

Experiencing the Urban Water Cycle:
SR 520 Montlake Stormwater Treatment Facility

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Abstract

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The goal of this thesis is to explore design potentials of a stormwater treatment facility that can serve as a link to involve people in the urban water cycle. The site I examine is the proposed stormwater treatment facility in Montlake, Seattle that needs to be placed to mitigate the impact of the State Route (SR) 520 Bridge Replacement and HOV Program. The site's location, bordering both its pollution source object (highway SR-520) and the affected water body (Lake Washington), provides an uncommon opportunity in the urban setting where people can directly observe different stages of the urban water cycle in the context of their everyday activities. Three key research areas are explored, changing aesthetics, historical urban water management and human experience design. Based on the research and case study findings, the design process adopts a balanced approach combining form, function and experience to design a successful urban stormwater facility. I believe the design outcome being proposed here is successful. It can not only support hydrologic functions, but can also align with interpretive opportunities to experience the water cycle as well as programmatic uses between the three zones.

Table of Contents

	Page
List of Figures	ii
List of Tables	iv
Chapter 1: Introduction	1
1.1 Background and Issues.....	1
1.2 Goals and Thesis Structure.....	4
Chapter 2: Context of SR 520 Bridge Replacement and HOV Program	5
2.1 General Background.....	5
2.2 Existing Document: Water Discipline Reports.....	9
2.3 Site: Montlake Neighborhood and Museum of History and Industry	13
2.4 Site: Photo Gallery.....	17
Chapter 3: Literature Review	19
3.1 Changing Aesthetics and Urban Nature.....	20
3.2 Historical and Modern Context of Urban Water Management.....	25
3.3 Human Experiences and Revealing Nature by Design.....	29
Chapter 4: Experiencing Stormwater – Case Studies	33
4.1 Case Study Framework: V.O.A.S.T Analysis.....	33
4.2 Case Studies / Discussion.....	35
4.3 Table of Summary.....	43
Chapter 5: Critical Position / Approaches to Design	45
5.1 Critical Stance: Form, Function and Experience.....	46
Chapter 6: Design Process	51
6.1 Context and Site Analysis.....	51
6.2 Design Goals and Strategies.....	58
6.3 Designing the Form: Reconciled Aesthetics.....	59
6.4 Designing the Function: Hybrid Natural System.....	63
6.5 Designing the Experience: Everyday Immersive Experience.....	71
Chapter 7: Critique and Conclusion	79
7.1 Critiquing The Design: Did I achieve key research and design goals?.....	79
7.2 Next Steps and Conclusion.....	81
Bibliography	83

LIST OF FIGURES

Figure Number	Page
1.1) Complexity of Urban Water Cycle (Portland Bureau of Water).....	3
2.1) SR 520 Program Structure (West, East, Pontoon) (WSDOT, 2011).....	5
2.2) Location of Affected Basins WRIA 8 (WSDOT, 2009).....	9
2.3) Proposed Stormwater Management Facility Map (WSDOT, 2011).....	11
2.4) Proposed TDA 7 to 14 for Study Area (WSDOT, 2011).....	11
2.5) Site Location – Aerial Photo (Google Maps).....	13
2.6) 2011_10_11 Montlake Board 2 Project Features (WSDOT, 2011).....	14
2.7) Conceptual Design Options from 2011_11_09 and 2011_12_07 Public Meetings (WSDOT, 2011).....	15
2.8) 2012_04_12 Alternative Options for Montlake Shelby/Hamlin Neighborhood (WSDOT, 2011).....	16
2.9) Views from the MOHAI Overlook Point.....	17
2.10) Conditions under the Existing SR 520 Structures.....	17
2.11) Shoreline Condition looking east	17
2.12) Panoramic View to north looking MOHAI.....	18
2.13) Panoramic View to northeast looking Lake Washington.....	18
2.14) Panoramic View to east looking MOHAI Parking Lot.....	18
3.1) Literature Review Plan.....	19
3.2) Wright’s Work and Jensen’s Work (http://www.fallingwater.org/ , http://www.fordhouse.org/).....	21
3.3) Hybrid Aesthetics / Hybrid Nature (MOMA.org).....	24
3.4) 19th century London: no clean water, toilets or sewer treatment (Potomac Watershed Partnership).....	26
3.5) four stages of urban water cycle (UNEP, 2008).....	27
3.6) Comparison of Sustainability Rating System on Water (Carbourn.com).....	28
4.1) Sketches from Thornton Creek Stormwater Treatment Channel.....	34
4.2) Diversity of Inlet, Pond and Outlet Structures.....	36
4.3) Consistency in Materials and Coloration	38
4.4) Contrasting Textures, Layers and Edge Conditions.....	40
4.5) Cold, Hard, Static / Warm, Soft and Moving.....	42
5.1) Literature Review – Critical Stance – Design Structure Diagram.....	45
5.2) Sidwell School’s Green Infrastructure Water System (ASLA.org).....	46
5.3) Applying Form and Function Frameworks.....	49

5.4) Applying Function and Experience Frameworks.....	49
6.1) Location Map.....	51
6.2) Wetlands and Drainage Basin Map.....	52
6.3) Existing Drainage.....	52
6.4) Existing Soil.....	52
6.5) Existing Vegetation.....	52
6.6) Regional Connections Map (WSDOT).....	53
6.7) Site Circulation Network (WSDOT, 2012).....	54
6.8) Elevated edges provide challenges in connection.....	55
6.9) Elevation Challenge in Axonometric View (WSDOT, 2012).....	55
6.10) Existing Topography.....	56
6.11) Seasonal Sun-Shade Model	56
6.12) North-South Section Locations	57
6.13) South-North Section Views (A,B,C,D).....	57
6.14) Conceptual Form-Making Process: Flow+Access=Form.....	60
6.15) Conceptual Drawings of Programmatic Zones and Stormwater flow.....	61
6.16) Drawings of Conceptual Evolution.....	61
6.17) Grading Plan.....	62
6.18) Final Concept.....	62
6.19) North-South Traverse Section Individual Profiles (2X vertical)	65
6.20) North-South Traverse Section Location: Axonometric View.....	66
6.21) North-South Traverse Section Location: Combined Profile View.....	66
6.22) Section A: Ramp Perspective Section Diagram.....	67
6.23) Section B: Wall Perspective Section Diagram.....	68
6.24) Section C: Stair Perspective Section Diagram.....	69
6.25) Section D: Climb Perspective Section Diagram.....	70
6.26) Steaming Compost Pile.....	71
6.27) Initial Study of Visualization.....	73
6.28) Perspective Viewing Locations.....	74
6.29) Perspective A: Awareness / Prospect Diagram.....	75
6.30) Perspective B: Appreciation / Interpretive Diagram.....	76
6.31) Perspective C: Direct Experience / Immersive Diagram.....	77

LIST OF TABLES

Table Number	Page
2.1) History of SR 520, I-5 to Medina Project NEPA Process (WSDOT, 2011).....	7
2.2) Ecology Regulation to Road Projects (WSDOT, 2009).....	10
2.3) Proposed Stormwater Management Facility Characteristics (WSDOT, 2011).....	12
3.1) Purposes and Qualities of Each Sequences (Cornell, 1998).....	30
4.1) Summary of Case Study Findings.....	43
5.1) Approaching Design: Organizational Framework Table.....	48

Chapter 1: Introduction

1.1 Background and Issues

Many urban areas in the United States suffer from an inability to provide their growing population with adequate water, energy, and transportation as a result of infrastructural shortages. The 2009 quadrennial report from the American Society of Civil Engineers (ASCE) rated America's roads 'D-' which is costing \$67 billion a year in repairs and operating cost just to maintain the current condition (ASCE, 2009). Drinking water and wastewater sectors were also given a 'D-', and a Government Accountability Office (GAO) survey found that water managers in 36 states anticipate water shortages by 2020 (Sisolak et al, 2011). The rising costs of energy and materials indicate that the United States needs to modernize its infrastructure and focus on containing costs, waste, and byproduct.

At the same time, urban areas are also suffering from an increasingly ambiguous relationship between people and their environments. Urban landscapes are disconnected and devalued by urban dwellers. Often times, people in the urban areas, especially 'well-designed and functional' urban areas, have difficulties defining the relationship between their everyday activities and the natural or designed infrastructural processes that are required to support them. These processes, such as generation, transmission and distribution of energy, as well as collection, treatment and distribution of potable water, make up most of the urban infrastructural processes. Although not recognized until recently, the group of eco-system services, comprised of plants and bio-communities on land and in soil, as well as the flood control function of watersheds, makes up an important part of urban infrastructural processes. It is interesting to note that many of these basic functions and processes are neither appreciated nor noticed until they malfunction, and what was once reliable no longer is- the process or a function that causes the most problems often gets talked about and gets the most attention. One of the best examples of this is automobile traffic congestion, which happens frequently enough that many pay attention, and significant resources are allocated to fix it.

On the other hand, infrastructural systems related to water rarely get noticed. Along with electricity and gas, water is well concealed by urban designers, but this infrastructure concealment has led to a disconnect between people and process, and many have a hard time imagining how their water system works, where the water comes from, and how their actions affect the watershed and its health.

Complicating matters further, modern designers of water infrastructure have successfully divided their water conveyance system into separate categories: industrial, potable, waste water and stormwater. The concept of watershed and ground water recharge has become almost metaphysical and can only be understood through flow charts or diagrams. Most people find it hard to imagine that their urban environment contains a true water cycle. Figure 1.1 shows the result of careful engineering and monitoring of modern water infrastructure systems. While the diagram shows only the supply network of drinking water around the region surrounding Portland, OR, the system is already beyond the conceptual understanding of an average person. A diagram of the full regional water cycle is vastly more complex, and would leave an unprepared viewer perplexed. There have been efforts to educate the public on water conservation and watershed protection, but they have not been around for very long. For most urban residents, it is very easy to assume fresh water will be supplied and wastewater taken away, as long bills are paid. It is significantly harder to understand the side effects and unintended consequences of our management of land and water on other natural processes and bio-communities.

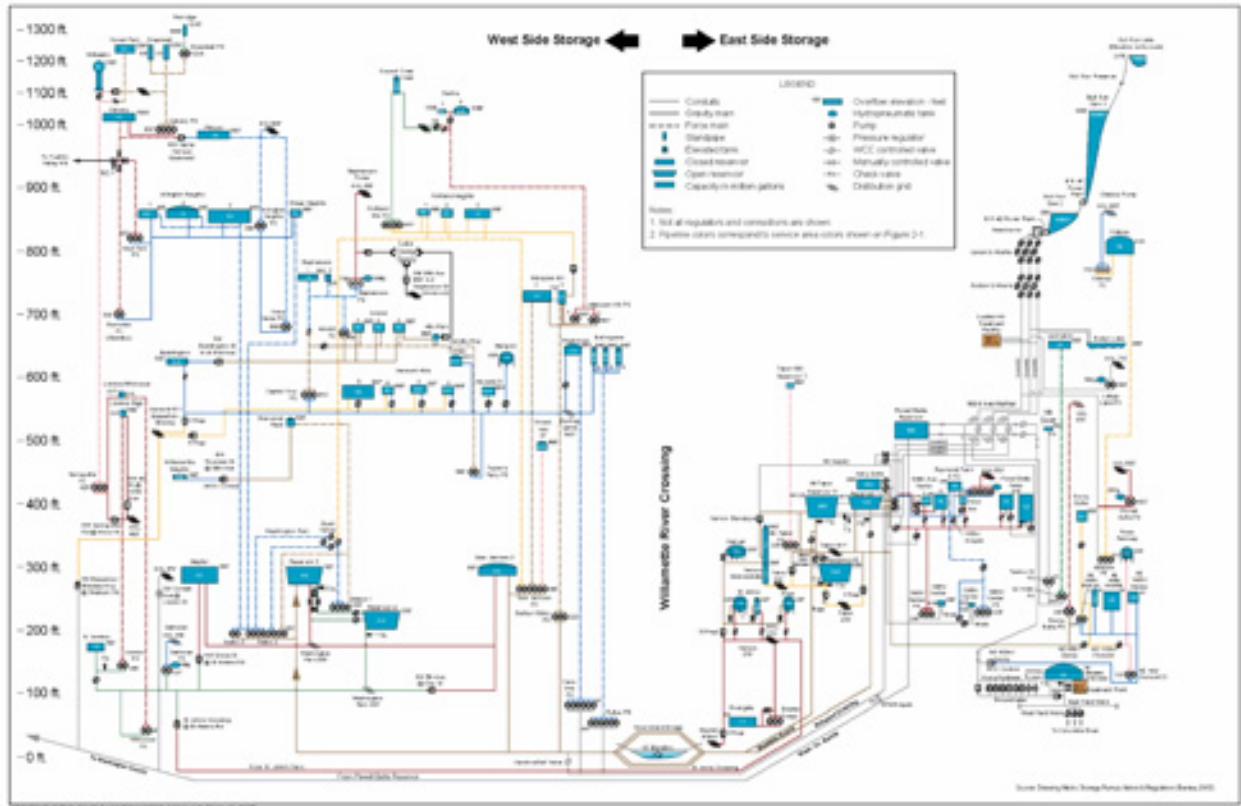


Figure 1.1) Complexity of Urban Water Cycle: Supply Network of drinking Water (Portland Bureau of Water)

1.2 Goals and Thesis Structure

This lack of understanding has led to a question: how can we reconnect urban people to the water cycle and reveal its processes? Bringing people back to the urban water cycle means re-establishing the connection between our everyday activities and the most basic element of our existence. It also means informing people on how their decisions to live, work, and play in the urban environment are closely connected to natural and cultural processes in multiple spatial and temporal scales. Thus, the key research and design goals of this thesis emerge below.

Key Research and Design Goals

1. Re-establish the connection between everyday activities and water cycle
2. Reveal processes in multiple temporal and spatial scales
3. Expose people to different stages of water cycle through multi-sensory experiences

In order to address above goals, I decided to explore design potentials of a stormwater treatment facility that can serve as a link to involve people in the urban water cycle. While a person living in a typical urban area United States consumes up to 400 gallons of water per day (UNDP, 2006), they have never been an informed, knowledgeable participant in the water cycle. The site I examine is the proposed stormwater mitigation facility in Montlake neighborhood, Seattle as a part of the State Route (SR) 520 Bridge Replacement and HOV Program. The site's location, bordering both its pollution source object (highway SR-520) and the affected water body (Lake Washington), provides an uncommon opportunity in an urban setting where people can directly observe different stages of the urban water cycle in the context of their everyday activities. The above-mentioned goals will be explored in the following chapters through literature research and case studies. The research will then be applied to create an organizational framework for approaching urban stormwater facility design. Finally, we will apply this framework to the Montlake site, and detail how its extraordinary potential can be maximized.

Chapter 2: Context of SR 520 Bridge Replacement and HOV Program

2.1 General Background

As described in the Chapter 1, the proposed stormwater facility is a part of the much larger SR 520 Bridge Replacement and HOV Program which aims to improve the condition of the critical east-west corridor, including a floating bridge that carries 115,000 vehicles across Lake Washington everyday (WSDOT, 2011). More specifically, the site is directly related to sub-sections of the entire project, which is called SR 520, I-5 to Medina project. As can be seen in the figure 2.1, this project deals with the western half of SR 520 (marked in green), from the interchange with Interstate 5 at the west end, to Evergreen Point, Medina in the east. Designated as one of the strategic projects in the Puget Sound Regional Council’s Vision 2040 plan (PSRC 2009), this is a very complex, regional-scale project which incorporates numerous transportation, engineering, environmental, culture and economic components. Although this thesis is focusing on one targeted area and its specific stormwater functions, it is necessary to provide an overview of the program’s background, objectives and technical requirements.

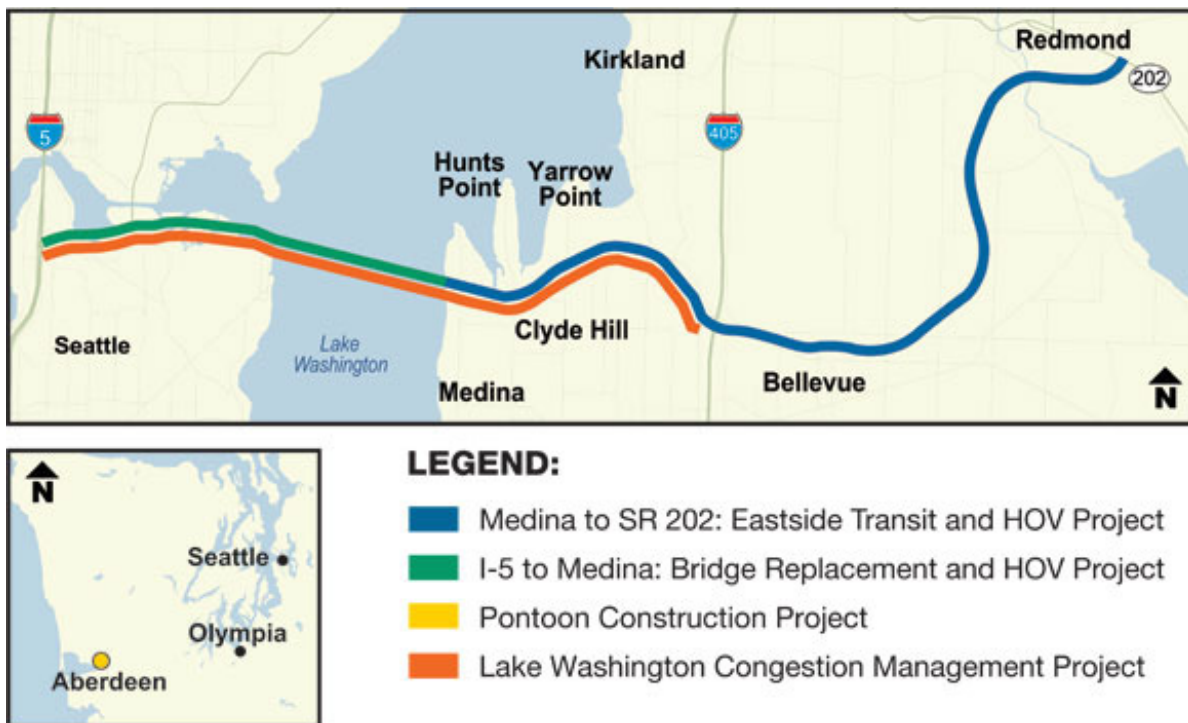


Figure 2.1) SR 520 Bridge Program Map (WSDOT, 2011, Figure ES-4)

Planning for SR 520 started in 1998 with the work of the Trans-Lake Washington Study, initiated by the state legislature to explore ways to improve mobility across and around Lake Washington (WSDOT, 2011). In 2000, the committee developed a statement of purpose for the overall SR 520 program:

The purpose of the project is to improve mobility for people and goods across Lake Washington within the SR 520 corridor from Seattle to Redmond in a manner that is safe, reliable, and cost effective, while avoiding, minimizing, and/or mitigating impacts on affected neighborhoods and the environment. (pp.3)

Following this direction, a series of environmental impact statements (EIS) and alternative screenings have been conducted in 2002, 2006, 2010. The final environmental impact statement (FEIS) was released in 2011 (WSDOT, 2011). The following table describes how WSDOT, FHWA, and numerous stakeholders have worked through the years to identify and screen potential alternatives and design options.

The central goal of “improving mobility for people and goods” along the SR 520 corridor from the initial statement of purpose in 2000 remained constant throughout the lengthy planning process. Each EIS evaluated multiple alternatives to the SR 520 corridor as is described in the above table. In the 2006 EIS analysis, it was indicated that the 6-lane alternative would provide substantial safety and mobility benefits. However, due to public concerns regarding the 6-lane alternative design, three different 6-lane design options (Options A, K and L) were evaluated in 2010 EIS. Then finally in 2011 FEIS, the preferred alternative was proposed, along with a comparison to the previous 6-lane alternative design options (WSDOT, 2011). Although not all design processes have been finalized as of May, 2012, the preferred alternative option described in the 2011 FEIS will be adopted as a baseline design for this thesis.

Trans-Lake Washington Study (1998 –1999)		
NEPA/Project Element	Goal	Address traffic congestion across and around Lake Washington.
	Screening	47-member study committee identified and evaluated potential solutions.
	Alternatives	Seven "solution sets" were developed representing different mixes of roadway, transit, transportation demand management, and transportation systems management solutions.
Process	Activities	Identified and evaluated potential solutions: new corridors, new modes (ferry, high-capacity transit), increased capacity on existing corridors, crossing methods (tubes, tunnels), demand management.
	Recommendations and Outcomes	Move forward with improvements to SR 520. Prepare EIS to evaluate the following alternatives: No Build, 4-Lane, 6-Lane (with and without high-capacity transit [HCT]), 8-Lane (with and without HCT).
EIS Initiation and Alternatives Screening (2000 – 2002)		
NEPA/Project Element	Project Purpose and Need	Improve mobility for people and goods across Lake Washington within the SR 520 corridor from Seattle to Redmond in a manner that is safe, reliable, and cost-effective, while avoiding, minimizing, and/or mitigating impacts on affected neighborhoods and the environment.
	Screening	Two levels of screening criteria developed from Purpose and Need and applied to Trans-Lake alternatives.
	Alternatives	Project corridor alternatives evaluated: No Build, 4-Lane, 6-Lane, 8-Lane.
Process	Activities	Developed Purpose and Need statement based on Trans-Lake findings. Established and applied screening criteria.
	Recommendations and Outcomes	Evaluate No Build, 4-Lane, and 6-Lane Alternatives in Draft EIS. Do not further evaluate 8-Lane Alternative. Do not further evaluate new corridors and crossing methods due to risk, impacts, and cost. Affirm regional planning assumption of I-90 as initial HCT corridor. Defer HCT on SR 520 in near term, but provide long-term compatibility.
Draft EIS (Released August 2006)		
NEPA/Project Element	Goal/Purpose and Need	Improve mobility for people and goods across Lake Washington within the SR 520 corridor from Seattle to Redmond in a manner that is safe, reliable, and cost-effective, while avoiding, minimizing, and/or mitigating impacts on affected neighborhoods and the environment.
	Screening	New design options proposed by community members were screened using original criteria, resulting in the 6-Lane design options (see below).
	Alternatives	Project corridor alternatives evaluated: No Build, 4-Lane, 6-Lane, 8-Lane (described rationale for dropping).
Process	6-Lane Design Options	Evaluated in Draft EIS: Pacific Street Interchange, Second Montlake Bridge, No Montlake Freeway Transit Stop.
	Activities	Conducted coordination and outreach with local jurisdictions, resource agencies, and the public. Prepared and published Draft EIS incorporating evaluation of No Build, 4-Lane, and 6-Lane Alternatives and 6-Lane design options.
	Recommendations and Outcomes	Traffic modeling identified 6-Lane Alternative as better meeting Purpose and Need. 4-Lane would provide safety, but would not improve mobility, while 6-Lane Alternative would improve both safety and mobility. The Pacific Street Interchange option would provide best local mobility in Seattle, but with greater impacts to wetlands, aquatic habitat, and parks compared to 6-Lane base. Gov. Gregoire's findings on Draft EIS identified 6-Lane Alternative as "best serving needs of regional transportation system," but identified the need for additional design refinement in Seattle portion of project area.

