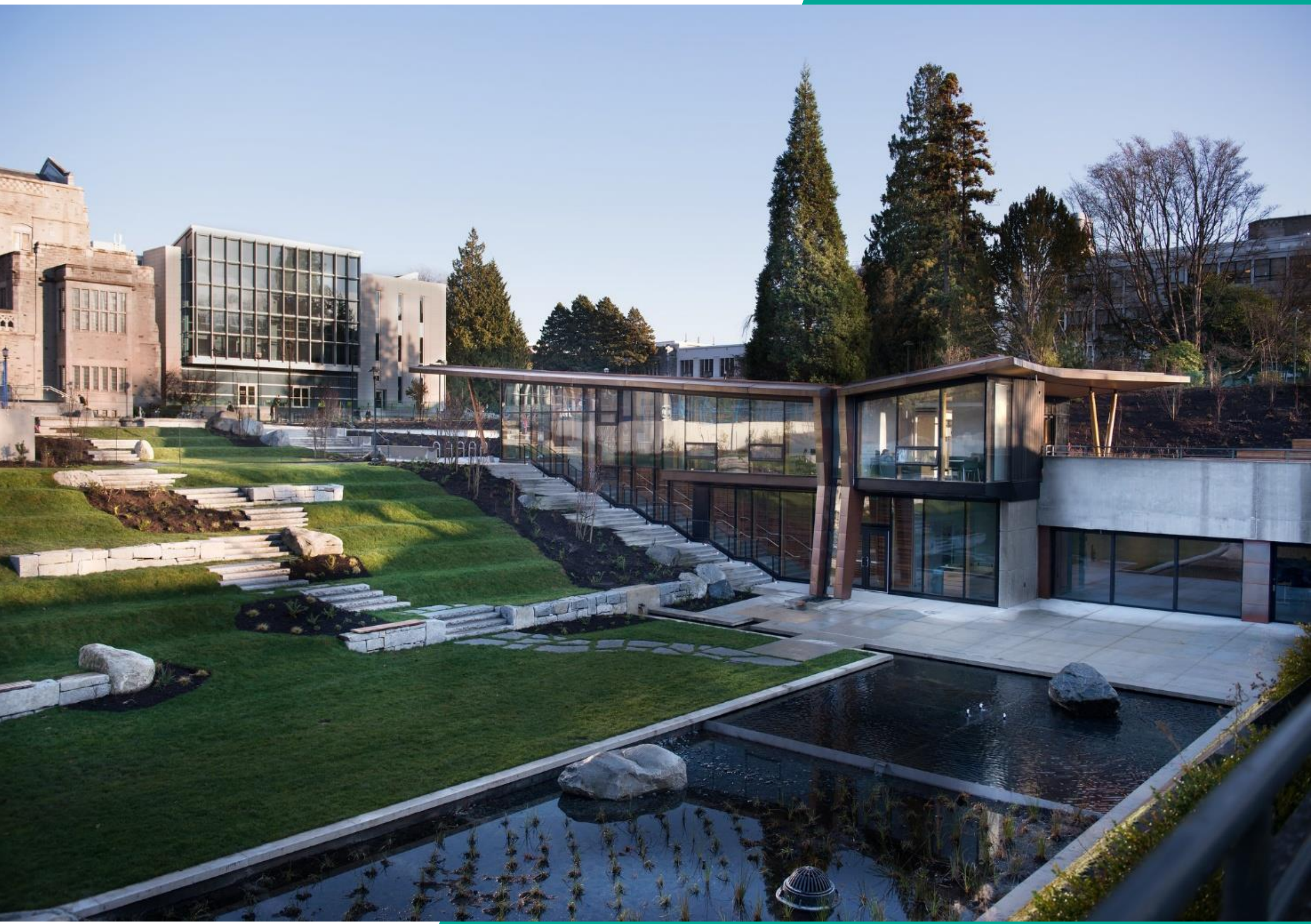
UBC Vancouver Green Rainwater Infrastructure Mapping and Asset Management



Prepared by: Eric Fang, Heather Li, Jessy Lin, and Ewan Painter
Prepared for: UBC SEEDS and UBC Campus + Community Planning
ENVR 400: Community Project in Environmental Science
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Practitioner Summary

Practitioner Summary

UBC Vancouver Green Rainwater Infrastructure Mapping (GRI) and Asset Management

Green Rainwater Infrastructure at UBC

- GRI are sustainable, nature-based equivalents to storm drains or pipes that infiltrate and capture rainwater
- Benefits of GRI include reduced runoff, rainwater filtration, increased utilization of precipitation, alleviation of urban heat islands, and enhancement of ecosystem service

Research Background

The Point Grey cliffs have seen increasing erosion rates due to excess rainwater runoff. This makes future infrastructure development unstable. Climate change is also impacting potential flooding across campus. GRI is a key tool to addressing these and other concerns brought on by climate change.

