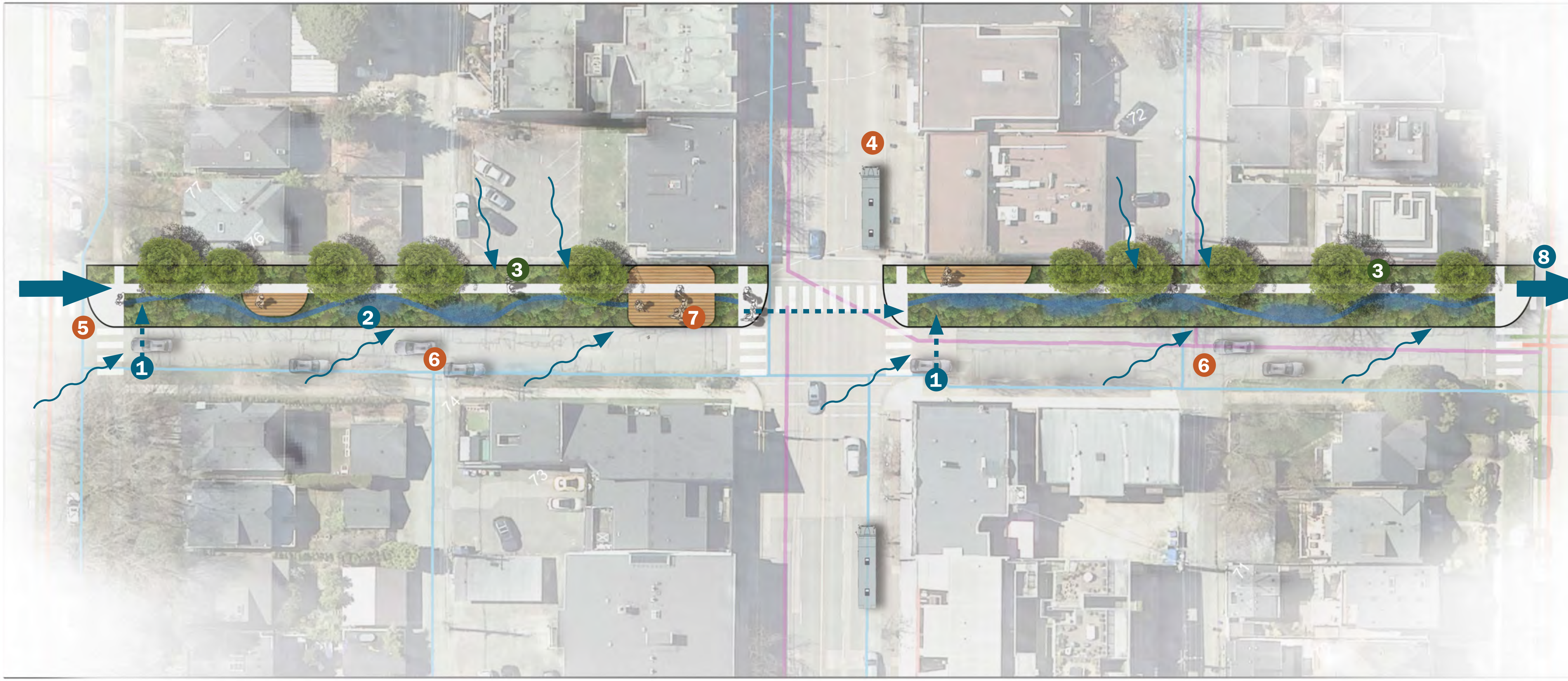
DEMONSTRATION SITE EXISTING CROSS SECTION



Typology 5: Seasonal Blueway

The Typology 5: Seasonal Blueway demonstration site utilizes a local road to manage local runoff and upstream BGS flow. A planted channel replaces a parking lane and travel lane to improve infiltration and rainwater storage and provide native pollinator habitat. To enhance tree canopy in the watershed, new trees are planted with tree trenches and structural soil underneath the sidewalk to maintain sufficient area for the tree roots to grow. Because the demonstration site intersects with a small commercial area with shops, restaurants, and a bus route, the demonstration site includes community amenities such as restaurant and cafe seating, park-line amenities (e.g. benches), and shaded sidewalks.

DEMONSTRATION SITE CONCEPT



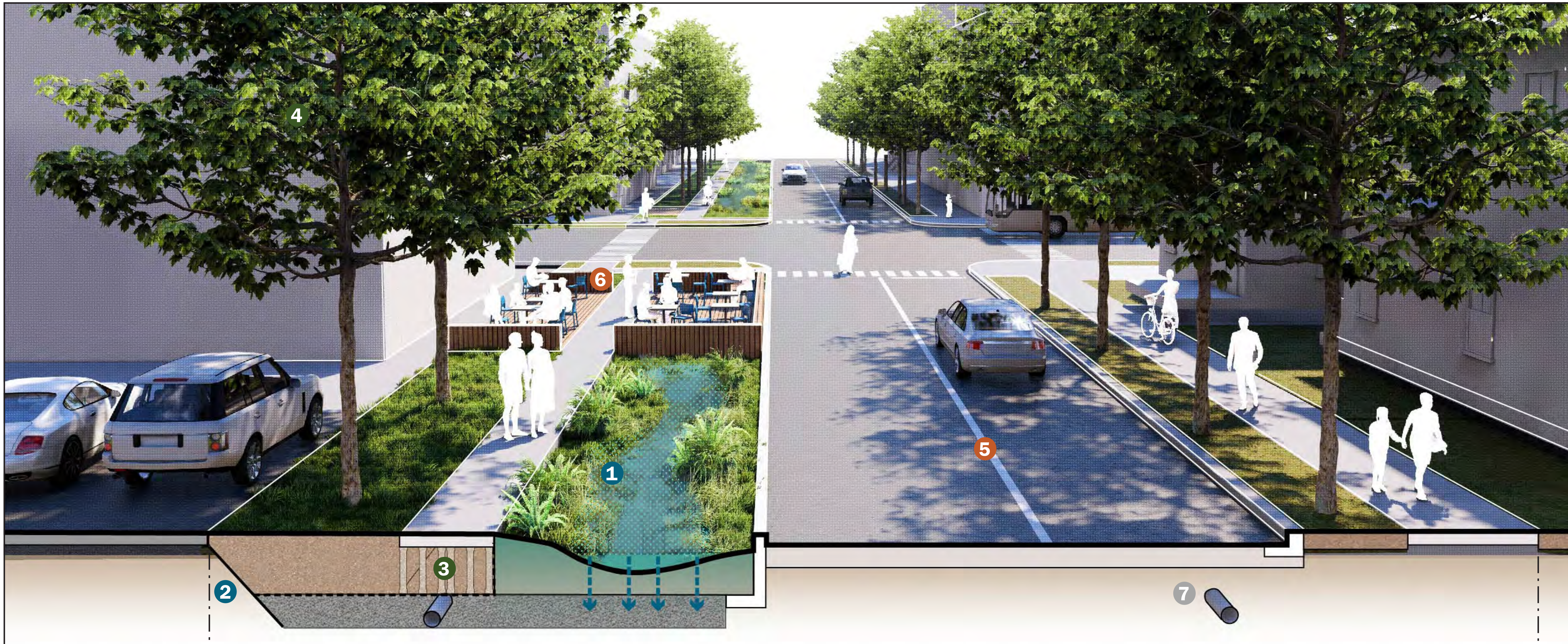
NOTE: This demonstration site is for conceptual illustration of Blue Green Systems planning. Any resemblance to recognizable locations does not imply plans or concepts for future design projects. All park GRI features would be determined by Park Board and transportation amenities by CoV Transportation.

- RUNOFF
- PIPED FLOW
- FLOW TO/FROM DOWNSTREAM / UPSTREAM BGS

1. RELOCATE CATCH BASIN AND CONVEY FLOW ACROSS STREET
2. MEANDERING CHANNEL
3. EXPANDED TREE CANOPY, TREE TRENCHES WITH STRUCTURAL SOIL
4. BUS ROUTE
5. REDUCED PARKING ON LOCAL ROAD
6. MAINTAIN TWO VEHICLE LANES
7. OUTDOOR COMMERCIAL SEATING
8. OVERFLOW TO DOWNSTREAM BGS

Typology 5: Seasonal Blueway

DEMONSTRATION SITE PERSPECTIVE



EXISTING CONDITIONS	SIDEWALK + VEGETATED STRIP	PARKING LANE	TRAVEL LANE	TRAVEL LANE	PARKING LANE	SIDEWALK + VEGETATED STRIP

NOTE: This demonstration site is for conceptual illustration of Blue Green Systems planning. Any resemblance to recognizable locations does not imply plans or concepts for future design projects. All park GRI features would be determined by Park Board and transportation amenities by CoV Transportation.

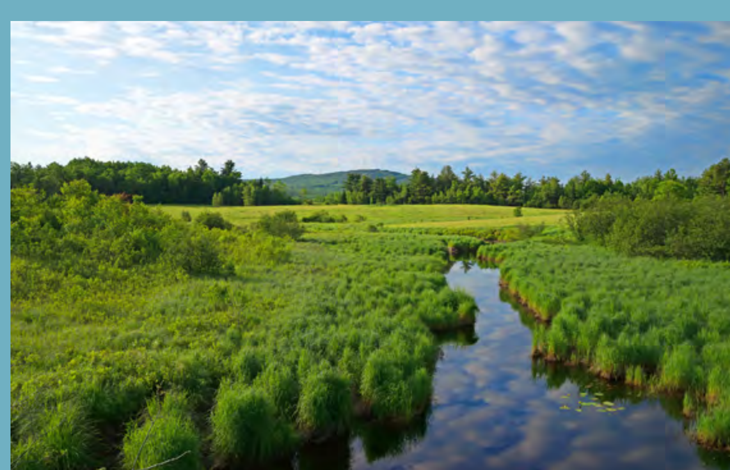
1. MEANDERING, VEGETATED CHANNEL
2. LINED EDGE TO PROTECT ADJACENT PROPERTIES
3. TREE TRENCHES WITH STRUCTURAL SOIL
4. EXPANDED TREE CANOPY
5. REDUCED PARKING, MAINTAIN VEHICLE LANES
6. OUTDOOR SEATING
7. EXISTING WATER UTILITY

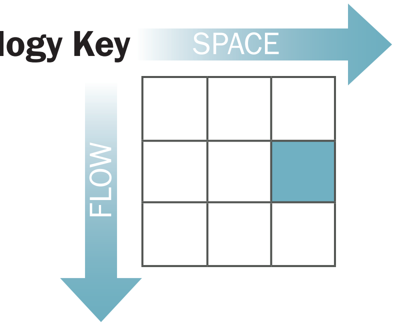
INFILTRATION

Typology 6: Seasonal Wetland

INSPIRED BY A STREAM + FLOODPLAIN WETLAND

In natural systems, meandering streams erode the stream banks and create a floodplain in wide valleys. During large storms, the floodplain slows and holds water in wetlands and depressions, which recharge groundwater or flow back into the stream channel. Natural floodplain wetlands can be open or forested, flat or terraced depending on the surrounding ecology and geology. The urban analog for this typology features continuous or linked larger GRI facilities that manage local and upstream runoff in wider sections of the right of way and adjacent open space parcels.





TYPOLOGY DESCRIPTION

Blue

1. Low to moderate flows from upstream BGS and local runoff.
2. Continuous or linked via piped connections
3. Recharges groundwater through infiltration when feasible.
4. Temporarily stores water in shallow ponding and soil
5. GRI is sized to manage all local runoff for average events on-site. Upstream BGS flow is conveyed to downstream BGS. Adjacent open space areas remain dry.
6. GRI sized to capture all runoff flows for a 10-year event. Connected floodplain wetlands hold excess rainwater and convey to downstream BGS.

Green

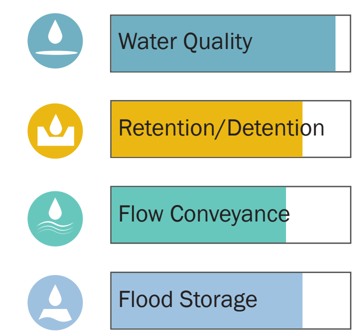
7. Native vegetation, native soil.
8. Drought-resistant trees
9. Floodable vegetated channels and open space

Connect

10. Extends into a portion of traffic lanes, possible lane closures or reroute traffic.
11. Extends into parking lane and intersections to calm neighbourhood traffic.
12. Extends into open space to create multi-functional rainwater parks

TYPOLOGY AT-A-GLANCE

Primary Mechanisms



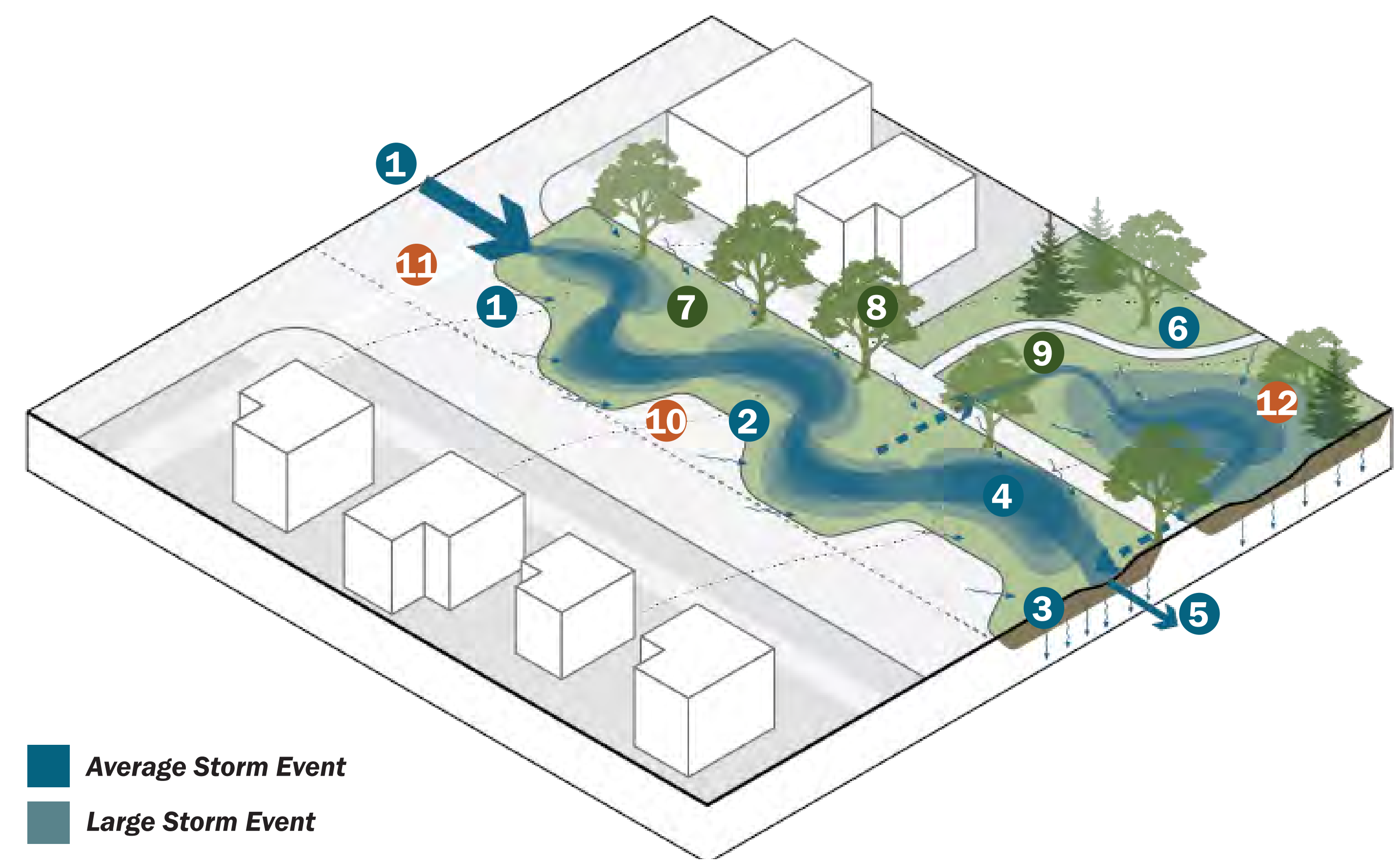
Characteristics

- Manages local + upstream flow
- Utilizes continuous or linked facilities
- Uses larger road cross section + adjacent open space

Potential Components

- Oversized bioretention planters/ bump-outs
- Oversized bioswales
- Tree trenches + potentially expanded soil volume
- Permeable paving + expanded soil volume
- Constructed wetlands or large surface storage

GENERAL TYPOLOGY CONCEPT



Typology 6: Seasonal Wetland

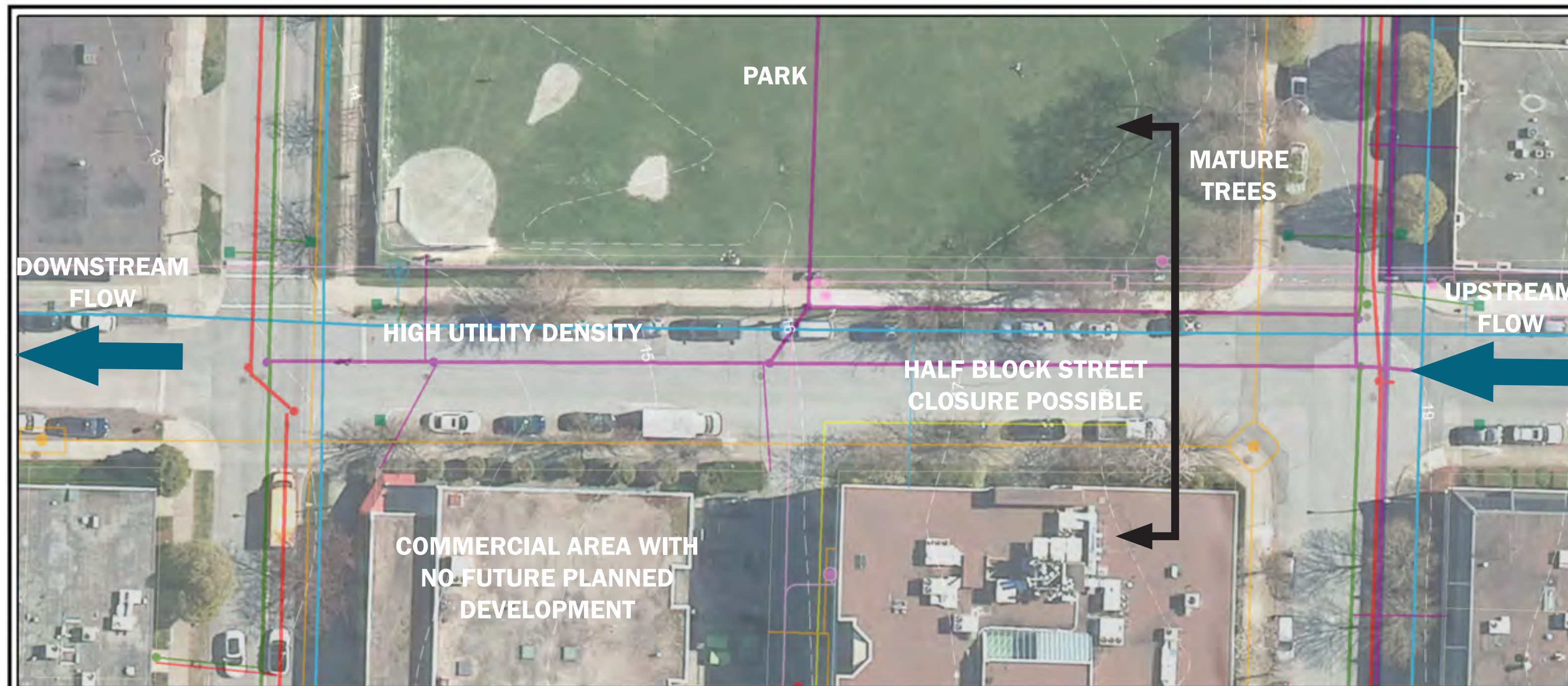
TYPOLOGY DEMONSTRATION SITE

The Typology 6: Seasonal Wetland demonstration site is located in a commercial area of the watershed along a local road. A partial street closure is possible to create a lively mixed-used district. Located in a combined sewer basin, peak flow and volume reduction is a priority to reduce CSO events by managing local flow and rainwater from upstream Blue Green Systems. The subsurface utility density is high, but the adjacent park provides additional space for rainwater storage and infiltration across a moderate grade change.

DEMONSTRATION SITE OBJECTIVES AND CONTEXT

	Blue	Green	Connect
Objectives	• **Peak flow reduction** • **Volume reduction** • Flood management • Water quality improvement	• Urban forest enhancement • Habitat connectivity • Pollinator habitat enhancement	• Active mobility improvement • Park connectivity • Cultural connections • Environmental education and stewardship
Neighbourhood Context	• Located in combined sewer area • Moderate contributing upland drainage area • Subject to minor surface flooding during 100-year flood • Near historic stream location	• Located in zone with low urban forest canopy (10-15%)	• Desire for a creative, cultural district with light industrial and mixed-used commercial • Located in high urban heat zone (41 to 49oC)
Site Context	• High infiltration capacity • Moderate slope (5-6%) • Moderate utility congestion, primarily combined sewer main. • Utilities 1 m underground.	• Adjacent to a park	• Located on proposed greenway • Future Rapid Transit Station nearby • Opportunity to partially close road for pedestrian priority

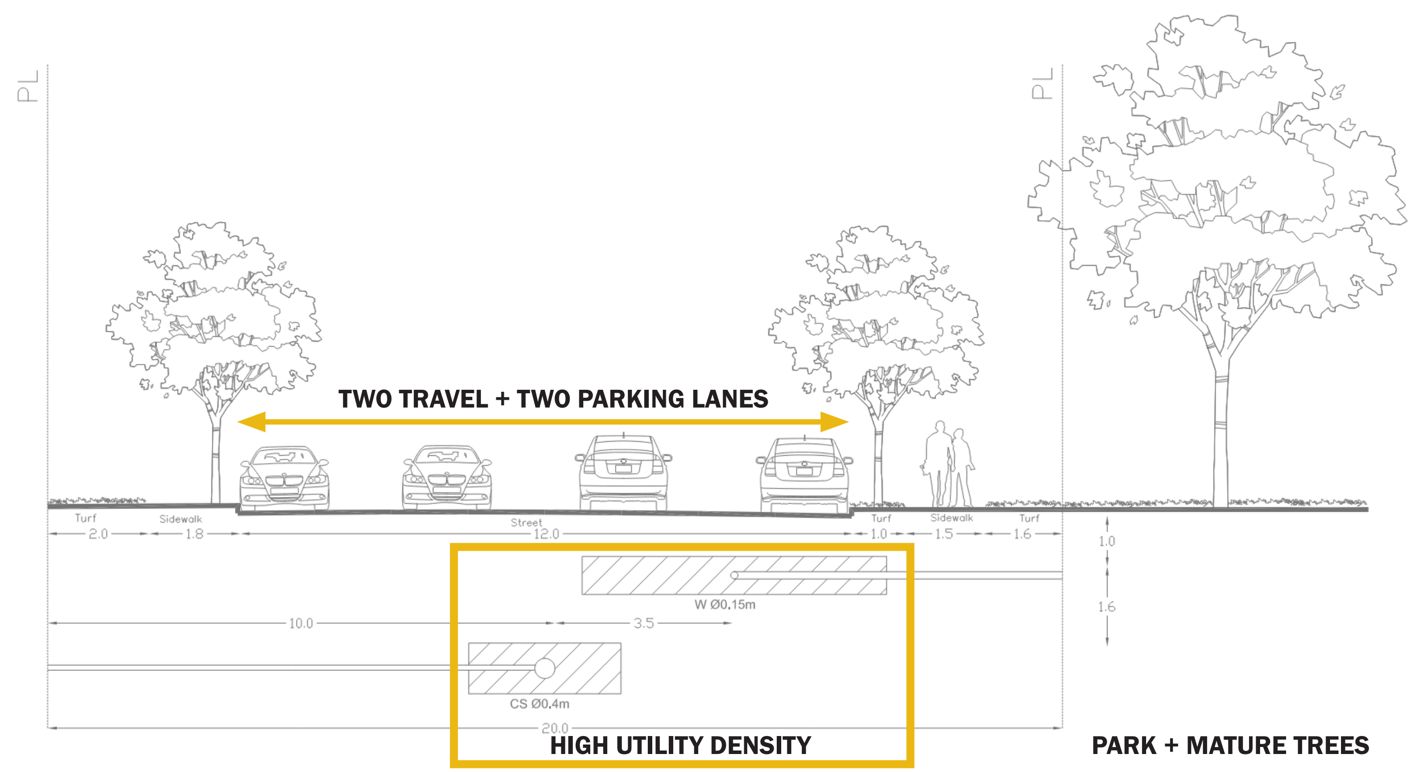
DEMONSTRATION SITE PLAN



NOTE: This demonstration site is for conceptual illustration of Blue Green Systems planning. Any resemblance to recognizable locations does not imply plans or concepts for future design projects. All park GRI features would be determined by Park Board and transportation amenities by CoV Transportation.

Sewer Catch Basins
Combined Sewer
Sanitary Sewer
Storm Sewer
Water Utility
Hydro Utility
Natural Gas Utility
Telecommunications
Contours
Property Parcels

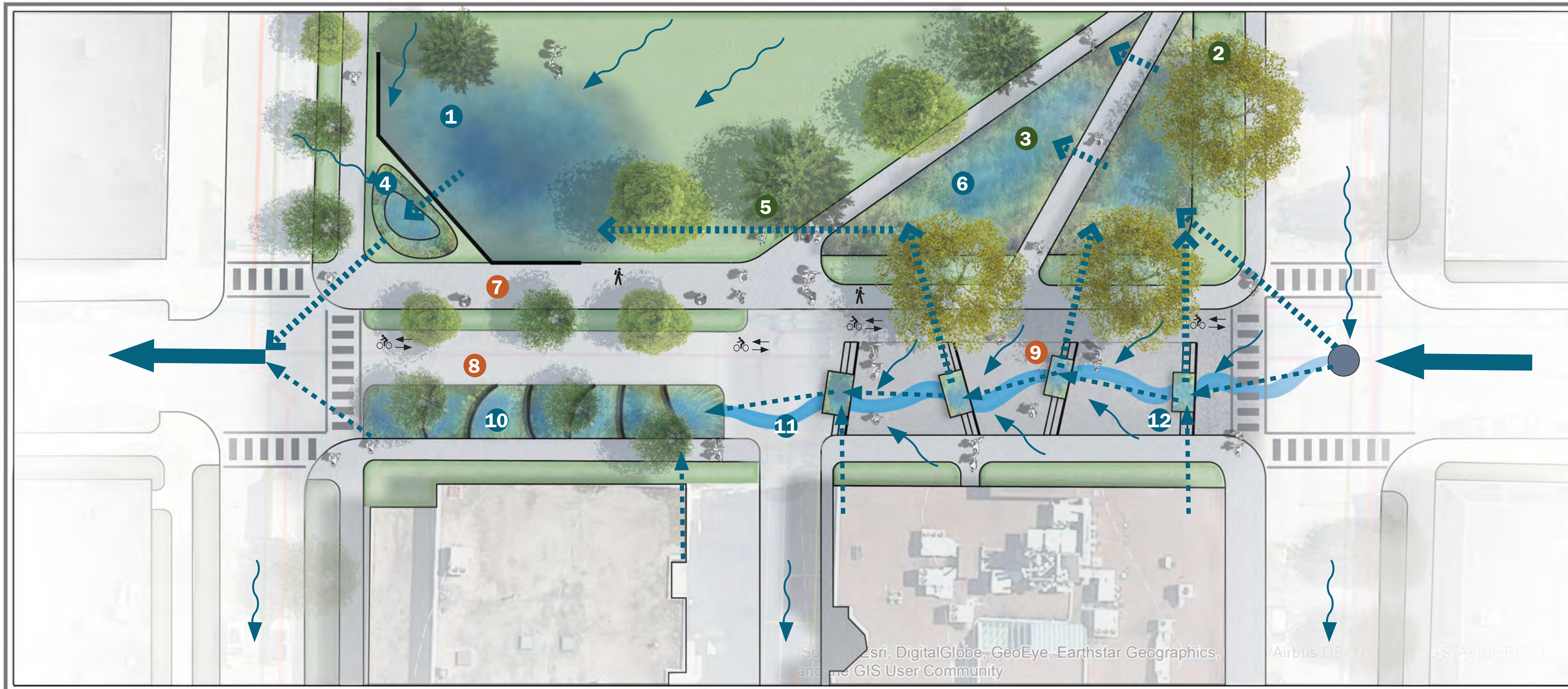
DEMONSTRATION SITE EXISTING CROSS SECTION



Typology 6: Seasonal Wetland

The Typology 6: Seasonal Wetland demonstration site utilizes a half-block road closure and adjacent park to manage local runoff and flow conveyed from upstream Blue Green Systems. Rainwater is directed to a series of linked bioretention planters that are integrated into a stepped plaza and community space. During high flow storms, rainwater is diverted into terraced wetland storage areas that hold and slow water while also enhancing urban habitat and tree canopy. At the downstream end of the park, a floodable field creates a recreational amenity that only floods during the most extreme events. Improved pedestrian sidewalks and a designated bike path connect people who work in the district or live nearby to existing bike routes, the park, and employment.

DEMONSTRATION SITE CONCEPT



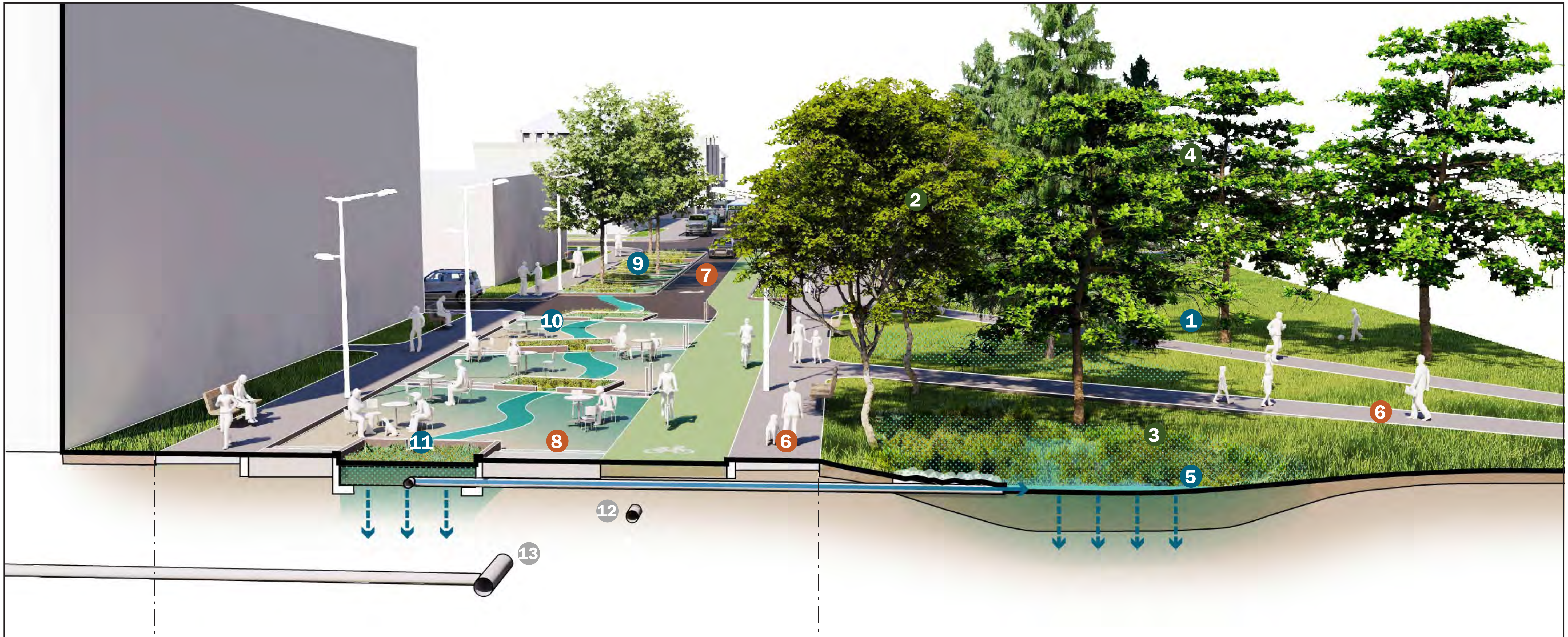
NOTE: This demonstration site is for conceptual illustration of Blue Green Systems planning. Any resemblance to recognizable locations does not imply plans or concepts for future design projects. All park GRI features would be determined by Park Board and transportation amenities by CoV Transportation.

