Options for Stormwater Management at Chancellor Blvd and NW Marine Drive

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Options for Stormwater Management

Suggested infrastructure interventions for stormwater management at the intersection of Chancellor Blvd. and NW Marine Drive, UBC in a 100-year storm event

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Cover Images: UBC's University Boulevard Water Feature and Google Earth image of the Point Grey campus.

Executive Summary

The University of British Columbia's (UBC) Integrated Stormwater Management Plan (2014) has identified risks of significant flooding at multiple key points on campus in the event of a 100-year storm. In addition to protecting its own assets, UBC's major concern is to ensure that stormwater runoff will not cause damage or erosion to adjacent land and infrastructure. In particular, the intersection of Chancellor Boulevard and Northwest Marine Drive has been identified as an area of high interest due to the close proximity to the University Endowment Lands and Metro Vancouver's Pacific Spirit Park. The location of the intersection and its proximity to the vulnerable cliffs, as well as the nature of UBC's aquifers are the key challenges of this report. However, other challenges such as cost effectiveness, practicality, sustainability, feasibility, and policy compliance are also considered and collectively form the objectives of this report.

The intent of this report is to provide solutions for possible infrastructure interventions at the intersection of Chancellor Boulevard and Northwest Marine Drive in innovative and responsible ways that adhere to the values of UBC. As part of preparing this report, a number of technical studies and planning documents have been reviewed and considered, which are referenced in Appendix C at the end of this report. After careful review of the available resources and a thorough analysis of various stormwater management options, the following strategies emerged as the recommended options for the intersection of Chancellor Boulevard and Northwest Marine Drive.

Recommended Options

1. A floodable basement at the Mary Bollert Hall that can be utilized as a stormwater detention facility as shown in Section 2.3.
2. A combination of tree trenches and gravel pits to retain and channel stormwater in several key locations shown in Section 2.4.

In addition, this report recognizes the need for a general focus of stormwater management strategies on campus, outside of specific problem areas. Instead, the emphasis should be on using multiple stormwater management initiatives in various locations across campus such that stormwater runoff can be conjointly managed. The following suggestions are included as a part of this report's final recommendation:

- Review and revamp policies to ensure future development meet more stringent construction codes for stormwater handling.
- Wherever possible, detain stormwater before runoff congregates into main stormwater infrastructure.
- Investigate possible ways to work with other parties (such as student body, UBC Botany Department, external consultants, and government bodies) to create innovative solutions and establish opportunities for collaboration.

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Section 1 - Context and Scope

1.1 Introduction

The University of British Columbia's (UBC) unique geography, peninsular topography, and climate, combined with increasing development, create a set of circumstances that could make UBC's infrastructure and population vulnerable to serious damage in severe storm events. To complicate matters, stormwater from UBC flows through adjacent property, Metro Vancouver's Pacific Spirit Park and the Province's University Endowment Lands (UEL), whose land and infrastructure is also at risk in these events, due to stormwater runoff from UBC land. UBC wants to protect its assets, and prevent damage to neighbouring lands in the case of a 100-year storm event, particularly at the intersection of Chancellor Boulevard and Northwest (NW) Marine Drive, whose proximity to the cliffs of the peninsula make it very vulnerable. The purpose of this report is to evaluate a range of stormwater management options and to help determine potential infrastructure interventions in this 100-year storm scenario, at this intersection that is particularly susceptible to flooding. Additionally, UBC is focused on developing strategies, best practices, and projects that promote sustainability and innovation.

1.1.1 Report Goals

The goal of this report is to analyze various stormwater management options and to suggest potential infrastructure interventions that will adequately handle the surplus water flow at the intersection of Chancellor Boulevard and NW Marine Drive in the event of a 100-year storm. The suggested options in this report are intended to mitigate potential risks of flood damage to land and properties that are adjacent to the intersection. In addition, this report aims to offer supplementary recommendations and examples of existing stormwater management options that could be implemented in other areas of campus.

1.1.2 Report Objectives

The most suitable options for the intersection of Chancellor Boulevard and NW Marine Drive were chosen according to the objectives outlined below. These objectives specify the priorities of the selection process and also help define the benefits of each potential option. Ultimately, these objectives help align the goals and the outcome of this report. The objectives of this report are to suggest stormwater management options based on the following criteria:

Capacity — Defined as the ability to handle 1,000 cubic meters of stormwater in the event of a 100-year storm.

Sustainability — Defined as having the lowest maintenance requirements, the smallest impact on the environment and surroundings, and having the highest likelihood to remain in place until the occurrence of a 100-year storm event.

Practicality — Defined as having the lowest maintenance requirements, the smallest impact on the environment and surroundings, and having the highest likelihood to remain in place until the occurrence of a 100-year storm event.

Cost effectiveness — Defined as the ability to produce the desired outcome with minimal financial expenditure, both in capital investment and ongoing costs.

Feasibility — Defined as the ability to accomplish the desired outcome with minimal technical and geographical challenges, policy hurdles, and negative impact on campus activity.

Compliancy — Defined as meeting the policy requirements and planning framework that are pertinent to the goals of this report. These include, but are not limited to the UBC Campus Plan and Integrated Stormwater Management Plan.

1.2 Context

This report is defined by certain aspects of the geography of UBC, stormwater systems, technical requirements and infrastructure, UBC policies and development, and time and cost implications of future stormwater projects.

1.2.1 Geography

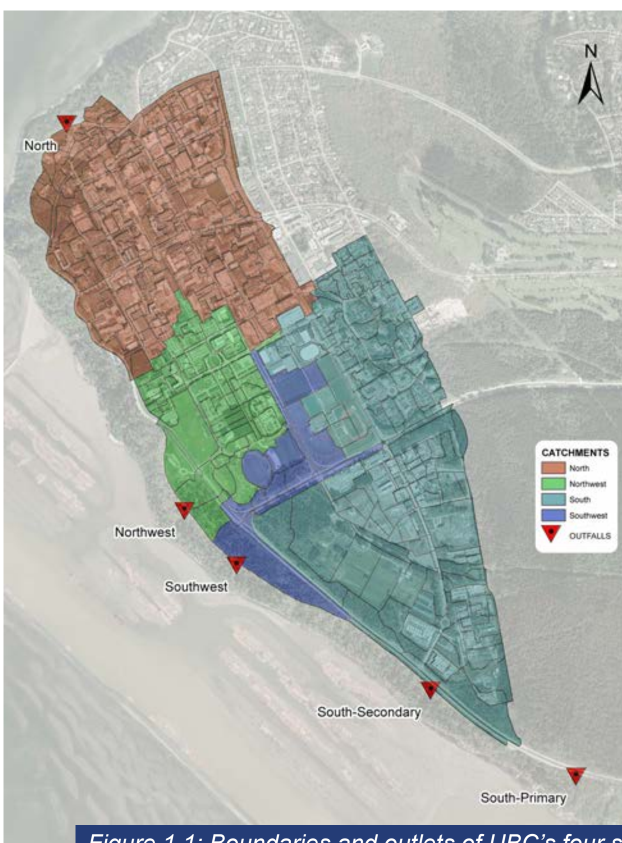


Figure 1.1: Boundaries and outlets of UBC's four stormwater catchments (GeoAdvice Engineering Inc., 2012).