Objectives

- Create an interactive ArcGIS map serving as a centralized platform to support the development and maintenance of UBC GRI
- Qualitatively assess the performance of GRI at UBC Vancouver

Methods

Literature Review of mapping and asset management techniques

Interviews with key stakeholders

Data Collection across 33 unique GRI sites at and around UBC

Deliverables

ArcGIS Map of UBC GRI

containing interactive elements including:

- filter display by types of GRI
- ownership and installation date
- images and site descriptions
- schematics and maintenance logs

Asset Management Plan

creating a framework and conducting site assessments of campus GRI to evaluate

- Level of Service
- Current State of Assets
- Life Cycle and Long Term Costing

Findings

Low Frequency of GRI Oversaturation

High Average GRI Condition Rating

Author Bios

ERIC FANG

Eric is an Environmental Science major, with a concentration in Water, Land, and Air systems. From previous internships and projects, he has developed a strong understanding and passion for Geographic Information Systems and a deep appreciation for its role in environmental planning and analysis. His passion lies in using spatial data to tell compelling environmental stories and inform decision-making.

HEATHER LI

Heather is an Environmental Science major, specializing in Sustainability with background knowledge in ecohydrology. From her co-op work terms, she has gained experience in professional environments and developed organizational skills with reporting writing and formatting. She values this project as a great opportunity for her to learn more about green infrastructure and asset management.

JESSY LIN

Jessy is an Environmental Science major specializing in Ecology and Conservation. Through her previous work, volunteering, and other experiences, she has developed strong scientific writing and analytical skills. She is passionate about ecological research and is committed to advancing conservation efforts.

EWAN PAINTER

Ewan is a 4th year Environmental Science Major with an area of concentration in Ecology and Conservation. From work experience, he has learned to work in a professional and academic environment. From classes at UBC, he has learned an appreciation for the diverse ecology and wildlife of British Columbia and hopes to travel further to different parts of Canada to learn more of the nature and wildlife elsewhere.

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Glossary

- Bioswale: A type of GRI designed with a swale drainage course with gentle slopes to guide rainwater into the swales.
- Detention Pond: An excavated area meant to temporarily hold rainwater to prevent flooding, runoff, and erosion. It also has vegetation to support infiltration.
- French Drain: A trench filled with rock or gravel that redirects surface water away from an area
- GIS: Geographic Information Services.
- Gray Infrastructure: Traditionally engineered infrastructures like sewers, drains, gutters, and pipes
- Green Rainwater Infrastructure (GRI): Infrastructure designed to manage rainwater runoff using vegetation, soil, and other practices to mimic natural hydrological processes.
- Green Roof: A type of GRI that involves planting on the surface of a roof with vegetation and is designed to provide ecosystem services and manage rainwater runoff.
- Infiltration Channel: A trench with aggregate fill, inlet structures, overflow systems, and vegetation cover to help mitigate flooding and rainwater runoff.
- Rainfall Event: A period of rainfall.
- Rain Garden: A type of GRI designed as gardens to collect, absorb, and clean rainwater runoff using natural processes.
- Recirculation Channel: Filters out pollutants and recirculates the rainwater
- University Neighbourhood Association (UNA): The association that operates facilities in UBC’s residential neighbourhoods and the owner of several GRI within the scope of this project

Introduction

RESEARCH TOPIC

This research project investigates the sustainability, performance, and management of Green Rainwater Infrastructure (GRI) on the UBC Vancouver campus. GRIs, which include bioswales, rain gardens, and green roofs, are evaluated for their effectiveness in stormwater mitigation, environmental benefits, and maintenance practices. The project identifies several current challenges, such as inconsistent maintenance and the absence of a centralized data system, while also exploring opportunities to strengthen stormwater resilience and improve landscape infrastructure. The research addresses both the fragmented management of existing GRI and an opportunity to advance nature-based urban planning solutions.