- RUNOFF
- PIPED BASE FLOW
- PIPED HIGH FLOW
- DIVERSION STRUCTURE
- FLOW TO/FROM UPSTREAM/ DOWNSTREAM BGS

1. FLOODABLE OPEN SPACE
2. PRESERVE EXISTING TREE CANOPY
3. URBAN WETLAND ECOSYSTEM
4. HIGH FLOW BIORETENTION
5. EXPANDED TREE CANOPY
6. TERRACED WETLAND STORAGE
7. PEDESTRIAN PATH
8. ACCESS ROAD
9. STEPPED PLAZA
10. CASCADING BIOSWALE
11. COMMEMORATION OF WATER MOVEMENT
12. LINKED BIORETENTION PLANTERS

Typology 6: Seasonal Wetland

DEMONSTRATION SITE PERSPECTIVE

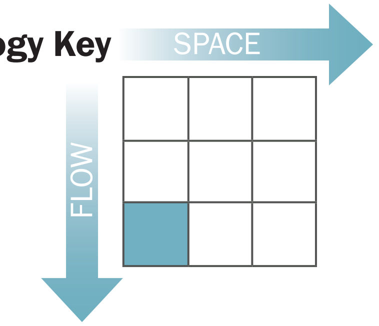


NOTE: This demonstration site is for conceptual illustration of Blue Green Systems planning. Any resemblance to recognizable locations does not imply plans or concepts for future design projects. All park GRI features would be determined by Park Board and transportation amenities by CoV Transportation.

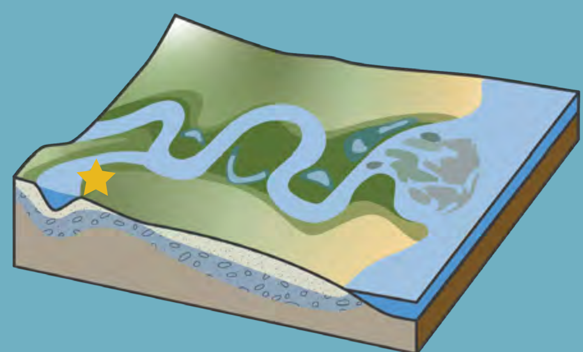
1. FLOODABLE OPEN SPACE
2. PRESERVE EXISTING TREE CANOPY
3. URBAN WETLAND ECOSYSTEM
4. EXPANDED TREE CANOPY
5. TERRACED WETLAND STORAGE
6. PEDESTRIAN PATH
7. ACCESS ROAD
8. STEPPED PLAZA
9. CASCADING BIOSWALE
10. ARTISTIC COMMEMORATION OF WATER MOVEMENT
11. LINKED BIORETENTION PLANTERS
12. EXISTING WATER UTILITY
13. EXISTING COMBINED SEWER UTILITY WITH SIDE SEWER CONNECTION

- PIPED CONNECTION
- INFILTRATION

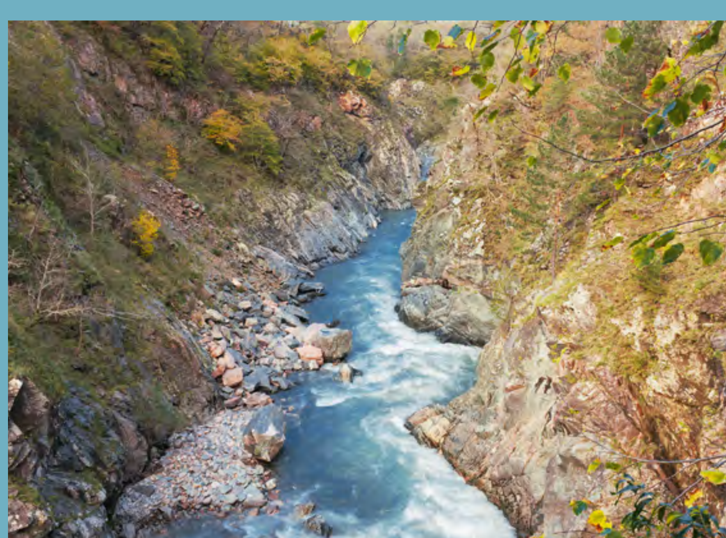
Typology 7: Perennial Rainway



INSPIRED BY A CONFINED RIVER



In natural systems, as water moves from the upland and transition zones to lowland zones, streams begin to merge into larger channels to form rivers. Confined rivers are found in restricted valleys where there is limited space for the channel to spread out. During routine rainfall, water in a confined river flows quickly through deeper pools and shallow gravel riffles. During larger storms, a confined river conveys water downstream within its banks. The urban analog for this typology features narrow, long, continuous GRI that manage large amounts of flow from upstream BGS in a narrow section of the right of way.



TYPOLOGY DESCRIPTION

Blue

1. Moderate to high flows from upstream BGS and local runoff.
2. Continuous surface flow path for conveyance.
3. Recharges groundwater though infiltration when feasible.
4. Temporarily stores water in facility soil and deeper ponding areas.
5. GRI is sized to manage all local runoff and upstream BGS flow for average events on-site. Excess flow conveyed to downstream BGS/receiving water body.
6. GRI sized to slow down and convey all runoff and upstream BGS flows for a 10-year event to downstream BGS / receiving water body.

Green

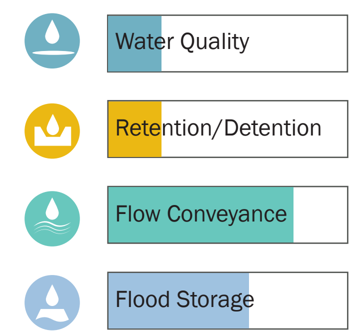
7. Native vegetation, native soils
8. Drought-resistant trees for shade, habitat.
9. Floodable vegetated channels

Connect

10. No encroachment into traffic lanes.
11. Extends into parking lane to calm traffic or pedestrian crossings.

TYPOLOGY AT-A-GLANCE

Primary Mechanisms



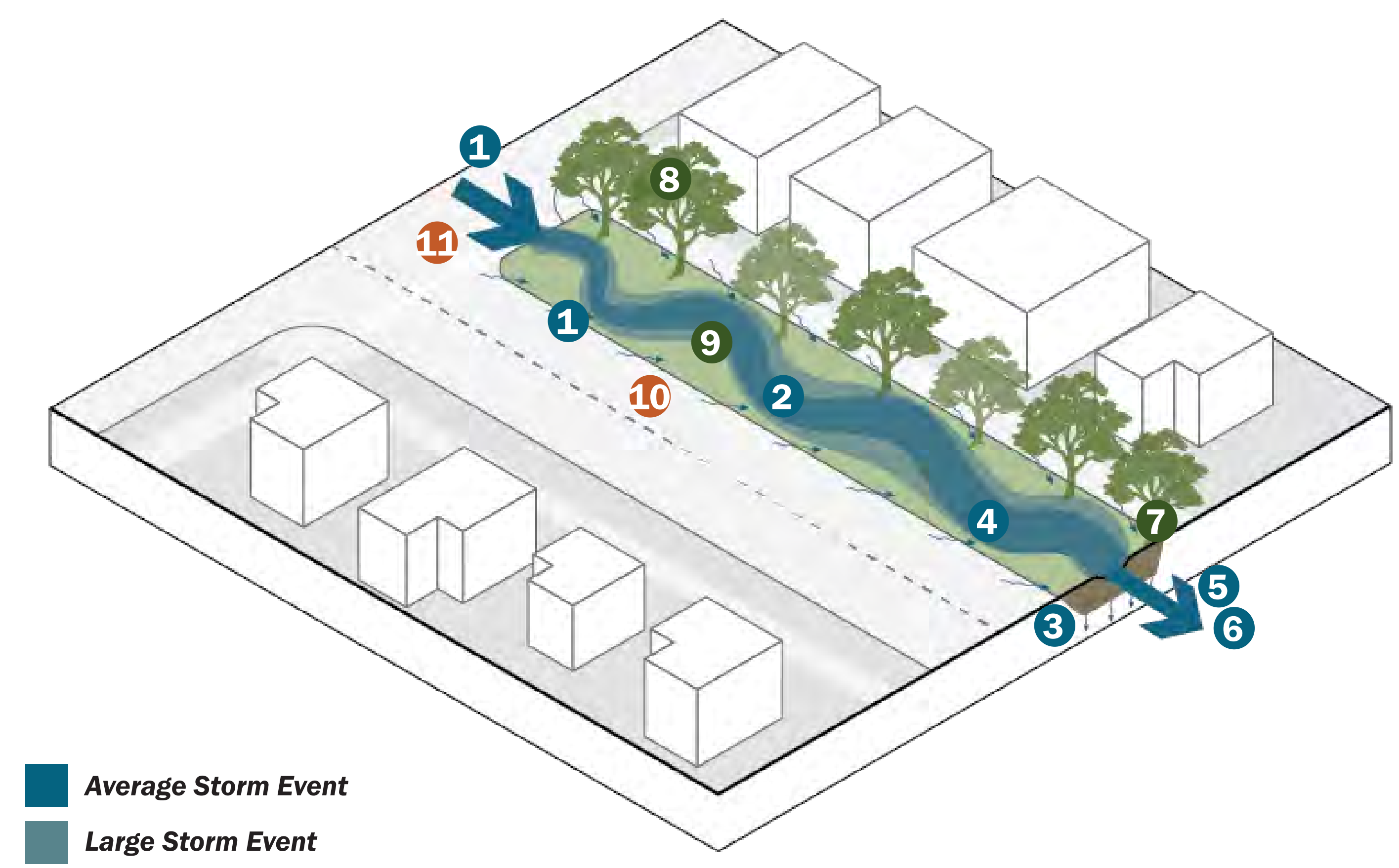
Characteristics

- Conveys large amounts of flow from upland and transition zones
- Manages local flow
- Utilizes continuous facilities
- Uses narrow road cross sections within ROW

Potential Components

- Bioretention planters/ bump-outs
- Bioswales with high and low flow terraces
- Tree trenches + expanded soil volume
- Permeable paving + expanded soil volume
- Subsurface storage
- Deep infiltration wells

GENERAL TYPOLOGY CONCEPT



Typology 7: Perennial Rainway

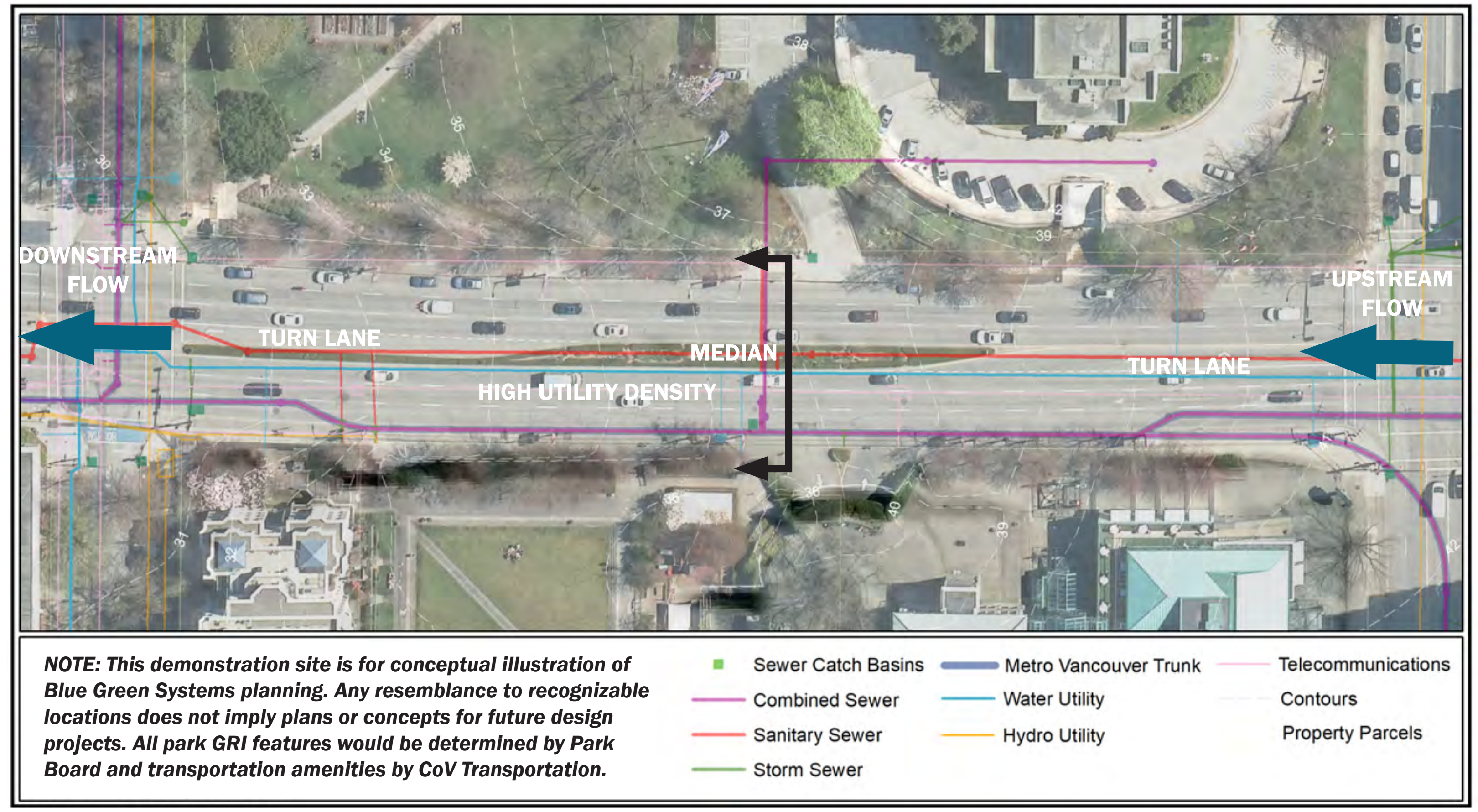
TYPOLOGY DEMONSTRATION SITE

The Typology 7: Perennial Rainway demonstration site is located in the lower watershed in a dense commercial neighbourhood on a major six lane arterial street. The street has a moderate slope with a vegetated median running nearly two-thirds the length of the block with two left-hand turn lanes at either end. The area is served by a large combined sewer main line draining over 500 hectares. The demonstration area is focused on peak flow and volume reduction to help prevent downstream CSOs. The road is crowned on both sides with subsurface utilities primarily located on the south side of the street, including the combined sewer main. The road is a major arterial, which limits space for the Blue Green System.

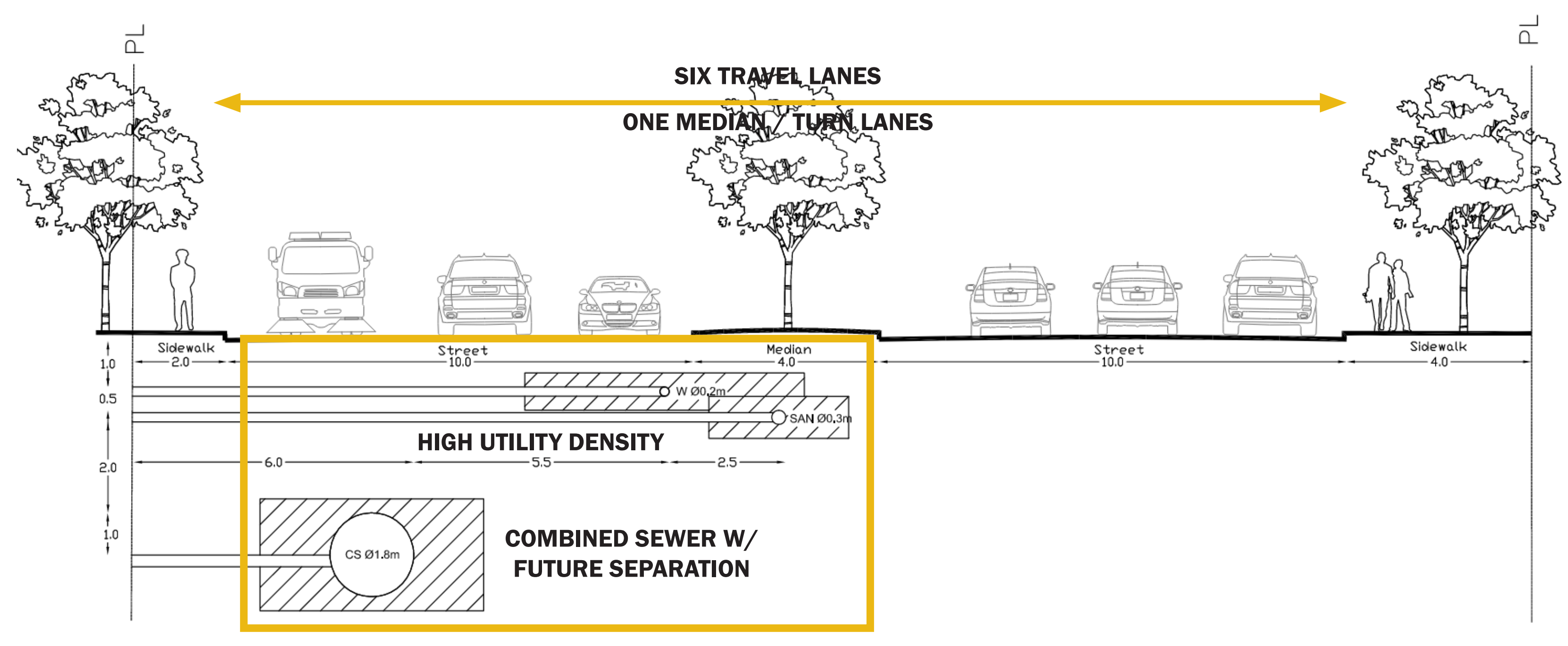
DEMONSTRATION SITE OBJECTIVES AND CONTEXT

	Blue	Green	Connect
Objectives	• **Peak flow reduction** • **Volume reduction** • Flood management	• Urban forest enhancement • Habitat connectivity	• Active mobility improvement • Environmental education and stewardship
Neighourhood Context	• Historic stream now piped to receiving water	• Nearby ecological corridor • Lack of urban canopy (10-15% coverage)	• Well connected through bikeways, and rapid transit • Commercial core
Site Context	• Future sewer separation • High utility congestion • Moderate slope (5-6%) • Low infiltration • Historic, buried stream	• Mature trees to preserve • Generally low canopy coverage	• Major arterial road • Commercial development area • Existing and expanding Rapid Transit

DEMONSTRATION SITE PLAN



DEMONSTRATION SITE EXISTING CROSS SECTION



Typology 7: Perennial Rainway

The Typology 7: Perennial Rainway demonstration site uses the limited area available to manage local runoff and convey flow from upstream Blue Green Systems. To maintain existing through traffic capacity yet adequately convey water volumes, a turn lane and a median are reconfigured to allow for a bioswale channel to be constructed. The channel is stepped with the moderate slope of the street and follows a "riffle-pool" sequence typically found in natural streams. The riffles are shallow segments of the channel with a gravel bottom. Deeper pools immediately follow the riffles and slow down and store larger volumes of water on the surface. Large subsurface gravel storage wells with a treatment media layer are located beneath the riffles and extend under a sidewalk. These storage wells mimic groundwater exchange that occurs in natural streams. The median is planted with drought-resistant trees to decrease urban heat and manage local runoff, with subsurface structural soil cells to support healthy tree roots. Bioretention facilities with underdrains along the other sidewalk protect pedestrians and manage local runoff. The bioswale channel, tree trenches, and bioretention cells converge at an in-line deep infiltration well at the end of the block to infiltrate as much of the collected flows as possible before conveying the remaining flow to downstream BGS.

DEMONSTRATION SITE CONCEPT

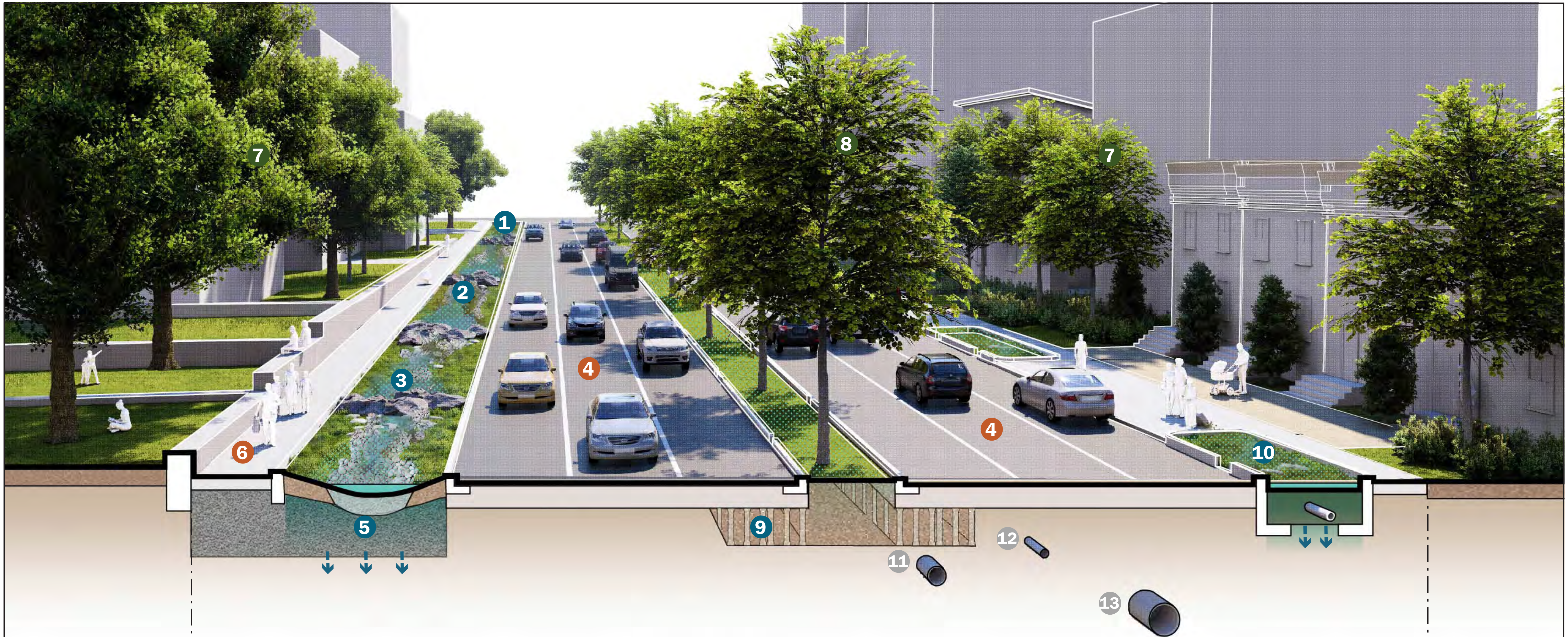
NOTE: This demonstration site is for conceptual illustration of Blue Green Systems planning. Any resemblance to recognizable locations does not imply plans or concepts for future design projects. All park GRI features would be determined by Park Board and transportation amenities by CoV Transportation.

- RUNOFF
- PIPED FLOW
- FLOW TO/FROM DOWNSTREAM / UPSTREAM BGS

1. FLOW FROM UPSTREAM BGS
2. CONFINED CHANNEL
3. POOLS
4. BIORETENTION WITH UNDERDRAIN
5. IMPROVED SIDEWALK
6. DEEP INFILTRATION WELL
7. SUBSURFACE LINED GRAVEL STORAGE FOR VOLUME + FLOW EXCHANGE
8. PRESERVED TREE CANOPY
9. NEW TREE CANOPY WITH TREE TRENCHES + SOIL CELLS FOR LOCAL RUNOFF
10. THROUGH TRAFFIC CAPACITY MAINTAINED

Typology 7: Perennial Rainway

DEMONSTRATION SITE PERSPECTIVE



EXISTING CONDITIONS	SIDEWALK	3 TRAVEL LANES	MEDIAN + TURN LANES	3 TRAVEL LANES	SIDEWALK

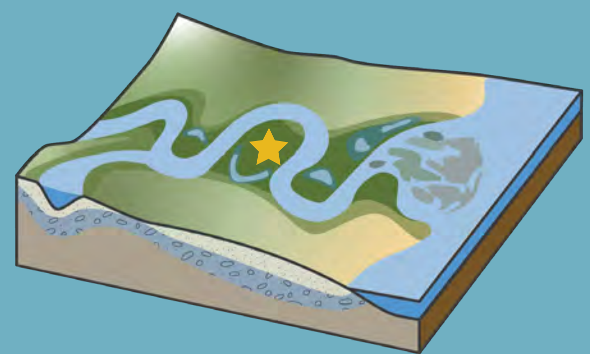
NOTE: This demonstration site is for conceptual illustration of Blue Green Systems planning. Any resemblance to recognizable locations does not imply plans or concepts for future design projects. All park GRI features would be determined by Park Board and transportation amenities by CoV Transportation.

1. FLOW FROM UPSTREAM BGS
2. CONFINED CHANNEL RIFFLES
3. POOLS
4. TRAFFIC CAPACITY MAINTAINED
5. SUBSURFACE LINED GRAVEL STORAGE FOR VOLUME + FLOW EXCHANGE
6. IMPROVED SIDEWALK
7. PRESERVED TREE CANOPY
8. NEW TREE CANOPY
9. TREE TRENCHES WITH SOIL CELLS FOR LOCAL RUNOFF
10. BIORETENTION WITH UNDERDRAIN
11. EXISTING SANITARY SEWER
12. EXISTING WATER UTILITY
13. EXISTING METRO VANCOUVER COMBINED SEWER TRUNK LINE

↓ LIMITED INFILTRATION

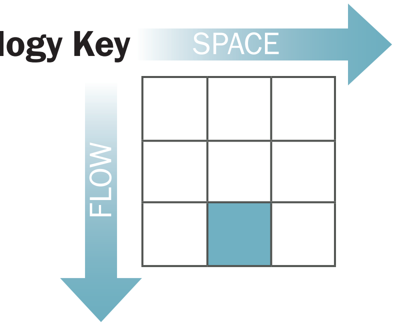
Typology 8: Perennial Blueway

INSPIRED BY A RIVER + WETLAND BENCH



In natural systems, wetland benches form in shallow depressions along the inside meanders of the river channel. Wetland benches are periodically inundated and slow water down and hold it before filtering through vegetation and soil to recharge groundwater or seep back into the river channel. Rivers with wetland benches provide more storage, retention, and conveyance. The urban analog for this typology features continuous, wider GRI that manage large amounts of upland flow in a larger portion of the right of way.

Typology Key



TYPOLOGY DESCRIPTION

Blue

1. Moderate to high flows from upstream BGS, impervious development, local runoff.
2. Continuous surface flow path for conveyance of local and upstream runoff.
3. Recharges groundwater through infiltration when feasible.
4. Temporarily stores water in deeper ponds and terraces along main channel.
5. GRI is sized to manage all local runoff and upstream BGS flow for average events on-site. Excess flow conveyed to downstream BGS/receiving water body.
6. GRI sized to slow down and convey all runoff and upstream BGS flows for a 10-year event to downstream BGS / receiving water body.

Green

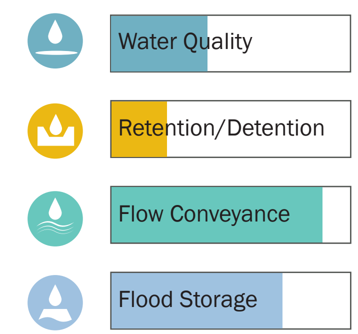
7. Native vegetation, native soil
8. Drought-resistant trees for shade, habitat
9. Vegetated, terraced channels for aquatic habitat.

Connect

10. Extends into a portion of traffic lanes, possible lane closures or reroute traffic.
11. Extends into parking lane and intersections to calm neighbourhood traffic.