UBC's Point Grey campus is located on the end of a peninsula, surrounded by cliffs, and bordered by Metro Vancouver's Pacific Spirit Park and the UEL. The topography of campus and its stormwater infrastructure create four distinct stormwater catchments, each with its own outlet, through Pacific Spirit Park, into the Strait of Georgia (Figure 1.1). This report examines specifically at how to prevent surface flooding at the intersection of Chancellor Boulevard and NW Marine Drive from reaching the edge of UBC property, flowing north into Pacific Spirit Park and cause major erosion and potential damage to the cliffs, roads and other infrastructure.

When it rains, water falling into each of these catchment areas flows through pipes to the outlet points in each catchment. The intersection of Chancellor Boulevard and

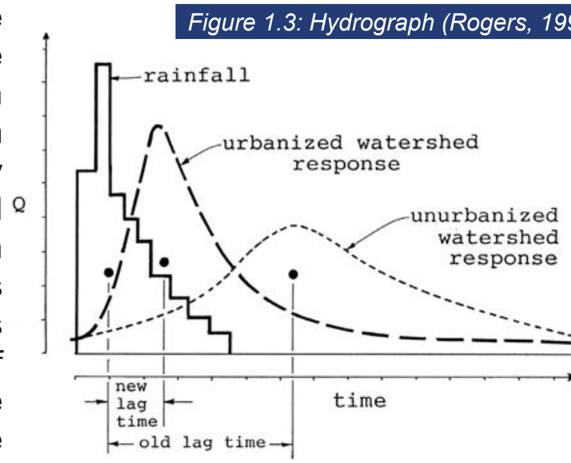
NW Marine Drive is located in the North Catchment, where stormwater drains to the spiral drain that is located in the northwest corner of campus. The spiral drain was built in 1938 to prevent stormwater rushing over the adjacent cliffs and causing erosion. It should be noted that the spiral drain is nearing the end of its productive life and surpasses its capacity even in storm events smaller than a 100-year event (University of British Columbia, 2014).

Figure 1.2 shows the building footprints and dedicated open spaces on UBC campus. The North Catchment of UBC is approximately 67% impervious surfaces, where water does not penetrate through to the aquifer, but rather creates runoff that must be handled in stormwater pipes (GeoAdvice Engineering Inc., 2012). The increasing development on UBC campus will lead to increased impervious surfaces.

Figure 1.2: Open spaces on UBC Campus (University of British Columbia, 2010).

1.2.2 Stormwater

Figure 1.3: Hydrograph (Rogers, 1997).



The hydrograph in Figure 1.3 shows the rate of water flow after a rainfall, where Q is volume of flow. The peak discharge time, which in this case represents when the maximum volume of water is trying to make its way through the North Catchment to the spiral drain, arrives faster and more intensely in urban environments with greater impervious surfaces. The increase in impervious surfaces in urban areas means more runoff and less infiltration, so the hydrograph curve is steeper, higher, and quicker, as more water enters the stormwater system faster. Stormwater management and infrastructure interventions, such as will be proposed in this report, are attempts to delay and decrease the peak discharge to the point where it can be adequately handled by the system. Many small changes, such as policies mandating stormwater management systems on new developments, can accumulate and contribute to reducing to the peak discharge rate (GeoAdvice Engineering Inc., 2013).

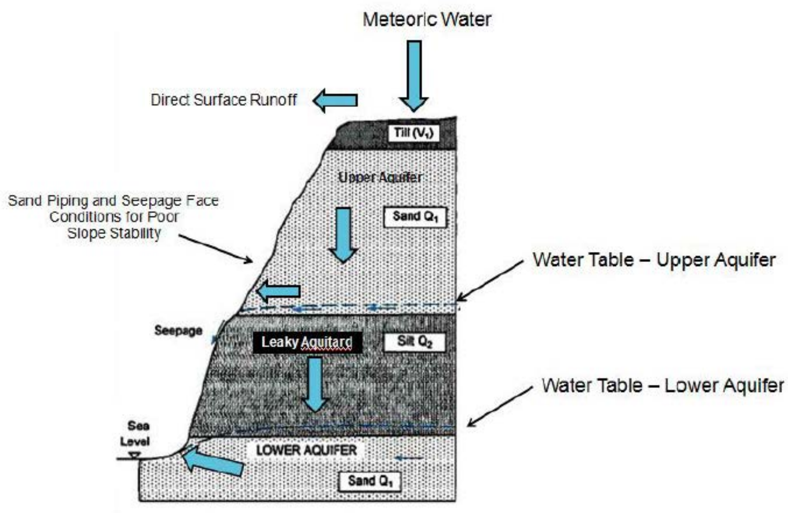


Figure 1.4: UBC's soil layers and aquifers (AECOM, 2013).

UBC campus is covered by approximately half a metre of topsoil over 30 metres of glacial till, as seen in Figure 1.4. The soil unit below, composed of glacial deposits known as the Quadra Sands, extends down to sea level and contains the upper and a lower aquifer. Groundwater seeping out of the upper aquifer, roughly 18 metres above sea level, can lead to erosion of the cliff face (AECOM, 2013).

1.2.3 Technical

Figure 1.5: Water mains and manholes near the intersection of NW Marine Drive and Chancellor Blvd and the spiral drain(GeoAdvice Engineering Inc.,