RESEARCH RELEVANCE

This study contributes to addressing the broader societal issue of climate resilience, especially in the face of urbanization and increased extreme rainfall events. By exploring nature-based solutions to stormwater management, the research offers valuable insights for municipalities and planners beyond UBC. On campus, the research supports sustainability and wellbeing objectives aligned with UBC's Integrated Stormwater Management Plan and Campus Vision 2050 (UBC Campus + Community Planning, 2017; UBC Campus + Community Planning, 2024). It also offers practical benefits to stakeholders such as SEEDS, Campus + Community Planning (C+CP), UBC Facilities, and campus residents by promoting more effective GRI maintenance and increasing public understanding of sustainable water systems. The outcomes of the project have potential to enhance operational efficiency and the educational impact of GRI installations.

PROJECT CONTEXT

The project builds upon previous UBC research and initiatives, including the 2024 studies on rain garden performance near the Campus Energy Centre (Zhou et al., 2024). These earlier efforts highlighted several persistent issues: performance limitations of GRIs under future climate conditions, maintenance shortcomings, and inadequate community engagement. In response, both SEEDS and C + CP have emphasized the need for a centralized, accessible, and interactive mapping and management system for GRI on campus. This need has informed and motivated the current research project, situating it within an ongoing institutional effort to improve infrastructure planning and resilience.

BACKGROUND

Green rainwater infrastructures (GRI) are infrastructures designed to help mitigate rainwater runoff and remove pollutants. The GRI at UBC Vancouver includes green roofs, rain gardens, bioswales, infiltration channels, recirculation channels, detention ponds, stormwater ponds, and French drains (Figure 1).

Green roofs are built on the surface of roofs with vegetation. Green roofs can be classified as either intensive, semi-intensive, and extensive. Intensive green roofs are heavy as it uses deep substrate and requires a lot of maintenance. Extensive green roofs require little maintenance and are designed to be self-sustaining over time. Semi-intensive green roofs are in between intensive and extensive (López-Silva et al., 2024). In addition to mitigating runoff, it also helps insulate buildings which can help reduce energy consumed by buildings which can help lower their emissions (López-Silva et al., 2022). Rain gardens are shallow ditch-like structures in the ground filled with soil, vegetation, and a layer of mulch. They absorb rainwater runoff which recharges underground aquifers and enhances the health of the surrounding ecosystem by filtering out pathogens, nutrients, metals, and other organic pollutants from rainwater (Sharma & Malaviya, 2021). Bioswales are shallow drainage courses filled with vegetation and designed to maximize the time rainwater spends in the swale to help trap and breakdown pollutants and sediments (Xiao et al., 2017). Infiltration channels are trenches with inlet structures, overflow systems, and vegetation covers to help rainwater infiltrate. Recirculation channels are similar however, it helps to recirculate the rainwater instead of infiltrate. Detention ponds temporarily hold rainwater to control runoff and prevent flooding. Stormwater ponds are designed for permanent water storage.

It is important to maintain and manage GRI regularly to ensure that they perform effectively in order to mitigate flooding on campus where tens of thousands of people live, learn, and work. This project aims to increase the efficiency of GRI management at UBC Vancouver and has identified challenges, including inconsistent maintenance and a lack of a centralized record system, while also highlighting opportunities to improve rainwater resilience and advance landscape practices. UBC SEEDS (Social Ecological Economic Development Studies) Sustainability Program and Campus + Community Planning (C + CP) have emphasized the need for a comprehensive, accessible, and interactive GRI map and management plan to better support infrastructure upkeep and decision-making.