TYPOLOGY AT-A-GLANCE

Primary Mechanisms



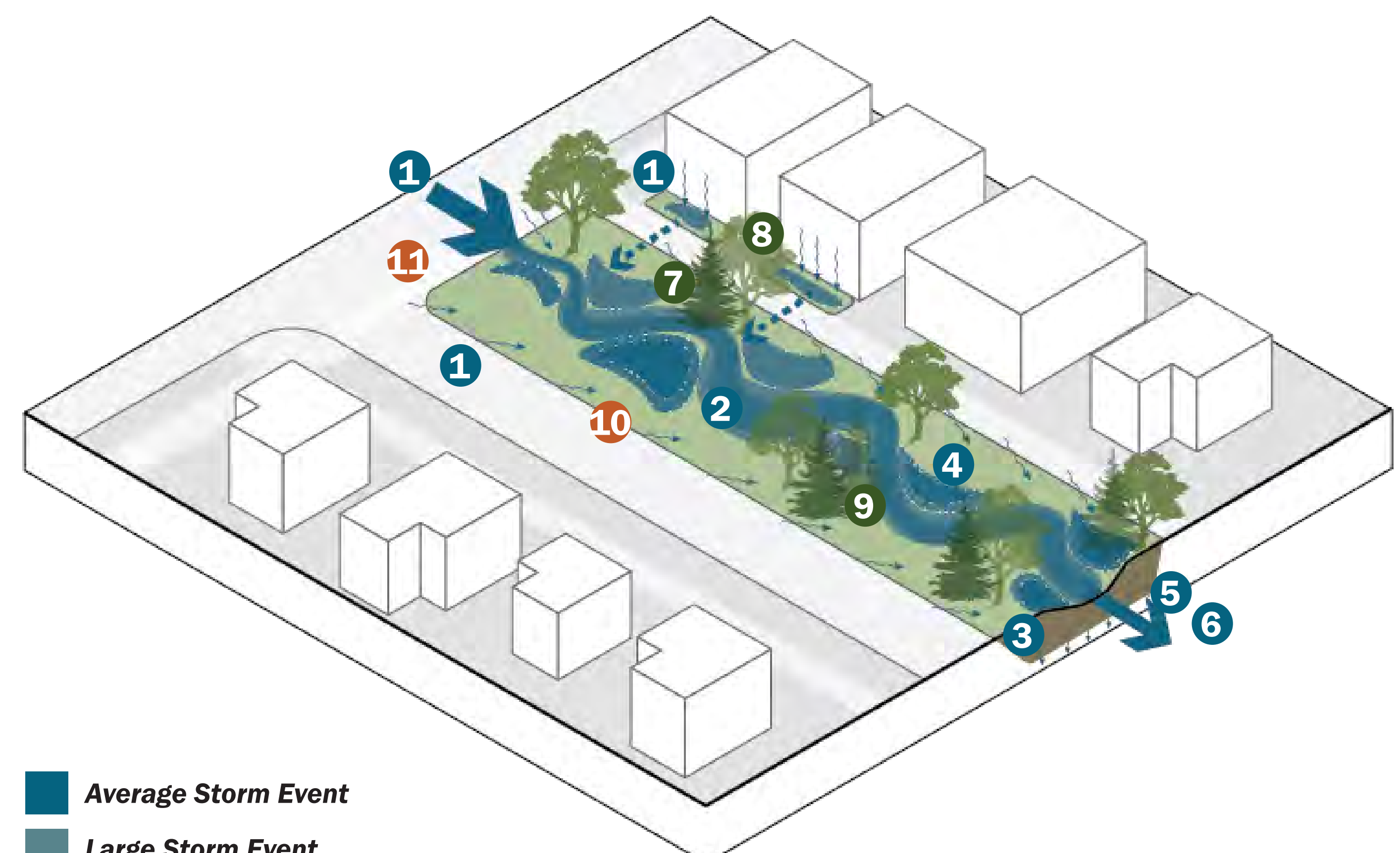
Characteristics

- Conveys large amounts of flow from upland and transition zones
- Manages local flow
- Utilizes continuous facilities
- Uses larger road cross sections within ROW to accommodate larger flows

Potential Components

- Oversized bioretention planters/bump-outs
- Oversized bioswales with high and low flow terraces
- Tree trenches + expanded soil volume
- Permeable paving + expanded soil volume
- Subsurface storage
- Deep infiltration wells

GENERAL TYPOLOGY CONCEPT



Typology 8: Perennial Blueway

TYPOLOGY DEMONSTRATION SITE

The Typology 8: Perennial Blueway demonstration site is located low in the watershed in an industrial and mixed-use commercial zone. Although the demonstration site is along a major arterial road, a future rapid transit station nearby will reduce non-essential traffic. This presents an opportunity to designate a larger portion of the arterial to a Blue Green System so that the large volume of rainwater collected from upstream Blue Green Systems can be managed to reduce overland flooding. The demonstration site includes an existing bikeway adjacent to planned commercial development, so spaces for people in addition to water are important to consider.

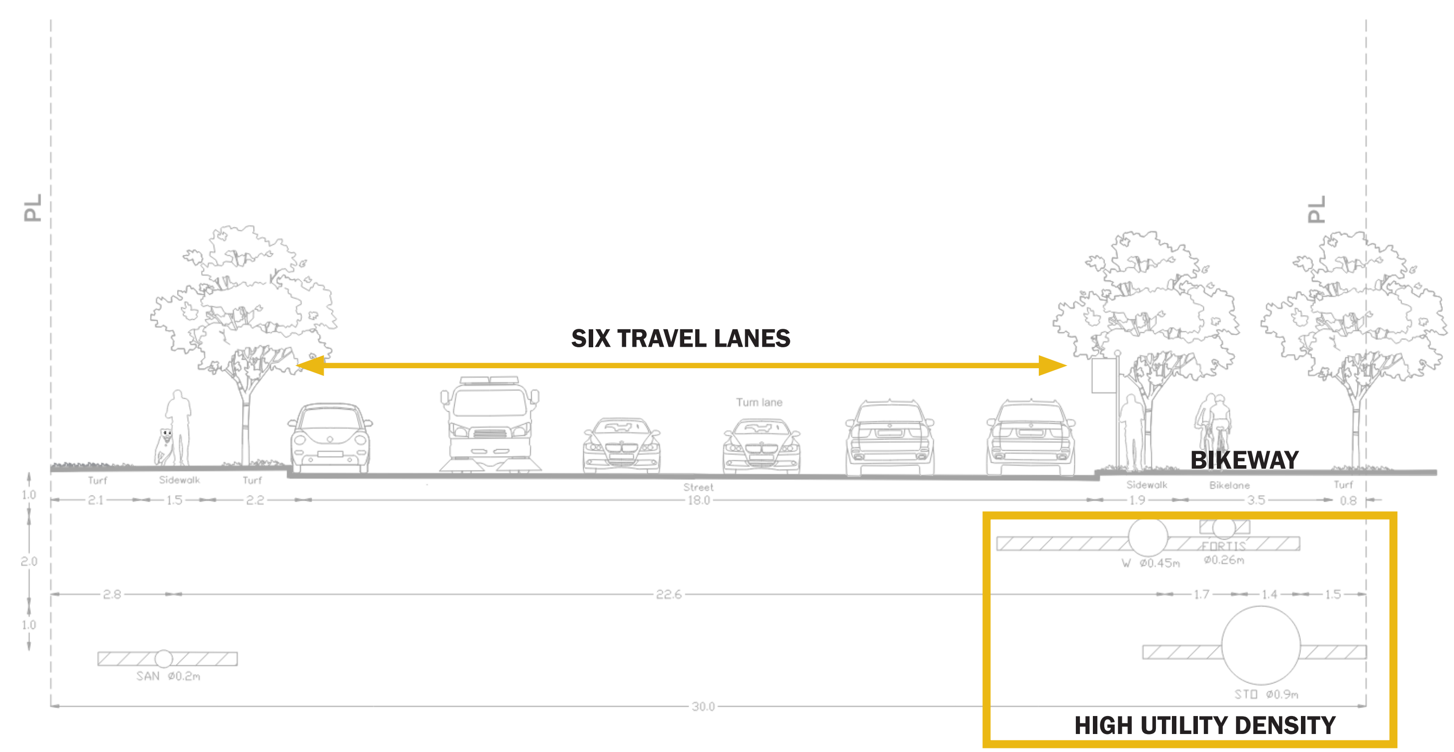
DEMONSTRATION SITE OBJECTIVES AND CONTEXT

	Blue	Green	Connect
Objectives	• **Flood management** • Volume reduction	• **Urban forest enhancement** • Habitat connectivity • Pollinator habitat enhancement	• Active transportation improvement • Environmental education and stewardship
Neighourhood Context	• Historic floodplain and stream in lowland basin • Low in the watershed with high flow accumulation • Separated storm sewer	• Ecologically-Sensitive Zone • Tree canopy deficit (10% coverage)	• Major arterial road • Existing bikeway route connections • Future Rapid Transit Station nearby
Site Context	• Flat, former floodplain (<1% slope) • Steep slope to the south creates fast runoff • Low infiltration capacity • High utility congestion	• Significant canopy decline • No mature trees • Extreme urban heat	• Industrial, commercial, and mixed-use zone • Goal to transform industrial area into modernized commercial hub. • Two-way greenway and pedestrian sidewalks

DEMONSTRATION SITE PLAN

NOTE: This demonstration site is for conceptual illustration of Blue Green Systems planning. Any resemblance to recognizable locations does not imply plans or concepts for future design projects. All park GRI features would be determined by Park Board and transportation amenities by CoV Transportation.

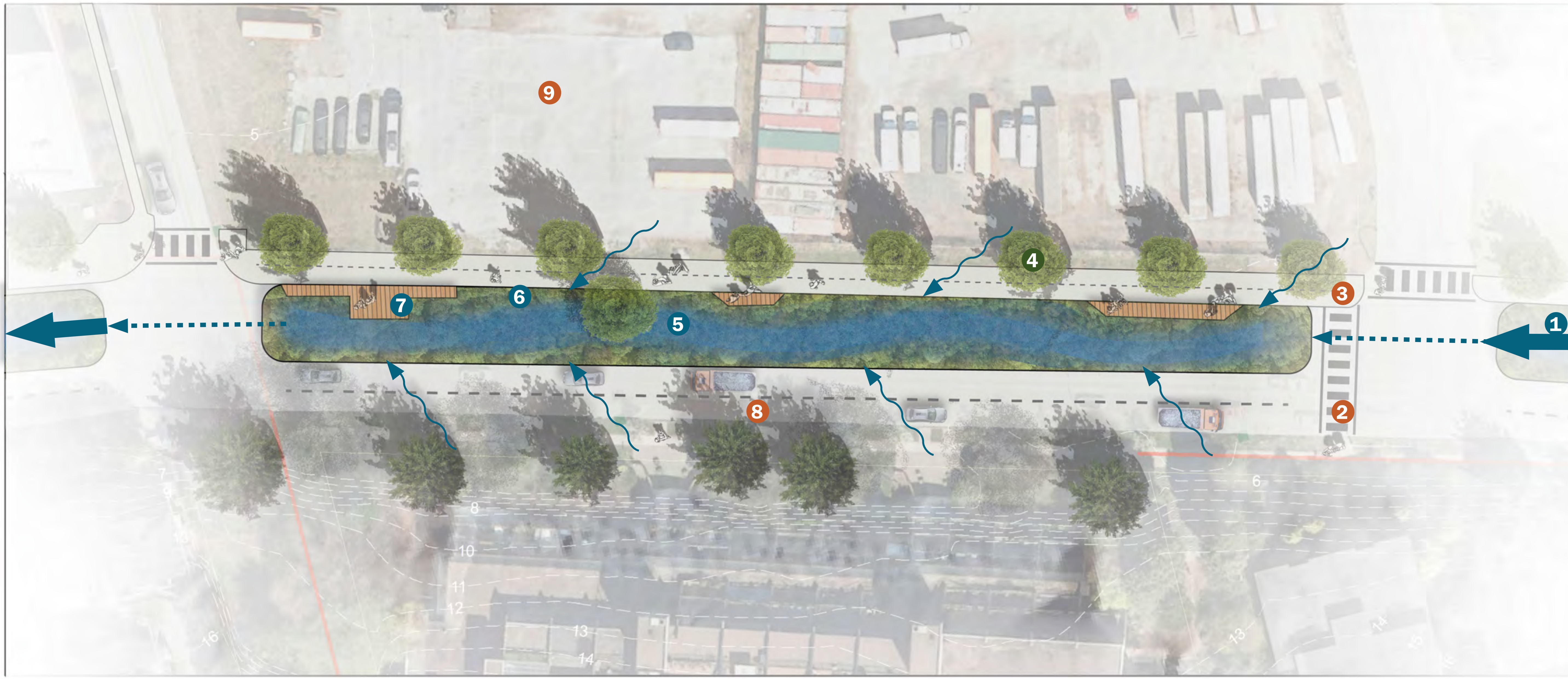
DEMONSTRATION SITE EXISTING CROSS SECTION



Typology 8: Perennial Blueway

The Typology 8: Perennial Blueway demonstration site requires a substantial portion of the major arterial road to accommodate the large volume of runoff received from upstream Blue Green Systems. Future rapid transit development allows the arterial road to be reduced to two lanes that support commercial traffic only. Runoff from upstream Blue Green Systems is managed in a large channel with tiered edges to create wetland zones that slow down the rainwater. The existing two-lane bikeway is preserved as essential infrastructure for people to access this developing mixed-use area. Public viewing platforms with benches allow people who work and recreate in this district to interact with the Blue Green System and enjoy public space shaded by an expanded urban tree canopy.

DEMONSTRATION SITE CONCEPT



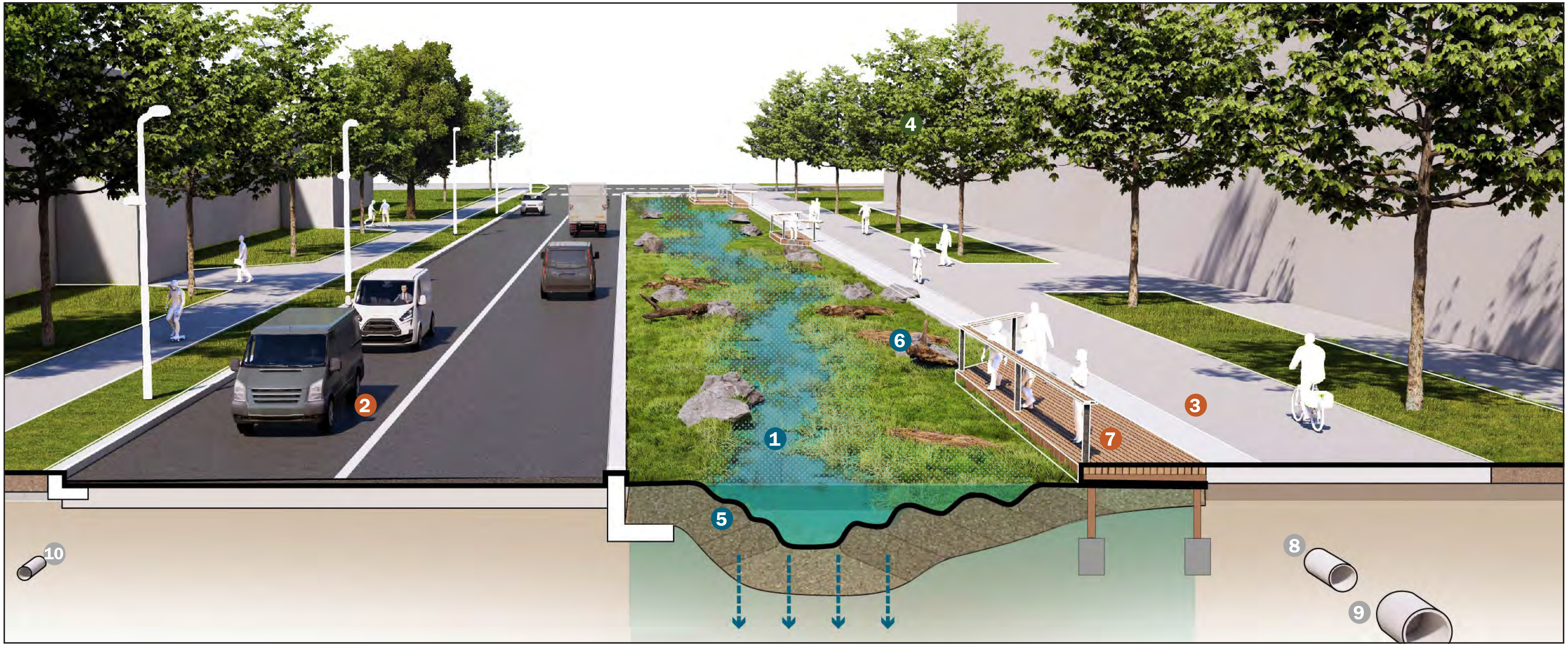
NOTE: This demonstration site is for conceptual illustration of Blue Green Systems planning. Any resemblance to recognizable locations does not imply plans or concepts for future design projects. All park GRI features would be determined by Park Board and transportation amenities by CoV Transportation.

RUNOFF
PIPED FLOW
FLOW TO/FROM DOWNSTREAM / UPSTREAM BGS

1. FLOW FROM UPSTREAM BGS
2. IMPROVED PEDESTRIAN CROSSWALKS
3. SHARED-USE PATH
4. EXPANDED TREE CANOPY
5. PERENNIAL BLUEWAY CHANNEL
6. WETLAND EDGES
7. BGS VIEWING PLATFORM
8. REDUCED VEHICLE LANES
9. FUTURE DEVELOPMENT AREA

Typology 8: Perennial Blueway

DEMONSTRATION SITE PERSPECTIVE



EXISTING CONDITIONS	TRAVEL LANE	TRAVEL LANE	TRAVEL LANE	TRAVEL LANE	BIKEWAY + VEGETATED STRIP

NOTE: This demonstration site is for conceptual illustration of Blue Green Systems planning. Any resemblance to recognizable locations does not imply plans or concepts for future design projects. All park GRI features would be determined by Park Board and transportation amenities by CoV Transportation.

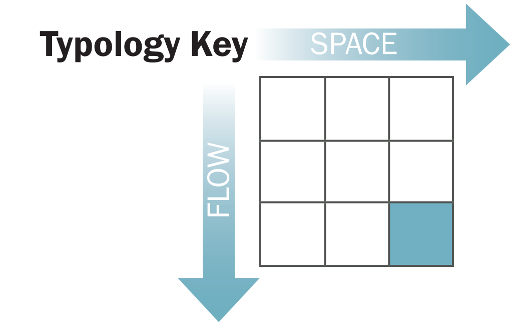
1. PERENNIAL BLUEWAY CHANNEL
2. VEHICLE LANES REDUCED TO ESSENTIAL VEHICLES
3. SHARED-USE PATH
4. EXPANDED TREE CANOPY
5. COIR BENCHES
6. WETLAND EDGES
7. BGS VIEWING PLATFORM
8. EXISTING WATER UTILITY
9. EXISTING STORM SEWER
10. EXISTING SANITARY SEWER

INFILTRATION

Typology 9: Perennial Wetland

INSPIRED BY A TIDAL MARSH

In natural systems, a tidal marsh is an open wetland found in the lowlands where streams and rivers flow into marine and estuarine water bodies. Tidal marshes are characterized by interconnected channels and depressions that hold and transport water as water levels fluctuate with tides. Plants and soils slow and filter water from the upstream watershed; provide protection from storm surges; and serve as critical habitat for a diverse mix of critical species, including plants, crustaceans, fish, birds, and mammals. The urban analog for this typology features large open spaces adjacent to the receiving water body where district-scale GRI can manage large amounts of rainwater from the entire urban watershed through detention and conveyance.



TYPOLOGY DESCRIPTION

Blue

1. Moderate to high flows from upstream BGS
2. Manage flow with conveyance via large channels and detention via deeper depressions.
3. District-scale GRI manages and treats all local runoff and upstream BGS flow for average events on-site before flowing to receiving water body.
4. District-scale GRI sized to slow down and convey all runoff and upstream BGS flows for a 10-year event to downstream BGS / receiving water body

Green

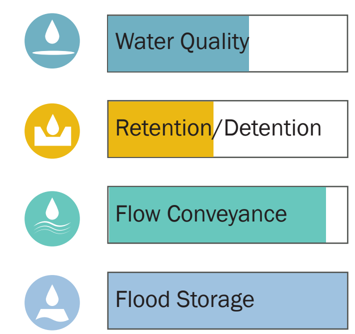
5. Native vegetation, native soils
6. Climate-adaptive plant species
7. Floodable tidal marsh ecosystem

Connect

8. District and neighbourhood-scale amenities
9. Incorporated into landscape to facilitate recreation, active mobility, and community engagement.

TYPOLOGY AT-A-GLANCE

Primary Mechanisms



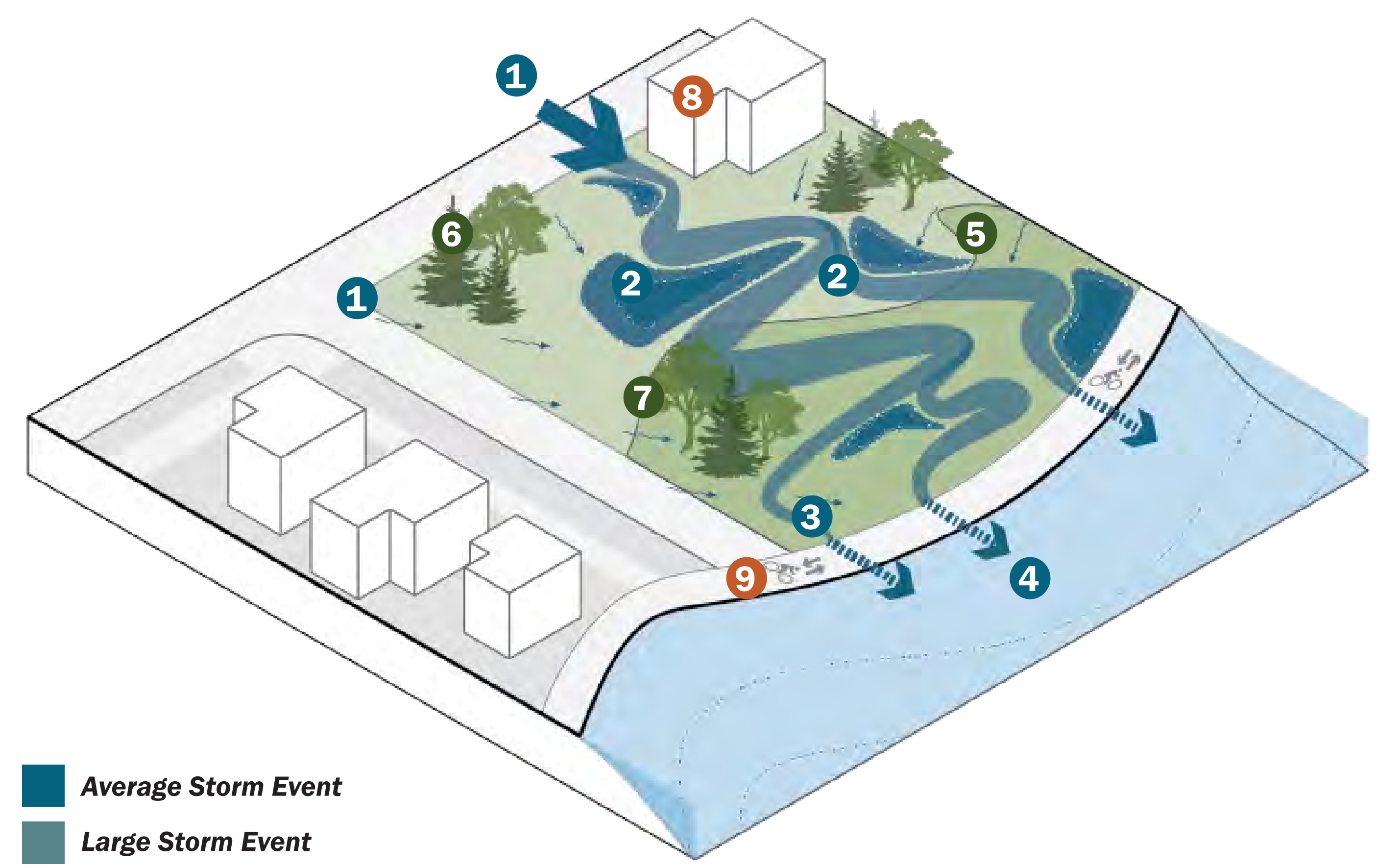
Characteristics

- Conveys large amounts of flow from upland and transition zones
- Manages local flow
- Utilizes continuous facilities
- Uses larger road cross section + adjacent open space to accommodate flows

Potential Components

- Oversized bioretention planters/bump-outs
- Oversized bioswales with high and low flow terraces
- Tree trenches + expanded soil volume
- Permeable paving + expanded soil volume
- Constructed wetlands or large surface storage
- Subsurface storage
- Deep infiltration wells

GENERAL TYPOLOGY CONCEPT



Typology 9: Perennial Wetland

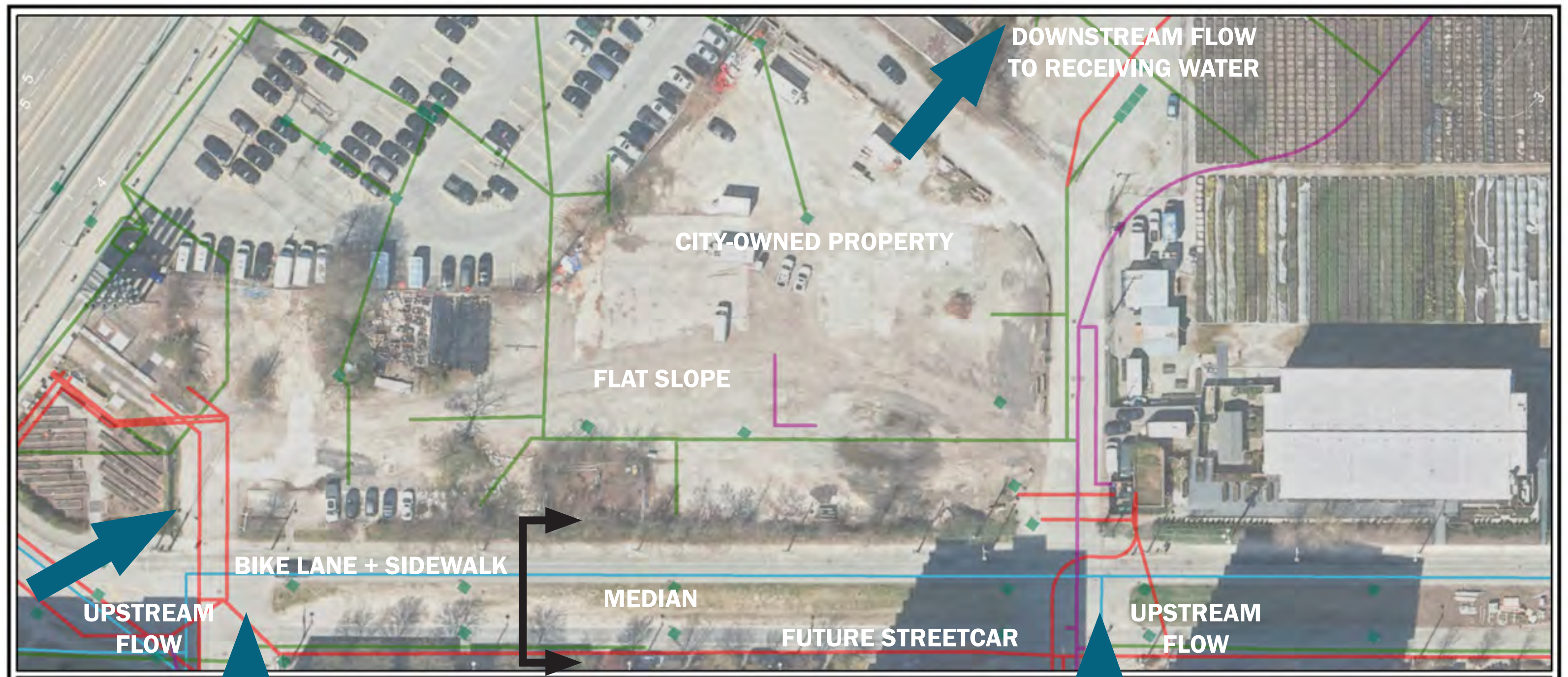
TYPOLOGY DEMONSTRATION SITE

The Typology 9: Perennial Wetland demonstration site is located low in the watershed where rainwater from upstream Blue Green Systems and lowland flooding meet. The site is along a local road with an existing bikeway and proposed streetcar that is adjacent to a large, empty City-owned property. Due to the large volume of water needed to be managed, as well as climate change concerns, flood management, sea level rise adaptation, and volume management are priorities. The site has low-infiltrating soils, shallow groundwater, and low utility congestion. Additionally, it is nearby to other lowland habitat restoration efforts, so the space available provides opportunities to improve habitat connectivity and flood management.

DEMONSTRATION SITE OBJECTIVES AND CONTEXT

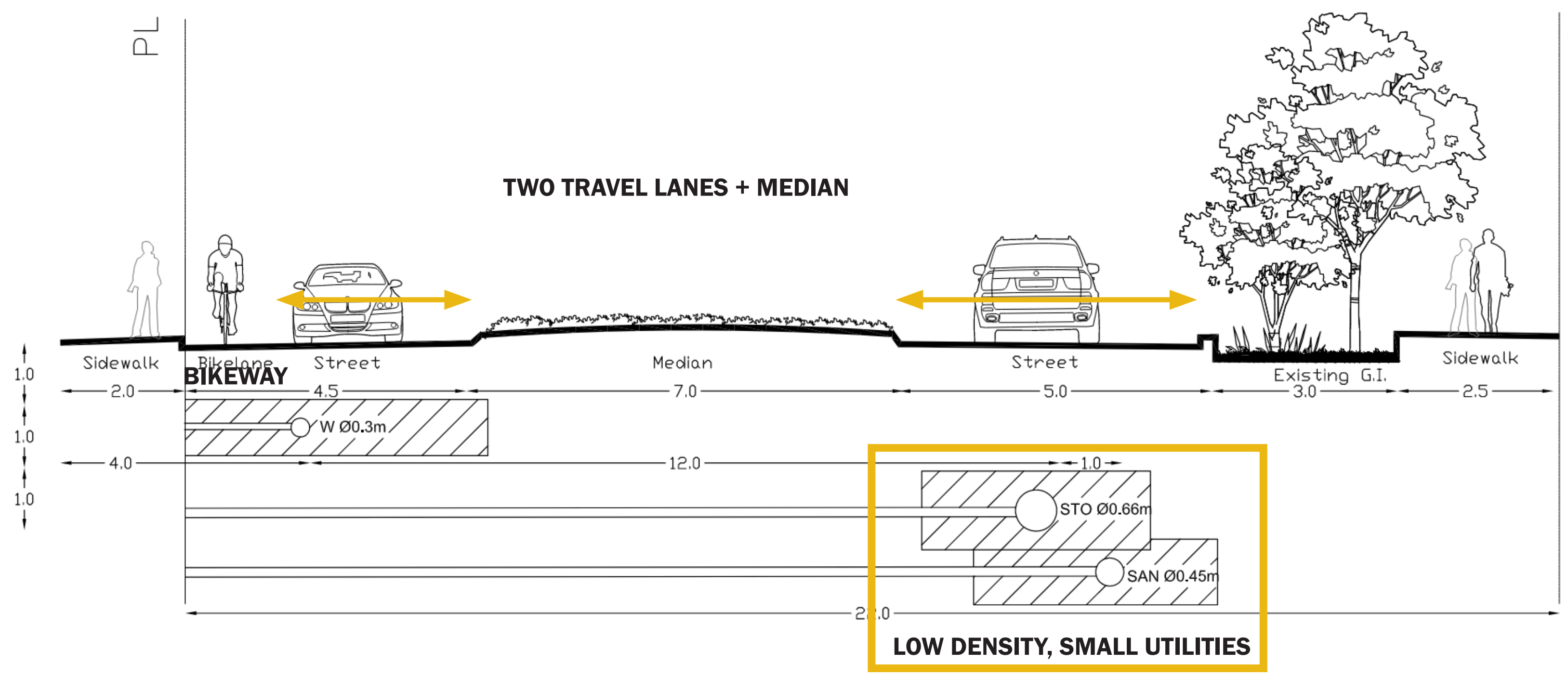
	Blue	Green	Connect
Objectives	• **Flood management** • **Sea level rise adaptation** • Water quality improvement	• **Habitat connectivity** • Pollinator habitat enhancement • Terrestrial and aquatic wildlife habitat enhancement	• Active mobility improvement • Park connectivity • Cultural connections • Environmental education and stewardship
Neighbourhood Context	• Tidal floodplain • Likely flooded in 1 m sea level rise conditions by 2100 • Lowlands of watershed receives large rainwater volumes • Impervious, infill area	• Nearby large tidal and wetland habitat networks	• Existing bikeway hub with connections across Vancouver • Planned expansion of transit network, including streetcar
Site Context	• Low utility congestion • Separated and combined sewer infrastructure • Very flat slope (<1%) • Historic stream • Low infiltration • Shallow groundwater	• Minimal tree canopy • Habitat restoration considers flooding and tidal influence	• Local road • City-owned property • Large commercial and industrial lots with low use • Interest in housing and community amenities

DEMONSTRATION SITE PLAN



NOTE: This demonstration site is for conceptual illustration of Blue Green Systems planning. Any resemblance to recognizable locations does not imply plans or concepts for future design projects. All park GRI features would be determined by Park Board and transportation amenities by CoV Transportation.