Table 2.1) History of SR 520, I-5 to Medina Project (WSDOT, 2011, Table ES-3)

Table 2.1 continued.

Supplemental Draft EIS (Released January 2010)		
NEPA/Project Element	Goal/Purpose and Need	Improve mobility for people and goods across Lake Washington within the SR 520 corridor from Seattle to Redmond in a manner that is safe, reliable, and cost-effective, while avoiding, minimizing, and/or mitigating impacts on affected neighborhoods and the environment.
	Screening	Mediation group identified shortlist of options (A, K, L); FHWA and WSDOT agreed to evaluate.
	Alternatives	Draft EIS "base" 6-Lane Alternative and design options dropped from further analysis. SDEIS evaluated: No Build, 4-Lane (traffic analysis only), 6-Lane with design options noted below.
Process	6-Lane Design Options	Evaluated: Option A (improvements to Montlake interchange plus second Montlake bascule bridge); Option K (tunnel under the Montlake Cut and lowered interchange east of Montlake); Option L (diagonal bridge over the Montlake Cut and elevated interchange east of Montlake).
	Activities	Legislation (ESSB 6099) directed development of a 6-lane corridor interchange design for the Montlake area through a mediated community involvement process. Mediation explored 12 design options but did not reach a consensus solution, electing further study of Options A, K, and L. WSDOT prepared discipline reports and Supplemental Draft EIS to evaluate the impacts of these options, and conducted coordination and outreach with agencies and the public. A legislative workgroup created by ESHB 2211 recommended Option A with suboptions as the preferred alternative.
	Recommendations and Outcomes	4-Lane Alternative not further considered after updated traffic analysis confirmed it failed to meet Purpose and Need. Mediation participants agreed on three options to carry forward: A, K, and L. WSDOT evaluated A, K, and L in the SDEIS; legislative workgroup recommended Option A with suboptions.
Final EIS (Released July 2011)		
NEPA/Project Element	Goal/Purpose and Need	Improve mobility for people and goods across Lake Washington within the SR 520 corridor from Seattle to Redmond in a manner that is safe, reliable, and cost-effective, while avoiding, minimizing, and/or mitigating impacts on affected neighborhoods and the environment.
	Alternatives	No Build, Preferred Alternative, and Options A, K, and L.
Process	6-Lane Design Options	Options A, K, and L compared to Preferred Alternative.
	Activities	In April 2010, following evaluation of comments on SDEIS, Gov. Gregoire announced selection of a Preferred Alternative (similar to Option A, but with design refinements) by FHWA and WSDOT. WSDOT prepared final evaluation of Preferred Alternative with comparisons to SDEIS design options. FHWA and WSDOT consulted with tribal governments, Section 106 consulting parties, resource agencies, and other project stakeholders to identify effects of the Preferred Alternative and determine appropriate mitigation.
	Recommendations and Outcomes	Proceed with preparation of Record of Decision.

2.2 Existing Document: Water Discipline Reports

Each environmental discipline; transportation, land use, cultural resources, air quality, water resources, ecosystems, and hazardous material, are accompanied by a discipline report which acts as an in-depth supplement with more in-depth information. The proposed site for this thesis is a property that WSDOT purchased for the mitigation of increased stormwater flow from the anticipated 6-lane 520 bridge structure. It is relevant to review water resources reports in order to understand the requirements and potential.

In discipline reports, “water resources” refers to surface water bodies, stormwater, and groundwater. Reports divided these into the two sections, one focusing on surface water bodies and stormwater treatment facilities, and the other on groundwater (WSDOT, 2006). For this thesis, it is helpful to learn about affected surface water bodies and stormwater management treatment options. First, the major surface water bodies within the project’s scope are Lake Union, Portage Bay, Lake Washington, and Arboretum Creek and located entirely in Water Resources Inventory Area (WRIA) 8, the most heavily developed of the 15 WRIs directly bordering Puget Sound. Within the two watersheds in WRIA 8, the project’s study area is located in Lake Washington/ Cedar watershed (WSDOT, 2010).

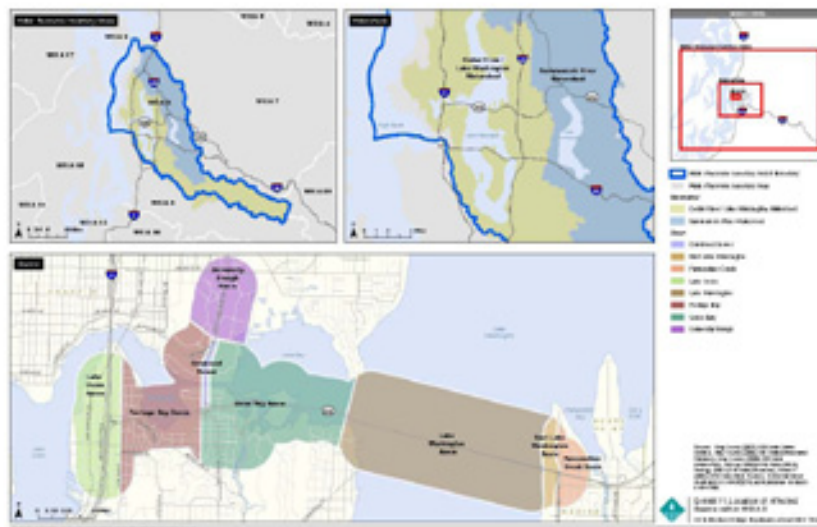


Figure 2.2) Location of Affected Basins WRIA 8 (WSDOT, 2010, Figure ES-28)

The summary of existing water resources characteristics examines similarities and differences between surface water bodies. It shows that even though all surface water bodies receive a similar quality of urban runoff, the quantity of runoff they receive and the volume of the receiving water body determines the receiving body’s overall condition and subsequently the level of stormwater treatment levels and flow control options.

- Surface water bodies in the study area currently receive urban surface runoff from roadways, commercial and industrial neighborhoods, residential areas, and combined sewer overflows (CSOs).
- Washington State Department Ecology (DoE) has designated Lake Union/ Ship Canal as impaired water bodies because of elevated concentrations of total phosphorus, lead, fecal coliform, and aldrin .
- Water quality in Lake Washington has improved over the last 50 years. Most parameters meet water quality standards, but the lake is still listed by Ecology as impaired because of bacterial contamination.
- DoE has listed most of the streams in the study area as impaired because of elevated water temperatures and bacteria levels .

(WSDOT, 2006, pp. 30)

In terms of existing stormwater management in the study area, most stormwater discharged from SR 520 is not treated before it is discharged. Current regulations by Department of Ecology, as described in the table 2.2, require treatment of the all new and existing impervious surfaces when renovated.

If...	Then	How Does this Apply to the I-5 to Medina: Bridge Replacement and HOV Project?
A project proposes to add new impervious surface	Stormwater from the new impervious surface area must be treated. In addition, stormwater flow control measures would be required when increased discharges to local streams would alter aquatic habitats.	This project must build and maintain stormwater treatment and required flow control facilities in areas where new impervious surfaces are proposed.
A project proposes to retrofit existing impervious surfaces where stormwater is not treated and flows are not controlled	A project must build a system to treat stormwater from the existing impervious surface area. In addition, flow control measures would be required when increased discharges to local streams would alter aquatic habitats.	This project must build and maintain stormwater treatment and required flow control facilities in areas where existing impervious surfaces would be replaced.

Table 2.2) Ecology Regulation to Road Projects (WSDOT, 2010, Table ES-2)

Thus, the proposed stormwater management facility in Montlake (facility M on figure 2.3) will need to treat the all of the existing and new runoff from Threshold Discharge Area (TDA) 9 and 10 shown in Figure 2.4. The required treatment volumes shown in table 2.3 for TDA 9 AND 10 are the combined volumes of the two areas- these need to be directed to the Montlake facility, and then discharged to Union Bay using a new WSDOT Outfall sited near the existing City of Seattle Outfall located on the west edge of the site (WSDOT, 2011).

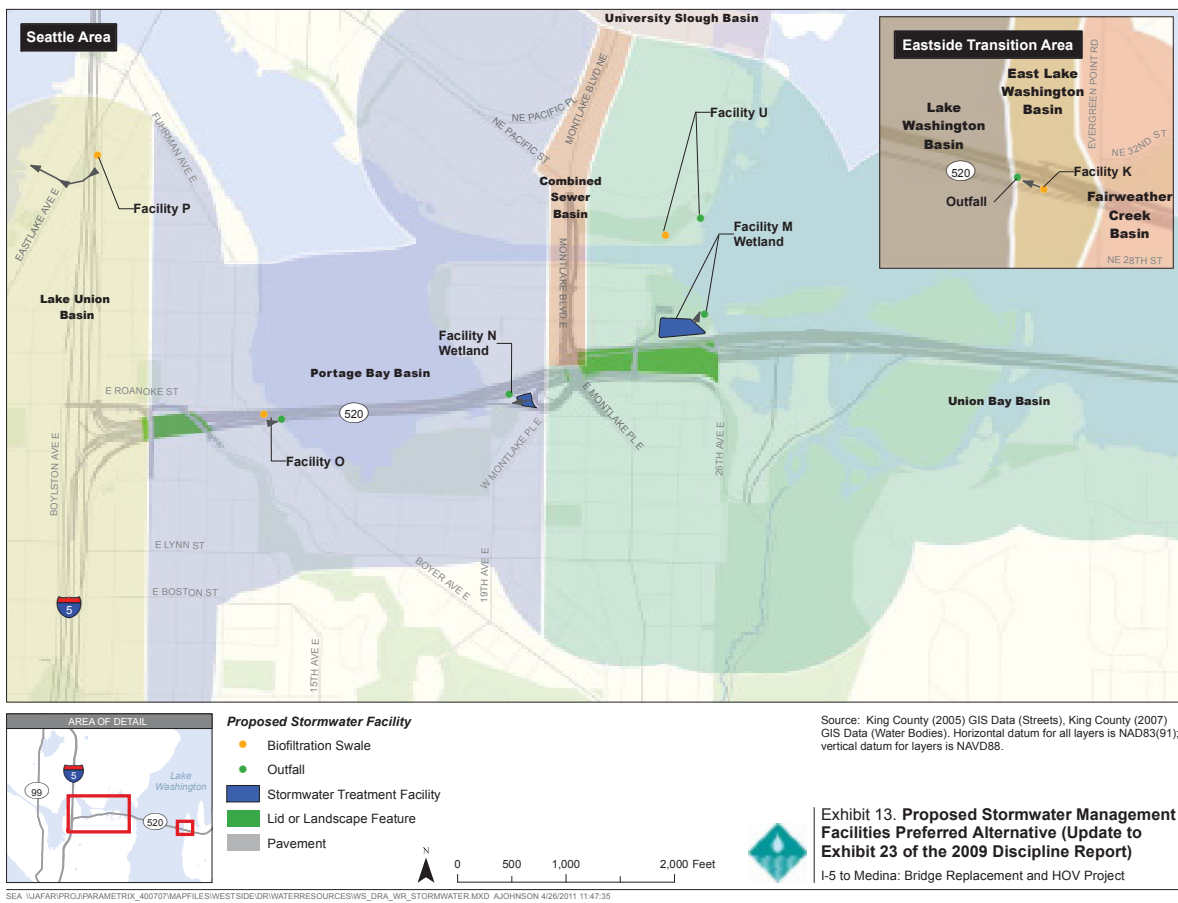


Figure 2.3) Proposed Stormwater Management Facility Map (WSDOT, 2011, Figure ES-29)

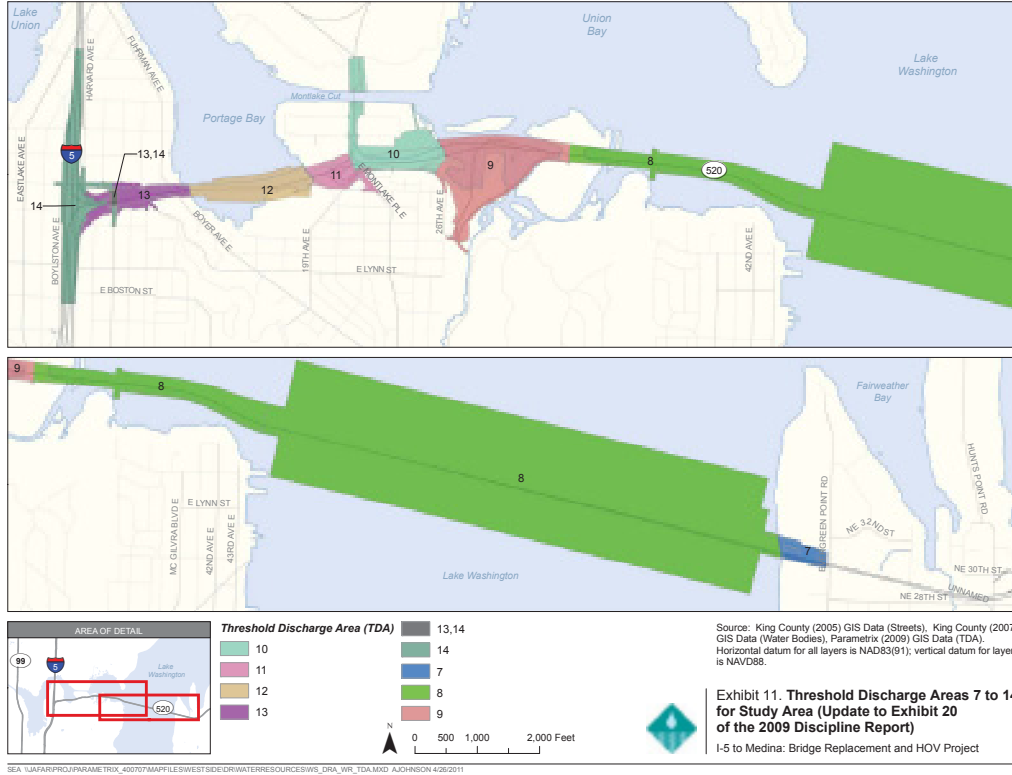


Figure 2.4) Proposed TDA 7 to 14 for Study Area (WSDOT, 2011, Figure ES-30)

TDA	14	13	12	11	10	9	8	7
Outfall Location	Lake Union via existing storm system at Allison Street	Portage Bay via existing storm drain outfall at western shoreline	Portage Bay via existing storm drain outfall at eastern shoreline	Portage Bay via existing storm drain outfall at eastern shoreline	Union Bay via existing City of Seattle outfall	Lake Washington	Lake Washington	Lake Washington
Detention Required	No	No	No	No	No	No	No	No
Quality Treatment Required	Basic	Basic	Basic	Basic	Basic	Basic	Basic	Basic
Type of Proposed Facility	Biofiltration swale	Biofiltration swale	Constructed stormwater treatment wetland	Constructed stormwater treatment wetland	Constructed stormwater treatment wetland, biofiltration swale	Constructed stormwater treatment wetland	Emerging Technology BMP (AKART)	Biofiltration swale
Stormwater Wetland/Wet Pond Depth (Average depth in wetland 1.5 feet)	N/A	N/A	2.5	2.5	2.5	2.5	N/A	N/A
Preferred Alternative								
Existing Impervious Area (acres)	17.4	4.6	3.2	5.4	14.9	9.1	17.8	1.7
Total Impervious Area (acres) (post-project) ^a	17.3	7.3	5.7	6.5	28.3	10.4	23.9	2.8
Net Impervious Area (acres)	-0.1	2.7	2.5	1.1	13.4	1.3	6.1	1.1
Net Impervious (%)	-0.6%	59%	78%	20%	90%	14%	34%	65%
Proposed Facilities	P	O	N	N	M, U	M	N/A	K
Treatment Volume (cubic feet)	17,718	13,009	38,347 ^b	38,347 ^b	104,067 ^c	104,067 ^c	N/A	N/A
Surface Area of Stormwater Wetland/Pond (square feet)	N/A	N/A	13,784 ^b	13,784 ^b	57,628 ^c	57,628 ^c	N/A	N/A
Biofiltration Swale Dimensions	14 x 292 feet	17 x 157 feet ^c	N/A	N/A	10 x 130 feet	N/A	N/A	7.5 x 110 feet

Source: WSDOT 2009d
 Note: TDAs are presented in order from west to east (i.e., TDA 14 is the westernmost TDA in the project)
^a Area includes totals of pollution-generating impervious surface and non-pollution-generating impervious surface
^b Treatment volume for Facility N is computed for TDAs 11 and 12 combined as a single facility
^c Treatment volume for Facility M is computed for TDAs 9 and 10 combined as a single facility

Table 2.3) Proposed Stormwater Management Facility Characteristics (WSDOT, 2011, Table 12)

2.3 Site: Montlake Neighborhood and Museum of History and Industry

The site is located in a historic Montlake neighborhood in the area north of a proposed SR-520 bicycle/pedestrian path between 24th avenue and the shoreline of Lake Washington. It will partially overlap with the current Museum of History and Industry (MOHAI), which will be relocated to its new South Lake Union building.



Figure 2.5) Site Location – Aerial Photo (Google Maps)

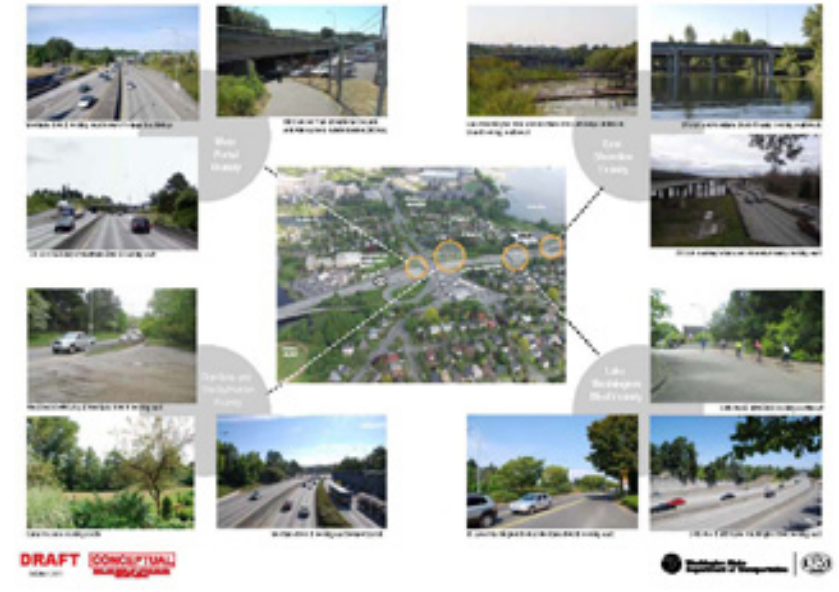
Montlake Community Design Process

In this section, the development of the relevant community design process will be discussed to identify some of the issues among key stakeholders in the area and to acknowledge conceptual design positions that have been presented to the community by SR-520 project consultants.

During the initial public meeting on October 1st 2011, pictures of existing conditions and preliminary designs of project features were shown to the community as shown in Figure 2.6. Public feedback focused on general themes of noise, traffic, bicycle paths, and the Lid design (WSDOT, 2011).

In public meetings on November 9th and December 7th 2011, similar background information

Montlake Area Existing Conditions



Montlake Area Basic Project Features

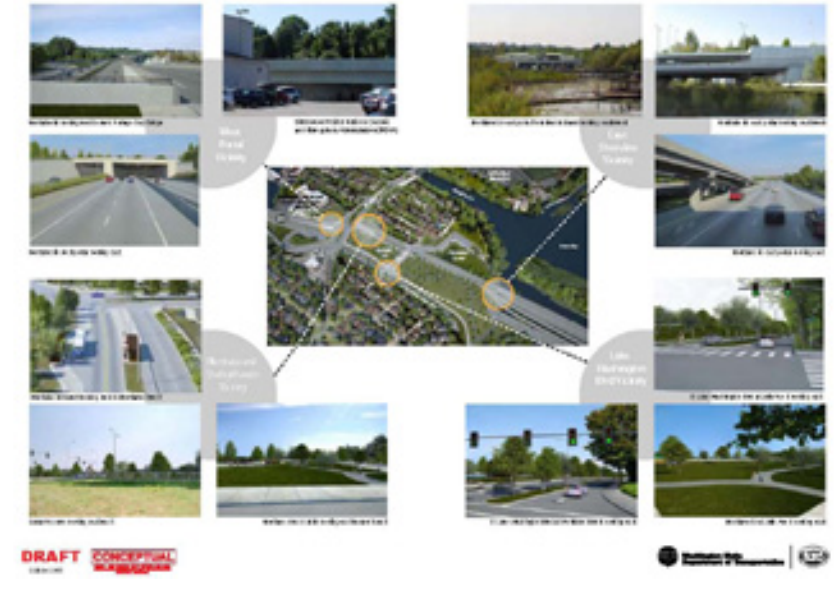


Figure 2.6) 2011_10_11 Montlake Existing Conditions and Project Features (WSDOT)

In the most recent public meeting on April 12th 2012, specific areas within the Montlake Shelby/Hamline neighborhood were explored. This allowed the planning team to present the most developed visualization materials and alternative options for each physical sub-section, such as East Montlake Park, East Montlake Shoreline, East Lake Washington Boulevard, and Lid and Canal reserve. In addition, there were visual materials regarding key public concerns raised in the previous sessions, such as view and connections (Figure 2.8).