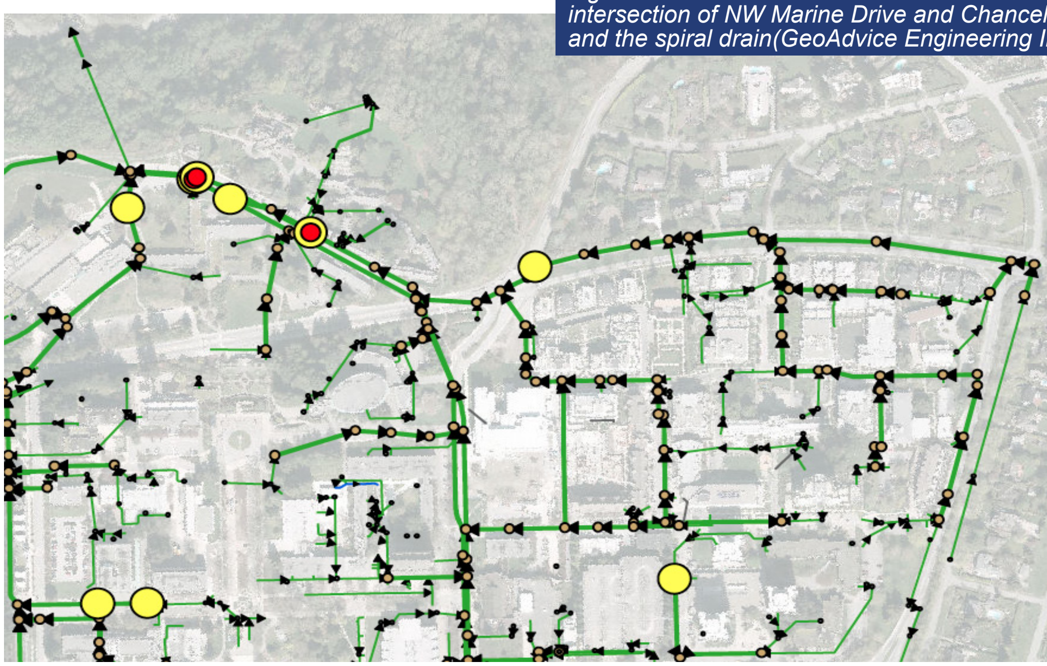


Figure 1.5 shows the extent and directionality of the stormwater pipe network in the North Catchment. The specific intersection, Chancellor Boulevard and NW Marine Drive, has been identified with a high risk of flooding in a 100-year storm. The surface overflow from the identified node is estimated to be 1,016 cubic meters, where the stormwater water flows primarily from the UBC neighbourhood to the east (GeoAdvice Engineering Inc., 2012). As shown in Figure 1.5, the primary area in which the stormwater originates from is this residential neighbourhood with very limited open space to implement stormwater management options. The minimal area that is available presents one of the key challenges of this report.

1.2.4 Future Development

Currently the North Catchment is approximately 67% impervious surface, and one model suggests that in this catchment there could be around 884 metres per hectare of runoff from these impervious surfaces (GeoAdvice Engineering Inc., 2012). The required floor space on UBC campus was expected to grow by about 436,620 gross square metres between 2008 and 2030, and UBC policies promote infill on existing sites wherever possible. When investigating possible synergies with future development, this report considered only the facilities identified in the Campus Plan as scheduled to be replaced by 2030 or shortly thereafter (University of British Columbia, 2010).

1.2.5 Time and Cost Limitations

A 100-year flood has the statistical chance of occurring once every hundred years, however this gives no indication of if or when it may occur. This provides an incentive to install any infrastructure interventions as soon as possible, in case the event should occur in the immediate future. The counter-argument to this is that spending large amounts of money on an event that may not happen in the foreseeable future, or at all, is a poor appropriation of funds. For the purposes of this report, it is assumed that UBC recognizes the financial and physical risk posed by a 100-year storm event, and is prepared to fund any infrastructure interventions to a limited degree, proportional to the observable risk. It is also assumed that UBC recognizes that climate change is linked to an increase in severe storm events. However, this report assumes that UBC will prefer a cost-effective strategy, with more expensive options being considered where they also speak to other aspects of UBC's goals and visions, such as providing learning opportunities. This report also assumes that a reasonable timeline for the installation of any major infrastructure interventions would be in the next five to fifteen years, while smaller interventions that could provide minor relief to the system in large storm events should be implemented as soon as possible.

1.3 Report Methodology

The following methodology was employed in order to propose and refine stormwater management solutions suitable for the intersection of Chancellor Boulevard and NW Marine Drive. This methodology aims to ensure that the goals and objectives of this report are met through a clear and fair selection process.

1.3.1 Literature Review

A number of technical, policy, and planning reports have been extensively reviewed in order to identify any constraints relevant to the intersection of Chancellor Boulevard and NW Marine Drive and UBC campus. The findings of these reports are discussed in Section 2.1 of this report.

1.3.2 Evaluation

Based on the literature review and an extensive mind mapping exercise (Appendix A), an evaluation matrix was constructed in order to objectively evaluate stormwater management strategies for the intersection of Chancellor Boulevard and NW Marine Drive. The evaluation was based on each strategy's ability to meet the objectives of this report. The evaluation matrix and a detailed explanation can be found in Section 2.2 of this report.order to identify any constraints relevant to the intersection of Chancellor Boulevard and NW Marine Drive and UBC campus. The findings of these reports are discussed in Section 2.1 of this report.

1.3.3 SWOT Analysis

The top strategies from the evaluation matrix have been further analyzed with a SWOT analysis (Strengths, Weaknesses, Opportunities, and Threats). This tool aims to identify how to best utilize the top strategies as well as reveal any barriers to achieving the objectives of this report. The SWOT analyses can be found in Sections 2.3.2 and 2.4.2 of this report.

1.3.4 Implementation

The top strategies in the SWOT analysis undergo a conceptual design stage to investigate their integration at the intersection of Chancellor Boulevard and NW Marine Drive. Potential areas in which the strategy can be implemented are identified.

1.3.5 Additional Recommendations

The additional recommendations will include any stormwater management options that have been identified as effective strategies but cannot be suitably implemented at the intersection of Chancellor Boulevard and NW Marine Drive. These recommended options are highlighted in Section 3 of this report due to their opportunity of being able to be implemented in other areas of the UBC campus.

Section 2 - Stormwater Management Options

2.1 Literature Review

2.1.1 UBC Campus Plan

The UBC Campus Plan focuses on five strategies, which provide insight to the types of interventions that the University might be open to:

- Create a sustainable campus
- Provide a campus for world class teaching, learning, and research
- Nurture a more vibrant and interesting campus for UBC's community of scholars
- Rediscover UBC's sense of place and natural west coast beauty
- Ensure a well-connected and accessible campus

The relevant policies from the Campus Plan (Part 2) considered relevant to this report are the following:

Policy 2:	"UBC will use its land resource sustainably and develop a denser, compact form through infill and taller buildings to avoid sprawl, improve walkability, strengthen social connections and reserve land for open space and future academic needs" (p. 12).
Policy 39:	"To the extent that the unique hydrogeology and cliff-erosion concerns of UBC's Vancouver Campus allow, stormwater management strategies will incorporate a natural systems approach in managing runoff volume to mitigate downstream impacts." (p. 40).

The Campus Plan also provides the list of facilities to be replaced by 2030, and those recommended to be replaced shortly after. This list provided direction to potential cost-sharing interventions. This list can be found in Appendix B.

2.1.2 UBC's Draft Integrated Stormwater Management Plan

The Integrated Stormwater Management Plan (ISMP), still in a final draft form at this time, provided background information and direction for this report. The ISMP highlighted the main components of stormwater management on campus, the key challenges, and provided guidelines for the forward-thinking direction UBC would like to take stormwater management in the future. The ISMP was informed greatly by the technical background studies. The objectives of the ISMP are as follows (p. 3):

- Protection from flooding and prevention of overland flooding across the cliffs
- Provide a campus for world class teaching, learning, and research

- Protect the campus environmental values and minimize the impact of campus discharge on neighbouring watercourses
- Improve the quality of the stormwater that leaves the campus
- Incorporate the natural hydrologic cycle into the stormwater system

These objectives were incorporated into the methodology of this report. Additionally, the ISMP provided the important scoping policy that "infiltration is not to be used within 300m of the top of the cliffs" (University of British Columbia, 2014, p. 5).

2.1.3 Technical Background Studies

UBC has already completed several technical studies that were used to inform this report. This report does not look to re-do any of the thorough technical studies that have already been completed, but to investigate the possibility of innovative and new ideas in line with these studies. The following background studies were consulted for this report:

- Hydrogeologic Stormwater Management Strategy - Phase 1
- UBC Stormwater Collection System - Technical Memo 2
- UBC's Stormwater Model System Analysis, Detention Analysis and System Optimization
- Best Management Practices for Stormwater Systems
- Stormwater Quality at UBC

2.1.4 Other Sources

An annotated list of all additional sources consulted for this report can be found in Appendix C.