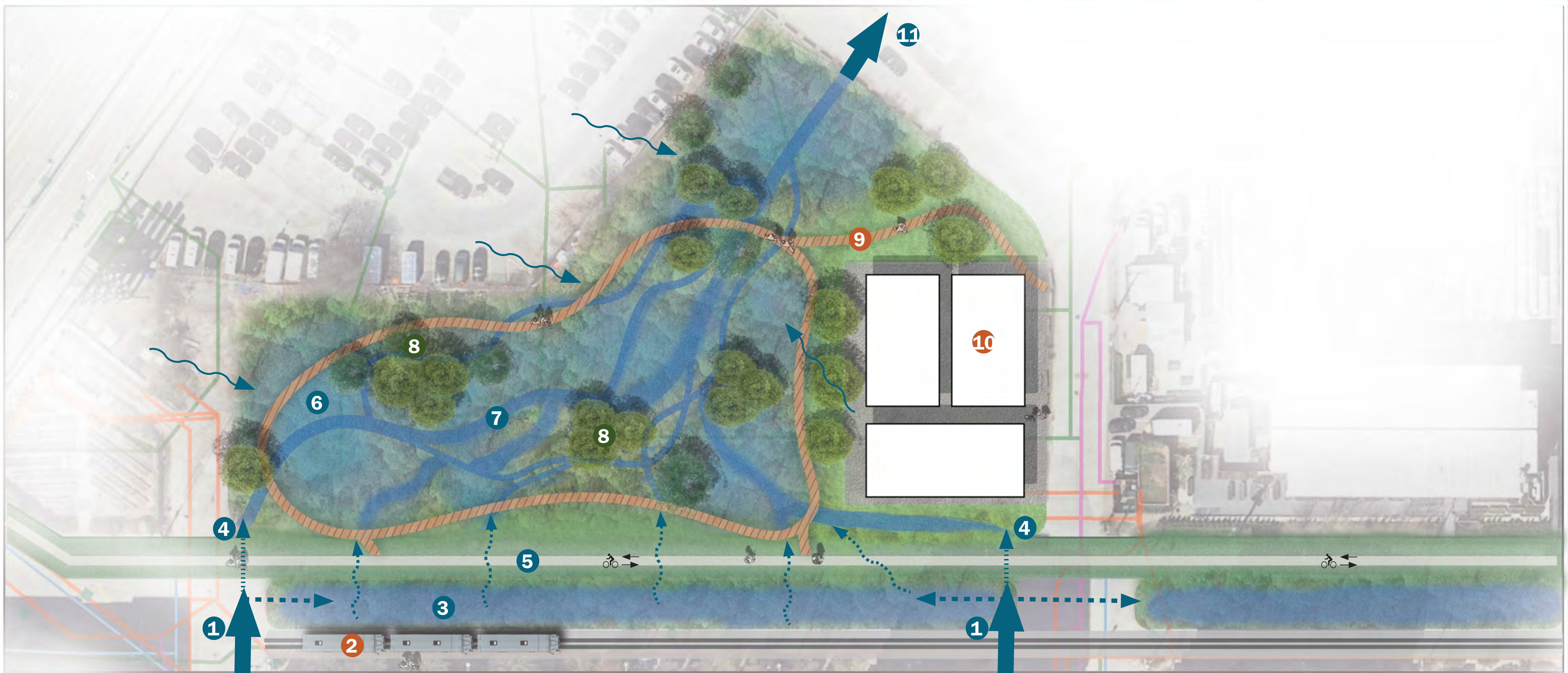
DEMONSTRATION SITE EXISTING CROSS SECTION



Typology 9: Perennial Wetland

The Typology 9: Perennial Wetland demonstration site receives large volumes of water conveyed from upstream Blue Green Systems before they reach natural receiving water bodies. The water flows from the upstream systems into a surface water storage channel buffered by a streetcar and permeable bikeway berm. The street car tracks are equipped with subsurface flood storage for large storms. The permeable bikeway berm buffers lowland flooding from inundating development along the streetcar and throughout the neighourhood. Rainwater held in the surface water storage channel seeps through the permeable berm into storage and treatment wetlands where water flows slowly through a wetland ecosystem and natural channels form and shift over time. Small landscape islands support wetland habitat and trees, creating a more varied ecosystem. The large amount of open space on site provides opportunities for modular housing or other adaptable community amenities, which are connected to the wetland with a boardwalk path.

DEMONSTRATION SITE CONCEPT



NOTE: This demonstration site is for conceptual illustration of Blue Green Systems planning. Any resemblance to recognizable locations does not imply plans or concepts for future design projects. All park GRI features would be determined by Park Board and transportation amenities by CoV Transportation.

- RUNOFF
- PERMEABLE SUBSURFACE WATER FLOW
- PIPED FLOW
- FLOW TO/FROM DOWNSTREAM / UPSTREAM BGS

1. FLOW FROM UPSTREAM BGS
2. STREETCAR W/ SUBSURFACE FLOOD STORAGE
3. SURFACE DEPRESSION STORAGE CHANNEL
4. EMERGENCY OVERFLOW ROUTE
5. PERMEABLE BIKEWAY BERM
6. STORAGE AND TREATMENT WETLANDS
7. NATURALIZED CHANNELS
8. HABITAT ISLANDS
9. BOARDWALK PATH
10. MODULAR HOUSING
11. TO RECEIVING NATURAL WATERBODY

Typology 9: Perennial Wetland

DEMONSTRATION SITE PERSPECTIVE

EXISTING CONDITIONS	PUBLIC PARKING LOT	BIKEWAY	TRAVEL LANE	MEDIAN	TRAVEL LANE	SIDEWALK + VEGETATED STRIP

NOTE: This demonstration site is for conceptual illustration of Blue Green Systems planning. Any resemblance to recognizable locations does not imply plans or concepts for future design projects. All park GRI features would be determined by Park Board and transportation amenities by CoV Transportation.

1. FLOW FROM UPSTREAM BGS
2. STREETCAR W/ SUBSURFACE FLOOD STORAGE
3. SURFACE DEPRESSION STORAGE CHANNEL
4. EMERGENCY OVERFLOW ROUTE
5. PERMEABLE BIKEWAY BERM
6. STORAGE AND TREATMENT WETLANDS
7. NATURALIZED CHANNELS
8. HABITAT ISLANDS
9. BOARDWALK PATH
10. MODULAR HOUSING
11. LIMITED INFILTRATION, SHALLOW GROUNDWATER

PIPED CONNECTION

INFILTRATION


E 53 RD AVE
300
6800 Prince Edward St
SUNSET PARK UPGRADES
EXCEPT BICYCLES

Conclusion

Conclusion

IMPLEMENTING A VISION FOR BLUE GREEN SYSTEMS

The Blue Green System framework and associated typologies represent a starting place for the City to continue to develop and refine its vision for Blue Green Systems. As the vision leads to the planning and implementation of future projects, the typologies will help guide conversations with City partners, developers, and community members about specific objectives and functions of Blue Green Systems; how watershed (flow) and site (spatial) contexts influence design and performance; ways other contexts and conditions affect design; and implementation considerations as the City works to achieve their vision.

DESIGNING FOR WATERSHED AND SITE CONTEXT

The nine Blue Green Systems typologies were developed to show how Blue Green Systems may look and function across a range of watershed and site contexts. It should be acknowledged again that these contexts represent a continuum of flows and space availability that may be encountered and that typology designs can be configured in numerous ways to respond to these contexts. Table 10 on the following page provides a summary snapshot for each of the nine typologies that includes expected Blue performance objectives, general mechanisms to achieve these objectives, and potential components.

DESIGNING FOR OTHER CONTEXTS AND CONDITIONS

The amount of flow being managed (watershed context) and the space available to do it (site context) are the two key factors that form the typology framework and distinguish between typologies. These are not the only factors however that affect the design of a particular Blue Green System segment. Many other location-specific factors or variables may be encountered that also influence design, including:

- **Infrastructure contexts** like existing water management systems, adjacent land use, and transportation needs, which directly relate to the specific Blue, Green, and Connect objectives of a particular Blue Green System segment.
- **Site conditions or characteristics**, which could serve as either an opportunity or a constraint for Blue Green System design. These include but are not limited to topography and slope, utility congestion, soil infiltration capacity, and groundwater elevation, among others.

Like the site and watershed contexts, these additional factors also rest on a continuum and directly influence the ways that Blue Green Systems can be expressed in an urban environment. The nine hypothetical typology demonstrations presented in the previous section were purposely curated and designed to highlight a range of these different factors and expressions.

Table 11 on the following pages provides a crosswalk of the various infrastructure contexts, design objectives, opportunities, and constraints encountered at each of the hypothetical typology demonstration sites. Table 11 also highlights the design strategy that was deployed in response to key factors. This table can be a useful aid for exploring design ideas within the typology demonstrations that are not inherently part of a particular typology. For example, low soil infiltration capacity is not part of the typology framework but could be a factor for any Blue Green System typology segment. A review of the table for designs that address low soil infiltration could provide inspiration for strategies to navigate this particular constraint on future Blue Green System projects.

Table 10: Designing for Watershed and Site Context

Performance		Narrow ROW	Expanded ROW	Expanded ROW + Open Space
Water quality treatment and retention/detention: 48 mm of local runoff **Peak flow reduction + conveyance of 10-year 1-hour storm:** Local runoff **Flood storage:** Minor events	**Upland Zone**	UPLAND RAINWAY **Discontinuous distributed facilities** • Bioretention planters/ bump-outs • Tree trenches • Permeable paving Water Quality Retention/Detention Flow Conveyance Flood Storage	UPLAND BLUEWAY **Discontinuous distributed facilities** • Oversized bioretention planters/bump-outs • Tree trenches • Permeable paving Water Quality Retention/Detention Flow Conveyance Flood Storage	UPLAND WET MEADOW **Discontinuous distributed facilities** • Oversized bioretention planters/bump-outs • Tree trenches • Permeable paving • Constructed wetlands or surface storage Water Quality Retention/Detention Flow Conveyance Flood Storage
Water quality treatment and retention/detention: 48 mm of local runoff **Peak flow reduction + safe conveyance of 10-year 1-hour storm:** Upstream BGS + local runoff **Flood storage:** Moderate events	**Transition Zone**	SEASONAL RAINWAY **Continuous or linked distributed facilities** • Bioretention planters/ bump-outs • Bioswales • Tree trenches + potentially expanded soil volume • Permeable paving + expanded soil volume Water Quality Retention/Detention Flow Conveyance Flood Storage	SEASONAL BLUEWAY **Continuous or linked distributed facilities** • Oversized bioretention planters/bump-outs • Oversized bioswales • Tree trenches + potentially expanded soil volume • Permeable paving + expanded soil volume Water Quality Retention/Detention Flow Conveyance Flood Storage	SEASONAL WETLAND **Continuous or linked distributed facilities** • Oversized bioretention planters/bump-outs • Oversized bioswales • Tree trenches + potentially expanded soil volume • Permeable paving + expanded soil volume • Constructed wetlands or large surface storage Water Quality Retention/Detention Flow Conveyance Flood Storage
Water quality treatment and retention/detention: 48 mm of local runoff **Peak flow reduction + safe conveyance of 10-year 1-hour storm:** Upstream BGS + local runoff **Flood storage:** Major events	**Lowland Zone**	PERENNIAL RAINWAY **Continuous facilities** • Bioretention planters/ bump-outs • Bioswales with high and low flow terraces • Tree trenches + expanded soil volume • Permeable paving + expanded soil volume • Subsurface storage • Deep infiltration well Water Quality Retention/Detention Flow Conveyance Flood Storage	PERENNIAL BLUEWAY **Continuous facilities** • Oversized bioretention planters/bump-outs • Oversized bioswales with high and low flow terraces • Tree trenches + expanded soil volume • Permeable paving + expanded soil volume • Subsurface storage • Deep infiltration well Water Quality Retention/Detention Flow Conveyance Flood Storage	PERENNIAL WETLAND **Continuous facilities** • Oversized bioretention planters/bump-outs • Oversized bioswales with high and low flow terraces • Tree trenches + expanded soil volume • Permeable paving + expanded soil volume • Constructed wetlands or large surface storage • Subsurface storage • Deep infiltration well Water Quality Retention/Detention Flow Conveyance Flood Storage

Table 11a: Designing for Other Contexts and Conditions, Upland Zone

UPLAND ZONE

General Typology Descriptions			Typology Demonstration Infrastructure Context			Typology Demonstration Objectives			Typology Demonstration Design Opportunities and Constraints					
ID	**Typology Name**	**Site Context**	**Water Management**	**Adjacent Land Use**	**Transportation**	**Blue Objectives**	**Green Objectives**	**Connect Objectives**		**Topography + Slope**	**Utility Congestion**	**Soil Infiltration Capacity**	**Groundwater Elevation**	**Other**
1	Upland Rainway	Narrow ROW	Separated sewer	Commercial comprehensive development	• Local road with two travel lanes + two parking lanes • Plan for future local bikeway • Adjacent to highways	• **Water quality improvement** • Volume reduction • Groundwater recharge	• **Habitat connectivity** • Pollinator habitat enhancement	• **Active mobility improvements**	Conditions	• Crowned road • Low slope (<1%)	• High congestion, conflicts on both sides of roads	• High infiltrating soils	• Moderately deep groundwater	• Mature trees in adjacent private property
									Design Strategy	» *Site distributed facilities on both sides of road with shallow overflow pipes connecting facilities*	» *Avoid siting facilities within utility setbacks where possible* » *Use lined perme-able pavement above water line*	» *Maximize use of infiltrating facilities* » *Use larger facility footprint at block end to manage flows from permeable pavement bike lane*	» *Provide treatment via biofiltration prior to infiltration to groundwater*	» *Site permeable pavement away from tree canopy to min-imize leaf litter accumulation*
2	Upland Blueway	Expanded ROW	Separated sewer	• Single- family Residential • Adjacent forested ecological corridor on private parcel	• Local green-way with two travel lanes + one parking lane • Prominent active mobility hub with planned expansion	• **Water quality improvement** • **Volume reduction** • Peak flow reduction	• **Habitat connectivity** • Urban forest enhancement • Pollinator habitat enhancement	• **Active mobility improvement**	Conditions	• Crowned road • Moderate slope (2-3%)	• High congestion, conflicts on both sides of road including laterals	• High infiltrating soils	• Deep groundwater	• Mature trees and vegetation in large adjacent private property
									Design Strategy	» *Site longer distributed facilities on both sides of road, add step weirs to accommodate slope in longer facilities*	» *Avoid siting facilities within utility setbacks, line facility areas over residential laterals and facilitate future access*	» *Maximize use of infiltrating facilities*	» *Provide treatment via biofiltration prior to infiltration to groundwater*	» *Site facilities to avoid impacting existing trees, add trees to fa-cilities to extend forest canopy over BGS*
3	Upland Wet Meadow	Expanded ROW + Adjacent Space	Separated sewer	• Single- family residential • Adjacent park + playfield • Adjacent school + community center	• Local road with two travel lanes + two parking lanes • Plan for future local bikeway	• **Water quality improvement** • Volume reduction	• **Habitat connectivity**	• **Active mobility improvement** • Park connectivity • Environmental education + stewardship	Conditions	• Crowned road • Moderate slope (3-4%)	• Moderate congestion • Small capacity utility conflicts on both sides of road	• Moderate infiltrating soils	• Moderately deep groundwater	• Preference to minimize mpact on park program-ming and create educational opportunities for school and park visitors
									Design Strategy	» *Site shorter distributed facilities on both sides of road, step facilities in adjacent park to accommodate slope*	» *Avoid siting facilities within utility setbacks where possible, use liners in few facilities sited above sanitary sewer and water line*	» *Maximize use of infiltrating facilities where possible, but use expanded storage to offset facilities that are lined to avoid utility conflicts*	» *Provide treatment via biofiltration prior to infiltration to groundwater*	» *Integrate boardwalks and educational signage into park's ephemeral wetlands*

Table 11b: Designing for Other Contexts and Conditions, Transition Zone

TRANSITION ZONE

General Typology Descriptions			Typology Demonstration Infrastructure Context			Typology Demonstration Objectives			Typology Demonstration Design Opportunities and Constraints					
ID	Typology Name	Site Context	Water Management	Adjacent Land Use	Transportation	Blue Objectives	Green Objectives	Connect Objectives		Topography + Slope	Utility Congestion	Soil Infiltration Capacity	Groundwater Elevation	Other
4	Seasonal Rainway	Narrow ROW	Combined Sewer	Single-family residential	Local road with two travel lanes + one parking lane	• **Peak flow reduction** • **Water quality improvement**	• Habitat connectivity • Pollinator habitat enhancement	• Active mobility improvement	Conditions	• Cross-sloped road • Very steep slope (8-9%)	• Low congestion • Small capacity utility conflicts on one side of road	• High infiltrating soils	• Moderately deep groundwater	• Preference to maintain some street parking
									Design Strategy	» *Site shorter distributed but connected facilities on one side of road, add step weirs to accommodate steep slope*	» *Site facilities on opposite side of road to avoid conflicts*	» *Maximize use of infiltrating facilities*	» *Provide treatment via biofiltration prior to infiltration to groundwater*	» *Utilize distributed facilities with chamfered curvi-linear edges that facilitate parking access*
5	Seasonal Blueway	Expanded ROW	Separated and combined sewer	• Single- family residential • Commercial	• Local road with two travel lanes + two parking lanes • Crosses arterial multi-modal “complete street”	• **Volume reduction** • Peak flow reduction • Water quality improvement	• **Habitat connectivity** • Urban forest enhancement	• Active mobility improvement • Environmental education + stewardship	Conditions	• Crowned road • Moderate slope (3-4%)	• Low congestion • Small capacity utility conflicts on one side of road	• High infiltrating soils	• Moderately deep groundwater	• Adjacent build-ings constructed to property line (zero lot line)
									Design Strategy	» *Site continuous facility on one side of road, use relocated catch basins and shallow pipes to bring flow from opposite side of road*	» *Site facilities on opposite side of road to avoid conflicts*	» *Maximize use of infiltrating facilities*	» *Provide treatment via biofiltration prior to infiltration to groundwater*	» *Line edges of infiltrating facil-ities to prevent lateral seepage into adjacent buildings*
6	Seasonal Wetland	Expanded ROW + Adjacent Space	Combined sewer	• Commercial • Adjacent park + playfield	• Local road with two travel lanes + two parking lanes • Plan for future greenway • Half street closure planned	• **Peak flow reduction** • **Volume reduction** • Flood management • Water quality improvement	• Urban forest enhancement • Habitat connectivity • Pollinator habitat enhancement	• Active mobility improvement • Park connectivity • Cultural connections • Environmental education + stewardship	Conditions	• Crowned road • Moderate slope (5-6%)	• Moderate congestion • Utility conflicts on one side of road	• High infiltrating soils	• Moderately deep groundwater	• Preference for ex-panded passive green or plaza space within half-street closure, especially in park-deficient areas of the city where pro-grammable park space is limited.
									Design Strategy	» *Site facilities on both sides of road, add weirs and stepped facilities to accommodate slope*	» *Site facilities on opposite side of road to avoid conflicts*	» *Maximize use of infiltrating facilities*	» *Provide treatment via biofiltration prior to infiltration to groundwater*	» *Integrate smaller facilities within plaza and use diversion structures to send higher flows to adjacent wetlands in park*

Table 11c: Designing for Other Contexts and Conditions, Lowland Zone

LOWLAND ZONE

General Typology Descriptions			Typology Demonstration Infrastructure Context			Typology Demonstration Objectives			Typology Demonstration Design Opportunities and Constraints					
ID	Typology Name	Site Context	Water Management	Adjacent Land Use	Transportation	Blue Objectives	Green Objectives	Connect Objectives		Topography + Slope	Utility Congestion	Soil Infiltration Capacity	Groundwater Elevation	Other
7	Perennial Rainway	Narrow ROW	Combined Sewer	Commercial	Major arterial boulevard with vegetated median and six travel lanes	• **Peak flow reduction** • **Volume reduction** • Flood management	• Urban forest enhancement • Habitat connectivity	• Active mobility improvement • Environmental education + stewardship	Conditions	• Crowned road on both sides of median • Moderate slope (5-6%)	• Moderate congestion • Utility conflicts on one side of road	• Low infiltrating soils	• Shallow groundwater	• Preference to maintain full vehicular traffic capacity
									Design Strategy	» *Site facilities on both sides of road and center median, add weirs and stepped facilities to accommodate slope*	» *Avoid siting facilities within utility setbacks where possible, use liners in facility sited above sanitary sewer*	» *Maximize use of subsurface storage to provide additional capacity for facilities that are lined or do not infiltrate*	» *Ensure depth of lined facilities are above seasonal shallow groundwater levels*	» *Utilize expanded storage under and adjacent to each facility*
8	Perennial Blueway	Expanded ROW	Separated Sewer	• Commercial • Light industrial	• Major arterial road with six travel lanes • Existing bikeway • Future rapid transit allows for road reconfiguration with reduced traffic capacity	• **Flood management** • Volume reduction	• **Urban forest enhancement** • Habitat connectivity • Pollinator habitat enhancement	• Active mobility improvement • Environmental education and stewardship	Conditions	• Crowned road • Low slope (<1%)	• Moderate congestion • Utility conflicts on one side of road	• Low infiltrating soils	• Shallow groundwater	• Desire to create high and low-flow terraces within facility treatment media
									Design Strategy	» *Road reconfiguration allows for creation of cross-slope and placement of facility on one side of road*	» *Avoid siting facilities within utility setbacks, small utilities can be relocated during road reconfiguration*	» *Maximize use of surface storage to provide additional capacity for facilities that do not infiltrate*	» *Provide treatment via biofiltration and ensure depth of facilities are above seasonal shallow groundwater levels*	» *Use media filled soil lifts to create stable terraces until plants are established*
9	Perennial Wetland	Expanded ROW + Adjacent Space	Separated and combined sewer	• Commercial • Light industrial • Future redevelopment planned	• Local road with vegetated median + two travel lanes • Existing bikeway • Future rapid transit allows for road reconfiguration	• **Flood management** • **Sea level rise adaptation** • Water quality improvement	• **Habitat connectivity** • Pollinator habitat enhancement • Terrestrial and aquatic wildlife habitat enhancement	• Active mobility improvement • Park connectivity • Cultural connections • Environmental education + stewardship	Conditions	• Very flat road and site (<1%)	• Moderate congestion • Small capacity utility conflicts on both sides of road	• Low infiltrating soils	• Very shallow groundwater	• Desire to create climate resilient landscape
									Design Strategy	» *Store runoff as high as possible on upgradient edge of BGS to allow for gravity flow through system*	» *Avoid siting facilities within utility setbacks, small utilities can be relocated during road reconfiguration*	» *Maximize use of surface and subsurface storage to provide primary water management capacity*	» *Allow interaction of surface water and groundwater through wetland features, maximize treatment prior to interaction with vegetation and soil media*	» *Provide basic structure and form for wetlands and habitat islands using natural materials, but allow natural processes to drive adaptation over time*

Conclusion

IMPLEMENTING BLUE GREEN SYSTEMS

One critical outcome of this study is the identification of planning, siting, design, and implementation considerations that require development, near-term adaptation, or refinement of policies or approaches to achieve the desired integrated outcomes of the City's Blue Green Systems vision.

Planning Considerations

Completion of the full network of Blue Green Systems will likely take many decades. The complex, interconnected nature of Blue Green Systems coupled with the need for multi-partner collaboration and the lengthy time horizon for implementation calls for development of a comprehensive plan to serve as a roadmap for implementation. This is consistent with one of the key takeaways from the precedent research conducted at the outset of this study. As described in Table 12, the plan should be adaptable to future uncertainty and should integrate across disciplines and City departments to lay out a detailed Blue Green Systems alignment, objectives, and performance standards.

Siting Considerations

The city-scale planning efforts noted in Table 12 are crucial for determining the alignment for Blue Green Systems and which streets, parks, and other parcels will be targeted for implementation. On the block-scale for an individual Blue Green Systems project, further consideration is needed for siting the individual GRI components that make up a Blue Green System. Many of these common GRI components have not been used at the scales proposed in the typologies and will require changes to some existing policies and standards related to siting. Recommended considerations are described in Table 13.

Design Considerations

Blue Green Systems may utilize a suite of new or refined GRI facilities that are not yet standardized in the City's design guidance. In addition, some existing standards may need to be modified to accommodate the more robust nature of GRI facilities as part of Blue Green Systems. Table 14 describes considerations for potential policy shifts to address design challenges.

Implementation and Funding Considerations

Implementation of Blue Green Systems is expected to occur via retrofit and capital renewal projects led by developers, the City, and potentially through partnerships between public and private entities. Table 15 describes consisderations for funding and implementation initiatives for successful Blue Green Systems.

Table 12: Planning Considerations

Potential Issue	Recommended Policy Shift
System complexity, longterm horizon for implementation, and need for multi-partner collaboration all contribute to potential misalignment.	Develop adaptable, comprehensive plan that lays out proposed alignments, objectives, and performance standards agreed upon through interdepartmental collaboration.
Precedents: *City of Seattle, WA "Shape Our Water" Plan, City of New Orleans, LA "Greater New Orleans Urban Water Plan", City of New York "Cloudburst Hubs" strategy*	

Table 13: Siting Considerations

Potential Issue	Recommended Policy Shift
Existing GRI setbacks restrict available space for BGS installation • Currently 5 m from buildings for infiltrating GRI • 1-3 m from utilities • Existing trees must be 2-3 m setback from utilities	Reduce or provide flexibility in GRI setbacks, such as: • Reduce to 1 m setback from buildings for infiltrating GRI • Allow setback variances for critical utilities • Create design standards for below-grade sealing, waterproofing, and other design approaches to accommodate more urban tree canopy and varied BGS siting.
Existing trees setbacks are 2-3 m from utilities, which limits placement of trees in BGS projects.	Consider reducing or providing flexibility in tree setbacks
Existing maximum road slope for GRI is 8%, which limits siting GRI on steeply sloped roads.	• Consider allowing for increased maximum road slope (up to 10%). • Create updated design standards for stepped facilities.
Precedents: *City of Denver, CO "Ultra Urban Green Infrastructure Guidelines", Denver Department of Transportation "Green Continuum Streets Guidelines"*	

Table 14: Design Considerations

Potential Issue	Recommended Policy Shift
Design Standards Gap No design standards currently exist for potentially new or refined GRI facilities, including terraced bioswales, expanded soil volumes adjacent to tree trenches and permeable pavement, and deep infiltration wells.	**Develop BGS-Specific Standards** • Create design standards for new GRI facility types. • Modify existing design standards to allow for more robust sizing and accommodate adaptability (softer edges, using natural materials, etc). • Develop BGS-specific design and O&M guidance, design toolkits, and calculators
Limited Ponding Depth Existing maximum ponding depth within GRI facilities is 15 cm. This limits facility sizing for larger storms and/or in narrow ROW conditions.	**Increase Ponding Depth Allowances** • Consider increasing maximum allowable ponding depth to 30 cm and up to 60 cm in terraced facilities for adequate protection. • Create updated design standards for pedestrian protection and access prevention.
Maximum Allowable Drop Existing maximum allowable drop to landscape areas is 17 cm when adjacent to pedestrian area. This limits depths of facilities and capacity to manage larger storms.	**Increase Maximum Allowable Drop + Safety Standards** • Consider increasing maximum allowable drop to 25 cm when adjacent to pedestrian area. • Create design standards for landscape edge conditions to signal to pedestrians about the drop.
Flat Vegetated Areas Existing preference in the design standards is for vegetated areas to be flat in GRI. This limits potential design capacity of BGS facilities.	**Encourage Vegetation on Sloped Areas** Consider standardizing steepest allowable vegetated slope and encourage use: • 3:1 is ideal • Maximum allowable is 2:1
Structural Soil Cell Limitations Structural soil cells limited to under sidewalks, bike lanes, and boulevards. This limits ability to connect BGS with larger storage volumes needed to reduce CSO overflows and utilize space for vehicles as multi-benefit infrastructure.	**Expand Structural Soil Cell Applications** Consider allowing structural soil cells under roads, parking areas, and curbs.
Limited Subsurface Storage Design Options Subsurface storage (crate-like systems) are not current practice under roadways due to gaps in product design and feasibility (e.g. loading limits). This limits application of subsurface storage to connect Upland BGS flows to Lowland BGS.	**Expand Subsurface Storage Applications** • Collaborate within City to develop loading capacity requirements for subsurface storage products • Create standards for subsurface storage products used in the ROW
Misaligned Performance Standards Existing sizing standards (48 mm retention) and peak flow management standards are not in line with proposed BGS performance standards. In addition, management of co-mingled runoff (e.g., private runoff on public property) is restricted. These limit potential performance of BGS.	**Develop BGS Performance Requirements** • Consider modifying City performance standards and/or modify BGS performance requirements. • Consider allowance of co-mingled runoff management.
Precedents: *City of Denver, CO "Ultra Urban Green Infrastructure Guidelines", Denver Department of Transportation "Green Continuum Streets Guidelines"*	

Table 15: Implementation and Funding Considerations

Potential Issue	Recommended Policy Shift
Implementation of BGS will take time and will likely result initially in a mosaic of disconnected BGS projects that do not provide the system performance of the full BGS network.	• Consider focusing City-led renewal and retrofit efforts at downstream ends of BGS alignments and build upland. • Consider developing a funding bank for developer-led projects that allows for focused investment in priority areas where BGS implementation is needed most. • Consider investigating the feasibility of a community-based public-private partnerships (CBP3) funding mechanism to fund and implement BGS projects.
Precedents: *City of Seattle, WA "RainCity" a Community-Based Public-Private Parterships (CBP3) initiative, Washington State Department of Ecology "Stormwater Community-Based Public-Private Partnership Program" funding stream*	

Conclusion

NEXT STEPS TOWARDS A BLUE-GREEN VANCOUVER

The Blue Green Systems Typology Study builds off the foundational work the City has led to envision healthy, resilient urban watersheds, ecosystems, and communities.

With the completion of the Blue Green Systems Typology Study, the City is anticipating next steps to move closer to their vision of a blue-green Vancouver. These next steps include city-wide analysis to apply the continuum of nature-based solutions spatially within the urban watersheds – upland zone, transition zone or lowland zone. The spatial analysis and high level feasibility testing is intended to set the stage for effective integration with other future work and the implementation of green rainwater infrastructure as part of ongoing sewer and drainage planning.