Figure 2.8) 2012_04_12 Alternative Options for Montlake Shelby/Hamlin Neighborhood (WSDOT)

2.4 Site: Photo Gallery



Figure 2.9) Views from the MOHAI Overlook Point



Figure 2.10) Conditions under the Existing SR 520 Structure



Figure 2.11) Shoreline Condition looking East





Figure 2.12) Panoramic View to north looking MOHAI



Figure 2.13) Panoramic View to northeast looking Lake Washington



Figure 2.14) Panoramic View to east looking MOHAI Parking Lot

Chapter 3: Literature Review

This chapter aims to explore and shape foundational ideas on which design frameworks for both urban stormwater facilities and site designs for the Montlake facility can be built. In order to do this, three key ideas must be explored. In the first section, “Changing aesthetics and urban nature”, the changing aesthetics of designed environments and notion of ‘urban nature’ are explored through various scholarly efforts which attempted to theorize increasingly complex relationships between human and nature in urban environments. The second, “Historical and modern context of urban water management,” describes the historical developments of urban water management practices that led to the current emphasis on sustainable and low impact water management strategies. The third, “Human experiences and revealing nature by design” is about design and non-design theories that discuss how people experience and interpret spatial and temporal information in their surroundings. The chapter will also review how this understanding has or has not been applied in design processes.

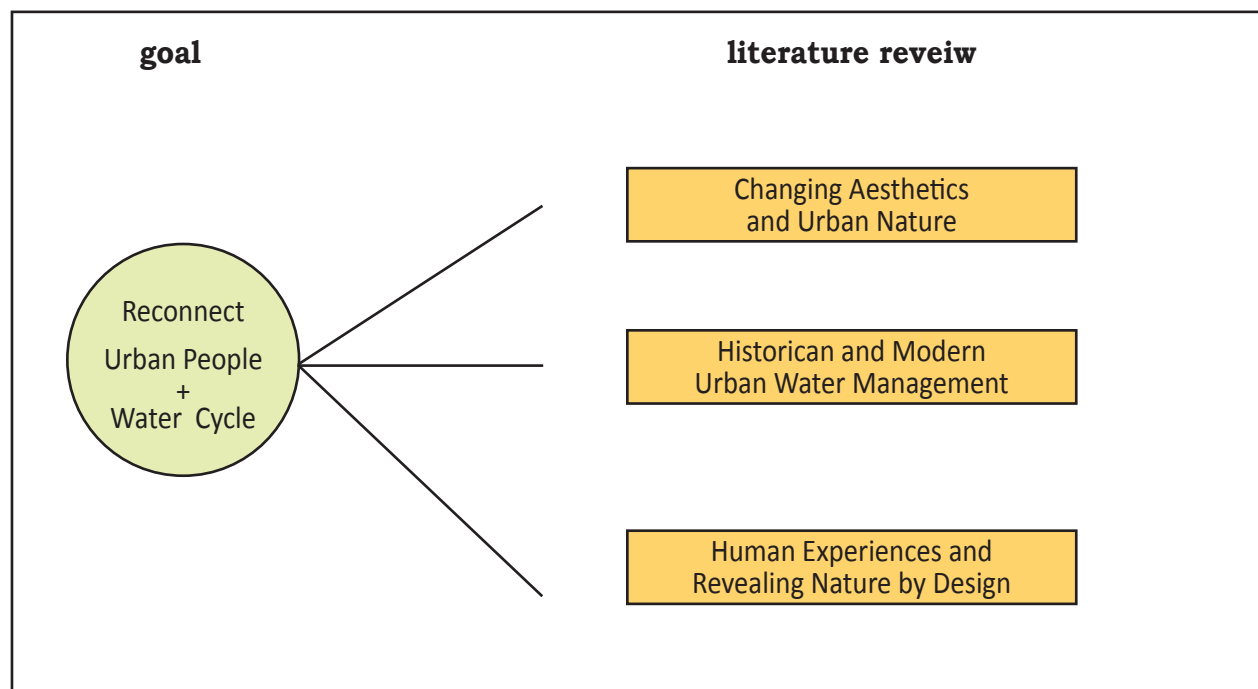


Figure 3.1) Literature Review Plan

3.1 Changing Aesthetics and Urban Nature

Before designing, it is necessary to understand the way urban people perceive the natural environments around them. From there, we are able to understand how the idea of 'nature' has changed and how it is valued differently by different cultures, societies, and individuals. The urbanization and industrialization of the 19th and 20th century have altered and obscured the appearance of nature in urban environments, but how we define and relate ourselves to the concept of nature has not changed or adapted as much from the 19th century view of nature as 'untouched and pristine'. In other words, our physical environments changed drastically, but our preferences in aesthetics and form-making have not kept up with the physical change, resulting in superficial ornamentation, camouflage and denial of urban landscapes. This confusion, or a gap, in understanding nature in urban environments is one of the important factors that can cause urban landscapes to be disconnected from, and devalued by, urban dwellers. They do not see 'real' nature in urban environments.

In this section, I will examine the scholarly works and positions that have been influencing our perception of urban nature. The discussion will range from theories put forth in the late 19th century to recent theories, to landscape ecology and landscape urbanism. Along the way, I will examine how this evolving relationship with nature has been influencing aesthetics and form-making in order to imagine an alternative aesthetic which can be used for the proposed site design later in this thesis.

Perspectives of Urban Nature

"Landscape architects have explored and debated what it means to design with nature well over a century". Conflict, Confusion, and Renewal (Sprin, 2001, pp.29)

The above question is relevant to landscape architects, whose work lies in the act of social and cultural manipulation of natural elements. Since the beginning of the profession, in the nineteenth century, practitioners have continued to strive to find a balance in the two. After all, 'land' represents the ecological character of a place and '-scape' implies the transformation of this land (Reimer, 2010). When Olmsted first conceived of urban parks in the United States, nature provided functions to cleanse air, drain water and regulate temperatures, but also worked as a scene wherein people can enjoy the setting (Meyer, 2008). Sprin provides an interesting example of the variation around the 'natural' idea, even among landscape architects: Frank Lloyd Wright and Jens Jensen both believed in 'the authority of nature' for design, but their work represents vastly different interpretations of the same ideas (Spirn, 2001).



Figure 3.2) Frank Lloyd Wright's Fallingwater and Jens Jensen's Garden of Ford Estate (<http://www.fallingwater.org/>, <http://www.fordhouse.org/>)

However variable the individual interpretations, there have been trends that have marked a few schools of thought concerning the perception of nature in human contexts: one such idea was “the perception of the world as ‘man versus nature’, strongly influenced by the ideas of the American transcendentalists, that has led to a conceptualization of nature as inherently good and cities and development as inherently bad” (Mossop, 2006). This relates to the view of nature as pristine and sacred, and human developments as harmful and damaging. This idea contributed to the environmentalist movements and served as a philosophical basis for the development of ecological planning methods by Ian McHarg in 1960s and 70s. The link was most apparent when McHarg condemned ‘non-ecological’ designs- “I conceive of non-ecological design as capricious, arbitrary, or idiosyncratic, and it is certainly irrelevant” (McHarg 1997). The failure to recognize the diversity and complexity of design processes was often criticized as idealizing nature and scientific design methods, which consequently resulted in uninspiring forms.

On the other hand, there were attempts to recognize diversity in the design processes and resulting forms in relation to nature. In the book *R.S.V.P Cycles*, Lawrence Halprin tried to capture the interaction between human and nature through the process of ‘scoring’ (Halprin, 1969). From Jens Jensen’s designs in the early 20th Century designs to the postmodern designs of Dan Kiley, Laurie Olin and Peter Walker, landscape architects have been primarily concerned with ‘the creation of spaces for the accommodation of human activity that delights senses’ (Mossop, 2006). Form-making and aesthetics based on anthropocentric motivations allowed such architects to incorporate natural processes and express it in various different styles. Yet the limitation of this approach was that it could not fully embrace the science of ecology, resulting in the separation of design and natural science, and a failure to engage people with the hidden processes.

Integrating Cities with Nature

There have been continuing efforts to integrate the two very different schools of thought on human and nature. It was recognized that people are not an antithesis to nature nor merely superficial observers. Research was able to prove the complexity, open-endedness, flexibility, resilience, and adaptation of ecology- this was in sharp contrast to the former mechanistic model of stability and control (Mostafavi, 2010). The new definition of nature and ecology led to recognition that cities are a physical and functional part of nature. Starting in the 1980s, the 'Unnaturalness of landscapes' began to be investigated as the field of urban ecology developed (Mossop, 2006). One of the works that helped to bring about this paradigm shift was *The Granite Garden: Urban Nature and Human Design* by Spirn. In this book, Spirn argues that constructed nature could also be considered nature- thus cities become a garden in the sense that cities are 'tended nature' (Spirn, 1984).

The fields of Landscape and Urban Ecology provide a useful framework to present an alternative view of human/ nature relationships. This theoretical development, in concert with developments in dynamic eco-systems theory, recognized the 'increasing awareness of environment as an even more intricate, entangled, diverse and unsettled system than we have ever imagined – a composite whole which can hardly even be understood in terms of 'system' but which requires totally new forms of imaginaries, languages and approaches' (Reimer, 2010). It was inevitable to think of the hybrid expression of newly imagined nature as 'mixing man-made and natural, social and ecological, urban and wild, aesthetic and ethical, appearance and performance, beauty and disturbance, aesthetics and sustainability' (Meyer, 2008). The new aesthetics and design strategies began to encompass the idea of human and nature in a dynamic relationship that is constantly shaping and affecting both. Mossop explains this idea as following:

This has led to new design strategies that are based on an acceptance of the disturbed and hybrid nature of these landscapes and the idea that landscape design can be instrumental in working with natural processes to make new hybrid ecological systems. It is clearly not about making approximations of pristine natural environments, but rather making functioning ecologically based systems that deal with

human activity and natural processes in the urban environment. Bringing all of the factors together is complex, requiring a synthesis of social, political, and economic factors, as well as issues related to urban wildlife and water management (p.172)

It is important that the human/ nature relationship was finally freed from the dichotomy of human separate and differentiable from nature, which had been separating both physically and conceptually. This enabled architects to think about a new way of expressing nature, not just in a formulaic and deterministic way, or solely for human perceptions and activities, but in a way that could reveal nature's processes while still enabling people to make a personal connection and understand their place in the diverse facets of nature. But still a question remains: how will this hybrid aesthetic expose natural processes, especially the urban water cycle, for the scope of this thesis? In order to do that, following sections will discuss developments of urban water management practices and ways to design human experiences to rediscover their place in the urban water cycle.



Figure 3.3) Hybrid Aesthetics / Hybrid Nature (MOMA.org)

3.2 Historical and Modern Context of Urban Water Management

This chapter is a review of historical water management trends that have led to the current technical issues in urban stormwater infrastructure. The water cycle in urban environments has been shaped by various policies and engineered solutions in much of the United States. In addition, understanding the history and current shape of the urban water cycle will help to visualize the impacts of ordinary activities on a larger, watershed-encompassing, scale. As continued population growth, urbanization, rapid industrialization, and expansion/ intensification of food production are driving a global water crisis (UNEP, 2010), contemporary mismanagement and exploitation of water resources must be recognized and researched on many different scales: local, regional, national and even global. Many independent reports provide a good breadth of information at the local, regional and global level. Examining the problem at these scales will also allow explanation as to how the current emphasis on sustainable water management and impact development was inevitable. More specifically, the recent status of ‘natural’ stormwater technologies will be reviewed to understand their advantages and limitations.

Historical Trend in Water Management

“The history of men is reflected in the history of sewers.... The sewer is the conscience of a city.”

(Hugo, 1862, book II, chapter1).

There have been two important factors in the history of urban water management. The first was the delivery of clean water and disposal of waste water, or the “sanitary revolution”. It was such an important advancement in the history of public health that it was chosen by the British Medical Journal as the most important medical milestone since 1840 (Ferriman, 2007). Clean water and sanitation are among the most powerful drivers of human development, and have allowed people to live in the dense urban conditions without risking their health and social opportunities due to the problems deriving from their waste. Now that clean water and sewer systems are taken for granted, it is hard to imagine that just over hundred years ago London, New York and Paris were centers of infectious disease, with diarrhea, dysentery and typhoid fever undermining pub-

lic health. In England, the infant mortality fell from 160 per 1,000 to 100, after public investment in water and sanitation during the late 19th and early 20th century (Ahmed, 2006). It is clear that the sanitary revolution was one of the most important factors in the growth of modern cities.

The history of stormwater management also began in the 19th century. Originally, urban 'drainage' received less attention because it seemed to require less technical advancement and investment as an infrastructural system, when compared to water and sanitation. In the 1850s, a debate arose concerning whether they should combine sanitary sewers with surface drainages in United States. The network of drainage systems were deployed afterwards, somewhat opportunistically combining existing surface and underground systems to catch up with the growth of many American cities. Only after the 1960s and 70s, did the quality of drainage water became an issue with the establishment of the Clean Water Act (CWA) and the formation of National Pollutant Discharge Elimination System (NPDES). Recently, there has been more insight into stormwater management, not only focusing on its conveyance and quality, but understanding it in relation to the hydrologic cycle and ecological factors (Karvonen, 2011).



Figure 3.4) 19th century London: no clean water, toilets or sewer treatment (Potomac Watershed Partnership).

Low-impact Water Management Strategies

As urban populations continue to increase to an estimated 6.4 billion by 2050, from 3.4 billion today (UNEP, 2010), we are forced to acknowledge that historical practices in water management are less applicable now than they have ever been. Water is a finite resource, and the natural hydrologic cycle is showing evidences that it cannot keep up with our conventional system, due to its waste. The report *Toward Net Zero Water* summarizes this situation as below.

Increased water quality standards and regulation, coupled with advancements in water treatment and delivery and wastewater disposal systems, have dramatically improved human health in American cities. These systems have also altered human settlement patterns by allowing communities to grow beyond the carrying capacity of their local eco-systems as “water-on-demand” and “waste-be-gone” systems became standard. These systems have required large energy and financial inputs to manufacture, install and operate. Now, this aging infrastructure is a financial burden for municipalities. (Sisolak et al, 2011, pp.10)

As a result, there have been many attempts to create low impact, sustainable water management strategies. On a global and regional scale, the United Nations Environmental Program published a report for urban and domestic water use efficiency. The report proposed Integrated Water Resources Management (IWRM), which redirects our attention to the four different stages of hydrologic cycle described in the Figure 3.5 (UNEP, 2008).

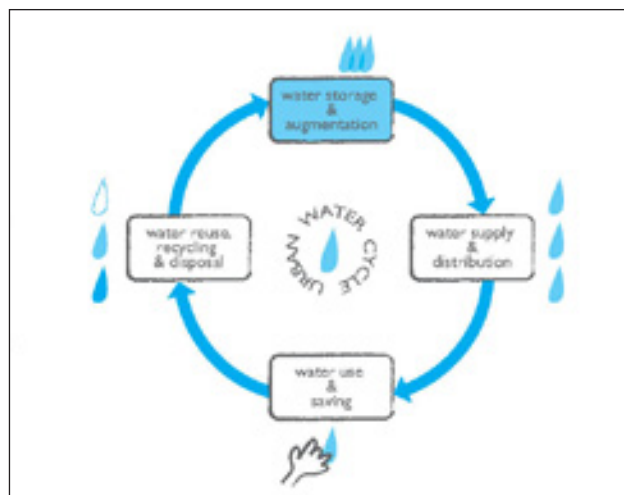


Figure 3.5) IWRM approaches to efficiency and fit (UNEP, 2008)

On the urban/ site scale, sustainability ratings systems, such as Living Building Challenge and LEED, consider the use of water as one of the important factors to determine the sustainability of built environments.

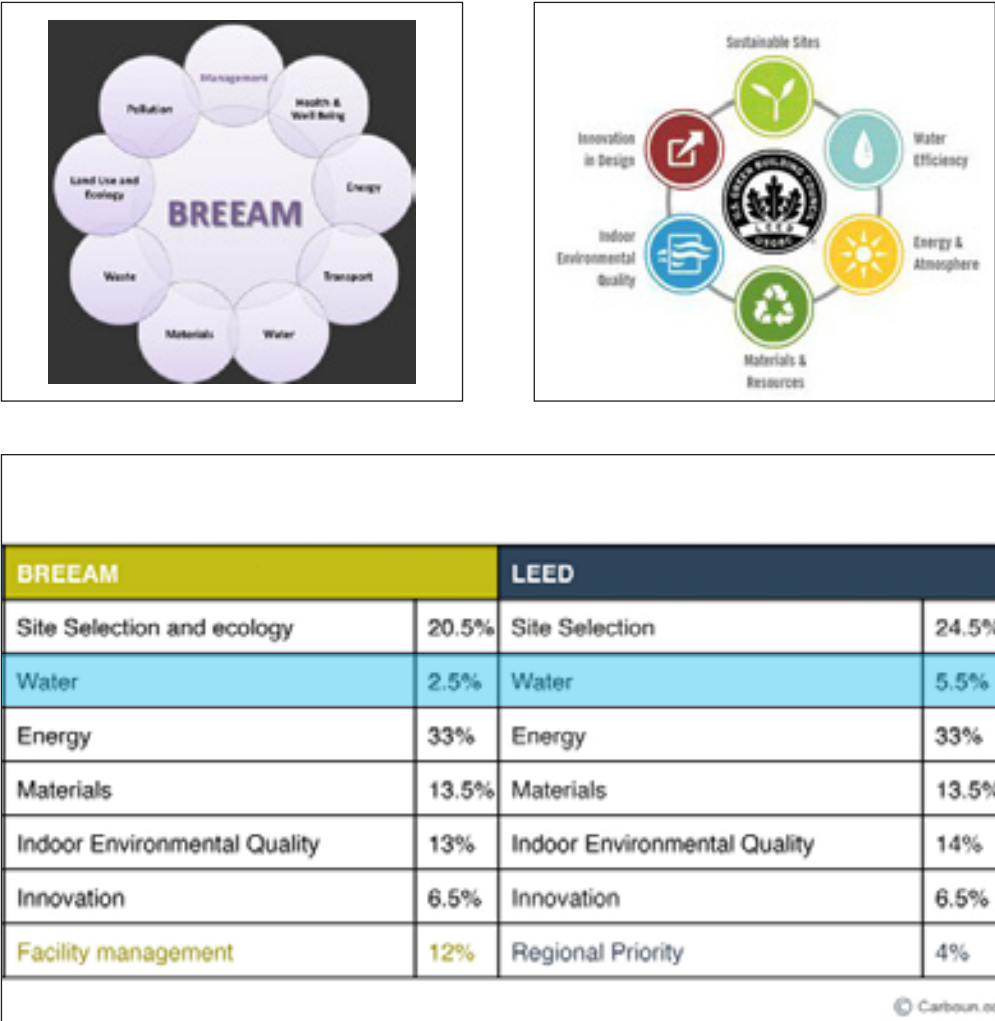


Figure 3.6) Comparison of Sustainability Rating System on Water (Cabourn.com)

3.3 Human Experiences and Revealing Nature by Design

“Landscape architects not only design landscape form and functions, they design our experience. They direct our vision and our movement; they emphasize, they accentuate, they reveal.”

- In *Eco-revelatory Design: Nature Constructed | Nature Revealed* (Brown et al, 1998, pp.xvi)

There is a long-standing design tradition, included in the landscape architecture tradition, that strong emphasis is made on the visual sensory experience in static time and place. Movement, however, implies an experience that spans a period of time, rather than simply an instance. This idea has often been neglected in designed landscapes, even ones that were meant to be interpretive experiences. Interpretive learning theories can help us understand how people learn- combined with landscape theories around perception and communication, we can understand how to design landscapes for maximal appeal to human senses.

Learning Theories

We read our books; watch TV or look at the other screens; read signs on streets; take notes from the boards in classrooms; and recognize numbers, colors, and shapes by seeing through our eyes. It is not surprising that research suggests people receive most of their information through sight- up to 75% out of the five senses (Countryside Commission, 1980). On the other hand, interpretive theories suggest that there are four modalities and three domains that people utilize to process information received, retain it, and recall it later on (Knudson et al, 2003). The four learning modalities are visual, auditory, kinesthetic, and symbolic/abstract, which can be used individually or simultaneously. It is known that when a participant’s entire range of senses are involved through all modalities, learning will happen at its most powerful and versatile level (Knudson et al, 2003). In addition, one can reach the largest number of people by telling a story not only with texts, but also through the sequence and display of objects that engage cognitive, affective and kinesthetic learning domains (Knudson et al, 2003). In short, even though much of the raw information we receive is visual, learning can happen most effectively and efficiently when multiple senses and learning modalities are stimulated at the same time. Those experiences can then be arranged in

sequences that engage different publics with cognitive, affective and kinesthetic learning aptitudes.