2.2 Evaluation Matrix

An evaluation matrix, Figure 2.1 on the following page, was devised to assess the potential stormwater management options that could be implemented at the intersection of Chancellor Boulevard and NW Marine Drive. These options are grouped into three separate strategies (Channelling, Detention, and Retention), which are defined as follows:

Channelling	Channelling strategies include options that are implemented primarily to control or divert the flow of stormwater.
Detention	Detention strategies include options that are able to hold and release a volume of stormwater at a specific time.
Retention	Retention strategies include passive options that retain a volume of stormwater and emulate a natural hydrological cycle.

	OPTIONS	OBJECTIVES					
		Capacity	Cost Effective	Practical	Sustainable	UBC Policies	Feasible
Channelling	Increase Pipe Pressure	H	M	L	M	M	M
	Increase Pipe Diameter	H	L	L	L	L	L
	Burried Pipe in Trail Gully	H	L	L	L	M	M
	Evestroughs/Gutters to Divert Flow	L	M	H	H	H	H
	Tree Trenches	M	H	H	H	H	H
Detention	Large Detention Tank	H	H	L	H	H	H
	Muti-small Detention Tanks/Dry Well	H	M	L	M	H	H
	Depressed Land (Rec Facility)	M	M	H	H	H	H
	Floodable Basement	H	H	H	H	H	H
Retention	Rain Barrels	M	H	H	H	H	H
	Blue Roofs and Green Roofs	L	M	H	H	H	H
	Dry Ponds	M	M	H	M	M	L
	Gravel Pits	M	M	H	H	H	H
	Bioswales / Wetland	H	M	L	L	M	L
	Planters / Bumpouts / Rain Gardens	L	M	H	M	H	H
	Aquifer Storage Recovery	H	L	H	H	H	L
	Porous Asphalt	L	M	H	M	H	H
Others	UBC Policy Updates	L	H	H	H	H	H
	Do Nothing	L	L	L	H	L	L
	Replace Spiral Drain	H	L	H	H	H	L

Each stormwater management option is evaluated against its ability to fulfill the objectives of this report and is then given a high, medium, or low rating based on this evaluation. The criteria of the evaluation are based on several critical questions where a high (H) rated option fully satisfies the questions, a medium (M) rated option partially satisfies the questions, and a low (L) rated option does not satisfy the questions. The evaluation criteria is as outlined below:

Capacity	Is the option able to adequately handle the required volume and flow of a 100-year storm event?
Sustainability	Does the option have the opportunity to be constructed in conjunction with other known or potential projects? Does the option require frequent and ongoing maintenance?
Practicality	Does the option have the opportunity to be used for a different purpose (multi-purpose) until required to handle stormwater?
Cost effectiveness	Are the construction, capital, and maintenance costs of the option reasonable?
Feasibility	Are there any technical and policy barriers to implementing the option? Would the construction of the option interfere with campus life and UBC operations?
Compliancy	Does the option adhere to all policies pertinent to the intersection? (i.e. UBC campus plan, Cliff Erosion Mitigation Plan, ISMP, etc.) Does the option go above and beyond existing policies?

Subsequently, the highest scoring option in each strategy (Channelling, Detention, and Retention) underwent a SWOT analysis. The selected options, along with the chosen location, will be discussed in detail in Sections 2.3 and 2.4 of this report below.

2.3 Option 1: Detention

2.3.1 Option 1: Description

From the evaluation matrix in Section 2.2, underground storage/flooded basement has the highest score for the Detention strategy. This solution can provide a large storage capacity that is able to temporarily contain a volume of stormwater, which can be drained at a predetermined rate after the storm has subsided. This option differs from a large detention tank, because, when not being used to detain stormwater, it has the opportunity to be used for other applications. The implementation of this option can be combined with the planned infill of the current Mary Bollert Hall site and would have a low impact on campus activity. An example of this option is depicted on the follow page.

2.3.2 Option 1: SWOT Analysis

Strengths	Weaknesses
• Suitable for large detention volumes • Can be used as parking/storage when not flooded • Good peak rate control	• Poor water quality treatment and sediment removal performance • Not in the perfect location, must direct the flow to the building • High cost • Must be drained post flooding
Opportunities	**Threats**
• Innovative ways to direct flow from intersection, including art pieces and green infrastructure	• Potential damage to building and contents • UBC electing not to infill the Mary Bollert Hall site in a reasonable time frame

2.3.3 Option 1: Implementation

A possible location to implement this option is at the Mary Bollert Hall site, adjacent to the intersection of Chancellor Boulevard and NW Marine Drive, as shown in the schematic on the page below. The Mary Bollert Hall is identified in the UBC Campus Plan as a future infill site post year 2030 (University of British Columbia, 2010). Due to the close proximity to the intersection of interest and the already existing plans for replacement in the future, the Mary Bollert Hall is a strong candidate to be implemented with the underground storage option. However, some channelling would have to be constructed in order to direct the overflowing stormwater into the building from the intersection of interest or from the nearby spiral drain.

2.3.4 Option 1: Schematics

Figure 2.2: Mary Bottert Hall, UBC (Google Earth).

Figure 2.3: Design for a floodable underground parking facility in Rotterdam, the Netherlands (National Mall Coalition, 2015).