Additionally, the City plans to:

- Advance other city-wide initiatives that support Blue Green Systems
- Identify where the Blue Green System typologies fit best along the network alignments identified through the spatial analysis.
- Identify where Blue Green Systems would be most feasible through feasibility testing
- Develop a list of capital projects to prioritize through the Blue Green System framework.

As the City begins to implement the Rain City Strategy and their other holistic visions for Vancouver's future, the Blue Green Systems Typology Study provides a framework for the City to take their next steps in planning, implementing, and designing a network of park-like streets and open spaces to celebrate water, ecology, movement, people, and culture all together.

City of Vancouver's Sunset Park Blue Green System. Photo Credit: City of Vancouver

Appendix: Precedent Research

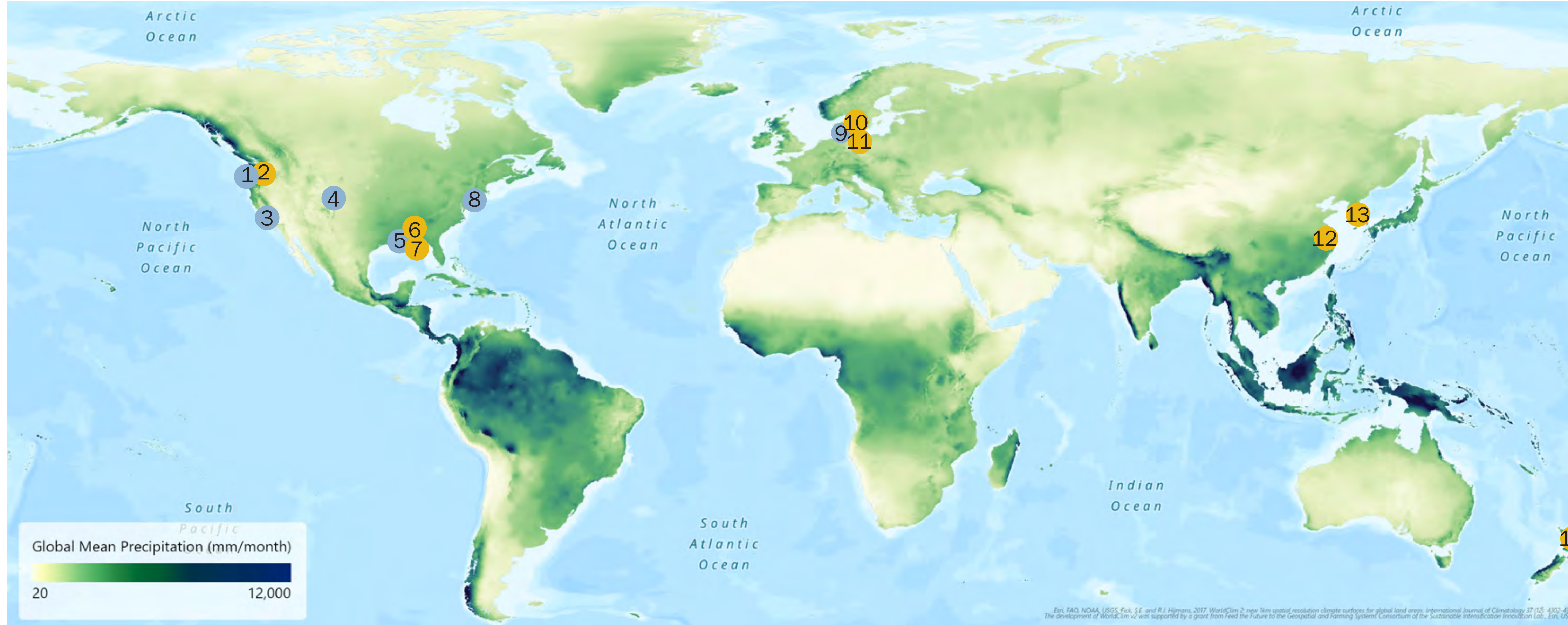
Precedent Research

One of the first steps of this study was to perform precedent research to compile examples of similar projects from other international cities. The goal of this research is to inspire the City's planning and to provide an understanding of how other cities have approached planning, design, and implementation of similar projects.

The Blue Green Systems precedent research was intentionally broad to capture a range of global geographies, visions, drivers and objectives, site conditions, and design approaches. While many of the precedent projects reviewed are not complete analogs for the City of Vancouver's Blue Green Systems, all have features, functions, and/or conditions that were deemed to be informative for the City's planning efforts.

Over two dozen potential precedent projects were initially identified and researched. Of these, 14 precedents were determined to have sufficient information available and to be at least partially analogous to the City's Blue Green Systems. These precedent projects represent a range of implementation stages from planning to fully constructed.

Each of the 14 precedent projects are briefly summarized in the following pages including a summary matrix that provides an at-a-glance comparison of key information for each precedent.



MAP NO.	PRECEDENT NAME	LOCATION	PAGE NO.	FLOOD CONVEYANCE	FLOOD STORAGE	FLOW CONTROL	WATER QUALITY	GROUNDWATER RECHARGE	OTHER
1	SWALE ON YALE	SEATTLE, WA, U.S.	P. 149				■		
2	VENEMA CREEK NATURAL DRAINAGE		P. 153			■	■		
3	21ST STREET GREEN/COMPLETE STREET IMPROVEMENTS	PASO ROBLES, CA, U.S.	P. 155		■			■	
4	39TH AVE OPEN CHANNEL GREENWAY	DENVER, CO, U.S.	P. 159	■	■				
5	BLUE AND GREEN CORRIDORS	NEW ORLEANS, LA, U.S.	P. 163	■	■			■	
6	CHURCHILL TECHNOLOGY PARK		P. 167		■	■			
7	LAKEVIEW/CITY PARK HAZARD MITIGATION		P. 169		■	■			
8	SOUTH JAMAICA HOUSING CLOUDBURST PLAN	QUEENS, NY, U.S.	P. 171		■	■			
9	THE SOUL OF NØRREBRO	COPENHAGEN, DENMARK	P. 175		■		■		
10	COPENHAGEN CLOUDBURST FORMULA		P. 181	■	■				
11	LINDEVANGS PARK		P. 183	■	■				
12	KUNSHAN CONSTRUCTED WETLANDS	KUNSHAN, CHINA	P. 185			■	■		
13	CHEONGGYECHEON STREAM RESTORATION	SEOUL, SOUTH KOREA	P. 187	■					
14	DALDY STREET LINEAR PARK	AUCKLAND, NEW ZEALAND	P. 189				■		■

NOTES:

Precedents marked with (X) had more extensive informaiton available for deeper research, and have typically two to three pages of information. Precedents marked with (X) have one page of summary information.

Precedent Research

Each of the 14 precedent projects are briefly summarized in Table A1 on the next two pages, which provide a comparison of key information for each precedent. A more detailed summary of each precedent follows with a one-page summary spread with important project identification, objective, and status details, as well as available contextual information (e.g., land use, topography, soil conditions, etc.) and design details (e.g., sizing and performance considerations, dimensions, etc.). Six of the precedent projects had more extensive information available. For those precedents, deeper research was conducted, and additional images and other key information are provided beyond the one-page summary. During subsequent stages of this study, these precedents were consulted to help inspire and inform development of Blue Green System typology demonstrations. They will also hopefully serve as inspiration for the City's further planning and design of real world Blue Green Systems.

Table A1: Precedent Research Summary

Project Name	1 Swale on Yale	2 Venema Creek	3 21st St Improvements	4 39th Ave Greenway	5 Blue + Green Corridors	6 Churchill Tech Park	7 Lakeview / City Park	8 South Jamaica Housing	9 The Soul of Norrebro	10 Copenhagen Cloudburst	11 Lindevangs Park	12 Kunshan Wetlands	13 Cheonggyecheon Stream	14 Daldy Street Linear Park
Location of Project	Seattle, Washington, United States	Seattle, Washington, United States	Paso Robles, California, United States	Denver, Colorado, United States	New Orleans, Louisiana, US	Avondale, Louisiana, United States (Greater New Orleans)	New Orleans, Louisiana, United States	Queens, New York, United States	Copenhagen, Denmark	Copenhagen, Denmark	Frederiksberg, Denmark (Greater Copenhagen)	Kunshan, China	Seoul, Korea	Auckland, New Zealand
Owner	Seattle Public Utilities	Seattle Public Utilities	City of Paso Robles	City of Denver	City of New Orleans, Resilience and Sustainability	Jefferson Parish Economic Development Commission (JEDCO)	Sewerage and Water Board of New Orleans	New York City Housing Authority (NYCHA)	The City of Copenhagen	Municipality of Copenhagen	Frederiksberg Municipality, Frederiksberg Supply	Kunshan City Construction, Investment, and Development Company	Seoul Metropolitan Government	Waterfront Auckland Development Agency
Primary Goals	Water quality, regulatory	Water quality, flow control	Flood storage, groundwater recharge	Flood conveyance, flood storage	Flood conveyance, flood storage, groundwater recharge	Flood storage, flow control	Flood storage, flow control	Flood storage, CSO flow control	Flood storage, water quality	Flood storage, flood conveyance	Flood storage, flood conveyance	Water quality, flow control, aesthetics	Flood conveyance	Water quality, urban development
Secondary Goals	Flood conveyance	Groundwater recharge, habitat	Water quality	Active mobility, habitat, community amenities	Cultural, economic, public health	Flood conveyance, active mobility	Shoreline erosion, water quality, habitat, groundwater recharge	Urban nature	Habitat, urban nature	Water quality, urban nature	Urban nature	Biodiversity	Biodiversity, greenspace, urban heat, air quality, economic	Greenspace, biodiversity, active mobility
Primary Driver(s)	Regulatory	Water quality, treatment	Aging infrastructure, drought, climate resilience	Flood risk, water quality, transit, outdoor recreation	Climate resilience	Climate resilience	Climate resilience, hurricanes	Climate resilience, CSO reduction	climate resilience, social cohesion, innovation	Climate resilience	Climate resilience	Water quality	Flood risk, economic development	Redevelopment, climate resilience, sea level rise
Location of Project	Street ROW	Street ROW (local)	Street ROW (arterial)	Street ROW	Street ROW (arterial, collector), public parcels	Private development	Public parcel	Public housing	Public parcels, street ROW	Street ROW, public parcels	Public parcel	Public	Street ROW (former highway)	Street ROW
Rainfall	100 cm/yr	100 cm/yr	36 cm/yr	20 - 38 cm/yr	152 cm/yr	162 cm/yr	163 cm/yr	102 - 132 cm/yr	75 cm/yr	74 cm/yr	74 cm/yr	130 cm/yr	137 cm/yr	112 cm/yr
Land Use	Mixed use	Low density residential	Low density residential	Mixed use, residential	Residential	Mixed use	Mixed use, residential	Mixed use	Neighbourhood	Mixed use, commercial	Mixed use, residential	Commercial - arts plaza	Transportation, mixed use	Mixed use
Topography	1-2% slope	Gradual slope	Unknown	Flat	Flat, more than 50% of City below sea level	Flat, below/at sea level	Unknown	Flat, 0 to 3%	Unknown	Primarily flat	Flat	Flat	Unknown	Flat
Soils	Non-infiltrating	11 m of glacial till, suitable for UIC well	Unknown	Remediated arsenic and lead on residential parcels	Alluvial deposits covered with peat (low infiltrating)	Low infiltration	Weak organic soils	Sandy, medium permeability	Unknown	Unknown	Unknown	Unknown	Unknown	Reclaimed land, marine mud, industrial contamination
Groundwater	Unknown	20 - 45 m	Unknown	Low	High	High	Shallow	Low water table	Unknown	Unknown	Unknown	Unknown	High (river)	1 - 1.5 m

Precedent Research

Table A1: Precedent Research Summary, Continued

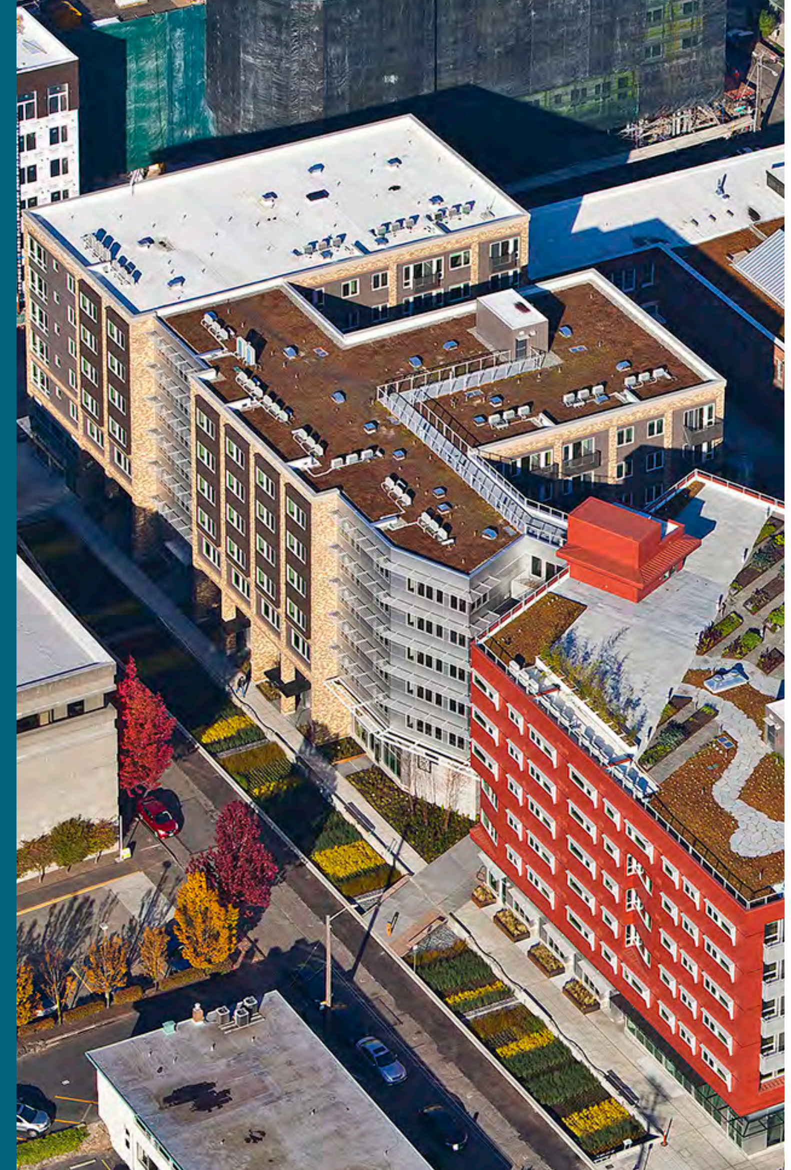
Project Name	1 Swale on Yale	2 Venema Creek	3 21st St Improvements	4 39th Ave Greenway	5 Blue + Green Corridors	6 Churchill Tech Park	7 Lakeview / City Park	8 South Jamaica Housing	9 The Soul of Norrebro	10 Copenhagen CloudBurst	11 Lindevangs Park	12 Kunshan Wetlands	13 Cheongg-gecheon Stream	14 Daldy Street Linear Park
Utilities	Unknown	Unknown	Moved overhead utilities underground, replaced aging sewer pipes.	Unknown	Unknown	Primarily proposed new utilities	Subsurface	N/A	Unknown	N/A - Master Plan	Unknown	Unknown	Unknown	Unknown
Type	Retrofit	Retrofit	Retrofit	Retrofit	Retrofit (major boulevards)	New development	Retrofit	Retrofit	Retrofit	Retrofit (Master Plan)	Retrofit	New development	Restoration	Rebuild
Runoff Source	Public, Private	Public	Public	Public, Private	Public, Private	Private	Public, Private	Public, Private	Public, Private	Public, Private (city-scale)	Public	Public, Private	Public, Private	Public, Private
Contributing Area (Total)	193 hectares	35 hectares	500 hectares	2600 hectares (Montclair Basin)	Unknown	57 hectares	14-square blocks	Unknown	8.5 hectares	10 km^2	5.4 hectares	Unknown	Unknown	32 hectares
Point of Downstream Discharge	Lake Union	Venema Creek	Salinas River	Globeville Landing Park outfall - South Platte River	Lake Pontchartrain	Levee south of the site	Lake Pontchartrain	Unknown	Peblinge Lake	Copenhagen Harbour, Øresund Strait	Unknown	Local stream	Han River	Waitemata Harbour
Design Criteria	712 m^3/yr, max 0.23 m^3/x flow into swale, up to 20.3 cm deep water.	Unknown	5-year storm 5 mm/hr	100-year storm, 76 m^3/s	Unknown	10-year storm, 60-min time of concentration, 87 mm/hr rainfall.	~650,000 m^3 of stormwater volume, 100-year storm	10-year storm event, Block 5 (580 m^3), Block 7 (610 m^3)	10-year, and 100-year rain events. 18,000 cubic meter, 24-hour retention	100-year storm, one sewer overflow per 10 years.	100-year storm	5-day wetland recirculation, 30-day wetland turnover time	200-year storm, 118 mm/hr	100-year storm surge, 2100 sea level rise
Length	4 blocks (335 m)	5 blocks	5 blocks	1.6 km	Unknown	Unknown	Unknown	N/A	N/A	N/A	N/A	N/A	5.8 km long	N/A
Width of All Elements	5.5 m bioswale, 8.2 m street, 18.3 m ROW	Unknown	25 m ROW, 4 m sidewalk, 1 m pervious pavers, 3 m bike lanes, 7 m vehicle lanes, 5 m median channel, 3 m bioretention	varies	Up to 22 m wide, 3 m deep.	Unknown	Unknown	N/A	N/A	N/A	Total area of 21000 m^2	1000 m^2 total wetland area, 300 mm avg water depth.	Total area 40.5 hectares	N/A
Description of Design Elements	Non-infiltrating bioswale, commercial storefronts	Natural drainage system (bioretention), native plantings including street trees, biofiltration, deep underground injection control (UIC) well	Pervious pavers, bioretention, structural soil cells with trees, natural channel with energy dissipation, infiltration trench, reduction in impervious surfaces	4.9 hectares multi-use trails, amphitheater, playgrounds, open conveyance channel, underground trash vaults, sidewalks and safe connections to transit stations.	Meandering waterway (retention basin) alongside roads, bike lanes and transit, and parks	Naturalized drainage canal, roadside rain gardens, trees, bioswales, detention ponds	Stormwater lagoons/detention basins, constructed wetlands, bioswales, native plantings, trees, stormwater treatment devices to remove trash, debris, sediment	Pervious pavers, rain gardens, trees, underground retention tanks	Floodable park, floodable street, biofiltration prior to discharge	Toolbox of 8 types of projects: park, plaza, street, green street, urban canal, urban creek, retention boulevard, boulevard with bioretention, floodable space, retention basins	Rain gardens, vegetated long basin, detention basin, outdoor theater, sunken public square	Series of 3 inter-connected stormwater wetland cells, includes recirculation and landscape pool, built into art center plaza	Highway removal, stream daylight, ecosystem restoration, connection to regional subways	Lined bioretention systems, primary storm sewer conveyance system, roof water raingardens, street water raingardens, 'water play' park facility

Swale on Yale

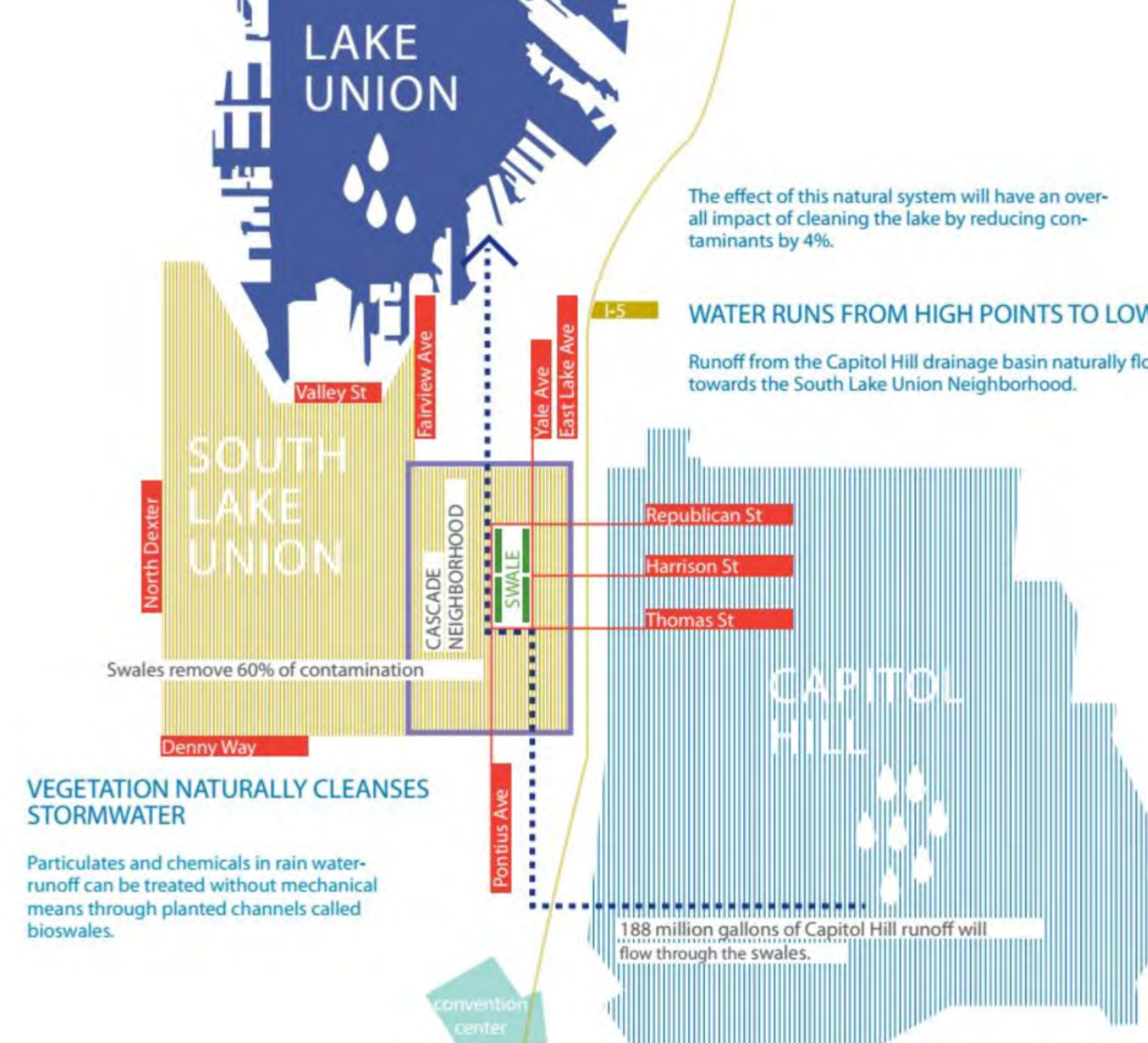
Seattle, Washington, U.S.

The Capitol Hill Water Quality Project, also know as the Swale on Yale, is a leading regional example of district-scale stormwater treatment and public-private partnerships with developers. This project was an early example of addressing stormwater quality and regulatory compliance by leveraging private developer partnerships to share costs. Swale on Yale successfully reduces Total Suspended Solids (TSS) pollutant loads by 60% before stormwater enters Lake Union, and monitoring efforts are ongoing today to help drive Seattle's policies and performance around stormwater treatment in the right of way.

OWNER	Seattle Public Utilities
DESIGNER	KPG, KPFF, Herrera
PARTNERS	Vulcan Real Estate Inc Seattle Dept. of Transportation
GOALS	PRIMARY: Water quality Regulatory compliance SECONDARY: Flood conveyance
STATUS	Constructed, Monitoring
YEAR	2012 - 2020
BUDGET	Unknown
FUNDING	Rate-payer funds, Private funds



Source: Vulcan Real Estate



Source: Jerome Unterreiner, ZGF Architects

CONTEXT

LOCATION	Street ROW
RAINFALL	100 cm/yr
LAND USE	Mixed Use
TOPOGRAPHY	1 -2% slope throughout
SOILS	Unknown - non-infiltrating
GROUNDWATER	Unknown
UTILITIES	Unknown
OTHER	N/A

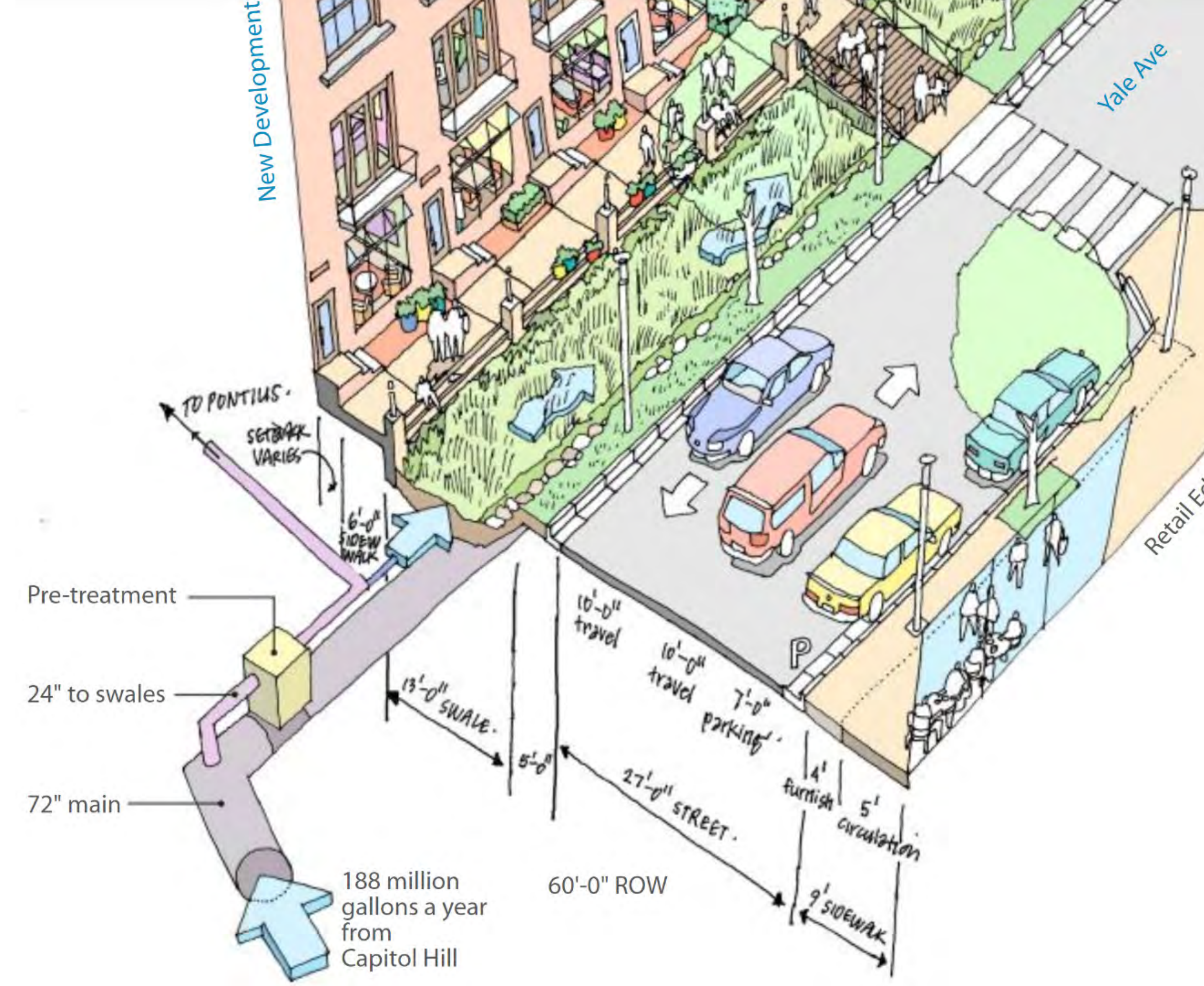
DESIGN DETAILS

PROJECT TYPE	Retrofit
RUNOFF SOURCE	Capitol Hill neighbourhood
CONTRIBUTING AREA	193 hectares
DISCHARGE	Lake Union
DESIGN STORM	up to 712,000 m^3/yr max 0.23 m^3/s flow into swale
DIMENSIONS	5.5 m wide bioswale 4 blocks long (335 m)
DESIGN ELEMENTS	Non-infiltrating bioswale adjacent to ground-level commercial storefronts with variable setbacks and public amenities,

PROJECT DESIGN

Swale on Yale was largely driven by regulatory requirements for improving the water quality of Lake Union in Seattle, WA. The four-block long design intercepts existing stormwater pipes in the Cascade Neighbourhood that carry stormwater from the upstream neighbourhood of Capital Hill to Lake Union for discharge. The bioswales are designed to accommodate up to 0.23 m^3/s of stormwater and up to 20.3 cm water depth at full capacity. Monitoring efforts show an average of 60% of TSS are removed by the swales before the stormwater discharges to Lake Union.

Source: Vulcan Real Estate



Source: Jerome Unterreiner, ZGF Architects

OTHER CONSIDERATIONS

URBAN ECOLOGY

- The bioswales are planted with rushes and sedges
- Beyond rushes and sedges, there are not other explicit urban ecology goals, as water quality was the primary driver.

TRANSPORTATION & MOBILITY

- This design is in the Cascade Neighbourhood of Seattle, with close proximity to I-5.
- 8.2 m of street (car travel and parking) was designed.
- No additional design to offer protection for bikers.
- Pedestrians have access to protected sidewalks and commercial amenities along the four blocks of swales.

COMMUNITY

- Vulcan Real Estate and Seattle Public Utilities worked together in a public-private partnership to design a mixed-use development while also improving water quality issues.

REGIONAL TREATMENT

- The Swale on Yale is an example of successful partnerships for regional stormwater treatment.
- The innovative nature of this design in the early 2000's has lead to extensive monitoring and evaluation of the performance, which still continues.
- The research on the regional treatment system, soil media enhancements, and water contaminant removal are being used to design and improve other facilities and regulations in Seattle.

Venema Creek Natural Drainage

Seattle, Washington, U.S.

Venema Creek is an example of successful green infrastructure in residential, low traffic neighbourhoods. Site conditions allowed for deep infiltration of stormwater to reduce stream channel erosion and improve groundwater recharge. This natural drainage system is one of many others in Seattle that are planned and implemented by SPU Capital Projects.

OWNER	Seattle Public Utilities (SPU)
DESIGNER	Cascade Design Collaborative, Osborn Consulting, Inc, Mayfly Engineering, Perteet, Applied Pro. Services, Assoc. Earth Services, SvR Design
PARTNERS	Seattle Dept. of Transportation, Washington Dept of Ecology
GOALS	PRIMARY Water quality Flow control SECONDARY Groundwater recharge Habitat
STATUS	Completed
YEAR	2013 - 2016
BUDGET	$10 million CAD* (for green infrastructure)
FUNDING	SPU, Dept of Ecology grant, Fee-in-Lieu from SDOT

Source: Osborn Consulting Inc

Source: Osborn Consulting Inc

Source: Osborn Consulting Inc

CONTEXT

LOCATION	Local Street ROW
RAINFALL	100 cm/yr
LAND USE	Low density residential
TOPOGRAPHY	Gradual slope
SOILS	11 m of glacial till with unsaturated advance outwash suitable for UIC
GROUNDWATER	20 - 45 m
UTILITIES	Unknown
OTHER	Similar to other natural drainage streets in Seattle, such as SEA Street #1

DESIGN DETAILS

PROJECT TYPE	Retrofit
RUNOFF SOURCE	Public
CONTRIBUTING AREA	35 hectares total (32 hectares impervious)
DISCHARGE	Venema Creek
DESIGN STORM	Unknown
DIMENSIONS	5 blocks long, unknown width
DESIGN ELEMENTS	Natural drainage system (bioretention), native plantings including street trees, biofiltration, and deep underground injection control (UIC) well.