How can we apply what we have discovered about learning to landscape design, especially urban stormwater facility design that must communicate largely invisible ideas about the regional water cycle? Flow Learning, an interdisciplinary approach to nature education developed by Joseph Cornell, suggests that creating sequences that flow from one to another in a logical manner can help (1998). Creating experiential sequences in Flow Learning is a four-step process: awaken enthusiasm, focus attention, direct experiences and share inspiration. Table 3.1 describes what qualities and benefits each sequence is intended to provide to all participants. The initial two sequences prepare participants with both playful and focused activities. Then, eventually the third sequence provides ‘a deep, uplifting’ experience that becomes an intimate part of participants through a sense of wonder and reflection (Csikszentmihalyi, 1990). This approach is not only helpful in spatial design, such as laying out paths and interpretive elements, but also in temporal design, such as thinking about one’s experience within a single site visit. In the next section, theories that are specific to landscape architecture will be explored to inquire about the full potential of multi-sensory design as well as the design of spatial and temporal experiences.

Stage	Purpose	Quality	Benefits
1	Awaken enthusiasm	Playfulness and alertness	<ul style="list-style-type: none"> • Builds on children’s love of play. • Creates an atmosphere of enthusiasm. • Dynamic beginning gets everyone saying “Yes!” • Develops full alertness, overcomes passivity. • Creates involvement. • Gets attention and minimizes discipline problems. • Develops rapport with the leader. • Creates good group dynamics. • Provides direction and structure. • Prepares for later, more sensitive activities.
2	Focus attention	Receptivity	<ul style="list-style-type: none"> • Increases attention span. • Deepens awareness by focusing attention. • Positively channels enthusiasm generated in Stage 1. • Develops observational skills. • Calms the mind. • Develops receptivity for more sensitive nature experiences.
3	Direct experience	Absorption	<ul style="list-style-type: none"> • People learn best by personal discovery. • Gives direct, experiential, intuitive understanding. • Fosters wonder, empathy, and love. • Develops personal commitment to ecological ideals.
4	Share inspiration	Idealism	<ul style="list-style-type: none"> • Clarifies and strengthens personal experiences. • Builds on uplifted mood. • Introduces inspiring role models. • Gives peer reinforcement. • Creates group bonding. • Provides feedback for the leader. • Leader shares with a receptive audience.

Table 3.1) Purposes and Qualities of Each Sequences (Cornell, 1998, Table 7.4)

Eco-revelatory Design and Beyond

Brown et al. declared that Eco-revelatory Design is landscape architecture intended to reveal and interpret ecological phenomena, processes and relationships (1998). It is a concept that is based on assumptions that landscape amalgamates nature and culture and designed landscapes have communicative power (Brown, 1998). How this communication can be achieved through the design of landscapes is acknowledged in the common themes of eco-revelatory design, such as the imperative to provoke reflection and stimulate an understanding of nature, express new and renewed understanding of ecology's entwinement of human psychology and reclaim landscape as a realm of representation (Brown, 1998). Based on these assumptions and backgrounds, the special issue of landscape journal, named Eco-Revelatory Design: Nature Constructed/Nature Revealed, showcased design strategies for eco-revelatory design. There are a few especially relevant ones that can be utilized in creating relationships with nature through different interactions and experiences.

Eco-revelatory Design Strategies (Brown et al, 1998)

- Expanding design vocabulary and altering perceptions
- Allow people to relate and providing tactile and kinetic experiences
- Varying scales, everyday versus removed/independent experiences
- Using water as spine, continuing focus, and source for the design
- Contrasting formal and informal, designed and natural
- Uncovering and celebrating to deal with multi-dimensional relationships to water

We learn from these various tactics to break out of 'seeing' as the primary meaning of the design process. Although the concept of eco-revelatory design can be interpreted as diversely as described above, what is also most useful for the purpose of this thesis is its potential to 'renew' an understanding of nature and immerse people to the landscape that can 'reveal' what they do not see or perceive normally. Providing opportunities for bodily experiences as well as activating multiple senses allow people to be immersed in the landscape and help them understand what is being revealed in front of them. Truly revealing experiences cannot be static in time and place

or limited to specific forms and aesthetics, rather they need to be continuous experiences that have been choreographed for varying times and spatial scales. Especially, placing these experiences within the context of a standard urban life daily cycle can significantly increase chances of 'renewal' and 'reveal' of the diverse group of urban people.

Chapter 4: Experiencing Stormwater – Case Studies

Cases were selected within the geographically adjacent area two to ten miles from the proposed stormwater facility site at Montlake. Considering that the design of stormwater facilities can be significantly influenced by the local and regional codes and regulations as much as climate, geology, and local hydrology, it was deemed more appropriate to limit selection of cases locally within the greater Seattle area. However, all of these cases have originated from different times within the last fifteen years, from the Waterworks Garden built in 1996 to the most recent Madison Valley Stormwater Park in 2011. Considering that the current emphasis on art, sustainability and resiliency of urban stormwater management evolved between the similar timeline, these cases very well represent how the approaches to the urban stormwater design have changed and how they can be evaluated in their ability to inform the public of the urban water cycle. Cases are organized from the least recent construction to the most recent to understand them in chronological order.

4.1 Case Study Framework: V.O.A.S.T Analysis

In an attempt to formalize a way to approach the multi-sensory experience design, the following cases will be analyzed through the framework called V.O.A.S.T analysis, an abbreviated term to represent visual, olfactory, acoustic and tactile experiences. Thus, the scope of this case study is less about the general design and functions, but more specifically about different senses that can be detected from the site and how those senses are helping visitors to understand visible and invisible processes occurring on the site.

From each site visit, a series of sketches was created to record how each of five senses are represented as a result of intended design strategies as well as a product of unintended natural and cultural processes. For example, sketches recorded from the visit to Thornton Creek Stormwater Treatment Channel describe the experiences of five different senses on the site (Figure 4.1). Among the sketches, it can be observed that three of five senses (V, A, S) were experienced through the designed elements that was most likely intended by designers. Meanwhile, the other senses (O, T) were experienced as a result of natural growth of vegetation and community care.

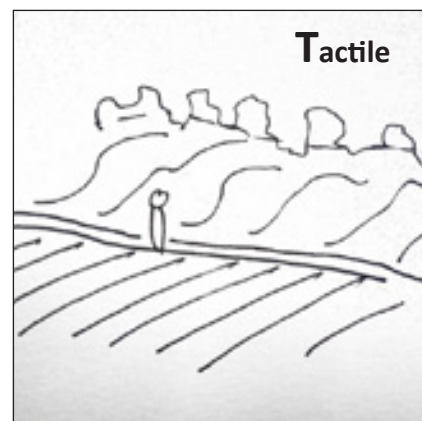
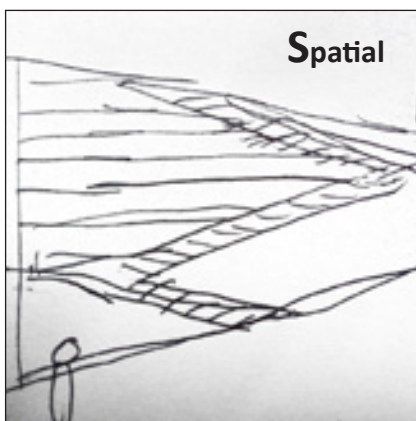
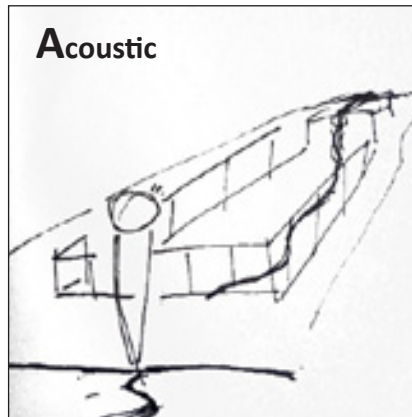
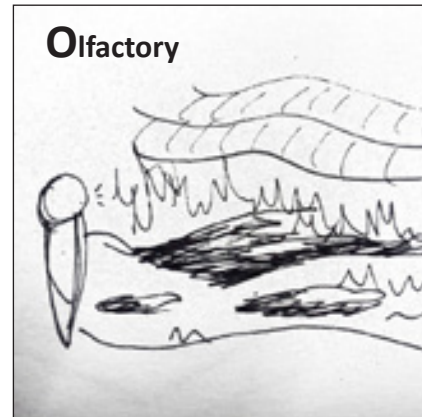
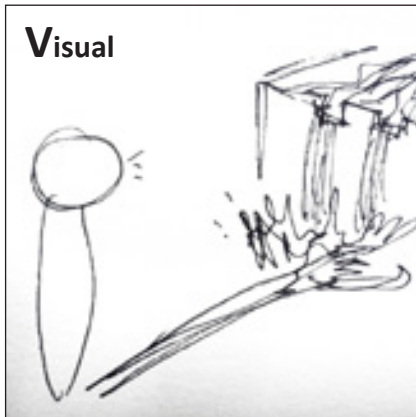


Figure 4.1) V.O.A.S.T. Sketches from Thornton Creek Stormwater Treatment Channel

4.2 Case Studies / Discussion

Waterworks Garden, Renton, WA (1996)

Background

The Waterworks Garden is characterized by a series of five garden spaces that can be experienced in a linear and sequential manner. These sequences closely mimic the path of stormwater from its entrance at the Knoll, followed by sub-sequential spaces called the Funnel, the Grotto, the Passage and finally the Release where the water flows back to the Springbrook Creek. The site's location is removed from the urban contexts, such as street grids, automobile traffic and other miscellaneous public uses, which helps the site to be experienced in the intended experiential sequences. As a result, the site can communicate with people about its hydrology and other natural processes in an elegant and sophisticated way with minimal signage.

The site also provides an ample opportunity for multi-sensory experiences. The summary of V.O.A.S.T analysis is as below.

Multi-Sensory Experiences

VISUAL (V)

- Open sightline between sequences allows depth and a cue to the next process, whether the site is approached from the higher ground or lower.

Olfactory (O)

- There is a slight standing water problem, but the issue is less significant due to the constant water inflow from the King County Wastewater Treatment Plan

Acoustic (A)

- Works as an important factor to locate flow of stormwater when visual cues are missing. There are different examples of inlet and outlets (Figure 4.2)

Spatial (S)

- Undulating and progressing from one area to another. Poplars have been well established to make a good spatial separations.

Tactile (T)

- Paving and materials transitions to different areas. Grotto area experiments with Gaudi-like shotcrete work.



Figure 4.2) Diversity of Inlet, Pond and Outlet Structures

Meadowbrook Pond, Seattle, WA (1998)

Background

It is less clear in Meadowbrook Pond to see how the site's hydrology is working. As the largest site (9 acres) of the four study cases, Meadowbrook Pond is characterized by the large detention pond at the center of the site, surrounded by a few different approaches connecting the site to the surrounding neighborhoods. The site must serve major flood control functions by receiving and detaining overflow from the Thornton Creek while enhancing the water quality through sedimentation. Without much background, it is difficult to understand the site's function as it is maintained by a series of flow control structures sometimes connected to underground pipes. Still, most of these structures, such as overflow weir, riser and diversion structures, are fairly accessible and provide good opportunities to visually communicate how hydrology actually works in an urban environment that has been modified to support human activities.

Multi-Sensory Experiences

VISUAL (V)

- There are less direct visual connections and cues for water flow and directions. However, the control of sightlines allows anticipation.

Olfactory (O)

- Wet and lushness is achieved with close planting, which helps to contain the olfactory experiences. Visually confirming.

Acoustic (A)

- Wildlife habitat provides a good ambient sound. Water flow is less evident, except during storm events.

Spatial (S)

- Rolling topography created by grading orients the site inwardly and provides contained experience.

Tactile (T)

- Artificial textures have been used for ground pavers. The use of materials and color provides consistency, although it is not very appealing one. (Figure 4.3)



Figure 4.3) Consistency in Materials and Coloration

Thornton Creek Stormwater Treatment Channel, Seattle, WA (2009)

Background

The SPU report noted that Thornton Creek Stormwater Treatment Channel is designed to remove pollutants from stormwater by slowing urban runoff before these flows enter the creek (2009). When a new development in the area was proposed, the community and advocates requested exposing the 60-inch storm drain to the surface in order to restore the historical connection of hydrology between the headwaters of Thornton Creek's South Fork and the wetlands surrounding North Seattle Community College (SPU, 2009). The facility is characterized by its hybrid system, which combines surface creek flow at normal flow and high-flow bypass system connected to 60-inch pipe buried underground.

Multi-Sensory Experiences

VISUAL (V)

- There are many visual connections to the stormwater flow as well as excellent cues to indicate the direction of the flow.

Olfactory (O)

- Poor smell can be detected in low points and pooling areas. More problematic when water level is low and flow is interfered by vegetation growths.

Acoustic (A)

- Acoustic devices allow the connection of one space to another, such as between the overpass that separates the channel in the middle where visual connection is interrupted.

Spatial (S)

- Rolling topography created by grading orients the site inwardly and provides contained experience. Large elevation drop was mitigated by the use of layered surfaces and varying textures (Figure 4.4).

Tactile (T)

- Community use and care determines the tactile experiences along the residential building. Transition from hard to soft and soft to hard can inform visitors about the edge conditions and programmatic uses.



Figure 4.4) Contrasting Textures, Layers and Edge Conditions

Madison Valley Stormwater Park, Seattle, WA (2011)

Background

Madison Valley Stormwater Park is a recent response to the need to protect the flood-prone area from extreme rain events, such as one that occurred in August 2004, which caused up to 5 feet of flooding in some houses. SPU expected there is a high chance of a similar event occurring again. The facility is designed to hold as much stormwater as was released into the area from the two largest storms in 157 years, one in 2004 and another in 2006 (SPU, 2011). This type of neighborhood stormwater facility symbolizes the changing climates and provides opportunities to think about new ways to deal with urban stormwater. It is also a great visual opportunity to observe the amount of stormwater that can be collected in one large storm event, which in this area can release up to 1.7 million gallons of stormwater (SPU, 2011).

Multi-Sensory Experiences

VISUAL (V)

- The site has a 'dry creek' where visitors can observe traces of flow. It is a designed element that clearly delineates murky residues from the last storm event, providing a good visual comparison of built and natural.

Olfactory (O)

- The same 'dry creek' feature has led to a residual standing water problem, especially toward the downstream.

Acoustic (A)

- Being in the urban residential neighborhoods, there is not much ambient sound, (rephrase) such as wildlife. The urban ambient sounds, such as traffic, is present, although minor.

Spatial (S)

- It is seemingly open, but over time trees along the diagonal approach will grow taller, eventually causing the site to be the site more inward-oriented with bowl-shaped topography.

Tactile (T)

- There is a stark contrast between murky water? and overly cold, hard and static architecture?, a possibly an intentional design strategy (Figure 4.5)



Figure 4.5) Cold, Hard, Static / Warm, Soft and Moving

4.3 Table of Summary














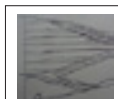






	Physical Factors	V isual	Q uifactory
<p>MADISON VALLEY STORMWATER PARK Seattle, WA (2011)</p>	<p>Type: detention pond Issue: RT / FC Site Area: 1 acres Drainage Area: ?</p>	<p>TRACE OF FLOW</p>  <p>LI FACTOR</p>	<p>RESIDUAL / STANDING</p>  <p>LI FACTOR</p>
<p>THORNTON CREEK STORMWATER TREATMENT CHANNEL Seattle, WA (2009)</p>	<p>Type: treatment channel Issue: quality / flooding Site Area: 2.3 acres Drainage Area: 680 acre</p>	<p>DIRECTION OF FLOW</p>  <p>LI FACTOR</p>	<p>RESIDUAL / STANDING</p>  <p>LI FACTOR</p>
<p>MEADOWBROOK POND Seattle, WA (1998)</p>	<p>Type: detention pond Issue: RT / FC Site Area: 9 acres Drainage Area: watershed</p>	<p>ANTICIPATION</p>  <p>LI FACTOR</p>	<p>WET / LUSH WITH PLANTS</p>  <p>LI FACTOR</p>
<p>WATERWORKS GARDEN Renton, WA (1992)</p>	<p>Type: artwork / treatment Issue: exhibit/ water qc Site Area: 8 Drainage Area: 50</p>	<p>DEPTH AND COLOR</p>  <p>LI FACTOR</p>	<p>FLOW / FRESH</p>  <p>LI FACTOR</p>

Table 4.1) Summary of Case Study Findings

continued from Table 4.1

A coustic	S patial	T actile
AMBIENT  LI FACTOR	INWARDLY / DIRECTED  LI FACTOR	CONTRAST  LI FACTOR
CONNECT  LI FACTOR	LAYERED SLOPE / SEQUENTIAL  LI FACTOR	TRANSITION  LI FACTOR
AMBIENT / ALL DIRECTIONAL + WILDLIFE  LI FACTOR	INWARDLY / CONTAINED YET FLEXIBLE WITHIN  LI FACTOR	REPEAT  LI FACTOR
CONNECT /  LI FACTOR	SEQUENTIAL / SEPERATION  LI FACTOR	TRANSITION  LI FACTOR

Chapter 5: Critical Position / Approaches to Design

The purpose of this chapter is to define the design criteria that can serve as the backbone of the design process. As described in the Chapter 1, this thesis is intended to create an organizational framework to approach urban stormwater site design before executing a site-based approach. This framework is composed of three different focus areas; form, function and experience. Each of three focus areas were informed by the three literature review sections discussed in Chapter 3. The ideas of designing human experiences were further explored and expanded through the case studies presented in the Chapter 4.

This structure, shown in Figure 5.1, represents the effort to come up with a balanced approach to the initial question of human and urban water.

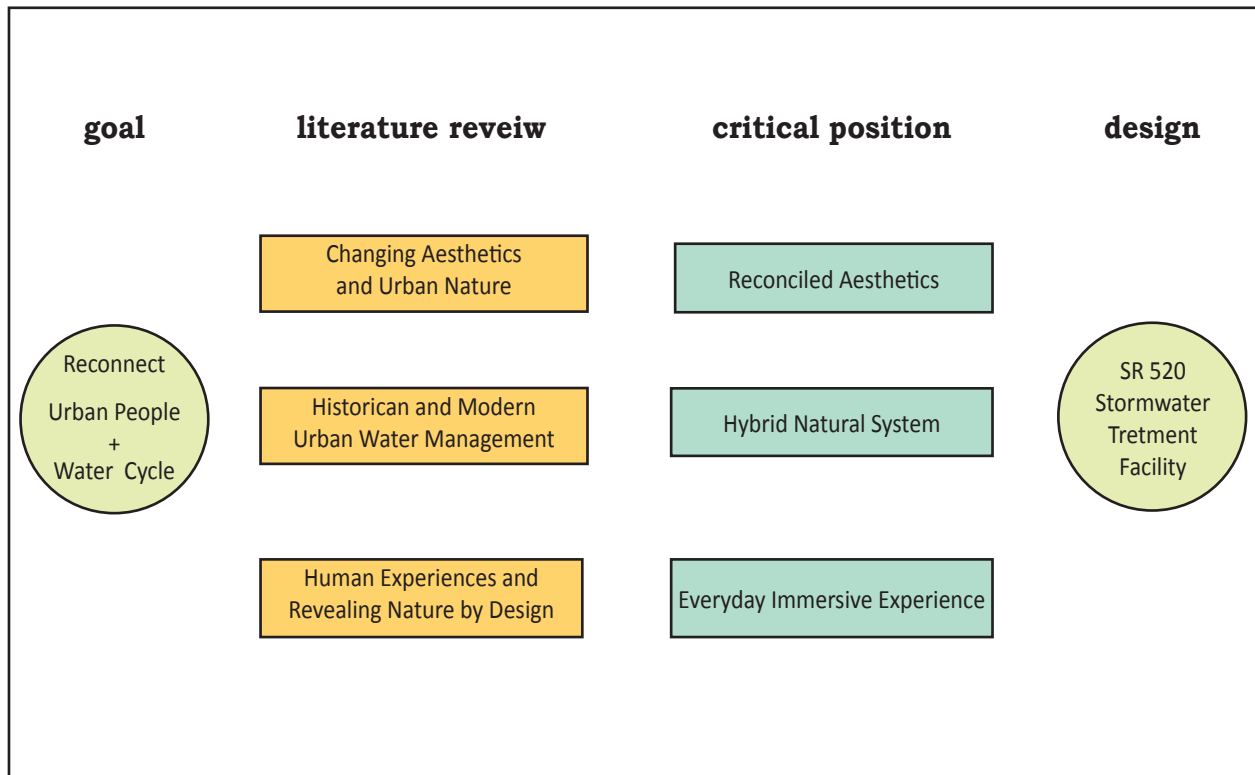


Figure 5.1) Literature Review – Critical Stance – Design Structure Diagram

5.1 Critical Stance: Form, Function and Experience

There are two primary approaches when designing sites that require urban ecological design, such as storm water treatment facilities. The first is a function-oriented design approach, and the second is a form-oriented design.

Figure 5.2 represents the typical urban green water infrastructure design. From this diagram, it is clear that the primary concern is for the physical functionality of the system. This approach is influenced by the tradition of modern water infrastructure, which has valued efficiency over all else, and focused on the fast conveyance of water into centralized facilities since the 18th Century (Sisolak et al, 2011). Even though current trends in green infrastructure have significantly improved the system's resiliency and sustainability, this function-oriented approach still communicates the idea that the water infrastructure is a technical problem beyond the realm of human activity or input.