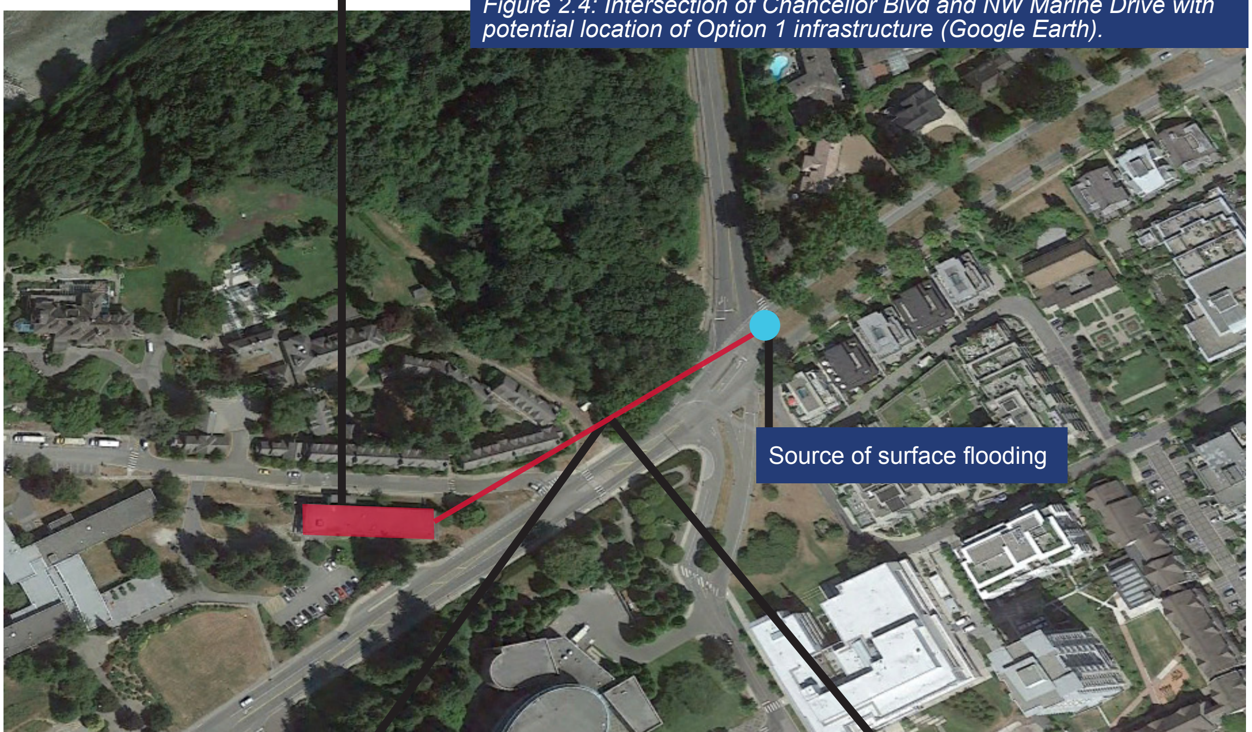


Figure 2.4: Intersection of Chancellor Blvd and NW Marine Drive with potential location of Option 1 infrastructure (Google Earth).

Figure 2.5: Calgary artwork Outflow *channelling water to the Bow River from stormwater system (Wood, 2015).*

Figure 2.6: Toronto's Sherbourne Common stormwater channelling system (GBSS, 2014).

2.4 Option 2: Retention and Channelling

2.4.1 Option 2: Description

In this option, a combination of tree trenches and gravel pits can provide temporary retention of stormwater and can slowly release accumulated runoff at a predetermined rate until empty. The basis of this option is that a series of tree trenches can retain and channel stormwater until it reaches capacity, where a perforated pipe can then channel excess stormwater into a gravel pit layered with a non-permeable membrane. The gravel pit can control the discharge rate as well as promote filtration prior to channelling stormwater back into the drainage system. The images on the page below are examples of tree trenches and gravel pits.

2.4.2 Option 2: SWOT Analysis

Strengths	**Weaknesses**
• Channels water flow • Gravel removes sediment • Minimal maintenance	• High area and volume demand (~1.5x water volume)
Opportunities	**Threats**
• High urban design potential at UBC entrance • Can be installed when the intersection is redesigned	• May require cooperation from Metro Vancouver and Province

2.4.3 Option 2: Implementation

The red lines in the schematic found on the page below correspond to the potential locations for tree trenches at the intersection. As the intersection itself may be redesigned in the near future, additional places for tree trenches could be added at that time. Due to the enhanced volume required for gravel pits, it is likely that several of these locations would have to be used. As was the case for Option 1, there could be small runoff channelling requirements to ensure the runoff reaches the tree trenches. Some examples of innovative channelling infrastructure can be found below in Section 3.

2.4.4 Option 2: Schematics

Figure 2.7: Intersection of Chancellor Blvd and NW Marine Drive with potential location of Option 2 infrastructure (Google Earth).

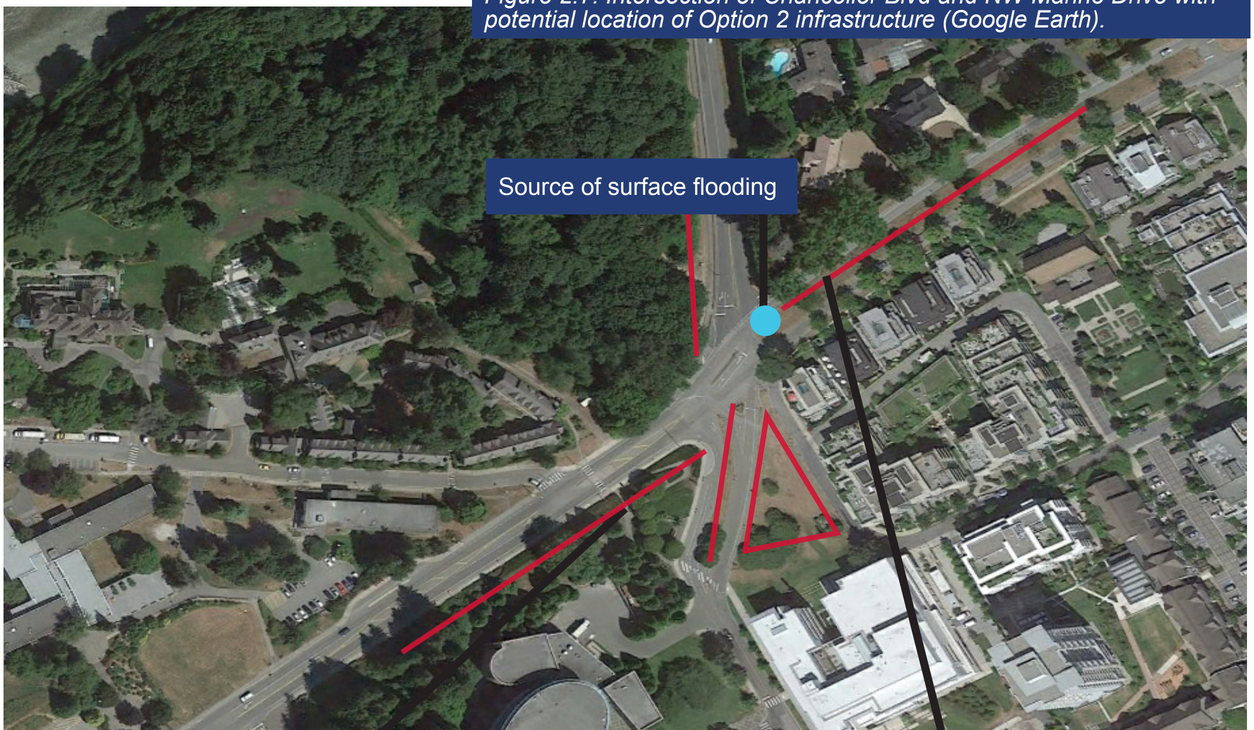


Figure 2.8: Design for a tree trench system in Philadelphia (Philadelphia Water, 2016).

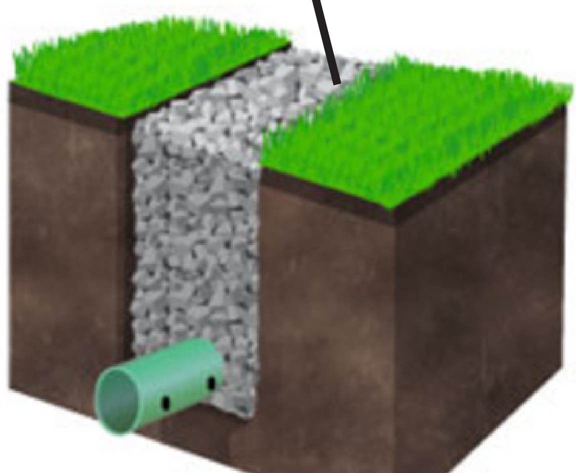


Figure 2.9: Design for a French Drain system, inspiration for the gravel pit with perforated pipe for this option (Lawn and Pool, 2016).