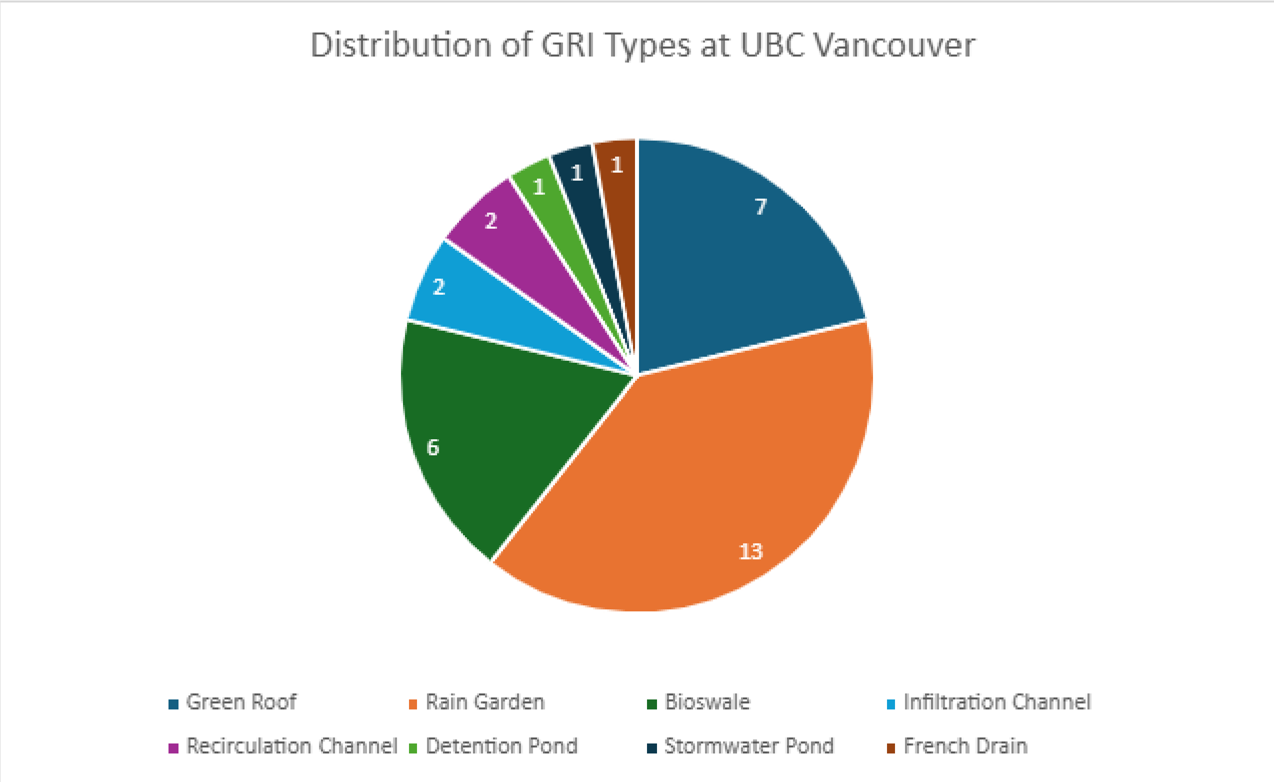


Figure 1. The distribution of the GRI types at on the UBC Vancouver campus. There are 7 green roofs, 13 rain gardens, 6 bioswales, 2 infiltration channels, 2 recirculation channels, 1 detention pond, 1 stormwater pond, and 1 French drain.