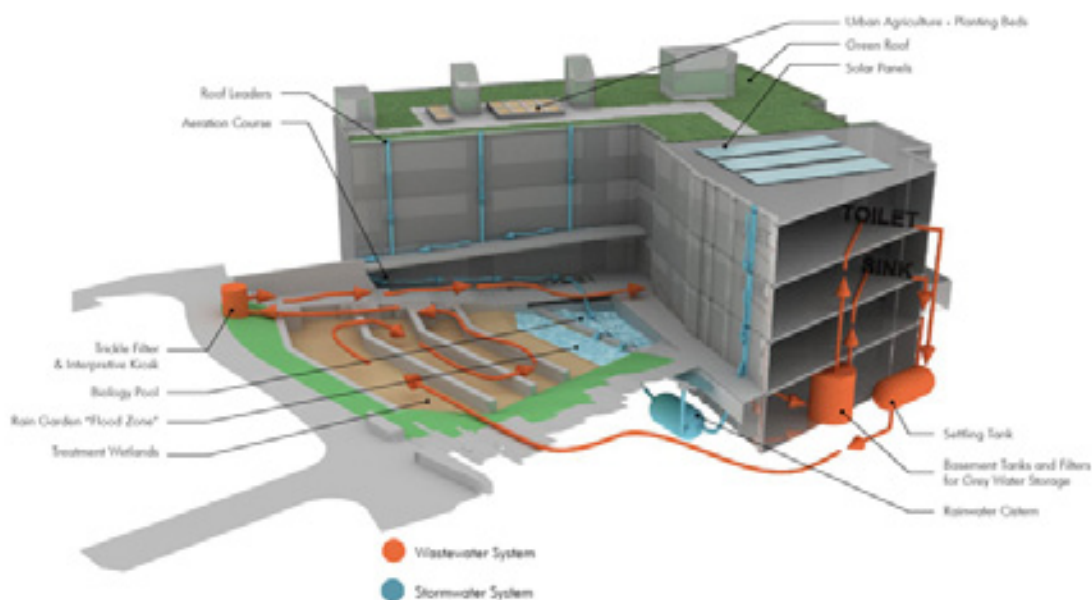


Figure 5.2) Common Green Infrastructure Water Diagram (ASLA.org)

This approach assumes that the solution cannot not be a solely form-oriented one. This might result in a 'naturalistic' design where water infrastructure, even if functional, can be simply ignored, abstracted, or considered as background without a connection to the context of either water or human activities. Eco-revelatory design or Eco-literacy can provide some methods for integrating water infrastructure in the surrounding physical and cultural landscapes. However, the concern remains that the efforts to communicate physical and cultural values often limit its scope to visual qualities or do not allow diverse interpretations, which are essential in defining one's own relationship with the natural environment.

Thus, what this thesis aims to accomplish is an approach to urban storm water sites in which they can be read as a clearly designed part of the human process, neither provoking nature nor alienating it. Even though the central goal of this thesis is based on restoring and recreating personal experiences in natural systems, a balanced approach combining form, function and experience is required to design successful urban stormwater facilities. Unlike single-purpose sites only for utility or education, urban stormwater facilities have to serve many different purposes and accommodate many different user groups. As a result, a design framework cannot be successful if we only emphasize its physical form, hydrological functions, or experiential qualities.

The organizational framework presented in the following section encompasses all three focus areas which have been explored in previous chapters.

Approaching Design: An Organizational Framework for Urban Stormwater Facilities

It is important to recognize that most design processes, including the one that this thesis will be presenting in the following chapter, tend to happen spontaneously, not in a clear order categorized by different focus areas. Therefore, the organizational framework here is not intended to be applied one by one, but rather to be referred to continuously as a design progresses. Figure 5.3 and 5.4 represent how this framew--ork might be utilized separately or cohesively when assessing and approaching the design of urban stormwater sites.

	Form: <i>Reconciled Aesthetics</i>	Function: <i>Hybrid Natural System</i>	Experience: <i>Everyday Immersive Design</i>
Existing Challenges	<ul style="list-style-type: none"> - Physical Change in Urban Nature - Confusion in perception and representation of 'Nature' 	<ul style="list-style-type: none"> - High waste and cost of traditional water management - Impossible to return to the pre-industrialization water cycle 	<ul style="list-style-type: none"> - Visually oriented design do not provide multi-sensory experiences - Designed landscape do not extend beyond static time and place
Approaching Framework	Reconciled form of urban nature aligning human and natural processes.	Hybrid natural system preserving the existing and yield flexibility.	Everyday Immersive design reveals the urban water cycle within the everyday context.

Table 5.1) Approaching Design: Organizational Framework Table

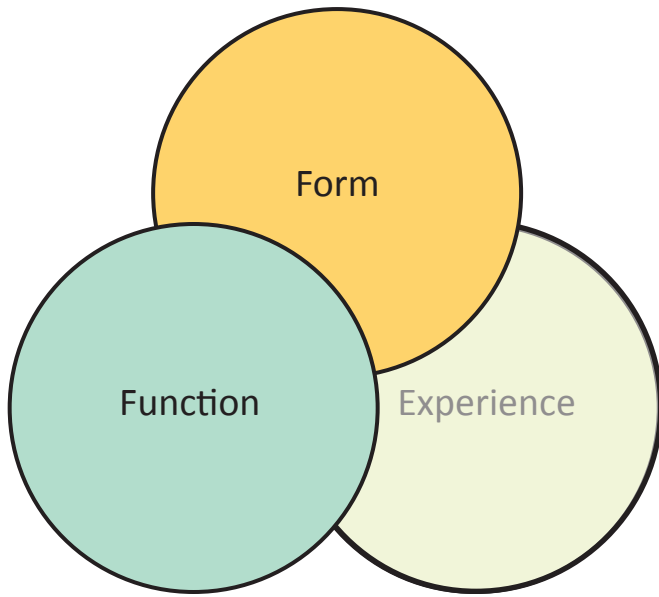


Figure 5.3) Applying Form and Function Frameworks

Hardscape + Rainwater Garden



image credit: artonfile



Earthwork + Water Detention



image credit: stranger.com

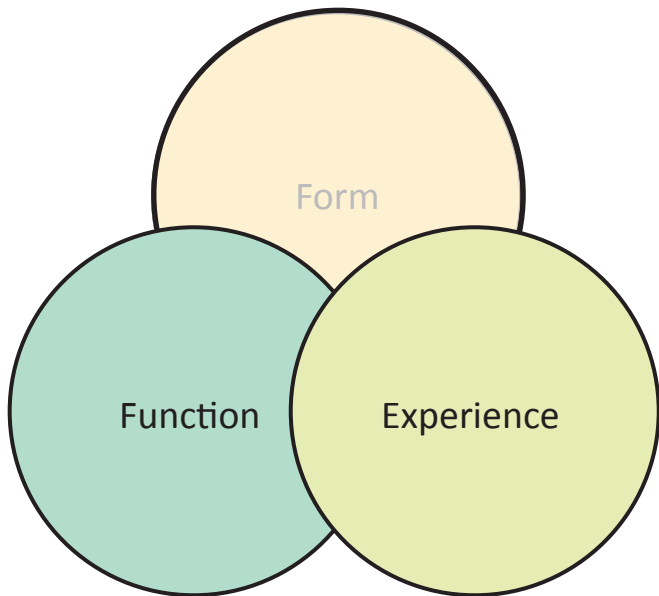


Figure 5.4) Applying Function and Experience Frameworks

Rain Cistern + Public Art



image credit: Clair Enlow



Roof Gutter + Rain Drums



image credit: Dan Corson

Chapter 6: Design Process

6.1 Context and Site Analysis

Context and Location

It was mentioned in Chapter 1 that the Montlake site has an uncommon location where people can directly observe different stages of the urban water cycle in one place. But not only the site's location is advantageous in revealing the water cycle, it is also surrounded by open spaces, historical neighborhoods, major water bodies and the largest research institution in the area.

Especially, the connection from the Washington Arboretum to the Union Bay Natural Area, not only provides the valuable public access to the water, but is also an important shoreline habitat as well as a regional circulation route.

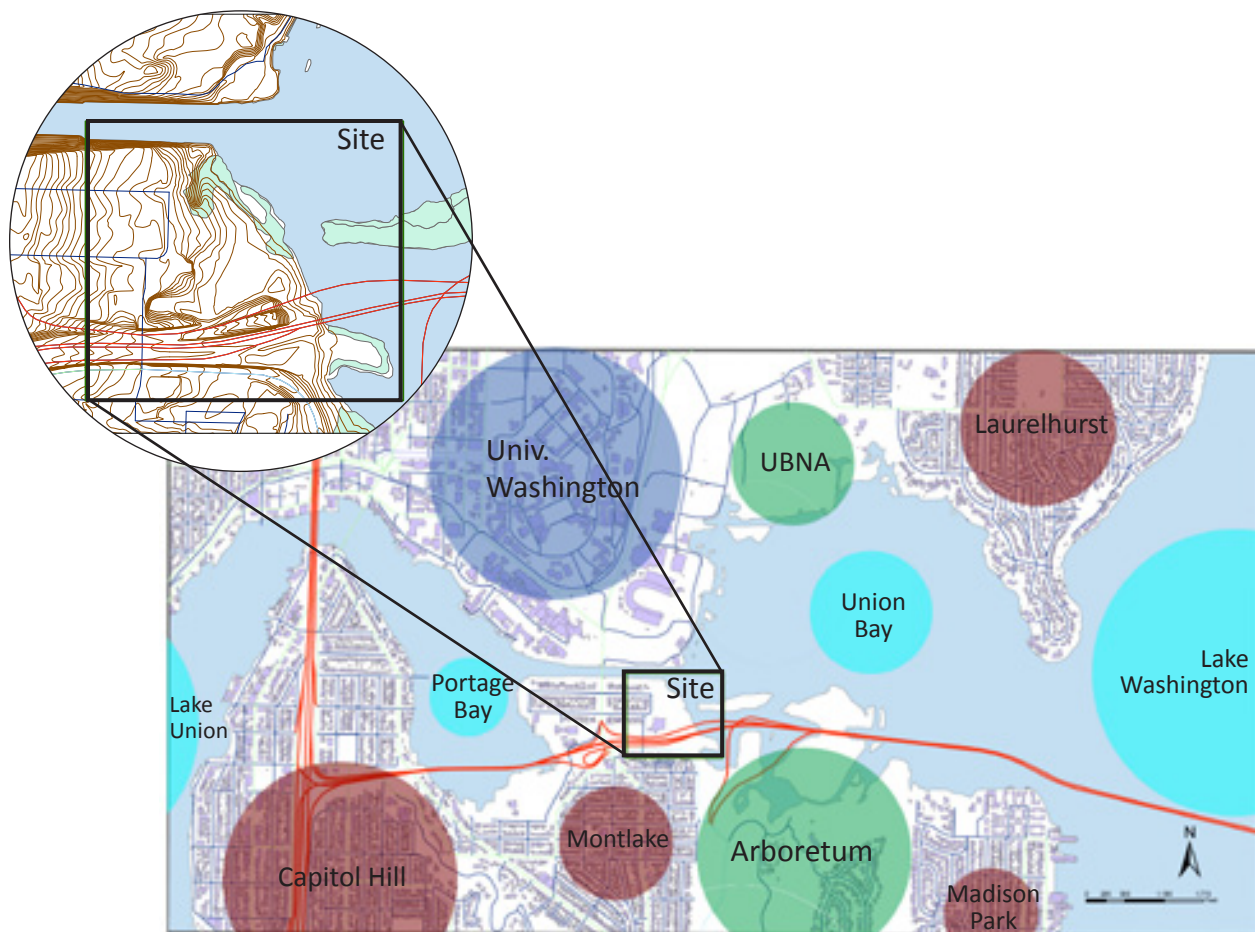


Figure 6.1) Location Map

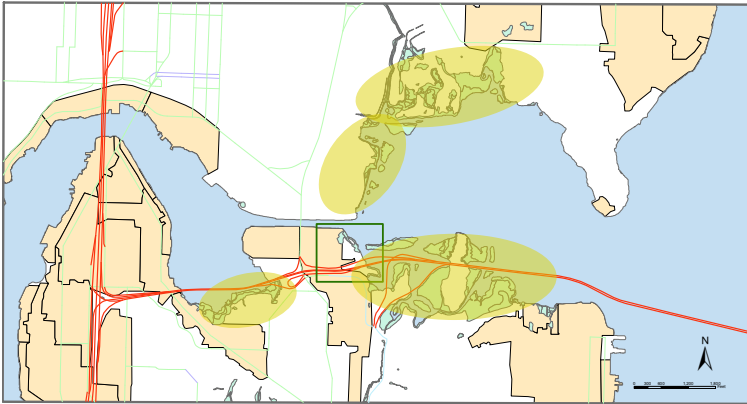


Figure 6.2) Wetlands and Drainage Basin Map

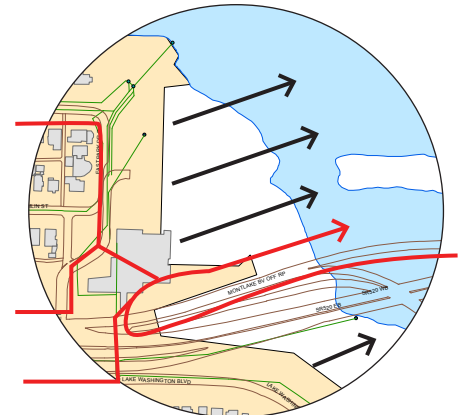


Figure 6.3) Existing Drainage

Environmental Conditions

Low lying topography and surrounding water body resulted in the wetlands that covers the much of the site's eastern shoreline, which stretches east to Marsh Island and south to the Arboretum Peninsula (Figure 6.2). The drainage of the area is separated by the line which can be extended from the eastern edge of the MOHAI building. To the east of this line, in the area that includes a portion of existing 520 structure, stormwater flows freely to Lake Washington. To the west of this line, stormwater is collected and drains to the existing City of Seattle outlet on the southeastern corner of the site (Figure 5.3). This drainage pattern can be directly observed in the site's soil and vegetation conditions. The eastern half of the site is characterized by wet meadow and emergent plants growing on the peat soil. The western half of the site is developed and features landscape trees, including a few arboretum specimens along the existing SR 520 structures.

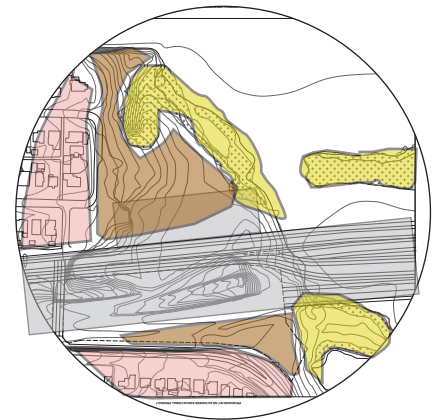


Figure 6.4) Existing Soil

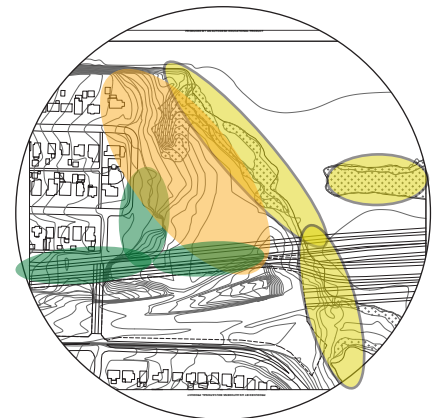


Figure 6.5) Existing Vegetation

Connections (vehicle, high-speed through ped/bike, low-speed ped/bike, HOV)

CITY/REGIONAL

The regional and neighborhood scale transportation network shown in Figure 6.6 indicate that long-distance commuting bicycle and pass-through traffic would most likely to increase along the Lake Washington shoreline as well as along the planned east-west elevated pedestrian/bike path. Thus, traffic moving through the site can be categorized by high speed pass-through, low-speed walk/stroll and vehicular access.

Vehicular traffic will increase with the expansion of SR 520 from the current 4-lane wide design to proposed 6-lane wide alternative. Majority of increased traffic will be diverted to the below-surface structure underneath the highway lid. However, increased traffic on HOV lanes and west-bound off-ramps directly next to the site is expected.



Figure 6.6) Regional Connections Map (WSDOT, Community Meeting, April 2012)

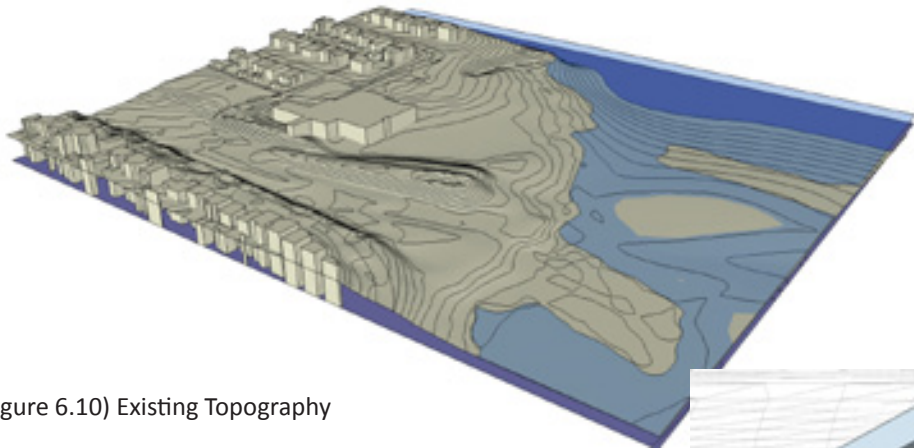
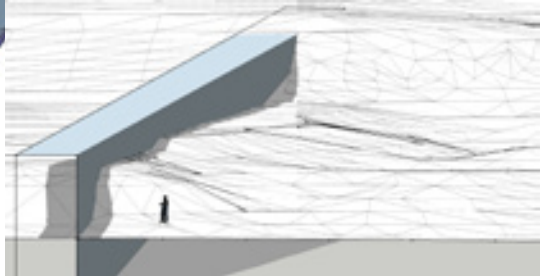


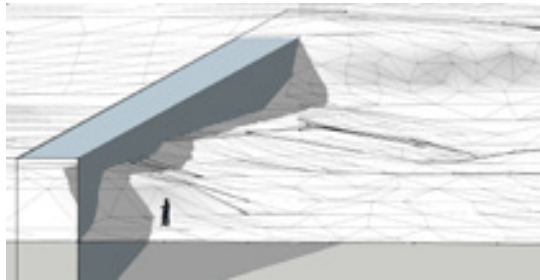
Figure 6.10) Existing Topography

First sections are to understand the seasonal sun/shade dynamics along the southern edge of the site. The proposed 520 structure will have substantial elevation differences from the ground level of the site. The tentative road alignment model indicates that the difference will be between the 10 to 20-foot range.

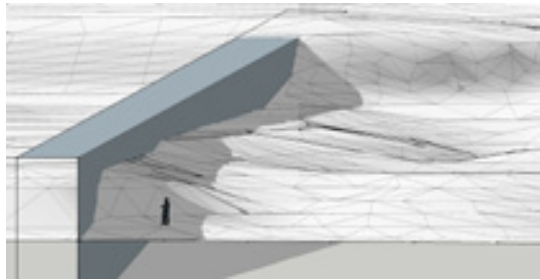
A simple 3-D mass model, shown in Figure 6.11, depicts the amount of shading that will be drawn over the southern edge of the site. It is important to understand the shaded area, not only because it is related to the quality of human environments, but also directly related to the performance of constructed wetlands, which requires live vegetation to treat the stormwater.



JUNE



MARCH/SEPTEMBER



DECEMBER

Figure 6.11) Seasonal Sun-Shade Model

The next series of sections show relative elevations from the south to the north end of the site. In Figure 6.13, it can be observed the existing topography provides the best opportunity to make the terrestrial connection along the section A, where the topography is the most flat. On the other hand, the section D provides the best opportunity to connect to water where the slope is the most gentle near the shoreline.

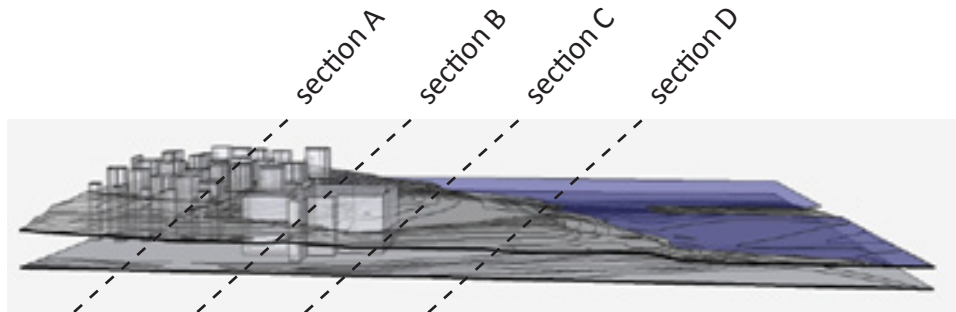


Figure 6.12) North-South Section Locations

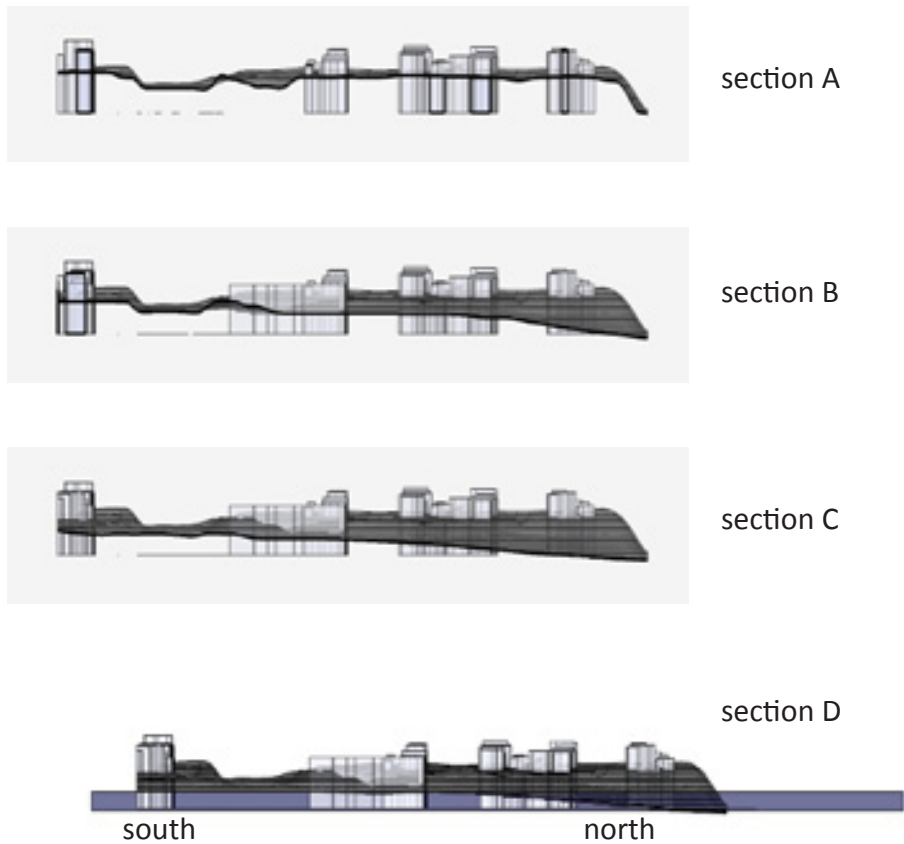


Figure 6.13) South-North Section Views (A,B,C,D)

6.2 Design Goals and Strategies

Revisiting the Key Research and Design Goals

It was the central goal of this thesis to:

1. Re-establish the connection between everyday activities and water cycle
2. Reveal processes in multiple temporal and spatial scale
3. Expose people to different stages of water cycle through multi-sensory experiences

These goals eventually converged with three key themes of literature reviews and critical position/design approach, which can now provide a good framework to approach the site design. However, every site has its unique challenges and opportunities. By combining knowledge learned from site analysis with knowledge gleaned from literature reviews, a design strategy/approach was formulated that became the basis of site design goals and strategies for Montlake Stormwater Treatment Facility.