Section 3 - Additional Recommendations

In the process of analyzing the most suitable method to handle the required volume in a 100-year storm event, several other stormwater management options have been considered worthy of mention. Though these options may not be able to handle the total volume or flow of the 100-year storm event if implemented individually, they can be combined with other stormwater management options to collectively handle stormwater in all areas on campus. By decreasing the stormwater runoff at upstream locations, the pressures on the stormwater system at vulnerable locations such as the intersection of NW Marine Drive and Chancellor Boulevard will be lessened. This section will provide examples of such additional recommendations.

3.1 Green Infrastructure Options

Smaller interventions, such as porous asphalt, and small green infrastructure interventions such as planters, rain gardens, and green roofs, can be combined to be very effective stormwater management techniques. Figure 14 demonstrates how they may all be used in the same location, and each contributes to slow the flow of stormwater into the system.

Figure 3.1: A vision of many small green infrastructure interventions (Philadelphia Water, 2016).

3.1.1 Porous Asphalt

Porous asphalt is considered a best stormwater management practice as it increases the total permeable surface and promotes infiltration (UBC Campus and Community Planning). When used in place of standard impervious paving material, it can reduce peak stormwater velocity and volume. However, the use of porous asphalt should be limited to pedestrian walkways due to its weaker material properties and high maintenance requirements. Porous asphalt used on major roadways will become packed with dirt and dust unless vacuumed or swept frequently, reducing its efficiency as a stormwater management tool (National Ready Mixed Concrete Association, 2011). Nonetheless, porous asphalt is an excellent option that should be extensively used in the interior of campus in order to promote infiltration and achieve the greatest impact in stormwater management.

Figure 3.2: Demonstrated difference between standard asphalt and porous asphalt (RCL Consulting Ltd., 2004).

3.1.2 Rain Barrels and Eavestroughs

The combined use of tailored eavestroughs, downspouts, planters, rain gardens and rain barrels can slow down the flow of rainwater to the stormwater system. Downspouts can be altered to incorporate planters, take a zigzag route, and direct water into rain barrels to delay and spread out the flow into pipes, as seen in Figure 3.3. These designs can be aesthetic and also be built into other channelling infrastructure or rain gardens, however, their capacity is not sufficient to handle severe storm events.

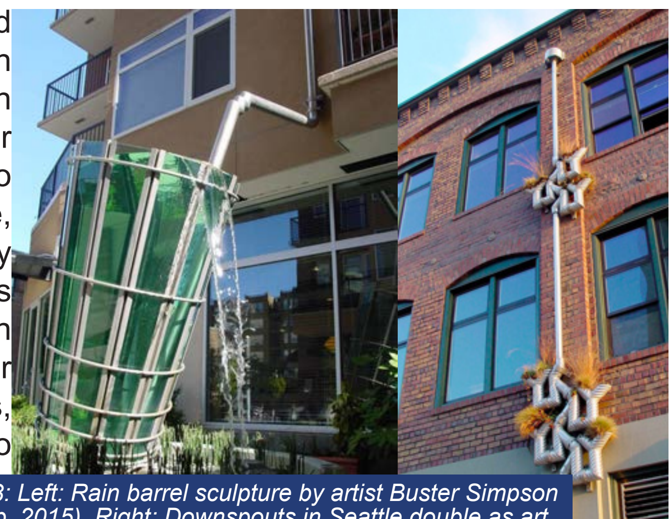


Figure 3.3: Left: Rain barrel sculpture by artist Buster Simpson (IBI Group, 2015), Right: Downspouts in Seattle double as art pieces and functional parts of the stormwater management system (Stafford & Stafford, 2013).

3.1.3 Bioswales and Dry Ponds

Bioswales and dry ponds are designed to detain stormwater and promote infiltration. The low trough shape of the bioswale channels stormwater through a tract of vegetation designed to remove sediment and filter the stormwater prior to entering stormwater pipes. Often integrated into road medians, ditches, and parking lots, bioswales are efficient channeling systems (Program for Resource Efficient Communities, 2008).

Dry ponds, like the one shown below in Figure 3.4, are a form of bioretention, which provide a location to hold the surplus of water in the case of a storm event and permit a gradual infiltration, often through a gravel lined base (Toronto Water, 2015).

Figure 3.4: Dry pond in Charlotte, North Carolina (Metrolina Landscape, 2015).

3.1.4 Blue Roofs and Green Roofs

Green roofs are used to detain stormwater in a soil layer on rooftops to nurture or irrigate vegetation, which can deal with stormwater through uptake and evapotranspiration. Excess stormwater can be drained through piping in severe storm events. Alternatively, blue roofs are temporary storage places for stormwater to slow down and control the flow into the stormwater system. While blue roofs can have a greater water storage capacity than green roofs, they are not multi-purpose. Both blue and green roofs reduce the urban heat island effect and help cool buildings and reduce utility bills in the hotter months (US Environmental Protection Agency, 2015). Examples of both blue and green roofs can be seen below in Figures 3.5 and 3.6.

Figure 3.5: Blue roof detention system in New York City (The City of New York, 2016).

Figure 3.6: 2.5 acre green roof of Morgan Mail Processing Facility, the green roof largest in New York City (Meinhold, 2009).

3.1.5 Roof Farms

Roof farms present a unique opportunity for UBC to handle stormwater in an attractive and useful way. One of Lufa Farms' rooftop greenhouses, as shown above in Figure 3.7, is an example of such innovations that can both re-use stormwater for irrigation as well as provide food that is sustainably farmed (Lufa Farms Inc., 2014). With help from the existing Botany department on campus, UBC can investigate how roof farms can reuse stormwater via drip irrigation, reduce storm-

Figure 3.7: Lufa Farms rooftop greenhouses, Montreal (Lufa Farms Inc., 2014)

water runoff, as well as provide food on campus (University of British Columbia, 2014). If successfully implemented, it would be an additional feature that can distinguish UBC as a centre for innovation and sustainability.

3.2 Large-Scale Options

3.2.1 Aquifer Recharge

Similar to the Middle Eastern qanat, aquifer recharge is the notion of managing stormwater by moving it directly into the lower aquifer through a series of wells. The ground has a high capacity for water storage, however these wells may not have the capacity to handle large storm events, particularly if the stormwater is treated prior to injection. Wells like this have already been investigated on UBC campus and are determined to contaminate the pristine groundwater of the lower aquifer and require too much maintenance to be worthwhile (University of British Columbia, 2014). However, they are used extensively in the United States, Australia, and other parts of the world.