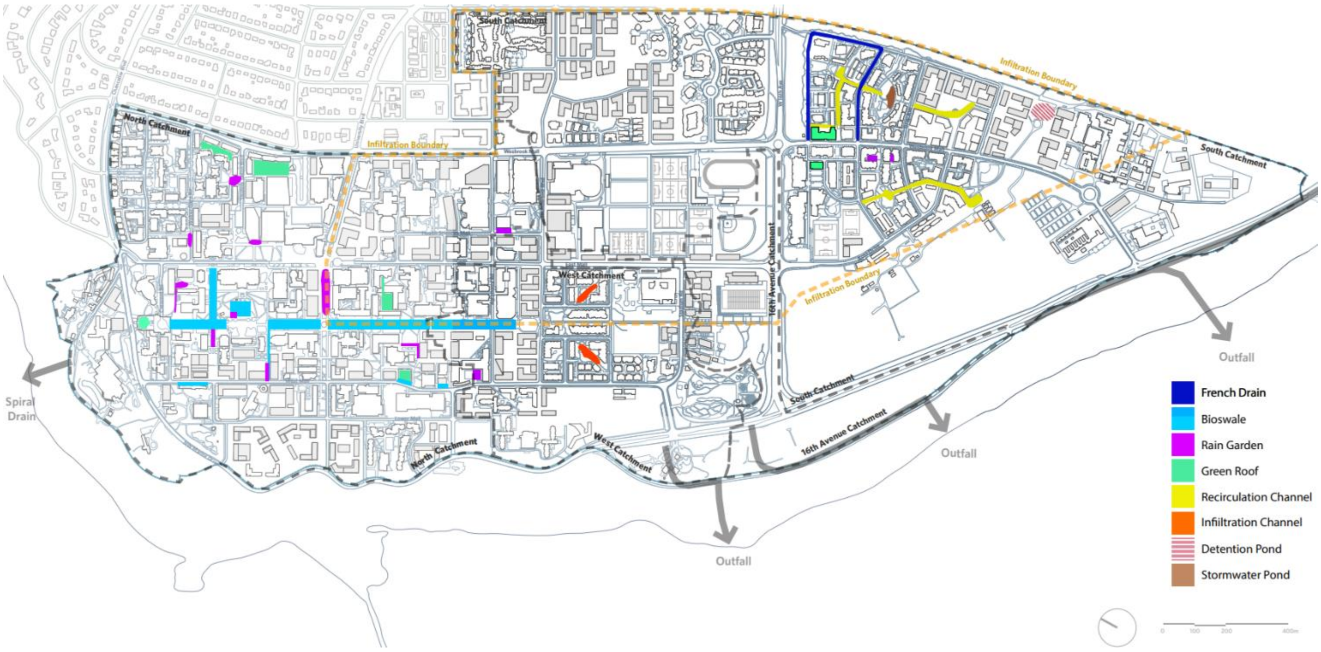
FUTURE CLIMATE IMPACTS

There has been an increase in severe rainwater events, such as atmospheric rivers, in the greater Vancouver area. These events are expected to increase as temperatures continue to rise as a result of climate change. This is a result of increased temperature in the air which increases the moisture content in the atmosphere and results in higher volumes of precipitation with unequal seasonal distribution (Jakob & Owen, 2021).

Gillett et al. (2022) have projected that the probability of extreme streamflow events in October to December has increased as a result of human activity by approximately 120-330%. Additionally, Prein et al. (2017) predicted that hourly precipitation will intensify in late fall and early winter by approximately 35% in Southwest Canada and an estimated increase in extreme precipitation at a rate approximately 7% per °C, varying on the region. Furthermore, urbanized areas can have an urban heat island effect which is a result of buildings and infrastructures absorb solar radiation and release more heat than the natural environment (Ronchi et al., 2002). This effect forms hot air flows over the city, which eventually forms precipitation and aggravates urban floods (Yang et al., 2021). It is imperative that UBC is prepared to face these challenges as they arise over the years as temperatures continue to rise and severe rainfall events are projected to increase in frequency.

PROJECT STUDY SITE: UBC VANCOUVER CAMPUS

The project site of this research is the UBC Vancouver campus, specifically the 33 GRIs scattered around the campus (Figure 2). The campus has 4 main rainwater catchments, North, South, West, and 16th Avenue and



each catchment has a corresponding drain for the collected rainwater. The North catchment contains 21 GRIs, and the rainwater is drained by a spiral drain adjacent to the Museum of Anthropology. The South Catchment has 9 GRI and drains most of the area south of 16th Avenue and drains out at Booming Ground Creek. The West catchment has 3 GRI and drains out the stream at Trail 7. The 16th Avenue catchment does not contain any GRI and drains rainwater out the Botanical Garden Creek (UBC Campus + Community Planning, 2017).

Figure 2. A map of the UBC Vancouver campus showing the GRI as well as the North, West, 16th Avenue, and South catchments and their rainwater outfall areas. The French drain is in navy blue, the bioswales are in sky blue, the rain gardens are in purple, the green roofs are in green, the recirculation channels are in yellow, the infiltration channels are in orange, the detention pond is striped in red, and the stormwater pond is in brown.

PROJECT PURPOSE AND OBJECTIVES

This project centralizes information regarding each GRI at the UBC Vancouver campus and identifies gaps in GRI maintenance and management in order to improve maintenance efficiency and enhance educational value of the GRI features. Through this research, we answered the following questions:

- How effectively do existing GRIs at UBC perform during observed rainfall events from January to March 2025, specifically in their capacity to prevent water pooling and effectively manage runoff?
- What are the existing gaps or issues affecting the current maintenance practices, centralized information management, and overall efficiency of GRIs on the UBC Vancouver campus?

Research Methodology and Methods

ARCGIS METHODOLOGY

To create a centralized and accessible record of GRI installations, this project utilizes ArcGIS technology to develop an interactive map of the UBC Vancouver campus and surrounding university neighborhoods. The methodology is divided into three key phases:

Data Acquisition

The initial phase involved creating a base map of existing GRIs from SEEDS and C + CP and assigning a number to each GRI (Figure 3). The preliminary resources provided coordinates and catchment areas for the current GRI features. The field teams then conducted on-site visits to validate the data through direct observation and to assess the physical conditions of each installation. Additionally, during weekly site visits, particularly during or after rainfall events, data was collected on rainfall intensity, presence of pooling water, and visual signs of deterioration or blockage.