PROJECT DESIGN

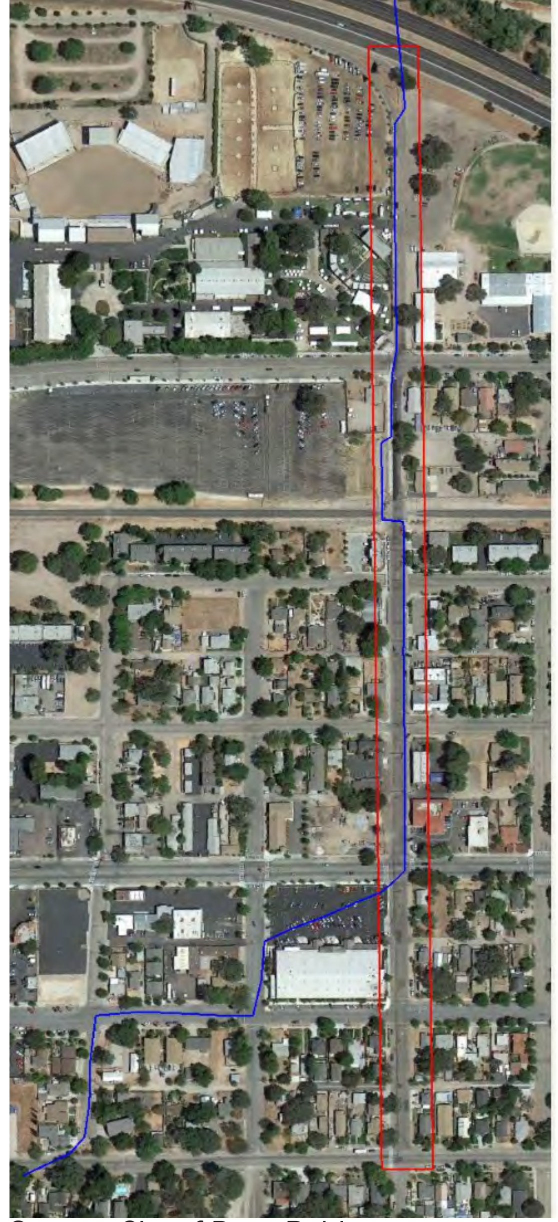
Venema Creek Natural Drainage System (NDS) was constructed in a primarily low density residential neighbourhood with low traffic volumes, but still sought to address water resources goals with habitat and neighbourhood transportation goals. The water is filtered through the NDS and then infiltrated into outwash soils to reduce the volume and speed of runoff into Venema Creek and Piper's Creek to reduce impacts to the creek channel and habitat. The project also improved pedestrian safety with 485 m of new sidewalks.

21st Street Green/ Complete Street Improvements

Paso Robles, California, U.S.

The 21st Street Green/Complete Street Improvements were driven by not only flood storage, groundwater recharge, and water quality needs, but also opportunities to replace aging infrastructure and address severe drought in Paso Robles. This project is a great example of leveraging state funding sources to support the design and implementation of blue-green infrastructure.

OWNER	City of Paso Robles
DESIGNER	SvR Design, Cannon, Earth Systems Pacific, Raminha Construction
PARTNERS	California Central Coast Low Impact Development Initiative, California Central Coast Water Board
GOALS	PRIMARY Flood storage Groundwater recharge SECONDARY Water quality
STATUS	Constructed in 2014
YEAR	2010 - 2014
BUDGET	$3.4 million CAD*
FUNDING	California Urban Greening Grant (partial funding)

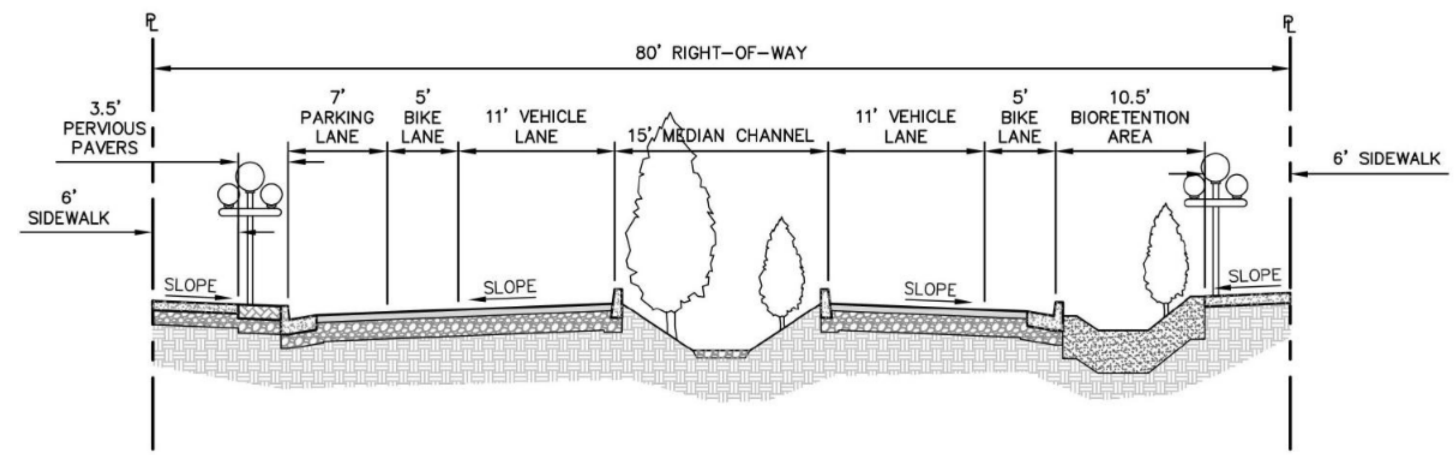


Source: City of Paso Robles

CONTEXT

LOCATION	Arterial street ROW
RAINFALL	36 cm/yr
LAND USE	Low density residential, some commercial
TOPOGRAPHY	Unknown
SOILS	Unknown
GROUNDWATER	Unknown
UTILITIES	Unknown
OTHER	Beyond primary goals, other drivers included aging infrastructure, drought, historic flooding

Source: Cannon



Source: City of Paso Robles

DESIGN DETAILS

PROJECT TYPE	Retrofit
RUNOFF SOURCE	Public
CONTRIBUTING AREA	500 hectares total (15 hectares impervious)
DISCHARGE	Salinas River
DESIGN STORM	5-year storm, 5 mm/hr
DIMENSIONS	25 m wide ROW, 5 blocks long 4 m sidewalk 1 m pervious pavers 3 m bike lanes 7 m vehicle lanes 5 m median channel 3 m bioretention

PROJECT DESIGN

The 21st Green Street Improvements include pervious pavers, bioretention, infiltration trenches, and structural soil cells with trees. The 5 m wide natural channel is designed for energy dissipation in the stormwater. The designs also consider improving traffic calming, increasing bike and pedestrian mobility, adding shade, and reducing impervious surfaces in the neighbourhood.


Source: Cannon


Source: SvR Design


Source: Cannon


Source: SvR Design

OTHER CONSIDERATIONS

URBAN ECOLOGY

- 81 large native trees were planted to improve shade and reduce urban heat island effects.
- A native and drought-tolerant plant palette replaced some asphalt along the street.
- Aside from improved shade and reduced water needs, native plants also support a healthy native urban ecology for pollinators, mammals, and other creatures in the region.
- The landscape design included a one-year plant establishment contract, O&M manual, and maintenance assessment district.

TRANSPORTATION & MOBILITY

- “Complete” streets are designed to connect people of all mobilities and transit modes with businesses, neighbourhoods, parks, and schools through holistic planning.
- The retrofitted street is one-third green infrastructure, which improves pedestrian and bicyclist safety through traffic calming and road width reduction.
- Intersection bump-outs to improve safety and visibility while crossing.
- 1.2 km of bike lanes and ADA sidewalks were also installed.

COMMUNITY

- Community voices were included throughout the entire design process.
- Local consultants were hired to support the conceptual design phase led by SvR Design and to ensure that local and regional knowledge was core to the design concepts.
- Local consultants on this project were also a key part of the process to build more local and regional capacity in green street retrofits to encourage future projects.

CLIMATE CHANGE

- Groundwater recharge, reduced flooding, and reduced stormwater discharge into the Salinas River are project drivers interconnected to climate change adaptation.
- California suffers from frequent drought, and this was considered through native planting and drought-tolerant design.
- 190 m^3 of runoff are retained and infiltrated for every rain event over 1.3 cm, which has significant impacts on California’s groundwater supply.

39th Ave Open Channel Greenway

Denver, Colorado, U.S.

The 39th Avenue Open Channel Greenway is a successful, built example of flood, mobility, and community space goals planned and designed cohesively. Although an arid climate, this project is a strong example of addressing urban flooding with sensitivity to site context, environmental history, and community engagement.

OWNER	City of Denver
DESIGNER	Felsburg Holt and Ullevig, Icon Engineering, DHM Design Group, SEMA, ECI Site Construction
PARTNERS	City of Denver Dept's of Public Works, Capital Projects, Parks and Recreation, Forestry, Green Infrastructure, Storm Water and Water Quality Design Working Group
GOALS	PRIMARY Flood conveyance, storage SECONDARY Active mobility Habitat Community amenities
STATUS	Constructed
YEAR	2016 - 2020, Design-Build
BUDGET	$123 million CAD*
FUNDING	Annual stormwater fee collections

Source: Livable Cities Studio

CONTEXT

LOCATION	Street ROW
RAINFALL	20 to 38 cm/yr
LAND USE	Mixed Use, Residential
TOPOGRAPHY	Generally flat
SOILS	Remediated of arsenic, lead on residential parcels
GROUNDWATER	Low
UTILITIES	Unknown
OTHER	The Montclair Basin was the largest historic basin in Denver. Montclair Creek was piped in early 1900s.

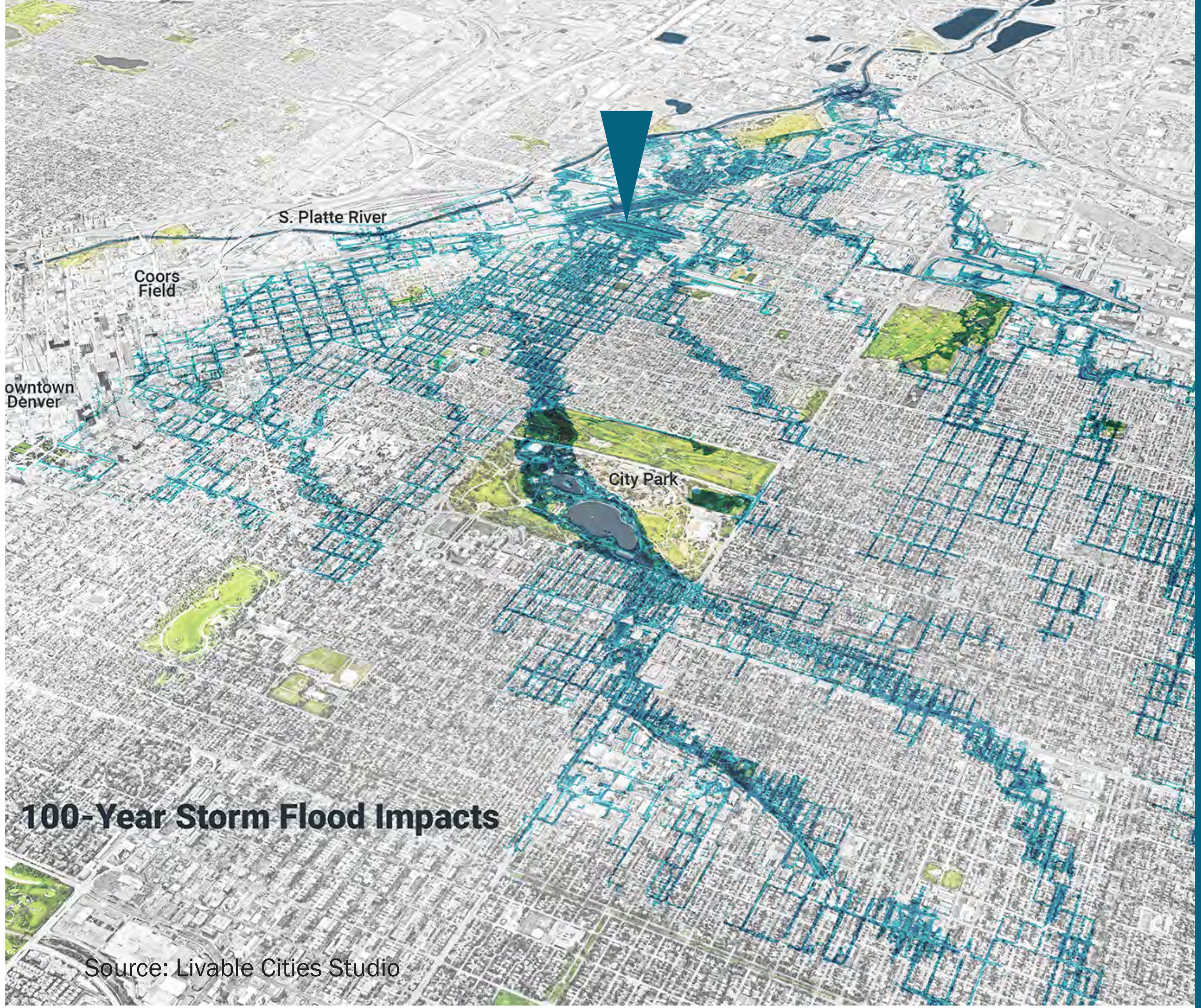
DESIGN DETAILS

PROJECT TYPE	Retrofit
RUNOFF SOURCE	Public and private
CONTRIBUTING AREA	2600 hectares (Montclair Basin)
DISCHARGE	Globeville Landing Park Outfall - South Platte River
DESIGN STORM	100-Year Storm, 76 m^3/s
DIMENSIONS	1.6 km long, varying widths
DESIGN ELEMENTS	4.9 hectares of multi-use trails, amphitheater, playgrounds, and recreational facilities alongside open conveyance channels.

PROJECT DESIGN

The 39th Ave Open Channel Greenway is part of a larger Platte to Park Hill Stormwater vision for Denver, CO and winds through the Cole neighbourhood. The main drivers of the design were reducing flood risk to residents and businesses while improving water quality, transit connections, and recreation. The open conveyance channel flows through the Cole neighbourhood for 1.6 km, before continuing in separated pipes to the Globeville Landing Park Outfall.

Source: City of Denver



Source: Livable Cities Studio

OTHER CONSIDERATIONS

URBAN ECOLOGY

- Specific considerations for pollinator gardens and habitat through native plans.
- Urban ecology intentionally designed for cottonwoods, willows, American plum, and snowberry.
- Designs focused on wildlife habitat, particularly for hawks, meadowlarks, foxes, and raccoons.
- Interpretive signage installed to educate the public about urban ecology.

TRANSPORTATION & MOBILITY

- Extensive investment in bicycle and pedestrian mobility.
- 4.9 hectares of multi-use trails and sidewalks.
- Intentional planning for safe connections to transit stations nearby.
- Multi-modal shared street designed to slow traffic. No curbs and cutters for a continuous street/ plaza experience for traffic and pedestrians.

COMMUNITY

- An extensive community-centered design process took place over 2 years to develop analysis, goals, design options, and design guidelines.
- Concerns about impacts of continued gentrification in the Cole neighbourhood arose amongst some residents in this historically Black and Blue Collar neighbourhood
- This site was remediated as a Superfund site in 2003 only on residential parcels. Public is concerned about potential contamination remaining in commercial and industrial parcels.

CLIMATE CHANGE

- Not much of the design explicitly calls out designing for climate change considerations beyond storm events.
- Sized for 100-year modeled storm events
- Part of regional planning effort, “Platte to Park Hill: Stormwater Systems”, to address flooding and urban watershed equity in Denver

Blue and Green Corridors

New Orleans, Louisiana, U.S.

The Blue and Green Corridors Project is responding to pressing climate change risks in New Orleans. Part of the larger Gentilly Resilience District planning effort, the project combines stormwater and flooding climate resilience with pedestrian amenities and public transportation investments. The Blue and Green Corridors Project is an example of leveraging emergency disaster funding to achieve multi-benefit, climate adaptive infrastructure and taking visions from planning to funding to construction.

OWNER City of New Orleans, Resilience and Sustainability

DESIGNER Stantec

PARTNERS Gentilly Resilience District, Batture, Ardura, Kenall, ILSI, GAEA, FedGeek, Procella Design, MIG/SvR, ISeeChange

GOALS PRIMARY
- Flood conveyance and storage
- Groundwater recharge
- Urban heat (shade, cooling)

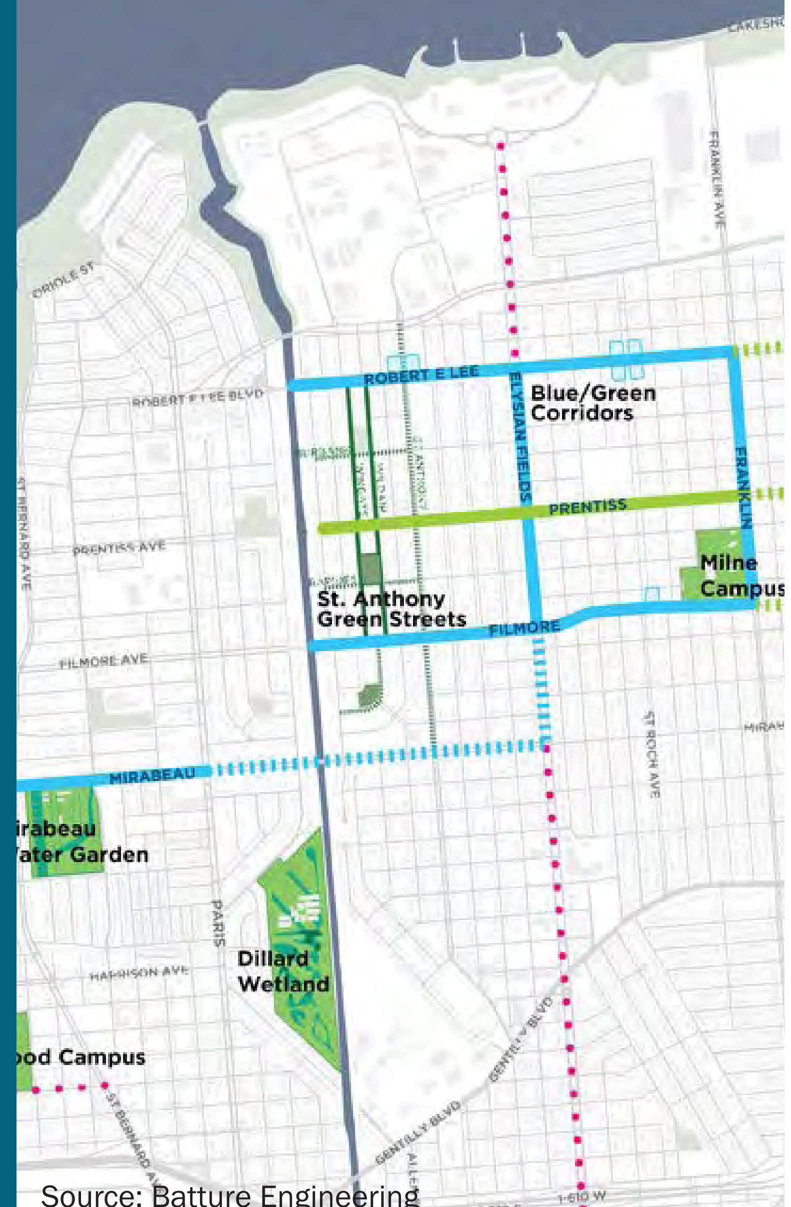
SECONDARY
- Cultural (destinations, education)
- Economic (funding, growth, risk)
- Public health (parks, recreation)

STATUS Design, Pre-Construction (Construction anticipated in 2023)

YEAR 2015 - Ongoing

BUDGET $55 million CAD*

FUNDING U.S. National Disaster Resilience Funding (HUD, FEMA) Rockefeller Foundation



Source: Batture Engineering

Source: City of New Orleans

CONTEXT

LOCATION	Street ROW, public land
RAINFALL	152 cm/year
LAND USE	Primarily residential
TOPOGRAPHY	Flat with more than 50% of City below sea level
SOILS	Alluvial deposits covered with peat (low infiltrating)
GROUNDWATER	High
UTILITIES	Unknown
OTHER	Located in the Mississippi River Delta, historically cypress marshes and coastal estuaries

DESIGN DETAILS

PROJECT TYPE	Retrofit of boulevards
RUNOFF SOURCE	Public and private
CONTRIBUTING AREA	Unknown
DISCHARGE	Lake Pontchartrain
DESIGN STORM	Unknown
DIMENSIONS	Up to 22 m wide, 3 m deep
DESIGN ELEMENTS	Meandering waterway (retention basin) alongside roads, bike lanes, public transportation, and parks.

PROJECT DESIGN

The Blue and Green Corridors Project retrofits four major boulevards in the Gentilly Resilience District into meandering waterways designed to slow down flood waters and improve groundwater recharge while also addressing the need for recreation, urban heat island mitigation, community destinations, and economic growth through investment and risk management. The waterways are designed for typically 1 to 1.5 m of water, but accommodate flooding up to 3 m deep and 22 m wide during major storms.

Source: City of New Orleans

Source: City of New Orleans

Source: City of New Orleans

OTHER CONSIDERATIONS

URBAN ECOLOGY

- No specific urban ecology considerations are described in project materials regarding plant or wildlife communities
- Mitigating the urban heat island effects are an explicit goal through increased shade around the project area
- Plants and trees designed for urban heat island effect mitigation will have secondary urban ecology and wildlife benefits
- Stormwater pumps incorporated to address public health concerns for standing water and pest breeding

TRANSPORTATION & MOBILITY

- Separated and protected bike lanes and sidewalks from traffic
- Connects to goals in "Moving New Orleans" multi-modal strategy
- Rain garden bump-outs at street crossings for pedestrian safety and traffic calming

COMMUNITY

- Blue-green infrastructure aligned with community goals, neighbourhood destinations, and community education
- Flood risks were co-examined with public health data, economic needs, urban heat impacts, and workforce development opportunities for additional community benefit and equity
- Stormwater storage combined with community center development (shown above)

CLIMATE CHANGE

- Stormwater storage accommodates a wide range of storm events
- Dually addresses mitigating urban heat island effects by shading urban environments with blue-green infrastructure
- Models back up the anticipated flood benefits within Gentilly District and outside neighbourhood boundaries for interconnected drainage systems

Churchill Technology Park

Avondale, Louisiana, U.S.

Churchill Technology Park is a vision for a new development based on blue-green infrastructure principles. Climate change resilience was a primary driver for this master plan, and Churchill Park is viewed as an opportunity to showcase resilient infrastructure.

OWNER Jefferson Parish Economic Development Commission

DESIGNER Perkins+Will, Point A Consulting, Nelson/Nygaard, Morphy Makofsky Inc

PARTNERS Churchill Master Plan Committee, Churchill Farms Inc, Jefferson EDGE, Greater New Orleans Water Collaborative, GNO Inc, Jefferson Parish Depts of Planning, Public Works, Hazard Mitigation, Floodplain Management, Stormwater Management, Coastal Management, and Engineering

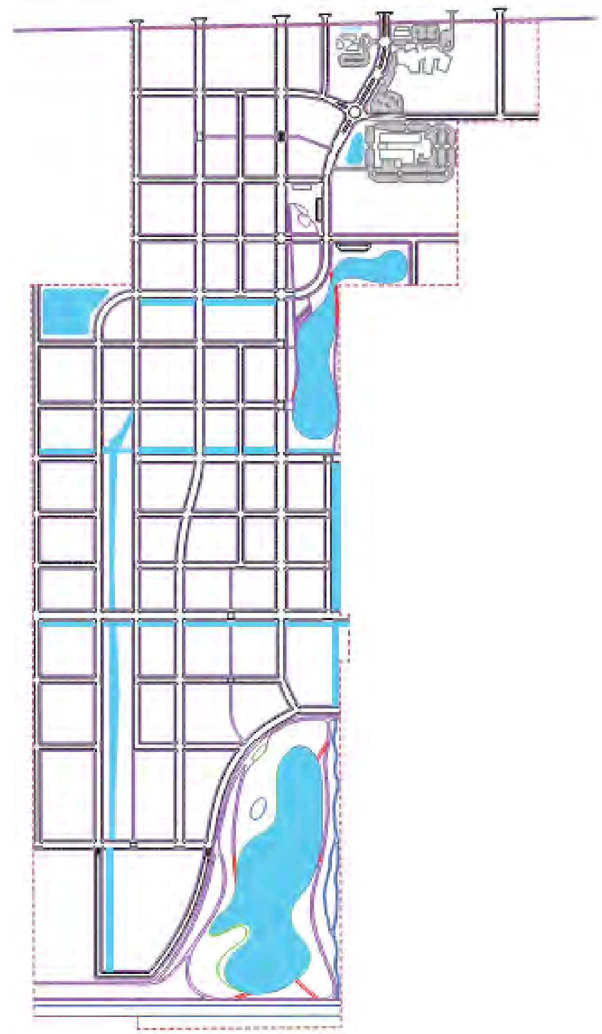
GOALS
PRIMARY
Flood storage, flow control
SECONDARY
Flood conveyance
Active mobility

STATUS Master Plan

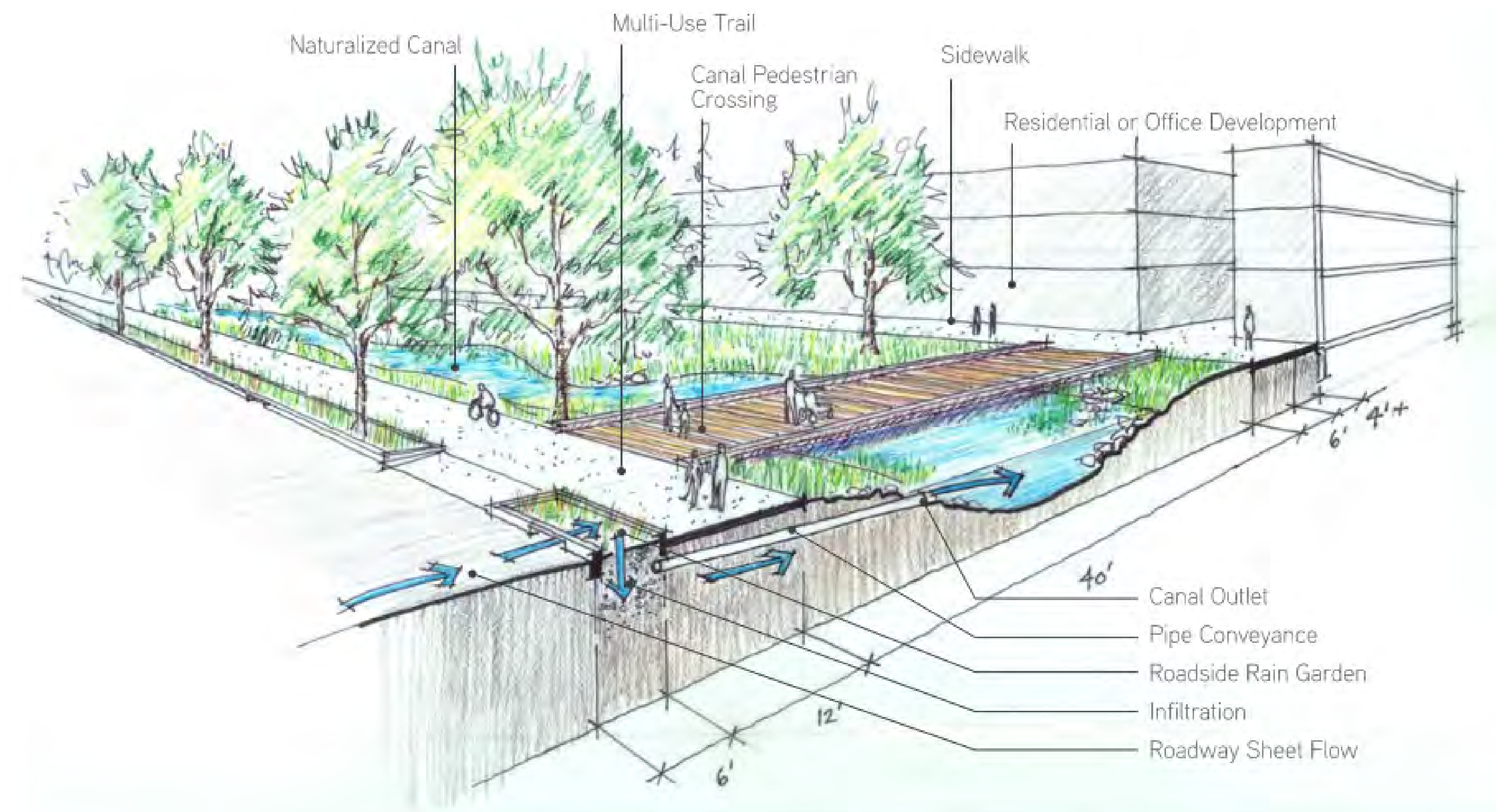
YEAR 2015 - 2019

BUDGET N/A

FUNDING N/A



Source: JEDCO



Source: JEDCO

CONTEXT

LOCATION Private development

RAINFALL 162 cm/yr

LAND USE Mixed use, commercial

TOPOGRAPHY Flat, below/at sea level

SOILS Low infiltration

GROUNDWATER High

UTILITIES Primarily proposed utilities

OTHER Historically swampland and farming. In Fairfield, the largest greenfield left within the protection levee.

DESIGN DETAILS

PROJECT TYPE New development

RUNOFF SOURCE Private

CONTRIBUTING AREA 57 hectares

DISCHARGE Levee south of site

DESIGN STORM 10-year design storm, 60-min time of concentration with 87 mm/hr of rainfall

DESIGN ELEMENTS Naturalized drainage canal, roadside rain gardens, trees, bioswales, detention ponds

PROJECT DESIGN

The Churchill Technology Park is a new development within the Churchill Master Plan, which sets a framework for new development that is ecologically and economically conscious. This development fits within a larger vision for integrated work, play, art, recreation, community events, and wildlife. Integrated stormwater features function together to address flood storage, water quality, and open space concerns with new a blue-green network of canals, bioretention, and rain gardens amongst new development.

Lakeview / City Park Hazard Mitigation Project

New Orleans, Louisiana, U.S.