Site Design Goals and Strategies

1. ***Spatial/Use Problem:*** Align needs of stormwater flow with need of site accessibility
2. ***Ecological Problem:*** Preserve the shoreline habitat while providing urban programmable spaces
3. ***Experiential Problem:*** Maximize opportunity for people to experience the water cycle and take advantage of the site's extraordinary location

6.3 Designing the Form: Reconciled Aesthetics

Conceptual Form-Making: Aligning Flow and Access

In Chapter 5, it was discussed that the designed forms will need to reconcile human and natural processes of human environments. For this site, this reconciliation can be translated to aligning the issue of stormwater and the issue of access. As discussed earlier, the Montlake stormwater site has specific challenges regarding the physical boundary presented by the proposed SR 520 structure and also regarding the different circulation flows for local and regional uses. Therefore, it was the main concern of the conceptual form-making process to align the flow of stormwater with the different needs of access and circulation.

Three different zones of human processes were named Source, Exchange and Release. They were delineated to accommodate the different needs of access and circulation. At the same time, it was attempted to link the entire experiences by the flow of stormwater following its logical and physical movement. The flow is meant to be used as a sensory guide to navigate the whole site and within itself, divided by three zones to represent three stages of hydrologic cycle. When aligned together, specific needs of the flow and the access defined what the initial form should look like and this conceptual form continuously evolved throughout the design process.

Conceptual Form-Making

Delineation of Zones feeding form-making process (source, exchange, release)

+

Flowline concept (single source, single exit, maximum exposure) Diagram

=

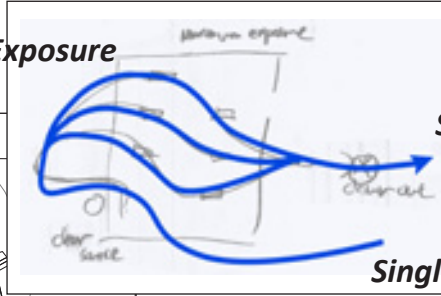
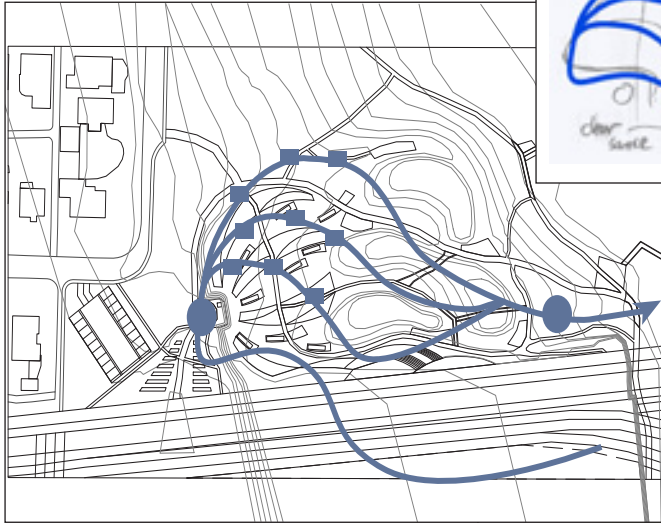
Resulting Initial Concept

(+ Continued Revision = Final Design Concept)

FLOW



Maximum Exposure



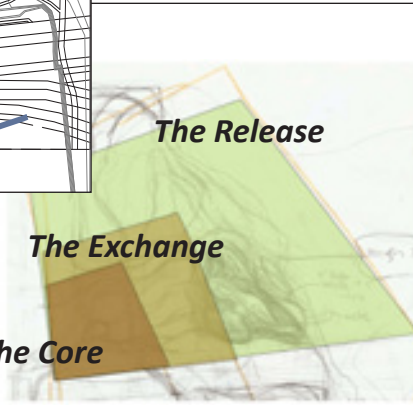
Single Exit

Single Source

The Release

The Exchange

The Core



ACCESS & CIRCULATION



FORM



Figure 6.14) Conceptual Form-Making Process: Flow+Access=Form

Concept Evolution / Showing the Process

Below Drawings show how the conceptual have been refined starting from the conceptual drawing of programmatic zones and the stormwater flow. Conceptual evolution is showing the merge of the two processes in three different stages. First emphasizing the flow (stormwater design), then emphasizing the access (circulation and hardscape design), and finally incorporating the two on the ground and grading the site to serve its needs.

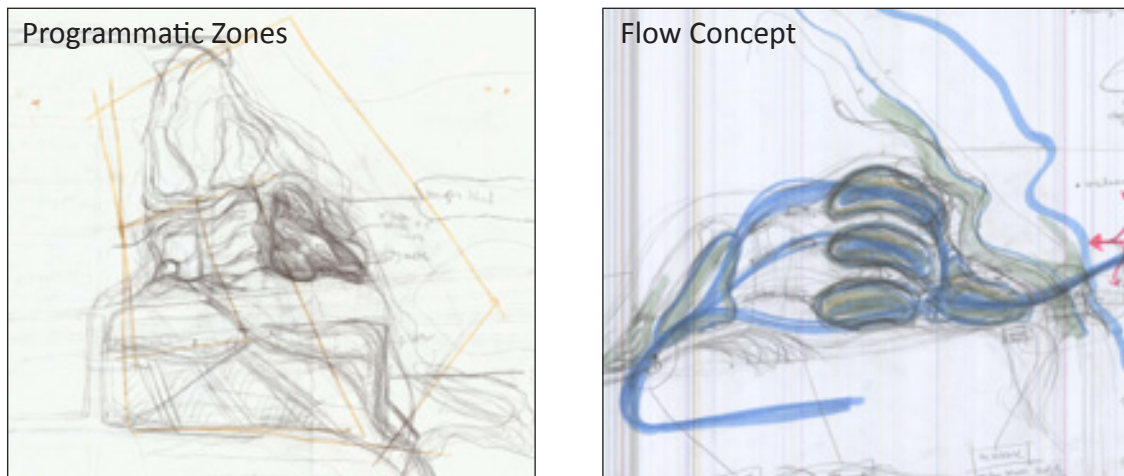


Figure 6.15) Conceptual Drawings of Programmatic Zones and Stormwater flow

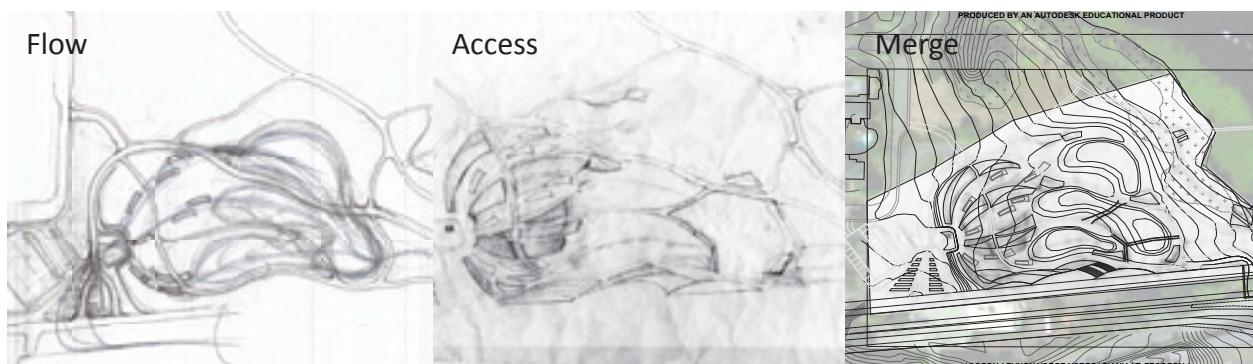


Figure 6.16) Drawings of Conceptual Evolution

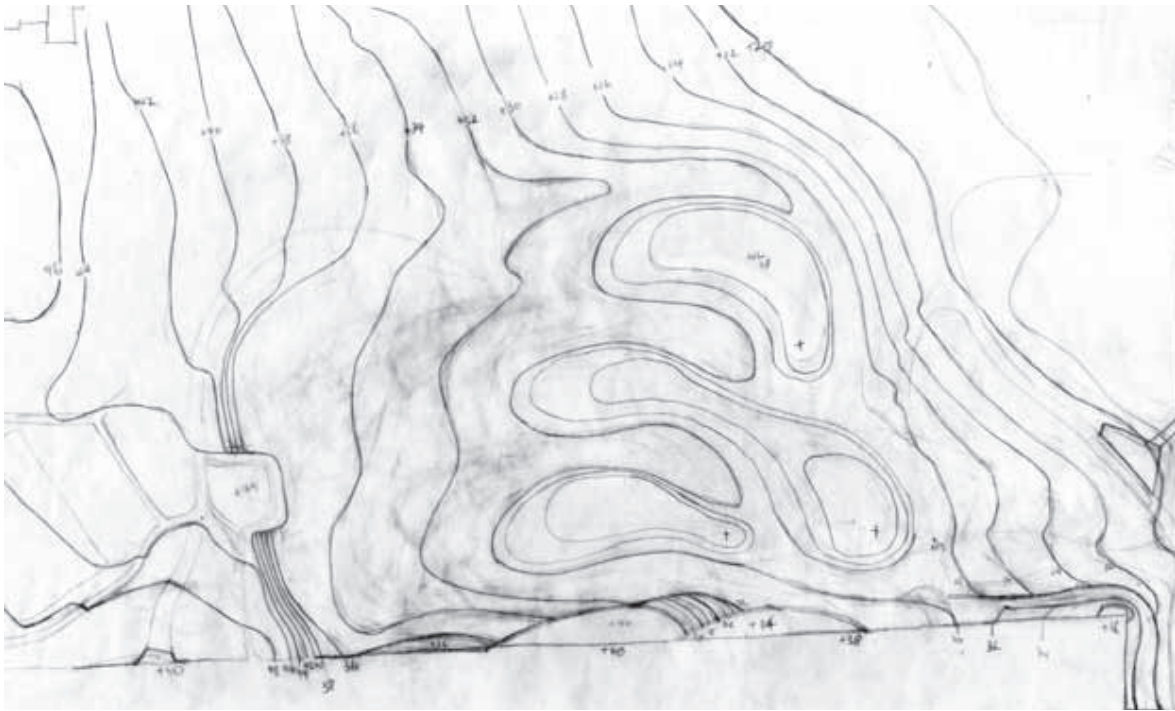


Figure 6.17) Grading Plan

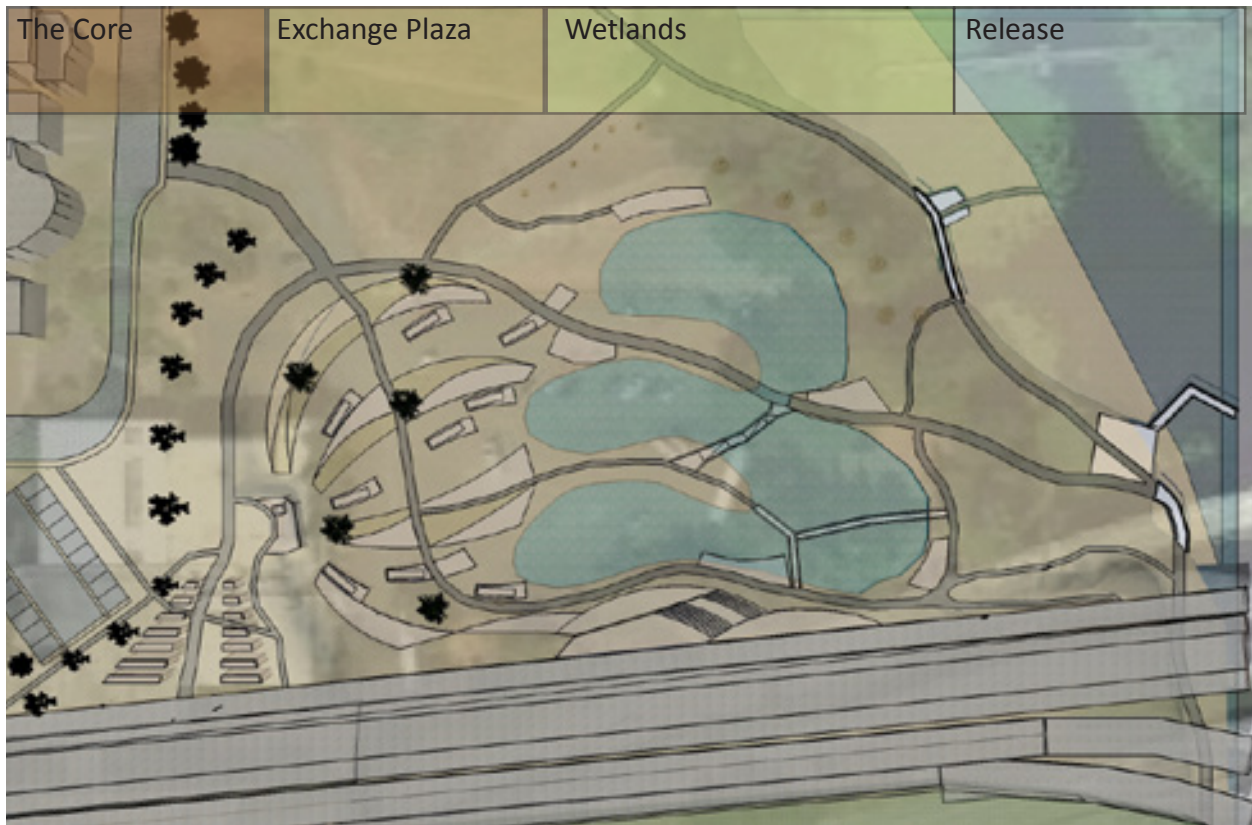


Figure 6.18) Final Concept

6.4 Designing the Function: Hybrid Natural System

Fulfilling the Requirements

It was stated in the Final Environmental Impact Statement that the site needs to treat all the existing and new stormwater discharge from Threshold Discharge Area (TDA) 9 and TDA 10 (WSDOT, 2011). The total volume (V_{total}) computed for the facility from a 6-month, 24 hour storm was 104,067 cubic feet. WSDOT Highway Runoff Manual generally recommend to appropriate 30 percent of the total volume to a pre-settlement cell. Thus, the volume of a pre-settlement cell (V_{pc}) can be computed to roughly 34,342 cubic feet. The foot print of the pre-settlement cell can vary depending on its depth measurement. For example, the footprint requires 6,868 square feet of spaces when we set the pool depth to 5 feet on average.

Such a large requirement of space can be a problem, especially when the pre-settlement pool needs to be placed near the point where the stormwater initially enters the site. This point must be close to the southwestern corner of the site, due to the issue of gravity that is collecting the stormwater from the SR 520 structure, feeding it into the site, and then eventually releasing it to the proposed WSDOT outlet on the southeastern edge of the site. The location for the pre-settlement pool also happens to be close to the 24th avenue which intersects with the proposed pedestrian/bike path. A conflict arises between the two different requirements of a stormwater function and a major circulation function.

In order to solve this issue, it is proposed that the pre-settlement pool be situated below the surface as a underground vault. The area can be covered with a thin layer of soil and hardscapes, which can serve much more versatile programmatic uses as well as accommodate anticipated high pedestrian/bike traffic.

Total surface area (A_{total}) required for the treatment can be computed by dividing the total volume by the average depth of the entire treatment system, which is around three feet. When surface area of pre-settlement cell subtracted from the total surface area, the surface area of constructed wetlands cell (A_{cw}) can be calculated as 28,966 square feet. This square footage is an area little more than a 0.6 acre and can take up much of the usable core space from the 3.5 acre

site. Therefore, a hybrid approach combining different technologies was required to free up the valuable core space and fulfill the functioning requirement of the stormwater facility.

Sub-surface wetlands (SSW) are a type of natural stormwater treatment technology that is becoming more popular for projects that need to be situated in urban areas. Opposed to the free water surface flow wetlands (FWS), SSWs do not expose any standing water on the surface by containing the stormwater flow underneath its filter media, usually composed of planted soil and substrate. Also, because of the existence of coarse filtering media that support absorption and contribute to microbial growth, SSWs require lower surface area and have higher treatment performances (Hoffman et al, 2010). Furthermore, SSWs can be contained and shaped in many different forms and their orientation can be adjusted by placing their inlet and outlet point in different places, resulting in more versatile design possibilities.

For example, Modular Wetland System (MWS), a type of horizontal flow SSF, can treat up to 4,000 cubic feet of stormwater within the footprint measured 22 feet by 5 feet (MWS Inc, 2012). Although this type of system requires higher initial cost for design and construction, its operational costs over time can actually be lower than traditional constructed wetlands as it does not require the draining of the cell. More importantly, it allows accommodating various urban programmatic activities and saving valuable spaces.

When treatment volumes for six MWS cell are taken into consideration, the final total area for constructed wetland cells (A_{wc2}) becomes 20,966 square feet, about 8,000 sq. ft. smaller than the original area. The overview of area and volume calculation is shown below.

Hybrid Natural Stormwater Area and Volume Calculation

$$V_{total} = 104,067 \text{ cu. ft.}$$

$$V_{pc} = 34,342 \text{ cu. ft.} \quad V_{pc} / 5 \text{ (depth)} = A_{pc} - 6,868 \text{ sq. ft.}$$

$$A_{total} = V_{total} / 3 = 34,689 \text{ sq. ft.}$$

$$A_{wc} = 34,689 - 6,868 (A_{pc}) = 28,966 \text{ sq. ft.}$$

$$A_{wc}^a = 28,966 - 8,000 (MWS \times 6) = 20,966 \text{ sq. ft.}$$

$$\text{Total area for the constructed wetlands } (A_{wc}^a) = \mathbf{20,966 \text{ square feet}}$$

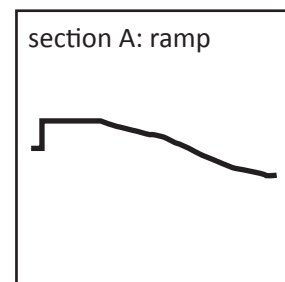
Traverse Sections: Sectional Relationship of Stormwater Function and Access

Four sectional diagrams along the edge of SR 520 are presented here to show sectional relationships of stormwater functions and the other functions the site must serve. Most importantly, different access points along this edge must be able to function in order to provide diverse options to enter and exit the site. It is evident that human flow into the site needs to be facilitated first in order to achieve the experiential goals of this thesis. Maximum exposure to the stormwater treatment process will have to take place first in order to initiate any experiential potential of the site. Following sectional diagrams show how stormwater functions are placed in order to maximize access to the different stages of hydrologic cycles.

Traverse Section Locations and Descriptions

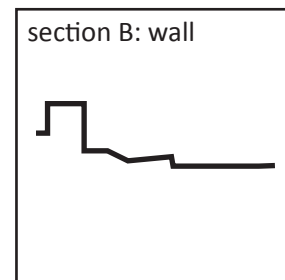
Section A: Ramp

The initial entry point of the stormwater to the site.
Intersection of 24th avenue and pedestrian/bike path.



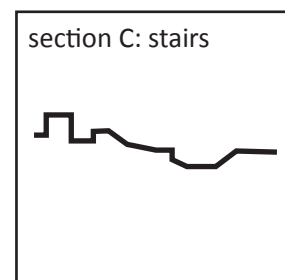
Section B: Wall

Stormwater cascades out from the presettling vault
The lookout point with the highest elevation change.