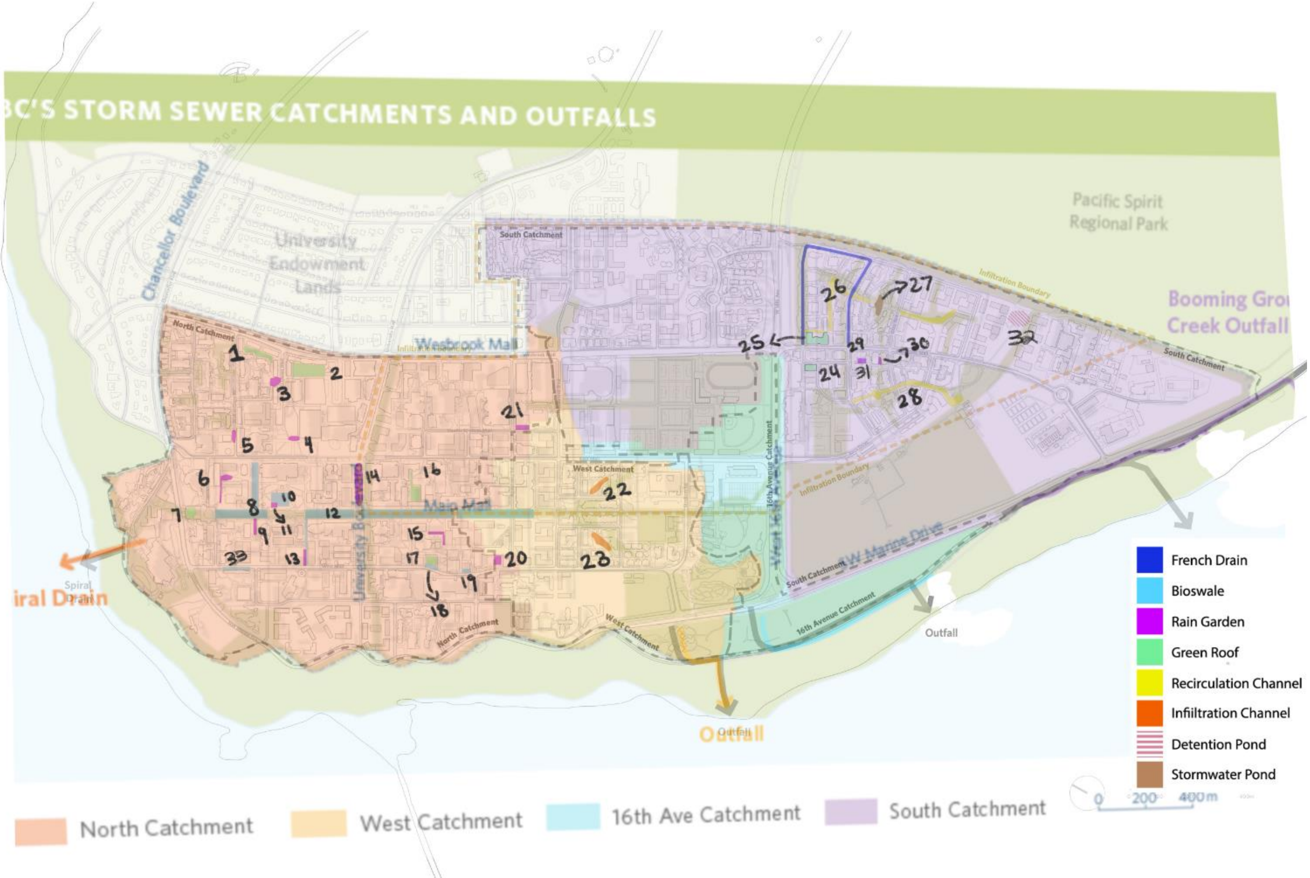


Figure 3. A map of UBC Vancouver highlighting the GRI and their assigned ID. French drains are in navy blue, bioswales are in sky blue, rain gardens are in magenta, green roofs are in green, recirculation channels are in yellow, infiltration channels are in orange, detention ponds are in red stripes, and stormwater ponds are in brown.

Map Construction in ArcGIS

To develop an interactive and informative spatial representation of GRI sites, compiled data were imported into ArcGIS Pro. Each GRI was digitized as a unique and individual polygon feature, representing the spatial reference of the system within the campus. A visual representation of the map making process can be found below (Figure 4). The polygons were then linked to a custom attribute table populated with site-specific metadata, including:

- System type (e.g., bioswale, green roof, rain garden)
- Description of the GRI
- Design schematics (linked if available)
- Installation date
- Surface area and perimeter
- Geospatial coordinates (longitude and latitude)
- Photographic documentation (curated into linked site-specific photo album)
- Monitoring log (linked)