3.2.2 Upgrading Pipe Sizes and Large Detention Tanks

Upgrading the pipe sizes in UBC's stormwater system to be able to handle a 100-year storm event has been thoroughly investigated in the technical background study, UBC's Stormwater Model System Analysis, Detention Analysis and System Optimization (GeoAdvice Engineering Inc., 2012). Oversized pipes can serve as both a detention and channelling system, but in this case, they must be used in conjunction with detention tanks to handle the total flow of the 100-year storm due to the limited capacity of the spiral drain and the sheer quantity of stormwater. This technical background study also investigated where and what size detention tanks would be required on campus, in combination with upgrading the pipe size in certain locations, which can be seen below in Figure 3.8 (GeoAdvice Engineering Inc., 2012). There are some concerns that building

Figure 3.8: Page from UBC UBC's Stormwater Model System Analysis, Detention Analysis and System Optimization study indicating the location and size of detention tanks required to handle surplus water (GeoAdvice Engineering Inc., 2013).

3.3 Technologically Innovative Options

3.3.1 Flow Management Devices (Vortex Flow Controls)

Figure 3.9: Left: Schematic of a flow management device in operation (Hydro International, 2016).Right: The Hydro-Brake Optimum, a vortex flow control device from the UK (ACO, 2010).

Stormwater flow management devices, such as the Hydro-Brake Optimum, depicted above in Figures 3.10 and 3.11, can be used to control stormwater flow in existing infrastructure (Faram, Stephenson, & Andoh, 2010) (Hydro International, 2016). They are self-activating devices that have no moving parts and do not require power. If implemented at strategic locations on campus, they can be used to direct and limit flooding to specific areas on campus and to alleviate flooding in high-risk areas. Although they are not long-term solutions for stormwater management, they can be exceptionally useful tools for controlling flooding in particularly vulnerable locations. Hence, it is recommended that more studies should be done to determine the potential use at UBC.

3.4 Policy Recommendations

In addition to infrastructure interventions, there are several policy recommendations that UBC could implement to enforce and uphold good stormwater management practices.

- Promote and require smaller, less expensive interventions wherever new development occurs, such as blue roofs or green roofs, planters, and rain gardens.
- Promote use of porous pavement on all pedestrian pathways, sidewalks, and parking lots.
- Restrict future development on what is currently open space, particularly in the interior of the campus where infiltration techniques should be promoted.

Section 4 - Conclusion

4.1 Recommended Next Steps

In addition to infrastructure interventions, there are several policy recommendations that UBC could implement to enforce and uphold good stormwater management practices.

- Host a UBC student design competition where design aspects are required for detention, channelling infrastructure, or green infrastructure interventions.
- Conduct a more in-depth analysis and modeling of how the alternative and innovative stormwater management options recommended in this report could handle stormwater in a 100-year storm event.
- Explore cost sharing solutions with Metro Vancouver and the provincial government.

These suggestions are intended to gather the collective creativity of UBC, to identify the most technically and financially feasible solution, and in the process create a sense of community between students, the University, and its neighbours.

4.2 Conclusion

This report has found that the most viable structural interventions for handling the stormwater runoff at Chancellor Boulevard and NW Marine Drive to be:

1. A floodable basement at the Mary Bollert Hall that can be utilized as a stormwater detention facility as shown in Section 2.3.
2. A combination of tree trenches and gravel pits to retain and channel stormwater in several key locations shown in Section 2.4.

These options are most in line with development on UBC campus and can be used to mitigate flooding risks to the neighbouring Pacific Spirit Park and University Endowment Land and erosion of the nearby cliffs. However, in order to effectively manage stormwater across campus, this report recommends taking a comprehensive approach to reduce impervious surfaces, and retain and recycle stormwater. This includes implementing multiple structural stormwater management interventions across campus as well as enforcing policies that can help shape the campus into a more sustainable, interactive, and educational neighbourhood.

As UBC has plans to increase the density of the Point Grey campus over the coming years, new buildings and walkways will gradually increase the amount of impervious area. Therefore, it is imperative that stormwater management strategies are included in the planning of campus development. A prompt and proactive approach to stormwater management is needed to protect people and properties at UBC and to uphold the ecological and social integrity of the Point Grey campus.

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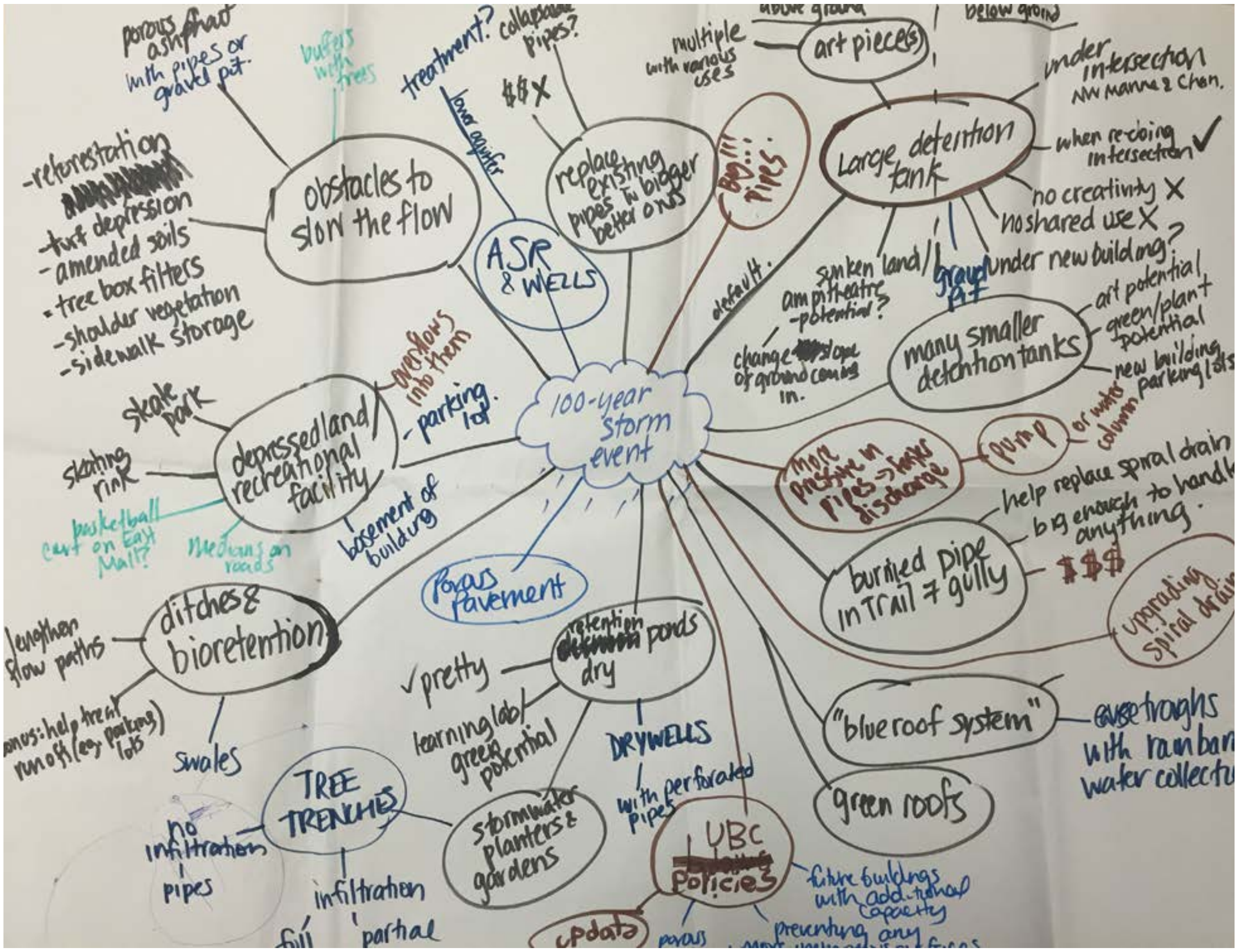
Appendices

Appendix A: Mind Map



Appendix B: UBC facilities scheduled to be replaced by 2030

FACILITIES TO BE REPLACED

The facilities listed in Table 2A-5 would be replaced over time to accommodate new academic and student housing facilities on the infill sites identified in Map 2-1 *Teaching, Learning and Research Land Use* and Map 2-2 *Student Housing Land Use*. The majority of facilities in Table 2A-5 are temporary structures or have reached the end of their building life-cycle.