Section C: Stairs

Stormwater passes MWS cells
The plaza has the widest access through the terrace stairs



Section D: Climb

Constructed wetlands hold and release stormwater
Narrow climb down to the sensitive habitat

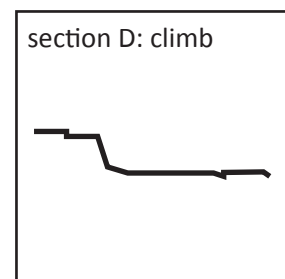


Figure 6.19) North-South Traverse Section Individual Profiles (2X vertical)

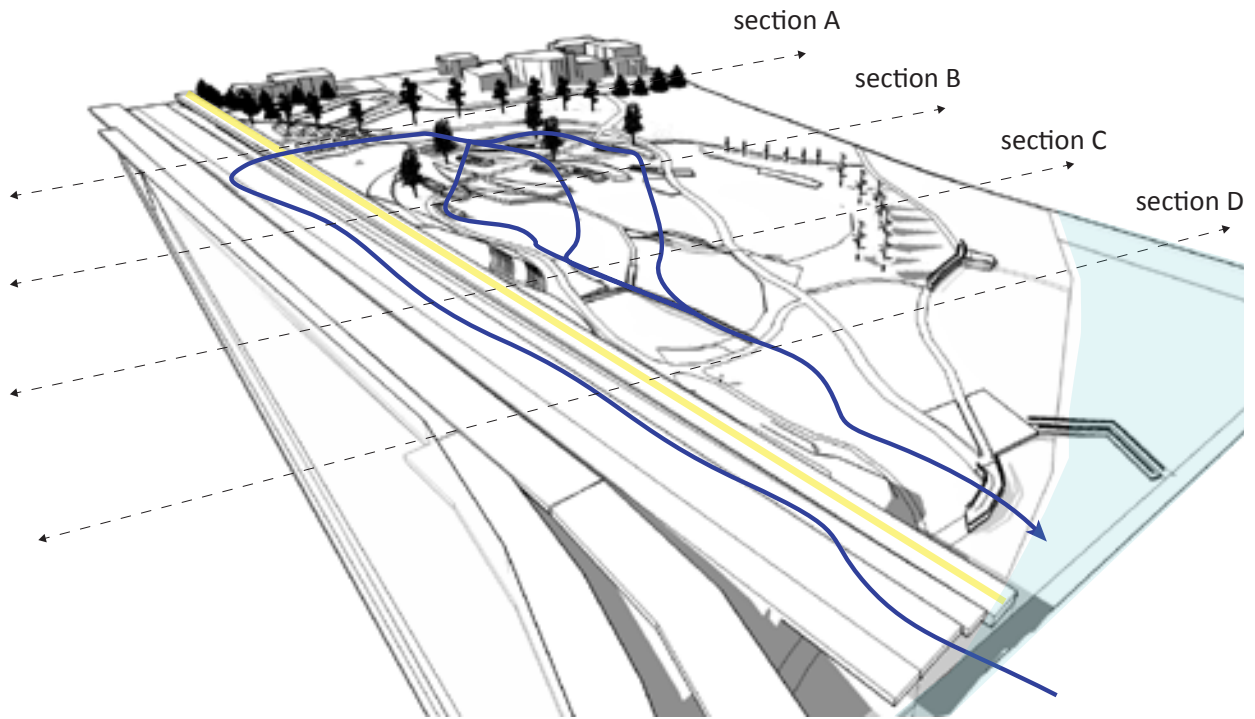


Figure 6.20) North-South Traverse Section Location: Axonometric View

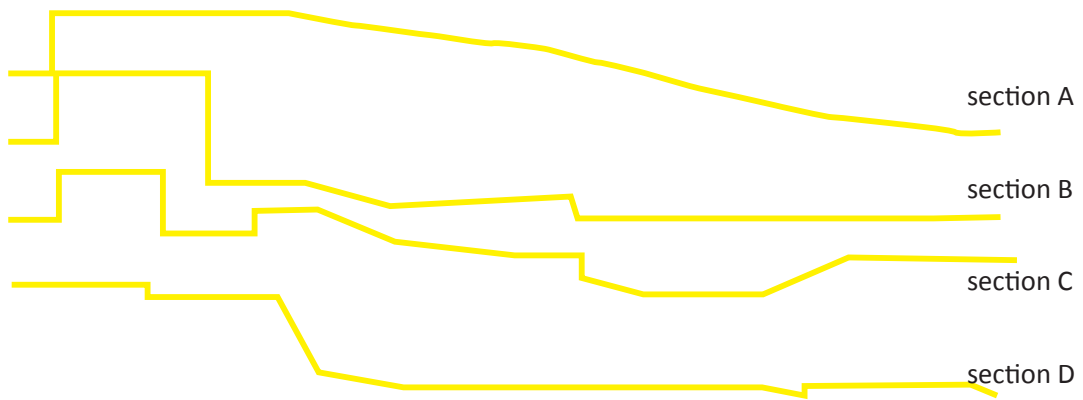


Figure 6.21) North-South Traverse Section Location: Combined Profile View

section A: ramp

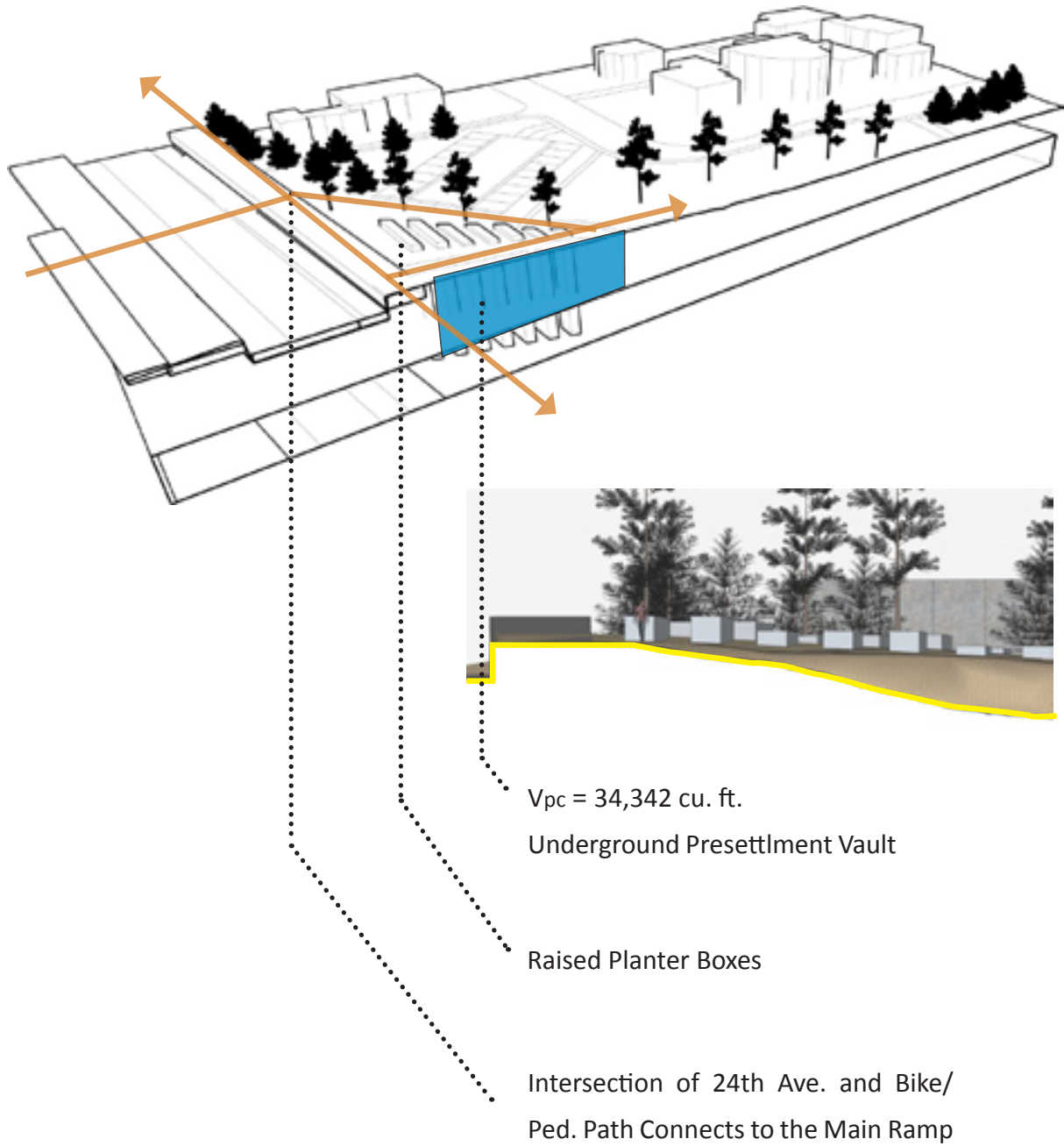


Figure 6.22) Section A: Ramp Perspective Section Diagram

section B: wall

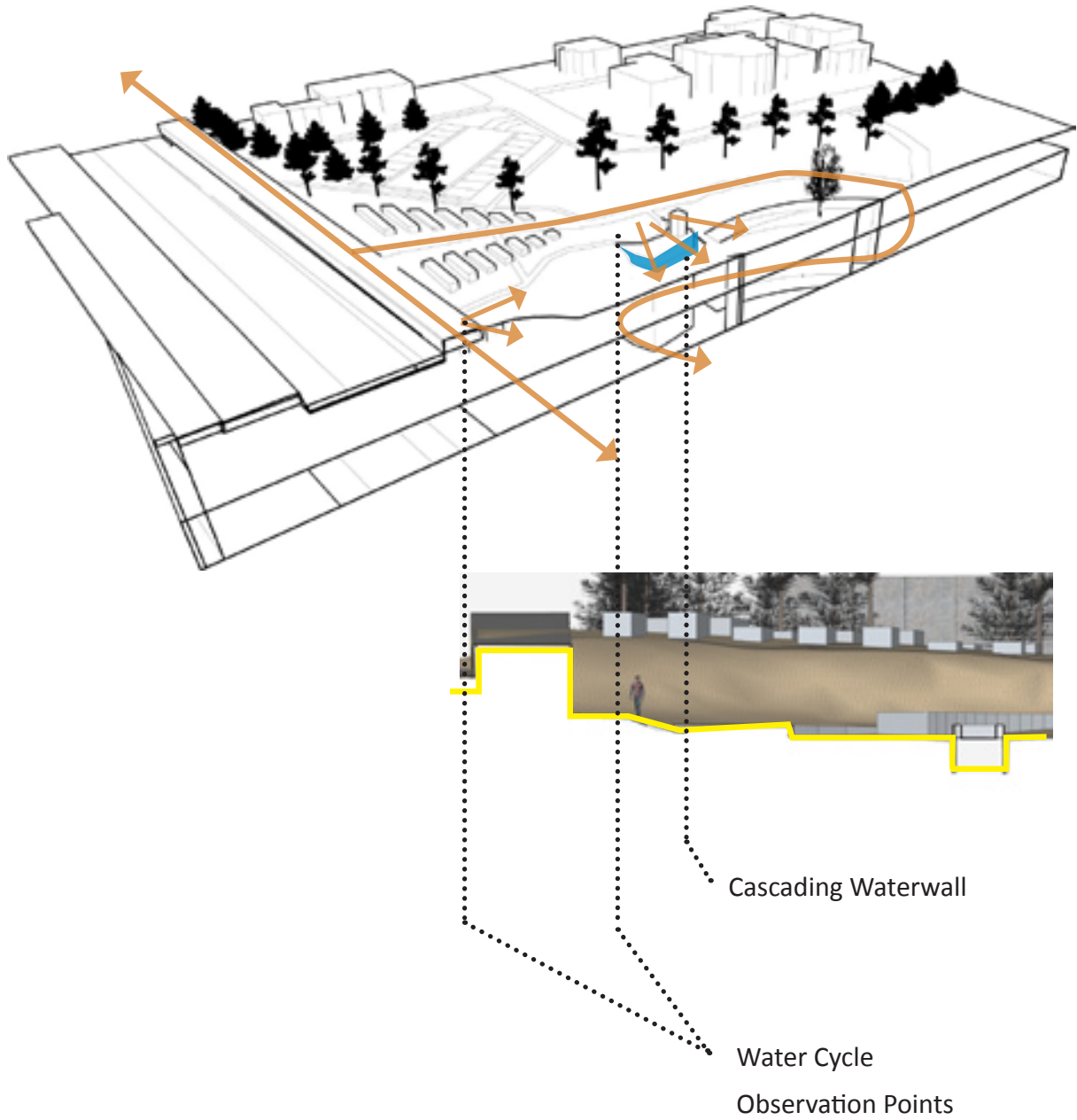


Figure 6.23) Section B: Wall Perspective Section Diagram

section C: stairs

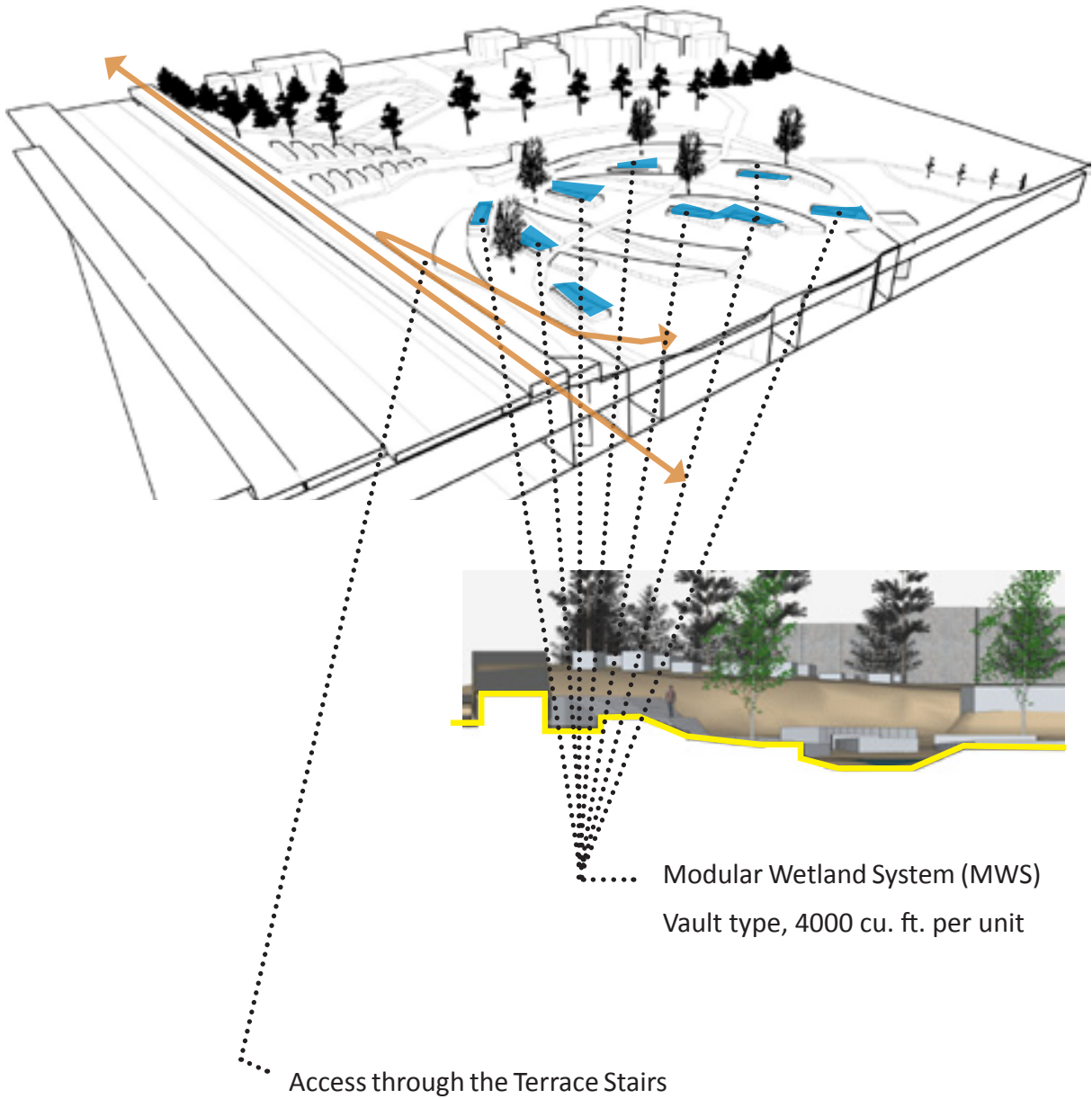


Figure 6.24) Section A: Stair Perspective Section Diagram

section D: climb

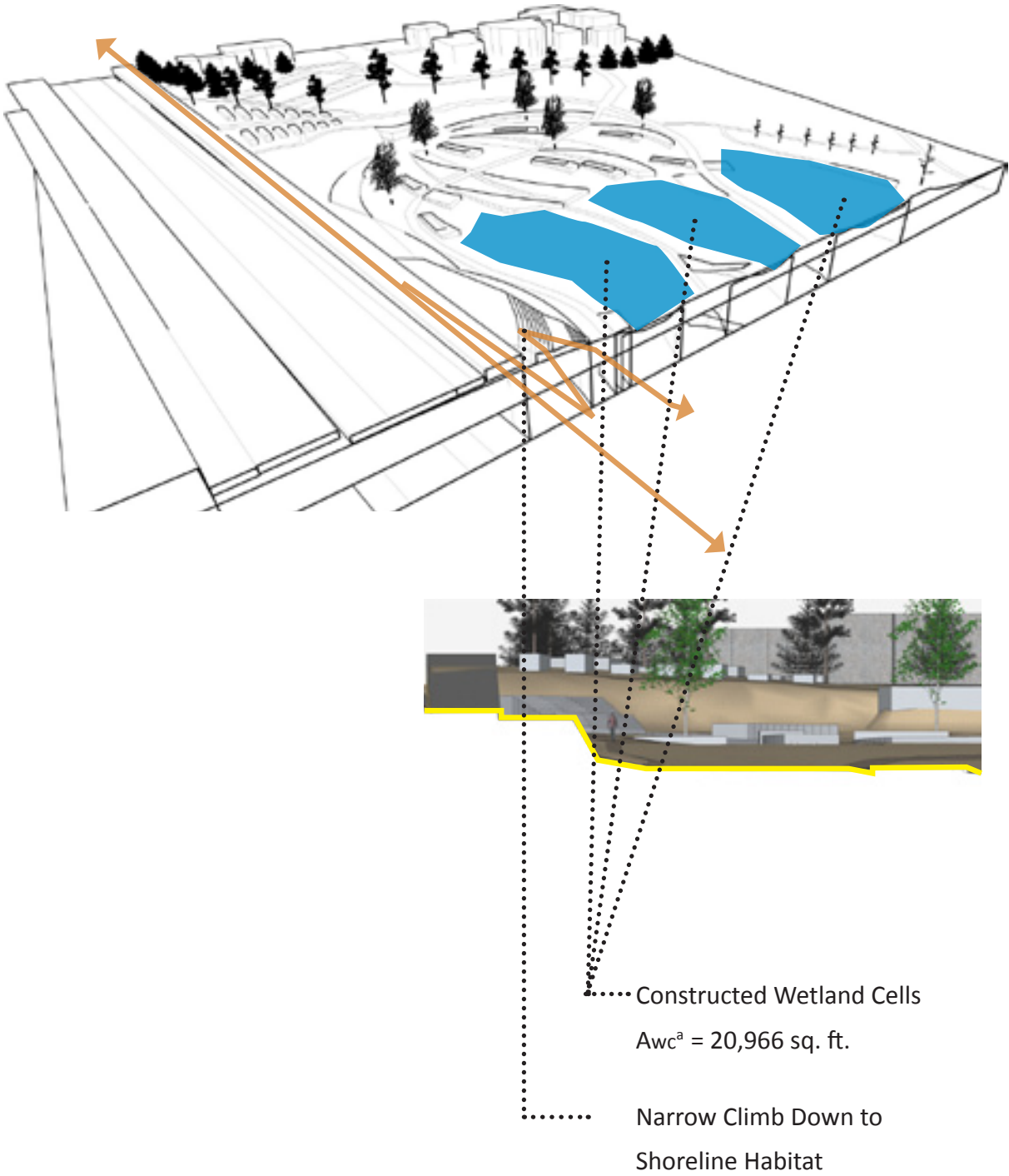


Figure 6.25) Section A: Climb Perspective Section Diagram

6.5 Designing the Experience: Everyday Immersive Experience

Visualizing the Invisible Experiences

A subtle stream of white steam comes out of the pile of compost as the rain that fell earlier in the morning evaporating from the heat of the compost pile. This moment is captured in the Figure 6.26, a photograph taken on the site on one cool rainy afternoon. This image had become a lasting metaphor to approach experiential design component of this thesis. How can we capture temporal and ephemeral events? How designed elements provide cues to the invisible processes? How do we visualize dynamic spatial relationship that is constantly changing? These were questions that were being asked during the experiential design process.



Figure 6.26) Steaming Compost Pile

Choreographing Experiences: Experiential Sequences

It was discussed in the Chapter 3 that sequential experiences, such as Flow Learning, can be a useful tool to introduce people to a concept that is unfamiliar or largely invisible. Urban water cycle can be a good topic to utilize sequential learning because it can ease the difficulty of introducing an unfamiliar concept of urban water cycle, which is often not very visible on the surface. Adapted from the Cornell's Flow Learning stages, experiential sequences for the Montlake storm-water facility have been laid out in the following order.

Experiential Sequence

Purpose:

1. *Awareness*

>

2. *Interest/Appreciation*

>

3. *Direct Experience*

>

4. *Resonance*

Quality:

Prospect

>

Up-Close / Interpretive

>

Immersive / Unstructured

>

Renewed Understanding

The ultimate goal of the four-stage experiential sequences is not just to reveal the site's hydrological process, but to resonate with social, cultural, emotional and intellectual values of all potential user group. Therefore, within each sequences, it is aimed to provide different levels, types and intensity of experiences and interactions. This thesis proposes that these experiences can be planned and measured in three ways as stated in the key research and design goal in Chapter 1: 1. Multi-sensory experiences, 2. Spatial experiences, 3. Temporal experiences

Experiential Diagrams: Visualizing Experiences

Although the four-stage sequences provide an important base for the experiential design, individual experiences in the Montlake site will not always follow the linear sequences as the site has numerous entry points and paths for people to enter and move around. In fact, this unstructured movement around the site is one of the greatest assets of the Montlake site. As many people utilizing diverse means of transportation converge and diverge to and from the site, people will relate to the site's dynamics in their own terms and their own pace. The design must provide opportunities to facilitate this process. These opportunities can be defined as below.