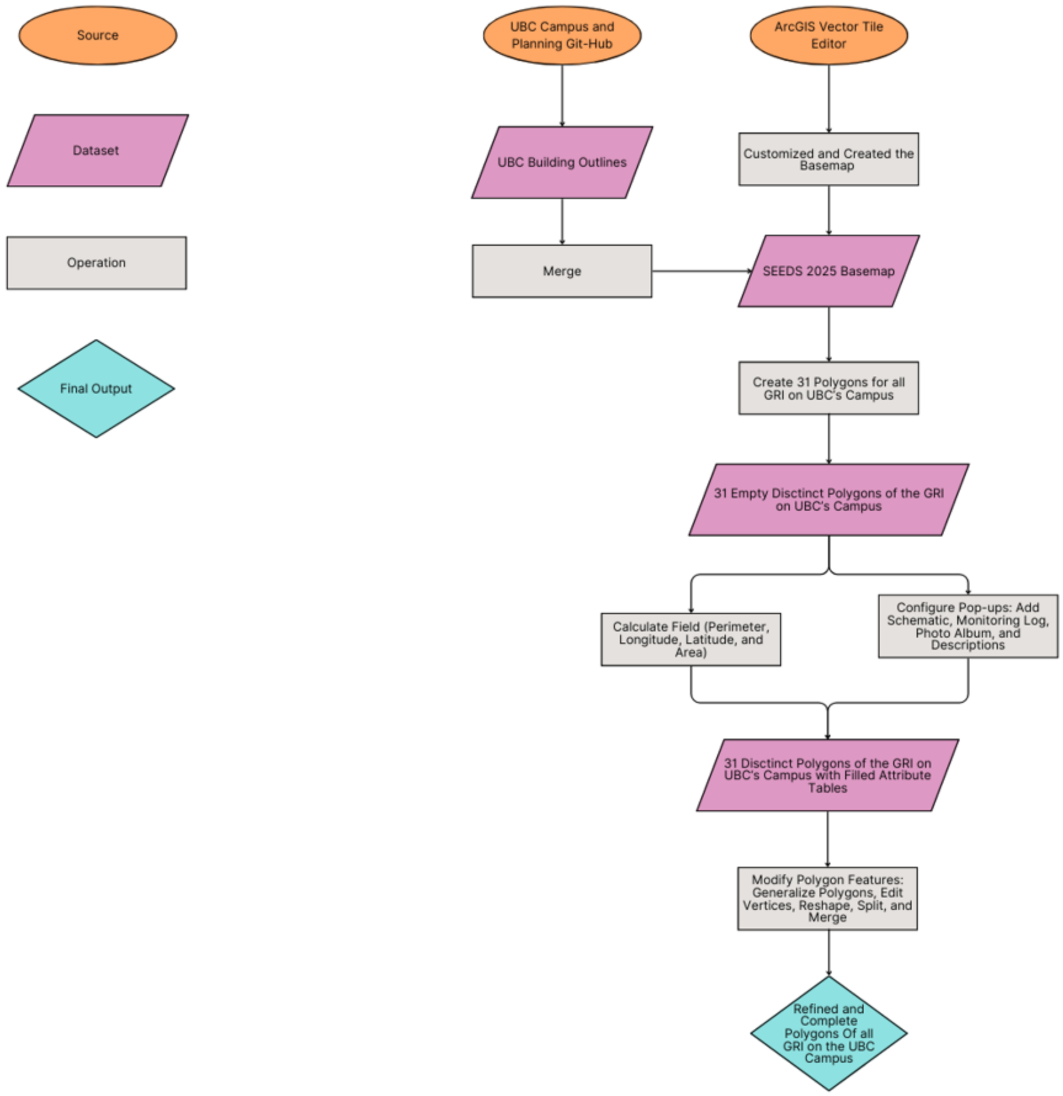


Figure 4. Workflow Diagram for GRI Mapping and Attribute Configuration in ArcGIS. This flowchart illustrates the step-by-step process used to construct the interactive GRI map for UBC's Vancouver campus using ArcGIS. The workflow begins by sourcing buildings outlines from the UBC Campus and Planning GitHub and customizing a basemap using ArcGIS vector Tile Editor. These inputs were merged to create the SEEDS 2025 Basemap, onto which 33 polygons were manually created to represent individual GRI features.

Feature Categorization and Thematic Layering

To enhance the visuals and interpretability, all GRI features were categorized by infrastructure type using standardized colours. Multiple map layers were constructed and organized into a layer toggle panel, allowing users to view GRIs by type or by installation year and overlay catchment boundaries. Additionally, custom legends and labelling were applied to maintain consistency and legibility across thematic layers.

ASSESSMENT OF SERVICES METHODOLOGY

Primary Data Collection

The map provided by SEEDS was used as a base for data collection and ground-truthing (Figure 3). The 33 sites were split amongst each group member for ground-truthing and monitoring (Table 1).