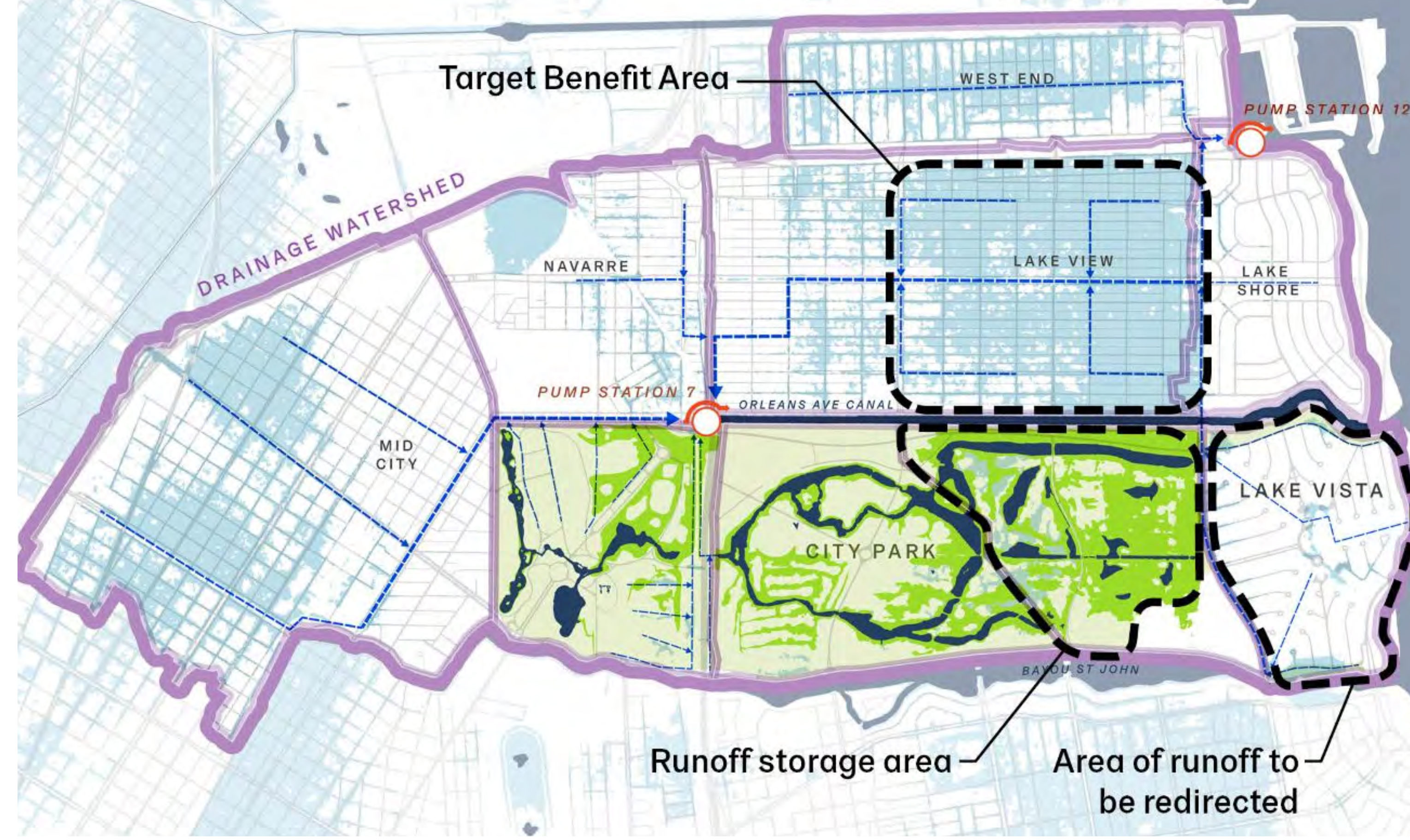
Lakeview/City Park is a demonstration project of the Greater New Orleans Urban Water Plan, which seeks to innovatively manage water, economic opportunities, and climate adaptation. The vision includes streets designed to promote stormwater infiltration to recharge groundwater levels and improve soil stabilization while also improving pedestrian and bicycle safety. City Park will be redesigned to hold and retain water.

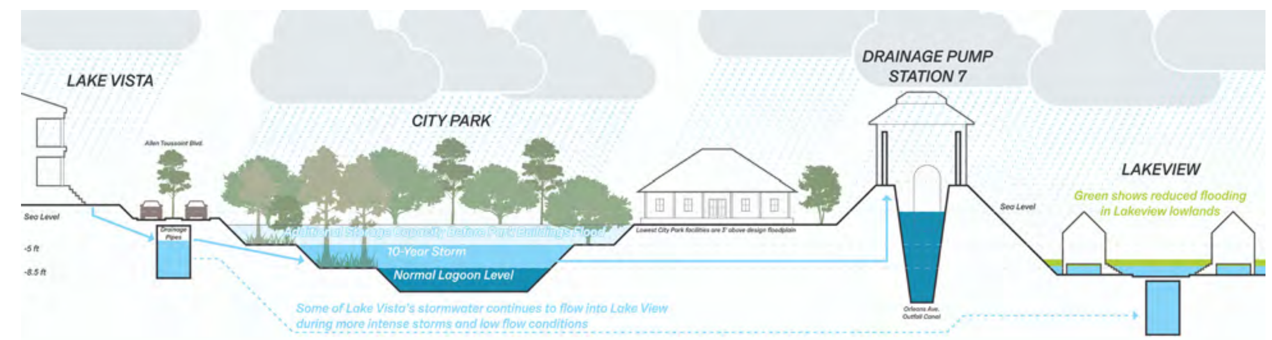
OWNER	Sewerage and Water Board of New Orleans
DESIGNER	Batture, Waggonner & Ball, Wingate Engineers, Rostan Solutions, Biohabitats, Eutis Engineering LLC, GrennPoint, Ardurra, Bosch Slabbers Landscape & Urban Design
PARTNERS	City of New Orleans Resilience and Sustainability, City Park New Orleans
GOALS	PRIMARY Flood storage, Flow control SECONDARY Shoreline erosion reduction, Water quality, Fish habitat, Groundwater recharge
STATUS	Planning
YEAR	Unknown
BUDGET	Unknown
FUNDING	FEMA Hazard Mitigation Grant

Source: Lakeview/City Park Hazard Mitigation Project

CONTEXT

LOCATION	Public parcel
RAINFALL	163 cm/yr
LAND USE	Mixed use, residential
TOPOGRAPHY	Unknown
SOILS	Weak organic soils
GROUNDWATER	Shallow
UTILITIES	Subsurface
OTHER	Part of the "Living With Water" approach to stormwater and groundwater management





DESIGN DETAILS

PROJECT TYPE	Retrofit
RUNOFF SOURCE	Public, private
CONTRIBUTING AREA	14 blocks
DISCHARGE	Lake Pontchartrain via the Orleans Ave Canal
DESIGN STORM	2, 5, 10, and 100-year storms 650,000 m^3 stormwater 55,000 m^3 flood reduction in Lakeview neighbourhood
DESIGN ELEMENTS	Stormwater lagoons (detention), constructed wetlands, bioswales, native plants, trees, stormwater treatment devices to remove trash and debris

PROJECT DESIGN

The project will manage 14 blocks in Lakeview and City Park will be redesigned to create space for water and enhance park ecosystems. Through stormwater detention, constructed wetlands, bioswales, and urban design strategically applied on major streets and alleys, the project aims to reduce flooding, improve groundwater recharge, and mitigate subsidence in the neighbourhood. There has been some opposition to the project from residents, who argue existing drainage pipes and pumps need to be fixed first and are concerned about managing so much stormwater in City Park.

South Jamaica Housing Cloudburst

Queens, New York, U.S.

The South Jamaica Housing Cloudburst Plan is driven by a need for climate resilience and combined sewer overflows in Queens, New York. In an innovative partnership with New York City Housing Authority, this plan utilizes public housing parcels to simultaneously address urban flooding and resident quality of life. This project is an excellent example of innovative and collaborative climate adaptation for all residents, regardless of income.

OWNER New York City Housing Authority

DESIGNER Rambøll, Hazen & Sawyer

PARTNERS NYC Dept. of Environmental Protection, NY State Energy Research & Development Authority, Marc Wouters | Studios, Grain Collective

GOALS PRIMARY:
- Flood storage
- CSO flow control

SECONDARY:
- Urban nature

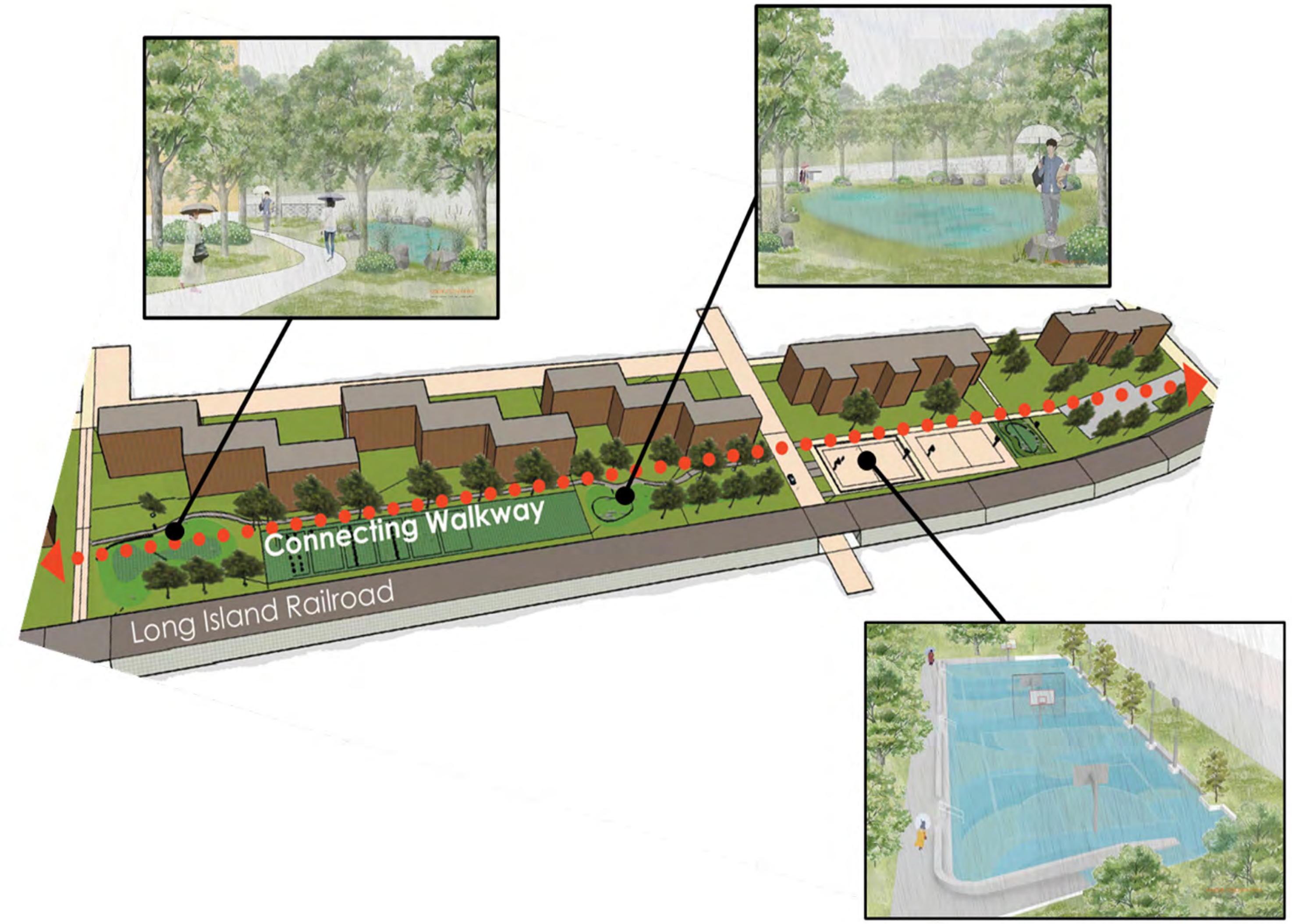
STATUS Conceptual Design

YEAR 2018, anticipated construction in 2023

BUDGET Unknown

FUNDING Unknown

Source: NYCDEP, Rambøll



Source: NYCDEP, NYC Housing Authority, Marc Wouters | Studios

CONTEXT

LOCATION	Public housing parcels
RAINFALL	102 - 132 cm/yr
LAND USE	Mixed use residential, nearby light industrial
TOPOGRAPHY	Flat, 0 to 3%
SOILS	Sandy, med. permeability (Flatbush Complex)
GROUNDWATER	Low water table
UTILITIES	N/A in conceptual design
OTHER	Case study as part of NYCDEP's Cloudburst Resiliency Plan

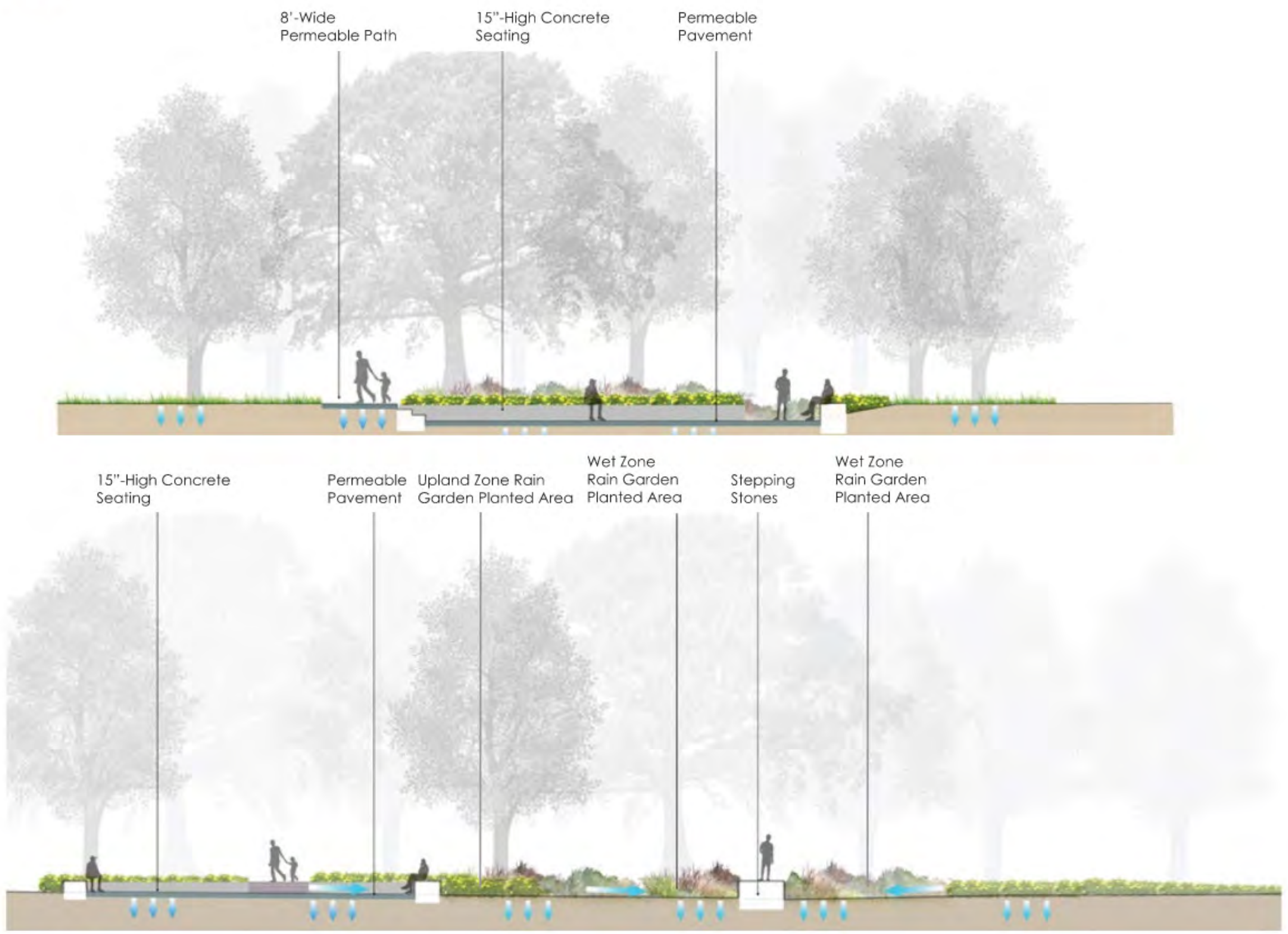
DESIGN DETAILS

PROJECT TYPE	Retrofit
RUNOFF SOURCE	Public and private
CONTRIBUTING AREA	Unknown
DISCHARGE	Unknown
DESIGN STORM	10-Year storm
DIMENSIONS	N/A - multiple parcels
DESIGN ELEMENTS	Pervious pavers, rain gardens, trees, underground retention tanks

PROJECT DESIGN

The South Jamaica Houses Cloudburst Plan was a collaborative effort with residents. The process evaluated a number of alternatives, including retention basins under courts, floodable spaces, deep and shallow basins, among others. Alternatives were then prioritized and preferred alternatives were furthered developed into conceptual designs. Two blocks (Block 5 and Block 7) of the South Jamaica Houses were estimated to manage 580 m^3 and 610 m^3 respectively.

A.2 Area 2



Source: NYCDEP, NYC Housing Authority, Marc Wouters | Studios


Future concept for South Jamaica Houses (dry day)


Future concept for South Jamaica Houses (very wet day)

Source: NYCDEP, Rambøll

OTHER CONSIDERATIONS

URBAN ECOLOGY

- Native species were selected so maintenance of bioretention areas would be minimal.
- Residents helped develop preferred planting palette with a mix of flowering plants and grasses.
- Plants were also selected for environmental conditions, particularly plants that thrive in wet vs dry zones.

TRANSPORTATION & MOBILITY

- The proposed conceptual designs do not describe in detail ideas for connecting to local transportation networks or improved mobility and safety for users.
- The overview conceptual plan does note where connecting bike paths would come through the primary road next to the South Jamaica Houses.

COMMUNITY

- The input of South Jamaica Housing residents was an essential part of the design process.
- Residents were included in a co-design process to help develop concepts, evaluate alternatives, and select plants.
- Design elements, such as basketball courts and gardens, were included with multiple benefits to address both hydrologic and community goals,

CLIMATE CHANGE

- The design process used a 10-year design storm to evaluate storm volumes and drive design constraints.
- There was not information on evaluation beyond a 10-year design storm.
- Part of a larger climate resilience planning effort across NYC.

The Soul of Nørrebro

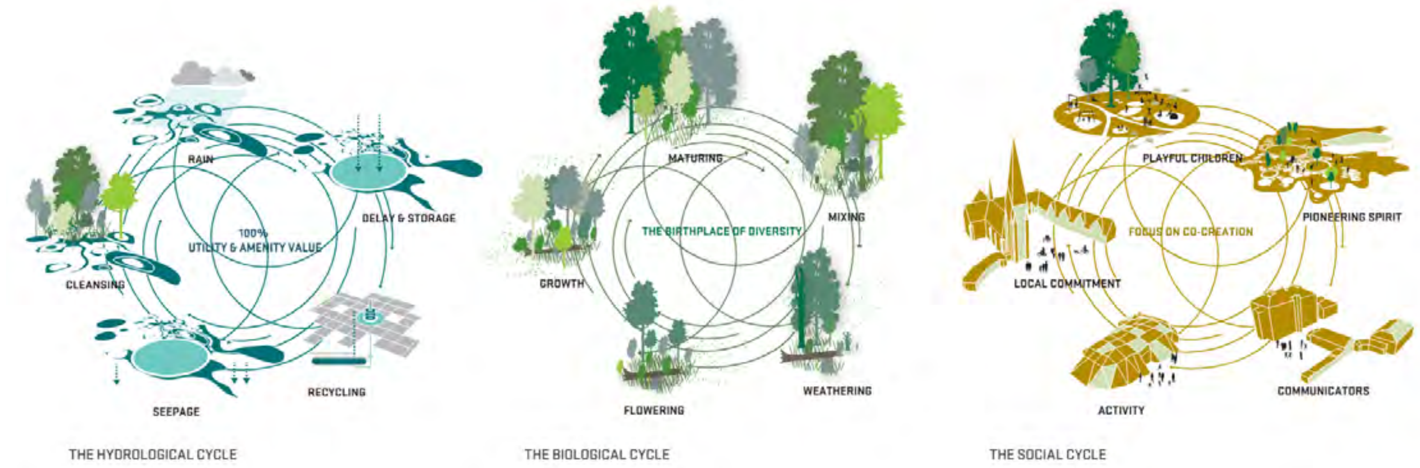
Hans Tavsens Park, Blågård School, & Korsgade

Copenhagen, Denmark

The designs for retrofitting Hans Tavsens Park and Korsgade Street emerged from a design competition following extreme flooding in Copenhagen. This project is driven primarily by city-wide goals for climate resilience, social cohesion, and urban innovation to address flood storage, water quality, habitat, and access to nature in urban environments. To achieve these goals, the design is guided by three complementary cycles: the hydrological cycle, the biological cycle, and the social cycle. This project is still in the design and pre-construction phases, but is an excellent example of designing for water quality and flood resilience while also intentionally designing for social benefit, learning, and urban nature.

OWNER	City of Copenhagen
DESIGNER	SLA
PARTNERS	Rambøll, ARki Lab, Den Nationale Platform for Gadeidraet, Aydin Soei, Social Action
GOALS	PRIMARY Flood storage Water quality SECONDARY Habitat and urban nature
STATUS	Design, Pre-Construction (anticipated completion in 2025)
YEAR	2016 - ongoing
BUDGET	$28 million CAD**
FUNDING	N/A

Source: SLA



Source: SLA

CONTEXT

LOCATION	Public parcels, Street ROW
RAINFALL	75 cm/yr
LAND USE	Neighbourhood
TOPOGRAPHY	Unknown
SOILS	Unknown
GROUNDWATER	Unknown
UTILITIES	Unknown

DESIGN DETAILS

PROJECT TYPE	Retrofit
RUNOFF SOURCE	Public and private
CONTRIBUTING AREA	8.5 hectares
DISCHARGE	Peblinge Lake
DESIGN STORM	Designed for daily, 10-yr, and 100-yr rain events. Up to 18,000 cubic meters 24-Hr retention time
DESIGN ELEMENTS	Floodable park, floodable street, biofiltration prior to discharge

PROJECT DESIGN

Roadway and neighbourhood runoff drains through a first-flush system using existing stormwater pipes. The remaining stormwater flows to Hans Tavsens Park, which can hold up to 18,000 cubic meters of water and is designed for a 24-hour retention time. Water then flows to Korsgade Road, which is also designed as a "V-profile" street to direct surface runoff into a biofiltration system before discharging to Peblinge Lake. The biofiltration system is designed to remove 50 to 100 kg of phosphorus annually using sand filters.

The diagrams illustrate the distribution of the rain water in different rain scenarios.

A_ Water tank for residents
B_ Water tank for the Municipality
C_ Discharge pipe
D_ Cleansing biotope
E_18,000 m3 delay reservoir

EVERYDAY EVENT

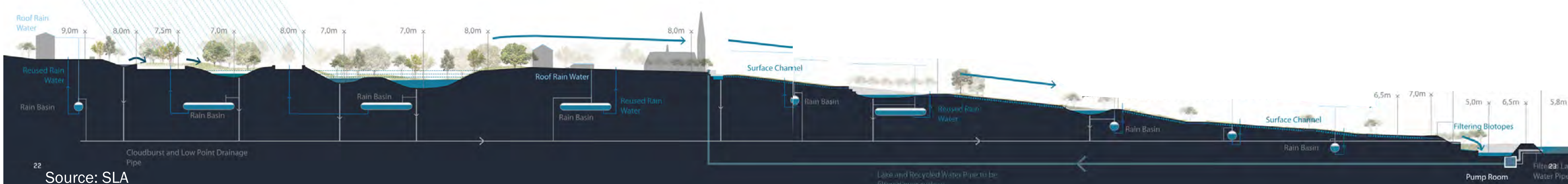
The lowest lying areas that are located closest to the discharge pipe in Hans Tavsens Park will fill up first. Just as the water tanks for residents and the municipality will be partially filled. The circular system that purifies the lake water in Korsgade will then be filled with roof water from Korsgade, water from side walks and second flush. All water is purified before discharge to lakes or infiltration into the water table.

TEN-YEAR EVENT

In case of a ten-year event a greater part of Hans Tavsens Park will fill up, but the islands and the arena will remain dry for sports activities, staying there and cultural events. The park will empty itself again after a maximum of 24 hours, using infiltration and throttle valve discharge to the discharge pipe. The cleansing biotopes in the park and Korsgade delay and purify all the rain water prior to infiltration into the water table or discharge to Peblinge Lake. From the water tanks there will be an overflow to Hans Tavsens Park or the cleansing biotopes in Korsgade.

CENTENNIAL EVENT

The arena will then also be filled with rain water and in the park's eastern section there is an overflow to Hans Tavsens Street which has been constructed as a cloudburst street. Rain water will be directed across the Church square towards Korsgade and water will be directed towards the easternmost biotope called Raikkonen (the lakeside balcony). Only in case of absolutely extreme events will cloudburst rain not be purified prior to discharge.



Source: SLA

PRECEDENT RESEARCH

Source: SLA

Source: SLA

OTHER CONSIDERATIONS

URBAN ECOLOGY

- The Biological Cycle is a core component to the design framework, especially the dynamic processes of natural environments.
- Variety of old grove urban trees preserved and new fruit trees planted.
- Attention to bird communities and lake habitat through a diverse planting palette of aesthetic and functional plant communities.
- Designs embrace new growth, old growth, weathering, death, and seasons.

TRANSPORTATION & MOBILITY

- Hans Tavsens Park and Korsgade are designed to be physical and visual links through the core of Nørrebro.
- Car lanes are narrowed on Korsgade to 3.75 m to make it possible to drive, but not desirable regularly.
- Two direction bike lanes and safe pedestrian experiences encourage walking and biking as primary modes of transportation.

COMMUNITY & CO-CREATORS

- Many schools are located next to Hans Tavsens Park and use the park as a learning and recreational amenity.
- The Blågård School and FABLAB are envisioned as resources for kids to learn about urban nature, climate change, and adaptation through exploration.

CLIMATE CHANGE

- A main driver of this project is rethinking rainwater as a resource and planning accordingly for everyday storms up to 100-year storms.
- Hans Tavsens Park is designed as a floodable space, holding rainwater until it can be treated and discharged.
- Korsgarde is designed as a V-profile street to direct water through biofiltration systems to improve nutrients and phosphorus levels in Peblinge Lake.

Copenhagen Cloudburst Formula

Copenhagen, Denmark

The Copenhagen Cloudburst Formula is a master plan for addressing extreme rainfall in Copenhagen, Denmark. A toolbox of 8 project strategies are proposed, along with a number of pilot projects to communicate how these strategies would leverage blue green infrastructure in everyday life. The master plan is a strong vision for guiding infrastructure decisions moving forward and understanding the economic investments and benefits of blue green infrastructure.

OWNER Municipality of Copenhagen

DESIGNER Rambøll, Rambøll Studio Dreiseitl

PARTNERS City of Copenhagen, Greater Copenhagen Utilities, City of Fredriksberg, Fredriksberg Utilities

GOALS PRIMARY
- Flood conveyance
- Flood storage

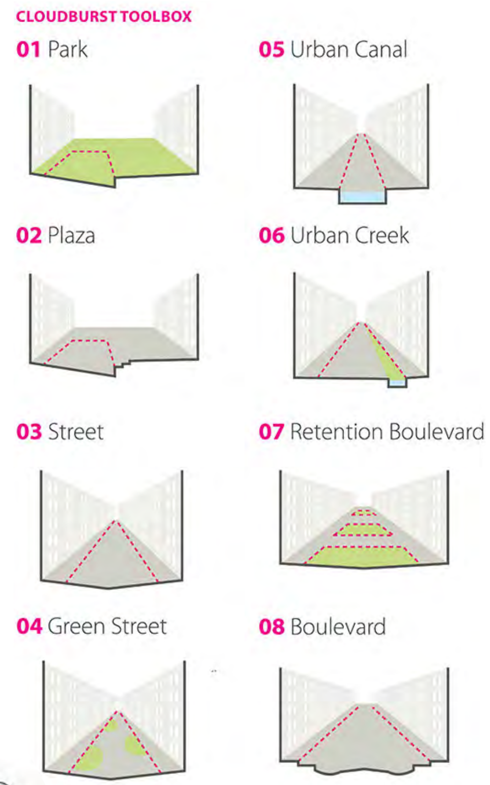
SECONDARY
- Water quality
- Urban nature

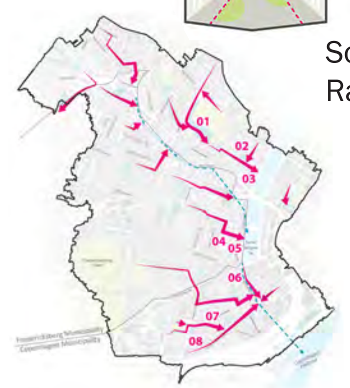
STATUS Planning

YEAR 2011

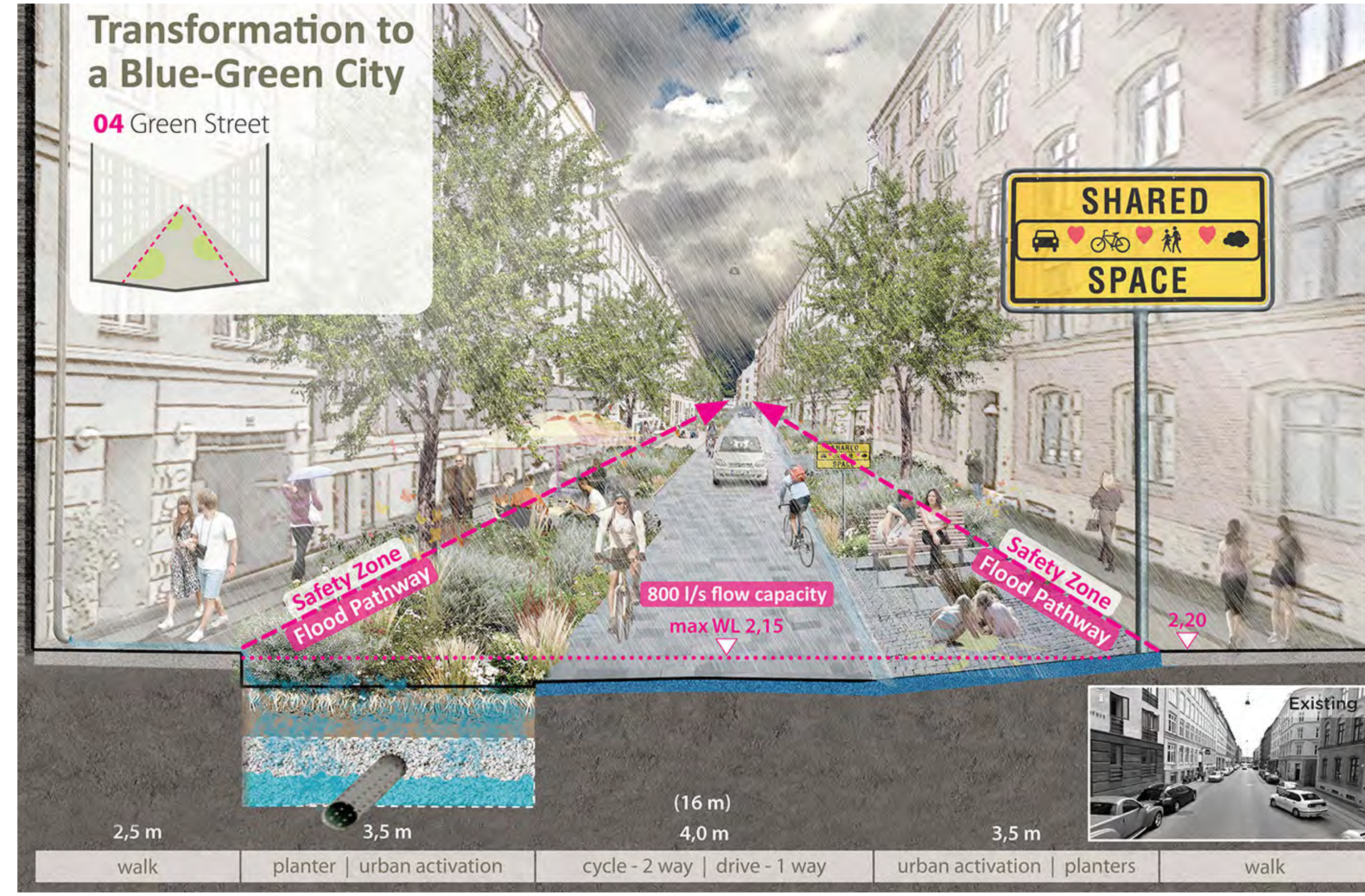
BUDGET $743 million CAD** estimated to implement plan by 2033

FUNDING Proposed combination of private financing, utility revenues, tax revenues





Source: Rambøll, Rambøll Studio Dreiseitl



Source: Rambøll and Rambøll Studio Dreiseitl

CONTEXT

LOCATION Street ROW, Public parcels

RAINFALL 74 cm/year

LAND USE Mixed use, commercial

TOPOGRAPHY Primarily flat, but varies

SOILS Unknown

GROUNDWATER Unknown - varies

UTILITIES N/A - Master Plan

OTHER Analyzed water catchment infrastructure, terrain, watersheds, and flooding potential to drive planning

DESIGN DETAILS

PROJECT TYPE Retrofit Master Plan

RUNOFF SOURCE City-scale runoff

CONTRIBUTING AREA 10 km^2

DISCHARGE Copenhagen Harbour, Øresund Strait

DESIGN STORM 100-Year Storm

DESIGN ELEMENTS Toolbox of 8 project types: Parks, Plazas, Streets, Green Streets, Urban Canals, Urban Creeks, Retention Boulevards, Boulevards with Bioretention, Floodable Space, Retention Basins

PROJECT DESIGN

The toolbox of strategies aims to meet 100-year storm water volume demands, as well as limit sewer discharge to the Harbour to once every 10 years. The strategies and pilot projects are designed to allow water levels to exceed ground level by 10 cm once every 100 years, except in specifically designed floodable spaces. These strategies also consider how recreation, urban mobility, and social benefit could be achieved at the same time. Gasvaerksvej is a pilot project Cloudburst street designed to be a total of 16 m wide with 2.5 m sidewalk and 3.5 m planters on each side of 4 m lanes for bicycles and cars.