TABLE 2A-5
LIST OF FACILITIES TO BE REPLACED ON THE VANCOUVER CAMPUS 2009-2030

BUILDING NUMBER	BUILDING NAME	MIXED-USE HUB	SITE FOR KNOWN ACADEMIC FACILITY
539	Ambulance Station		X
045	Auditorium Annex Offices A		X
863-2	Auditorium Annex Offices B		X
098	Botanical Garden Centre — Campbell Building	X	
729	Botany Annex		X
113	Brock Hall Annex		X
632	Plant Operations Annex F	X	
580	Plant Operations Nursery — Gardener's Residence and Lab	X	
583	Plant Operations Nursery — Greenhouse No. 1	X	
581	Plant Operations Nursery — Soil Shed	X	
730	Ponderosa Annex H		X
192	Ponderosa Centre		X
726	Power House — Oil Storage Facility		X
863-1	West Mall Annex		X

The facilities listed in Table 2A-6 are located on sites designated for infill development after 2030, once the infill sites for known projects to 2030 have been used. The decision to replace the facilities identified in Table 2A-6 can be re-evaluated post 2030 in view of conditions at that time.

TABLE 2A-6
LIST OF POTENTIAL REPLACEMENTS ON THE VANCOUVER CAMPUS POST-2030

BUILDING NUMBER	BUILDING NAME
871-2	Ponderosa Annex Office E — English Annex
090	Botanical Gardens — Workshop
079	Botanical Gardens — Greenhouse and Workshop
643	Campus & Community Planning 1
029	Campus & Community Planning 2
865-1	Ponderosa Office Annex A
077-2	Botanical Garden Nursery — Shadehouse
051	The Barn Coffee Shop
871-3	Ponderosa Annex Office F — Student Services
513	Library Processing Center
077-1	Botanical Garden Nursery — Greenhouse
865-3	Ponderosa Office Annex C
638	South Campus Warehouse
579	Labour Hut
766	Refuse Compaction Site
765	South Campus Substation — Switching Station 12KV
430	Robert F. Osborne Centre — Unit 1
022	Lower Mall Research Station
614	Mary Bollert Hall
431	Robert F. Osborne Centre — Unit 2
024-6	Research Station Annex 6
024-5	Lower Mall Header House
401	Geography Building

Figure B: List of UBC facilities scheduled to for infill before and after 2030 (University of British Columbia, 2010).

Appendix C: Annotated Bibliography

Source Name	Author	Location	URL	Date	Topic	Main Points
Resilient Design Institute	Alex Wilson	VT, USA	http://www.resilientdesign.org/fundamentals-of-resilient-design-wet-floodproofing/	15-04-20	Flooded basement	Safe methods for building flooding, floodproofing graphics, cost estimates for floodproofing
Guidelines for the design and construction of stormwater managment system	New York City Department of Environmental Protection	New York City, NY, USA	http://www.nyc.gov/html/dep/pdf/green_infrastructure/stormwater_guidelines_2012_final.pdf	12-07-01	Stormwater systems	Efficiency and capacity of systems and interventions, sizing and volume reduction, sizing stormwater management systems
Climate Tech Wiki: Flood-proofing	Matthew M. Linham & Robert J. Nicholls	USA	http://www.climatetechwiki.org/content/flood-proofing	-	Floodproofing	Wet Floodproofing Cost Estimation
A Sustainable Drainage Strategy for the South Campus Neighbourhood	Aplin & Martin Consultants Ltd. & Holland Barrs Planning Group Inc.	UBC	http://planning.ubc.ca/sites/planning.ubc.ca/files/documents/planning-services/policies-plans/SC_StormwaterMgmtStrategy.pdf	05-01-01	Stormwater and flooding analysis and proposed solutions for the South Catchment of UBC campus	
Adding Creativity to Urban Stormwater Treatment Design - "Rainwater Art"	Bruce Phillips, PACE Advanced Water Engineering	CA, USA	https://www.casqa.org/asca/adding-creativity-urban-stormwater-treatment-design-rainwater-art	14-12-15	Creative Designs	Examples of creative stormwater treatment designs
Stormwater Management Tools - Ideas and Innovative Techniques	Tom Ballestero, University of New Hampshire Stormwater Center	NH, USA	http://www.lakesrpc.org/stormwater/Ballestero.pdf	13-03-29	Creative Designs	Examples of creative stormwater treatment designs
Buster Simpson's Environmental Projects website	Buster Simpson	Global	http://www.bustersimpson.net/workinprogress/	-	Art and Environment	Using artwork to increase environmental awareness, global examples of rainwater collection artwork
Rotterdam: the water city of the future	Linnie Mackenzie	Rotterdam, the Netherlands	http://www.waterworld.com/articles/wwi/print/volume-25/issue-5/editorial-focus/rainwater-harvesting/rotterdam-the-water-city-of-the-future.html	2010	Innovative stormwater management practices	Underground storage, sunken recreation facilities, incentives for installing green roofs
Artful Rainwater Design in the Urban Landscape	Stuart Echols		https://stuckeman.psu.edu/sites/default/files/facultycontent/jgb_fall07_b00_echols_-_artful_rainwater_design_in_the_urban_landscape.pdf	15-05-01	Evaluation Criteria	Values and attributes of sustainable stormwater treatment designs
Stormwater Management Report - Jacob's Trail Phase 2 Subdivision, Township of Woolwich	Meritech	Cambridge, ON, CA	http://www.woolwich.ca/en/resourcesGeneral/Planning_Documents/Valleyview_Subdivision/Meritech_SWM_Report_March_2014.pdf	14-02-01	Evaluation Criteria	Values and attributes of sustainable stormwater treatment designs
University of Victoria Integrated Stormwater Management Plan	RCL Consultanting Ltd	Victoria, BC, CA	https://www.uvic.ca/sustainability/assets/docs/policy/integrated-stormwater-management-plan.pdf	04-05-01	University of Victoria stormwater management strategies	Bioswales and porous asphalt
Water Management at UBC	Daniel R. Klein, Ghazal Ebrahimi, Lucas Navilloz, and Boris Thurm	UBC	https://watergovernance.ca/wp-content/uploads/2014/08/UBC-IRM-Strategy-with-a-Water-Lens-FINAL-Aug-2014.pdf	14-08-01		