Experiential Opportunities

1. Access points and pathways that have the maximum contact opportunities with the natural and design elements of the site.
2. Clear evidences of the stormwater that inform people about the presence of the stormwater with multi-sensory cues
3. A few minimally disruptive designed elements that can enhance the breadth of experiential opportunities

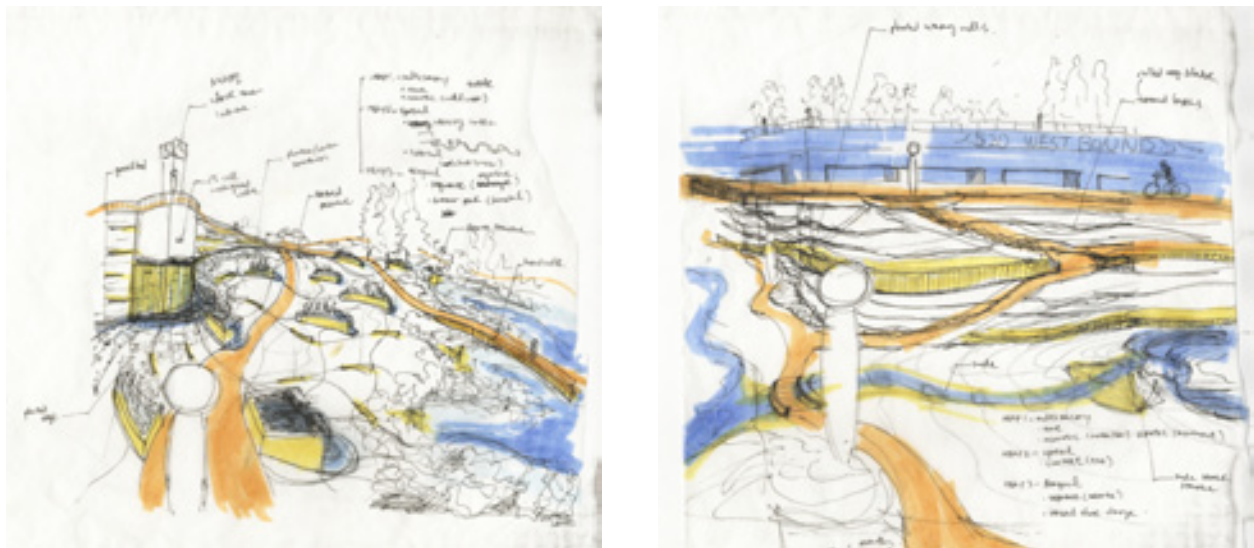


Figure 6.27) Initial Study of Visualization

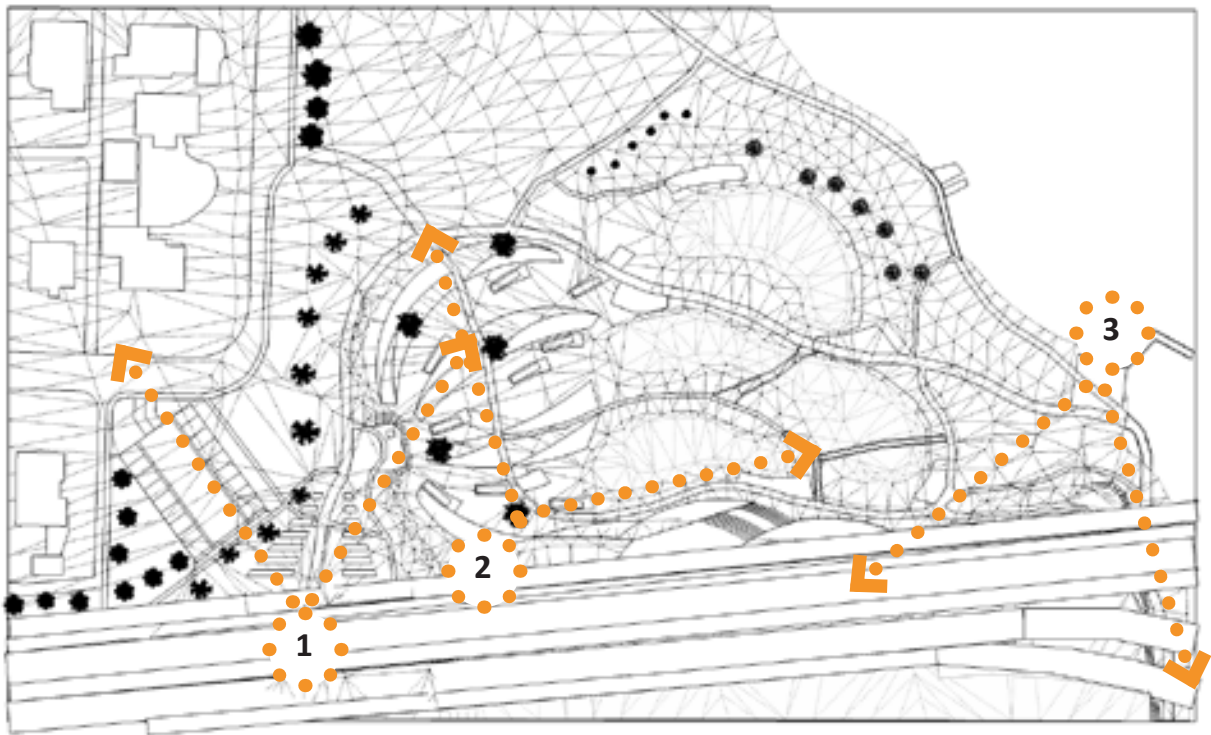


Figure 6.28) Perspective Viewing Location

Perspective A: Awareness / Prospect

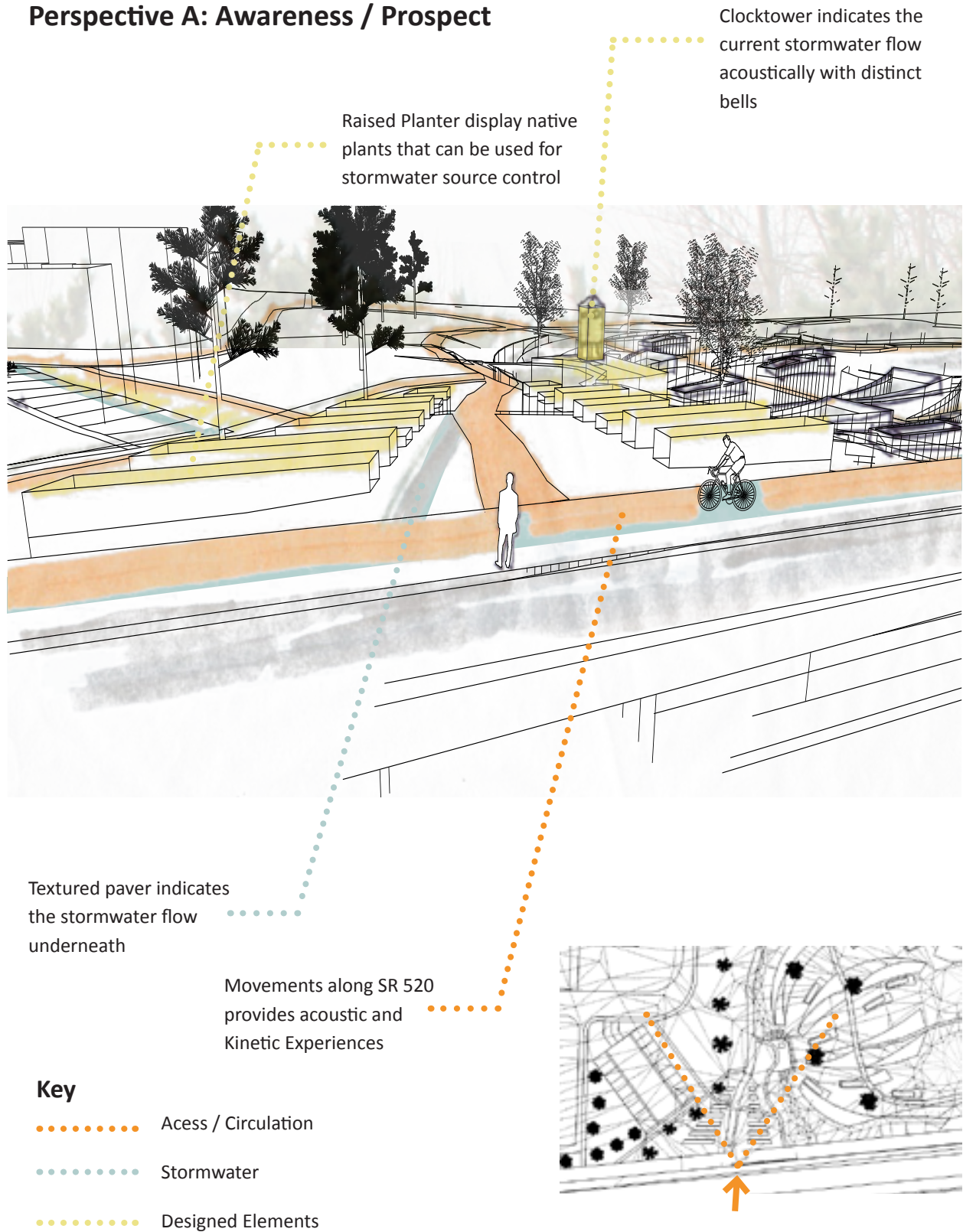


Figure 6.29) Perspective A: Awareness / Prospect Diagram

Perspective B: Appreciation / Interpretive

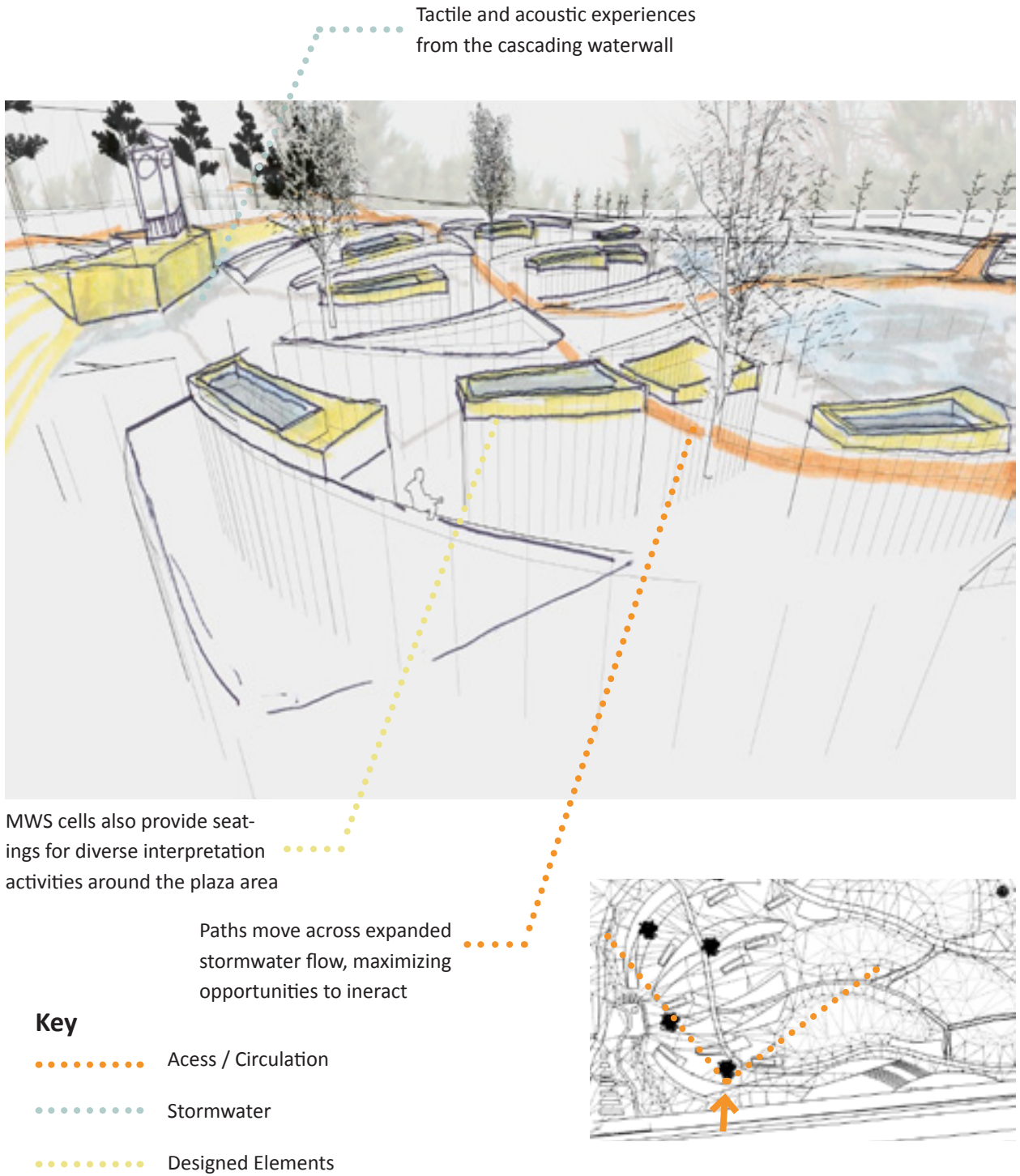


Figure 6.30) Perspective B: Appreciation / Interpretive Diagram

Perspective C: Direct Experience / Immersive

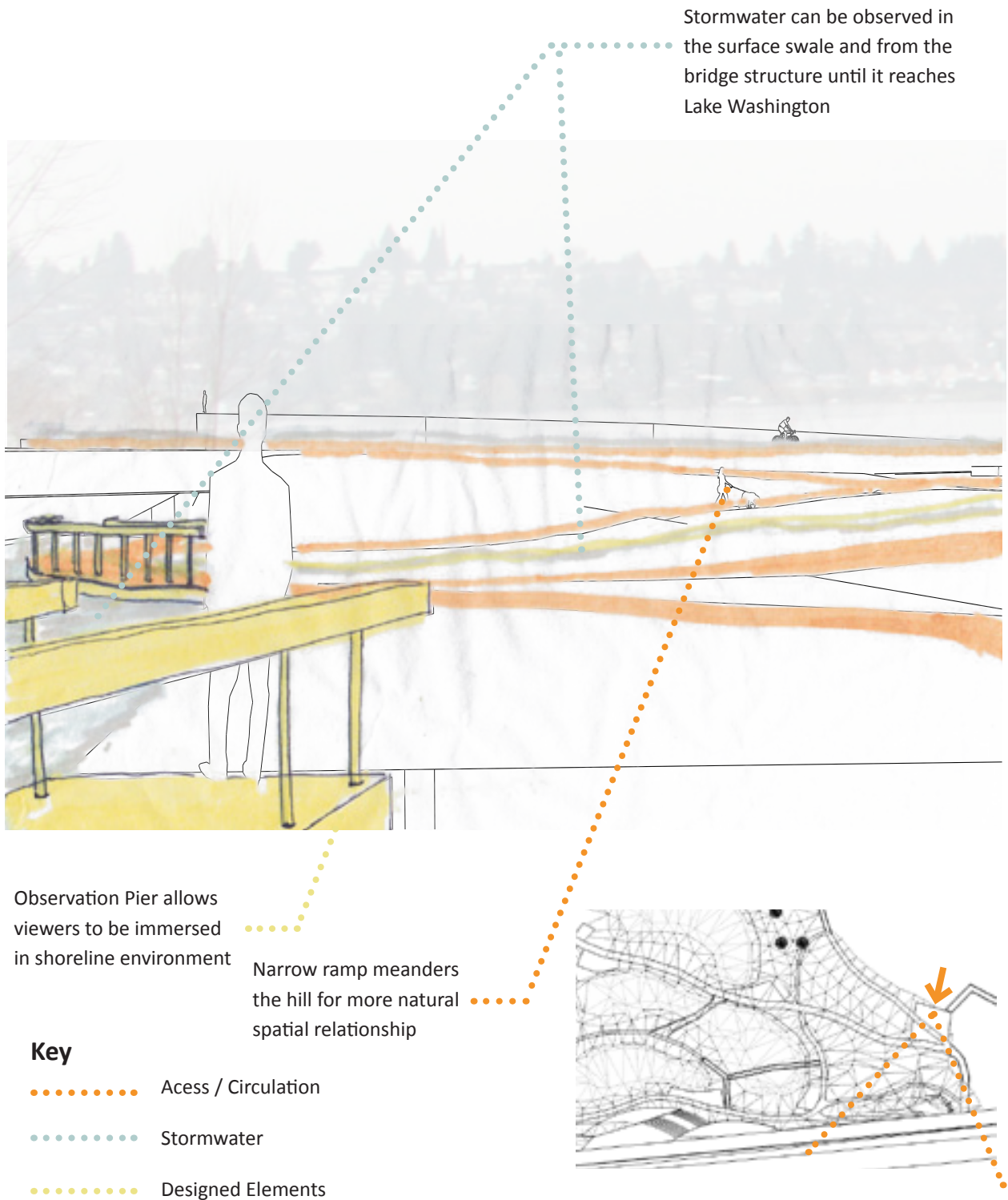


Figure 6.31) Perspective C: Direct Experience / Immersive Diagram

Chapter 7: Critique and Conclusion

The process of creating this thesis developed differently than expected. I came to be interested in a question that had more social breadth and depth than my initial thesis topic. My initial topic for the thesis was evaluation of natural stormwater technologies and their monitoring results, which would have been much more technical than this thesis. One reason why I changed the topic was my lack of experiences in technical research methods, but also a realization that numerical performance alone could not satisfy all requirements of successful urban stormwater facilities. Looking back on how the thesis has progressed and evolved, I feel that the entire project was a process to define what it takes to design a successful urban stormwater facility. I decided to focus on the topic of human experience because I believe that human experience is the area that is most neglected in the current discussion of green infrastructure. At the same time, I cannot ignore the other considerations urban stormwater facilities, such as form and functions??. These other considerations return to my original interest in natural stormwater treatment technologies.

I attempted to formulate a balanced approach that combines aesthetics, functions and experiences. I wanted to create a frame work that can be generally applied to all urban stormwater facilities as well as the specific site design. The broad research area and scope of the thesis limited my ability to fully elaborate each issues as well as develop a detailed site design. However, it was personally a very fulfilling experience to think and learn about wide range of subjects that I normally am not able to incorporate into my design process.

In order to complete a full design thesis, I will critique my own design by reflecting on the key research and design goals that were proposed at the beginning of this thesis.

7.1 Critiquing The Design: Did I achieve key research and design goals?

1. Re-establish the connection between everyday activities and water cycle

It was my intention to provide the most opportunity for people to come in contact with the proposed design within the routine of their daily life cycle. It was the first and foremost important

thing to achieve in order to initiate any meaningful experiences or contacts through any design efforts.

I learned from the site analysis that different types of pedestrian and bike circulation need to be accommodated around the site and each circulation will require a different type of access point to the site, which also need to be aligned with the functions within the site. Therefore, I resolved the issue of access by anticipating different uses around the site, which eventually increased the chances of having more people to experience what is being designed for the site.

2. Reveal processes in multiple temporal and spatial scales

I tried to embed different temporal and spatial scales in every design decisions that I made. I often found the main problem to be the visualization of different time or spaces on fixed pages. I tried to solve this issue by thinking about the movement on the site. It was one of the site's characteristic to be located next to the major circulation corridor, which means there will be a constant source of movements in various forms. The design will have to be as appealing to the person who is biking along the elevated path as to person walking through the site. Movements also can be a spatial and temporal sequences being experienced by a person. I tried to include sequential experiences as a part of the design. I attempted to capture and depict these dynamic experiences, and I would like to continue this experimentation with the representational techniques in the future.

3. Expose people to different stages of water cycle through multi-sensory experiences

It was not possible to impose linear sequential experiences as in Waterworks Garden due to the site's location within the urban environments. As mentioned earlier, it was more important to keep the all the possible accesses into the site open to facilitate circulations around the site. Therefore, the experiential sequences were not based on the organization of spaces, but based on individual interpretive experiences which can happen on one site visit or multiple passing through. Opportunity for multi-sensory experiences was also designed in similarly unstructured manner. I thought overly designed objects can get old quickly, especially when it is not relevant to the context of the site's key processes, such as stormwater flow. I hoped that primarily emphasizing the flow of the stormwater and making its presence clear will help people to engage in a

'direct experience' rather than a forced one. However, there is one thing I really hope to explore, but could not include in the thesis. I had prepared different planting strategies which can accommodate functional requirements of the stormwater as well as provide dynamic experiential qualities, but I did not have a chance to elaborate it into the design within the given time frame.

7.2 Next Steps and Conclusion

I believe the process of making hybrid form for stormwater infrastructure was successful. The design proposed in here would not only support hydrologic functions, but would also align with interpretive opportunities following the water cycle as well as programmatic uses between the three zones.

There were some difficulties during the process. Sometimes, it was very difficult to settle on a design as the scope of research kept expanding. In all three research areas, I was learning so much new information and was curious to continue learning. However, that is what made this thesis relevant and valuable in the end. It was an indispensable learning experience to be able to back up my own design with concrete research and knowledge.

There are a few things I would like to build upon from this thesis in the future. First, I propose studying other cases that share similar interests in experiential qualities. When I picked my cases, I was only concerned about its location and function as a stormwater facility. However, I think it would have been more helpful to pick cases that specifically dealt with interpretive opportunity of various natural and cultural processes.

Second, I will include a research on how people experience the site differently by conducting a survey or personal interviews. The question of subjectivity and variability of experiences still remains and I believe a research on this topic will allow me to refine design options to even finer scales.

I am glad that I was able to finish the thesis with these questions as they will allow me to explore even further to design a functional infrastructure that can also truly resonate with human heart.

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