Lindevangs Park

Frederiksberg, Denmark

Lindevangs Park is designed with children, learning, and climate adaptation in mind, creating a public space that is inviting, fun, and functional. The park is designed to accommodate 100-year cloudburst storms, as well as invite exploration and learning in fruit tree gardens and the sunken square. Lindevangs Park is an example of functional and beautiful floodable public space that connects into cloudburst (floodable) roads and the existing sewer system to reduce flooding and overflows.

OWNER Frederiksberg Municipality

DESIGNER Marianne Levinsen Landscape, Niras A/S

PARTNERS Frederiksberg Council, Frederiksberg Water Supplier

GOALS PRIMARY
- Flood storage
- Flood conveyance

SECONDARY
- Urban nature

STATUS Completed

YEAR 2015

BUDGET $6.9 million CAD**

FUNDING VANDPLUS

Source: Marianne Levinsen Lanscape

Source: Marianne Levinsen Lanscape

Source: Marianne Levinsen Lanscape

CONTEXT

LOCATION Public parcel

RAINFALL 74 cm/yr

LAND USE Mixed use, mostly residential

TOPOGRAPHY Flat

SOILS Unknown

GROUNDWATER Unknown

UTILITIES Unknown

OTHER N/A

DESIGN DETAILS

PROJECT TYPE Retrofit

RUNOFF SOURCE Public

CONTRIBUTING AREA 5.4 hectares

DISCHARGE Unknown

DESIGN STORM 100-year storm

DIMENSIONS Total area 21,000 m^2

DESIGN ELEMENTS Rain gardens, vegetated long basin, detention basin, outdoor theater, sunken public square

PROJECT DESIGN

Elevated rain gardens with filter soil are connected to a 250 m^3 vegetated basin with filter soil and recreational elements. These elements connect to a 100 m^3 “soakaway” with the potential for irrigation capture. A 1600 m^3 detention basin sits under a partially paved outdoor theater and a 500 m^3 detention basin is under the sunken public square. In extreme events, water overflows to adjacent cloudburst roads and sewer system.

Kunshan Culture & Arts Precinct Constructed Wetlands

Kunshan, China

The Kunshan Culture & Arts Precinct Constructed Wetlands demonstrate how public open spaces can provide numerous ecosystem services in an urban environment. The wetlands are one of many 'sponge-city' and water sensitive design projects in Kunshan, the 2010 winner of the UN Habitat Scroll of Honour Award, that clean stormwater on-site while increasing biodiversity and functional ecological landscapes.

OWNER Kunshan City Construction, Investment and Development Company

DESIGNER FRC Design, E2DesignLab

PARTNERS Unknown

GOALS PRIMARY
- Water quality
- Flow control
- Aesthetics

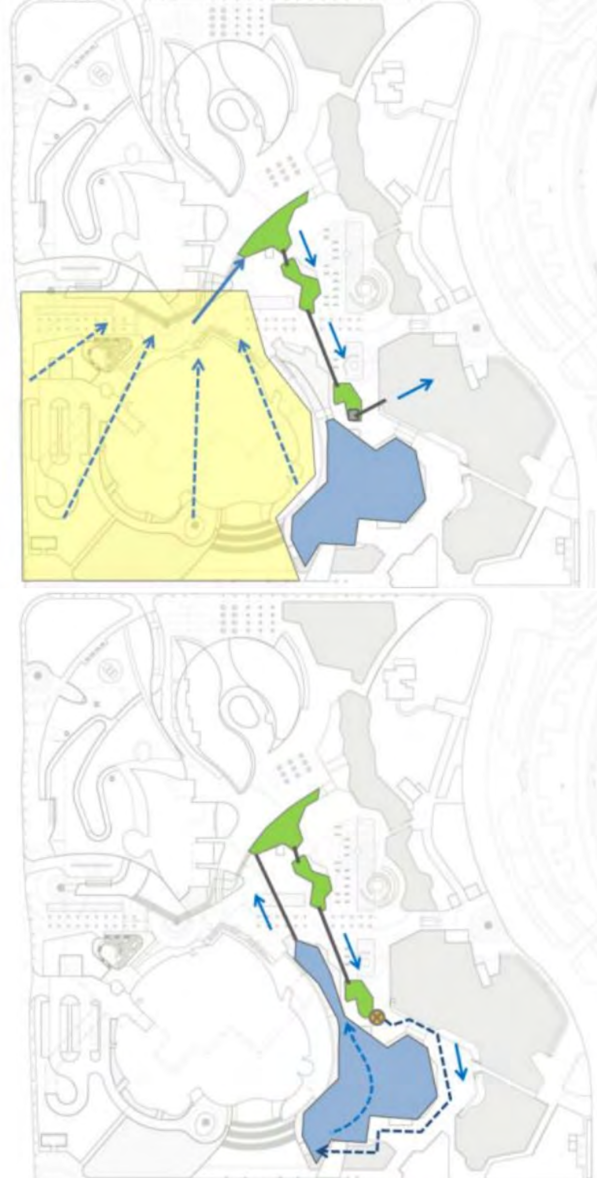
SECONDARY
- Biodiversity

STATUS Completed

YEAR 2013

BUDGET Unknown

FUNDING Governmental funding



Source: FRC Studio

Source: CRC Water Sensitive Cities

CONTEXT

LOCATION Public parcel

RAINFALL 130 cm/yr

LAND USE Commercial (Arts Plaza)

TOPOGRAPHY Flat

SOILS Unknown

GROUNDWATER Unknown

UTILITIES Unknown

OTHER N/A

DESIGN DETAILS

PROJECT TYPE New development

RUNOFF SOURCE Public and private

CONTRIBUTING AREA Unknown

DISCHARGE Local stream

DESIGN ELEMENTS
5-day wetland recirculation
30-day wetland turnover time
1000 m^2 total wetland area
300 mm avg. water depth
400 mm max water depth

Additional sedimentation zone and hydraulic connectivity between wetland cells.

PROJECT DESIGN

A series of three 1,000 m^2 inter-connected stormwater wetland cells and a 10,000 m^2 landscape pool capture, treat, and re-circulate on-site stormwater to reduce flooding and provide ornamental water features. Some off-site water from an external waterway is treated in the wetland system and discharged after treatment. Initial monitoring showed effective pollutant removal and increased biodiversity.

Cheonggyecheon Stream Restoration

Seoul, Korea

Seoul's Cheonggyecheon Stream Restoration is a paradigm shifting project that transformed an aging, congested, elevated freeway into a daylit stream in the heart of the city. The project has had major, measurable environmental, social, and environmental benefits including reduced urban temperatures, reduced small-particle air pollution, increased biodiversity, increased cooling wind speeds, increased bus and subway ridership, increased tourism, and increased business.

OWNER Seoul Metropolitan Government

DESIGNER Cheongsuk Engineering, Saman Engineernig, Dongmyung Engineering,

PARTNERS SeoAhn Total Landscape, Daelim, LG Construction, Hyndai Construction, Suhyoung Engineering, Cheil Engineering,

GOALS
PRIMARY
- Flood conveyance

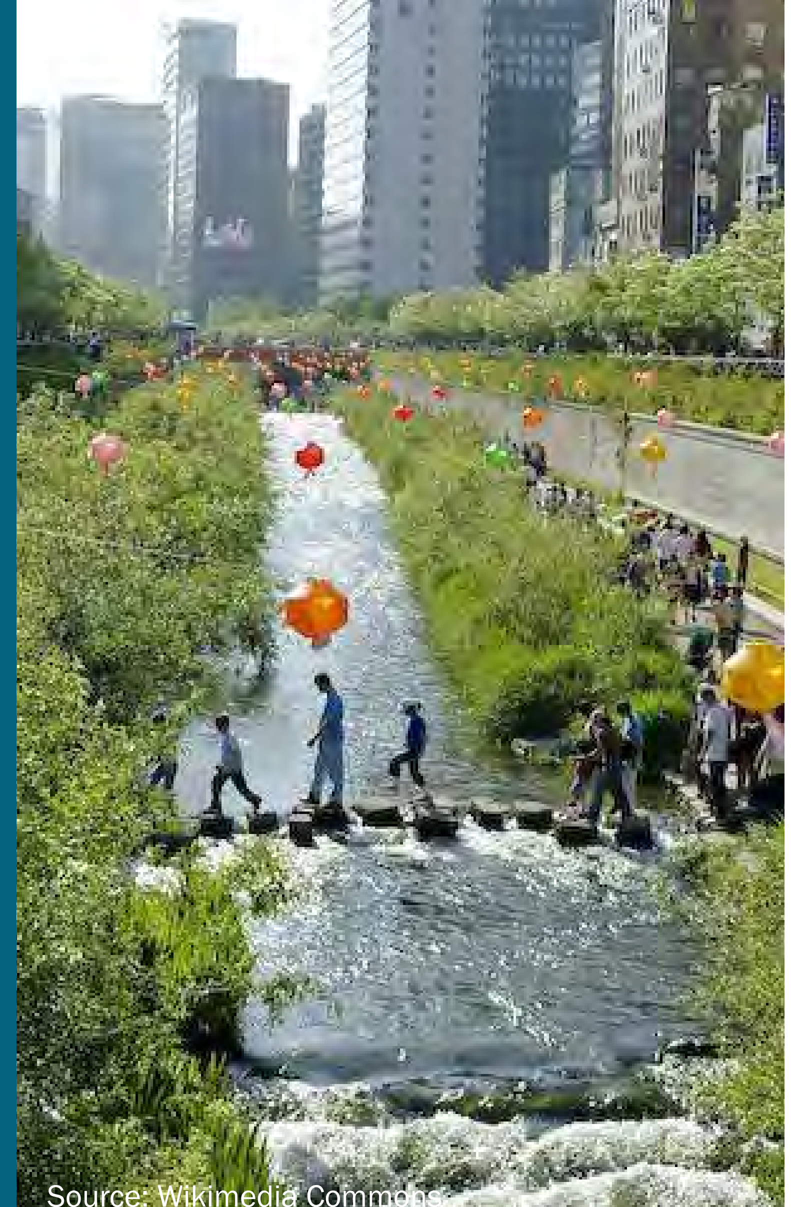
SECONDARY
- Biodiversity, Green space
- Urban heat, Air quality
- Economic development

STATUS Completed

YEAR 2005

BUDGET $513 million CAD*

FUNDING Unknown


Source: Wikimedia Commons


Source: Alexander Robinson


Source: Plataforma Urbana

CONTEXT

LOCATION	Street ROW (former highway), former river
RAINFALL	137 cm/yr
LAND USE	Mixed Use, Transportation
TOPOGRAPHY	Unknown
SOILS	Unknown
GROUNDWATER	High (river)
UTILITIES	Unknown
OTHER	Water is only naturally present during summer rainy season,

DESIGN DETAILS

PROJECT TYPE	Restoration	**DESIGN STORM**	200-yr storm, 118 mm/hr
RUNOFF SOURCE	Public and private	**DIMENSIONS**	5.8 km long, 40.5 hectares
CONTRIBUTING AREA	Unknown	**DESIGN ELEMENTS**	Highway removal, stream daylighting, ecosystem restoration, pedestrian and vehicle bridges, connection to regional subways
DISCHARGE	Han River		

PROJECT DESIGN

3.6 miles of historic Cheonggyecheon Stream were daylit with the removal of a four-lane highway overpass. The restored stream provides flood protection for up to a 200-year flood event and can sustain a flow rate of 118 mm/hour. Because rainfall occurs only in the summer, water is pumped and treated with subway pump stations to create a consistent flow and average depth of 40 cm. The design includes fish spawning grounds, native willow swamps, shallows, and marshes, and terraced walls that allow visitor access as water levels change.

Daldy Street Linear Park

Auckland, New Zealand

The Daldy Street Linear Park is part of Auckland's largest urban renewal project and is focused on waterfront redevelopment and the creation of a 'blue green' environment. Consideration of tidal influences and future sea level rise projections, contaminated soils, and flat terrain led to non-conventional stormwater management that blends a traditional sewer system with above-ground linear bioretention, roof runoff rain gardens, rainwater harvesting, and water play features.

OWNER	Waterfront Auckland Development Agency
DESIGNER	Opus International Consultants
PARTNERS	Unknown
GOALS	PRIMARY Water quality Urban development SECONDARY Green space Biodiversity Active mobility
STATUS	Completed
YEAR	2020
BUDGET	$27 million CAD*
FUNDING	Unknown

Source: Opus International Consultants

Source: Opus International Consultants

CONTEXT

LOCATION	Street ROW
RAINFALL	112 cm/yr
LAND USE	Mixed use
TOPOGRAPHY	Flat
SOILS	Reclaimed land, marine mud, contamination
GROUNDWATER	1 - 1.5 m below ground
UTILITIES	Unknown
OTHER	+3m to +5m above relative sea level Contaminated soils from port-related industries

DESIGN DETAILS

PROJECT TYPE	Rebuild / Redevelop
RUNOFF SOURCE	Public and private
CONTRIBUTING AREA	32 hectares
DISCHARGE	Waitemata Harbour
DESIGN STORM	100-yr storm surge 2100 sea level rise
DESIGN ELEMENTS	Lined bioretention systems, primary storm sewer conveyance, roof water rain gardens, street water rain gardens, 'water play' park facility

PROJECT DESIGN

Multiple small sub-catchments are linked together in a treatment train through lined bioretention systems that discharge into a piped conveyance network. Bioretention tree pits capture roof runoff on-site and a linear street swale collects overland flow. A 'water play' park facility and non-functional water towers located above below-ground stormwater reuse collection tanks add educational and visual interest. The linear swales are designed to fully convey a 20-year storm, while a 100-year storm will rely on the pipe network to fully manage.

References

Swale on Yale

White, Jordyn (2021). "Swale on Yale: A Breakthrough Discovery in Biofiltration Systems". Herrera, Inc. Accessed May 2023, https://www.herrerainc.com/swale-on-yale-a-breakthrough-discovery-in-biofiltration-systems/

Seattle Public Utilities (2012). "Capitol Hill Water Quality Project – the Swale on Yale". Spring 2012 Restore Our Waters E-News. Accessed May 2023, PDF.

Unterreiner, Jerome (2010). "Swale on Yale". Issuu publication. Accessed May 2023, https://issuu.com/urban_theater/docs/issuu_swale_on_yale_boards_3.19.08_final

Ahearn, Dylan and Doug Hutchinson (2017). "Swale on Yale: Innovative Regional Green Stormwater Infrastructure in an Urban Neighborhood". StormCon White Paper. Accessed May 2023, PDF.

KPG (n.d.) "Swale on Yale". KPG Psomas Projects. Accessed May 2023, https://www.kpg.com/project/swale-on-yale/

KPFF (n.d.). "Swale on Yale". KPFF Projects. Accessed May 2023, https://www.kpff.com/project/swale-on-yale-kpff/

Venema Creek

City of Seattle (n.d.), "Venema Creek natural Drainage System." Seattle Green Infrastructure Innovation Case Study Series. Accessed May 2023, PDF.

Koger, Curtis (n.d.), "Hydrogeologic Evaluation of a Combined GSI and Deep UIC Well Infiltration System for Flow Control – Venema NDS Project, Seattle, Washington." Presentation, Associated Earth Sciences, Inc in partnership with Seattle Public Utilities and SvR Design Company. Accessed May 2023, PDF.

Osborn Consulting (2017), "Using UIC's in the Right of Way". Presentation, APWA-WA Spring Conference 2017. Accessed May 2023, PDF.

Osborn Consulting (n.d.), "Venema Natural Drainage System." Osborn Consulting Incorporated, Projects. Accessed May 2023, https://osbornconsulting.com/venema-natural-drainage/

SPU (n.d.), "Venema Natural Drainage Project." Seattle Public Utilities, Neighborhood Projects. Accessed May 2023, https://www.seattle.gov/utilities/neighborhood-projects/venema

21st Street Green/Complete Street Improvements

Adaptation Clearinghouse (2013). "Redesign of 21st Street, Paso Robles, California." Adaptation Clearinghouse Case Study. Accessed May 2023, PDF.

Cannon (n.d.). "The City of Paso Robles 21st Street Green/Complete Street Improvements". Presentation, Cannon and the City of Paso Robles. Accessed May 2023, PDF.

Central Coast LIDI (n.d.), "21st Street Complete/Green Street." Central Coast LIDI Case Study Details. Accessed May 2023, https://www.centralcoastlidi.org/case-study-details.php?id=2

Global Street Design Guide (n.d.), "Case Study: 21st Street, Paso Robles, USA." Global Designing Cities Initiative. Accessed May 2023, https://globaldesigningcities.org/publication/global-street-design-guide/streets/special-conditions/streets-to-streams/case-study-21st-street-paso-robles-usa/

Rowe, Andy and Larry Kraemer (2015). "21st Street for the 21st Century." ASCE Civil Engineering Magazine. May 2015. Accessed May 2023, PDF.

39th Ave Open Channel Greenway

Beaty, Kevin (2018), "As a big chunk of a Superfund nears closing, north Denver residents worry polluted soils still pose a threat." Denverite. Accessed May 2023, https://www.aslacolorado.org/award/39th-avenue-greenway/

Beaty, Kevin (2019), "EPA says most of north Denver is no longer toxic, locals aren't so sure." Denverite. Accessed May 2023, https://denverite.com/2019/02/06/epa-says-most-of-north-denver-is-no-longer-toxic/

Beaty, Kevin (2020), "The 39th Avenue Greenway is now open for recreation and excess rain." Denverite. Accessed May 2023, https://denverite.com/2020/11/16/the-39th-avenue-greenway-is-now-open-for-recreation-and-excess-rain/.

City of Denver (n.d.), "39th Avenue Greenway and Open Channel Factsheet". Platte to Park Hill: Stormwater Systems. Accessed May 2023, PDF.

Denver Public Works (n.d.), "Green Infrastructure Implementation Strategy." The City and County of Denver, Public Works. Accessed May 2023, PDF.

DHM Design (2022), "39th Avenue Greenway". ALSA Colorado Honor Award, Urban Design. Accessed May 2023, https://www.aslacolorado.org/award/39th-avenue-greenway/

Felsburg, Holt, and Ullevig (2022), "39th Avenue Greenway Design-Build." 2022 CASFM Outstanding Construction Project. Accessed May 2023, PDF.

Blue and Green Corridors

Batture (n.d.) "Blue and Green Corridors". Batture LLC. Accessed May 2023, https://www.batture-eng.com/project/blue-green-corridors/

City of New Orleans (2020). "Blue and Green Corridors 90% Design Update Community Meeting". City of New Orleans, Gentilly Resilience District. Accessed May 2023, PDF.

City of New Orleans (2020). "Blue and Green Corridors Project Fact Sheet". City of New Orleans, Gentilly Resilience District. Accessed May 2023, PDF.

City of New Orleans (2022). "Blue and Green Corridors Project Fact Sheet". City of New Orleans, Gentilly Resilience District. Accessed May 2023, PDF.

City of New Orleans (n.d.). "Blue and Green Renderings". Nola.gov. Accessed May 2023, https://nola.gov/getattachment/Resilience/Projects/Gentilly-(1)/Urban-Water-Projects/Blue-Green-Corridors/Blue-Green-renderings.pdf/?lang=en-US

City of New Orleans (n.d.). "Resilience and Sustainability: Blue and Green Corridors". Nola.gov. Accessed May 2023, https://nola.gov/resilience-sustainability/gentilly-resilience-district/blue-green-corridors/

Kincaid, Mary (n.d.) “City of New Orleans Stormwater Management”. City of New Orleans. Accessed May 2023, PDF.

MSMM Engineering, LLC (n.d.). “Blue and Green Corridors Stormwater Resilience”. MSMM Engineering, LLC. Accessed May 2023, https://msmmeng.com/project/blue-and-green-corridors-stormwater-resilience/

Stantec (n.d.). “How to manage flooding while improving the cityscape”. Stantec – Landscape Architecture. Accessed May 2023, https://www.stantec.com/en/services/landscape-architecture/living-with-water-new-orleans

Churchill Technology Master Park

Churchill (n.d.). “Green and Blue Streets”. Churchill Technology and Business Park. Accessed May 2023, https://www.churchilltechpark.org/green-blue-streets/

JEDCO (2019), “Churchill Technology and Business Park Master Plan.” Accessed May 2023, PDF.

Lakeview Floating Streets

City of New Orleans (2018), “Lakeview Drainage Updates and Green Infrastructure Factsheet.” Capital Improvement Program. Accessed May 2023, PDF.

City of New Orleans (n.d.), “Lakeview/City Park Hazard Mitigation Project.” StoryMap. Accessed May 2023, https://storymaps.arcgis.com/stories/e4c179fb90f3444a9327a035ad9b75c9

Myers, Ben (2022), “Mayor LaToya Cantrell blames Lakeview residents for drainage project delays, threatens funding.” Nola.com News. Accessed May 2023, https://www.nola.com/news/politics/mayor-latoya-cantrell-blames-lakeview-residents-for-drainage-project-delays-threatens-funding/article_fcd534ea-eb6b-11ec-aff6-cb2a53b5d8a0.html

Waggonner & Ball Architects (2013), “Greater New Orleans Urban Water Plan: Implementation.” Waggonner & Ball Projects. Accessed May 2023, https://wbae.com/projects/greater-new-orleans-urban-water-plan-2/#:~:text=The%20Greater%20New%20Orleans%20Urban,and%20drain%20only%20as%20necessary.

South Jamaica Housing Cloudburst Plan

Landers, Jay (2023). “New York City pursues resilience with ‘cloudburst’ projects.” ASCE Projects. Accessed May 2023, https://www.asce.org/publications-and-news/civil-engineering-source/civil-engineering-magazine/article/2023/03/new-york-city-pursues-resilience-with-cloudburst-projects

NYC Environmental Protection (2018), “NYCHA: South Jamaica Houses Cloudburst Master Plan 2018.” South Jamaica Houses Cloudburst Conceptual Plan—Marc Wouters | Studios and Grain Collective Landscape Architects. Accessed May 2023, PDF.

NYC Environmental Protection and Ramboll (2017), “Cloudburst Resiliency Planning Study, Executive Summary.” New York City Department of Environmental Protection. Accessed May 2023, PDF.

NYC HPD (2022). “South Jamaica Houses – Cloudburst PLA Additions.” NYC Department of Housing Preservation and Development. Accessed May 2023, https://databook.wegov.nyc/p/HAM22SJCB_south-jamaica-houses-cloudburst-pla-additions

Rosenberg, Eric (2022). “Climate Resiliency and Stormwater Management in the Big Apple.” Hazen and Sawyer. Accessed May 2023, https://www.hazenandsawyer.com/articles/climate-resiliency-in-the-big-apple

The Soul of Nørrebro

Jen, David (2023). “Park designed to flood during cloudbursts in Copenhagen.” ASCE Project Highlight. Accessed May 2023, https://www.asce.org/publications-and-news/civil-engineering-source/civil-engineering-magazine/article/2023/02/park-designed-to-flood-during-cloudbursts-in-copenhagen

Lynch, Patrick (n.d.). “Masterplan by SLA and Ramboll Aims to Alleviate Flooding in Copenhagen”. Arch Daily. Accessed May 2023, https://www.archdaily.com/790331/masterplan-by-sla-and-saunders-aims-to-alleviate-flooding-in-copenhagen

Mairs, Jessica (2016). “Sunken pools and planting proposed to ease flooding in Copenhagen neighbourhood”. Dezeen. Accessed May 2023, https://www.dezeen.com/2016/07/12/hans-tavsens-park-korsgade-sla-copenhagen-denmark-flooding-urban-planning/

Nordic Jury (2016). “Nordic Built Cities Challenge: Evaluations by the Nordic/International Jury”. Nordic Built Cities Challenge. Accessed May 2023. PDF. https://www.nordicinnovation.org/programs/soul-norrebro

SLA (2016). “Hans Tavsen’s Park and Korsgade”. SLA Cases. Accessed May 2023, https://www.sla.dk/cases/hans-tavsens-park-and-korsgade/

SLA, et al. (2016). “The Soul of Norrebro: Hans Tavsens Park, Blagard School, and Korsgade Booklet”. Nordic Built Cities Challenge. Accessed May 2023, PDF. https://www.nordicinnovation.org/programs/soul-norrebro

Copenhagen Cloudburst Formula

City of Copenhagen (2012), “The City of Copenhagen Cloudburst Management Plan 2012”. The City of Copenhagen. Accessed May 2023, https://en.klimatilpasning.dk/media/665626/cph_-_cloudburst_management_plan.pdf

Climate ADAPT (2016), “The economics of managing heavy rains and stormwater in Copenhagen – The Cloudburst Management Plan”. Accessed May 2023, https://climate-adapt.eea.europa.eu/en/metadata/case-studies/the-economics-of-managing-heavy-rains-and-stormwater-in-copenhagen-2013-the-cloudburst-management-plan/#cost_benefit_anchor

Larsen, Henning (2015), “Copenhagen Strategic Flood Masterplan”. Landezine. Accessed May 2023, https://landezine.com/copenhagen-strategic-flood-masterplan-by-henning-larsen/

Network Nature (n.d.), “Cloudburst Management Plan, Copenhagen”. Accessed May 2023, https://networknature.eu/embedded-case-study/18017

Ramboll and Ramboll Studio Dreiseitl (2016), “The Copenhagen Cloudburst Formula: A strategic Process for Planning and Designing Blue-Green Interventions”. ALSA Award of Excellence, Analysis and Planning. Accessed May 2023, https://www.asla.org/2016awards/171784.html

Lindevangs Park

Hauer, Alexander (n.d.), “Lindevangs Park – An Urban Oasis, Providing Space for Protection and Recreation.” CALL Copenhagen: Climate Adaptation Living Lab. Accessed May 2023, https://call.dnnk.dk/en/lindevangs-park-an-urban-oasis-providing-space-for-protection-recreation/

NIRAS (2020), “Climate adaptation brings a traditional park up to date.” State of Green – Climate Change Adaptation. Accessed May 2023, https://stateofgreen.com/en/solutions/climate-adaptation-brings-a-traditional-park-up-to-date/

Michael, Ulla (2020), “Lindevangsparken and the Loop.” Danish Association of Architectural Firms. Accessed May 2023, https://www.danskeark.com/content/lindevangsparken-slojfen.

Liu, et al (2019), “Blue-Green Infrastructure for Sustainable Urban Stormwater Management, Lessons from Six Municipality-Led Pilot Projects in Beijing and Copenhagen.” Journal of Water, Urban Water Management Section. Accessed May 2023, https://doi.org/10.3390/w11102024

Landezine (2017), “Lindevangs Park.” Accessed May 2023, https://landezine.com/lindevangs-park-by-marianne-levinsen-landscape/

Kunshan Wetland

Wang, et al (2013), “Water sensitive development in Kunshan, China.” FRC Studio. Accessed May 2023, https://www.frcstudio.com/upload/essay13.pdf

Cheonggyecheon Stream Restoration

Robinson, Alexander, and Myvonwynn Hopton (2011). “Cheonggyecheon Stream Restoration Project.” Landscape Performance Series, Landscape Architecture Foundation. Accessed May 2023, https://doi.org/10.31353/cs0140

Daldy Street

Khareedi, et al (2012), “Wynard Quarter Development – Providing Stormwater Solutions in a Highly Constrained, Iconic, Urban Environment.” Opus International Consultants. Accessed May 2023, https://www.waternz.org.nz/Attachment?Action=Download&Attachment_id=859

BLUE GREEN SYSTEMS TYPOLOGY STUDY

CITY OF VANCOUVER INTEGRATED SEWER + DRAINAGE PLANNING
SEPTEMBER 2024

CITY OF VANCOUVER

HERRERA
Science + Planning + Design

MITHŪN