Table 1. Assigned GRI for data collection. GRI No. corresponds with Figure 3.

GRI No.	GRI Type	Assigned To	GRI No.	GRI Type	Assigned To
1	Green Roof	Eric	**18**	Bioswale	Jessy
2	Green Roof	Eric	**19**	Bioswale	Jessy
3	Rain Garden	Eric	**20**	Rain Garden	Jessy
4	Rain Garden	Eric	**21**	Rain Garden	Heather
5	Rain Garden	Eric	**22**	Infiltration Channel	Jessy
6	Rain Garden	Eric	**23**	Infiltration Channel	Jessy
7	Green Roof	Heather	**24**	Green Roof	Ewan
8	Bioswale	Heather	**25**	Green Roof	Ewan
9	Rain Garden	Heather	**26**	Recirculation Channel	Ewan
10	Bioswale	Heather	**27**	Stormwater Pond	Ewan
11	Rain Garden	Heather	**28**	Recirculation Channel	Ewan
12	Bioswale	Heather	**29**	Rain Garden	Ewan
13	Rain Garden	Heather	**30**	Rain Garden	Ewan
14	Rain Garden	Eric	**31**	French Drain	Ewan
15	Rain Garden	Jessy	**32**	Detention Pond	Ewan
16	Green Roof	Heather	**33**	Bioswale	Heather
17	Green Roof	Jessy			

Ground-truthing was requested because some GRI sites had not been visited by client for several years and their precise location had been not verified. Ground-truth coordinates of GRI were obtained but have not been implemented in the GIS map. Instead, coordinates were generalized to maximize visibility of GRI on the map. Monitoring and data collection consisted of looking for pooling water at sites, recording coordinates for ground-truthing, and taking pictures. Rainfall intensity data was requested from UBC meteorology to link to observed presence of pooling water. The first several months planned for data collection were incredibly dry and opportunities for data collection were limited. Snowfall additionally limited potential for data collection. As such, we adjusted the scope of data collection to include generalized site descriptions made during visits without rainfall.

Secondary Data Collection

The first part of the data collection was identifying any malfunction of GRI during rainfall events and noting any pooling water on site, connected to overflow of infiltration capacity of the GRI. We additionally generated a service matrix to standardize our analysis of the state of each GRI. Five categories were established for this matrix in consultation with SEEDS and clients and through literature review including methodology ascribed in the Green Infrastructure Ontario Coalition Asset Management Toolkit (*Green Stormwater Infrastructure Asset Management Resources Toolkit,* 2021). Careful attention was paid to this to build criteria relevant to the climate and ecology of British Columbia. The categories established includes “Level of Service”, “Current State of Assets”, “Long Term Funding”, and “Life Cycle Costing”.

- Level of Service - This covers both ecological and human derived benefits from a site. Ecological benefits are categorized as “Core Services”. Human derived benefits are categorized as “Secondary Services”. Common ecological benefits across multiple types of GRI include water management, water purification, habitat provisioning, and groundwater recharge. Common human derived benefits include accessibility of pathways, space for communal gathering, mental health benefits, and aesthetics of the space (Appendix A).

- Current State of Assets - This includes a holistic site description and prominent features of each particular site. A generalized score is developed based on this site assessment, termed “Condition Rating”. This rating ranges from “Very Poor” to “Poor” to “Fair” to “Good” to “Very Good” with the specified criteria for each (Appendix C). Other items, such as ownership and year of construction are additionally noted here.
- Long Term Funding - This serves as a strategy to document costs associated with types of GRI in time frames past the lifecycle of the GRI, typically in the range of 25-50 years. Initially, common management activities, such as removal of invasives or filter changes, can be ascribed to types of GRI to provide an estimate for funding that must be garnered and set aside to manage GRI. Documentation of management procedures as they occur can, in the long term, provide more accurate numbers for funding.
- Life Cycle Costing – Life cycle costing deals with ascribing management practices to types of GRI, or specific GRI in special cases where more active management may be necessary. Notably, differentiating from Long Term Funding, this does not include management tasks associated with replacement of GRI at the end of its lifetime. As an example, a green roof typically has a lifespan of 25 years, after which vegetation and soil must be removed and eventually replaced such that filters and drains can be serviced.

Results

ARCGIS MAP

The map is currently hosted on UBC’s ArcGIS Web map platform and is accessible to project collaborators and members and members of the UBC community with appropriate permissions. Depending on what SEEDS and clients wants to do in the future, the map can be viewable by the public.

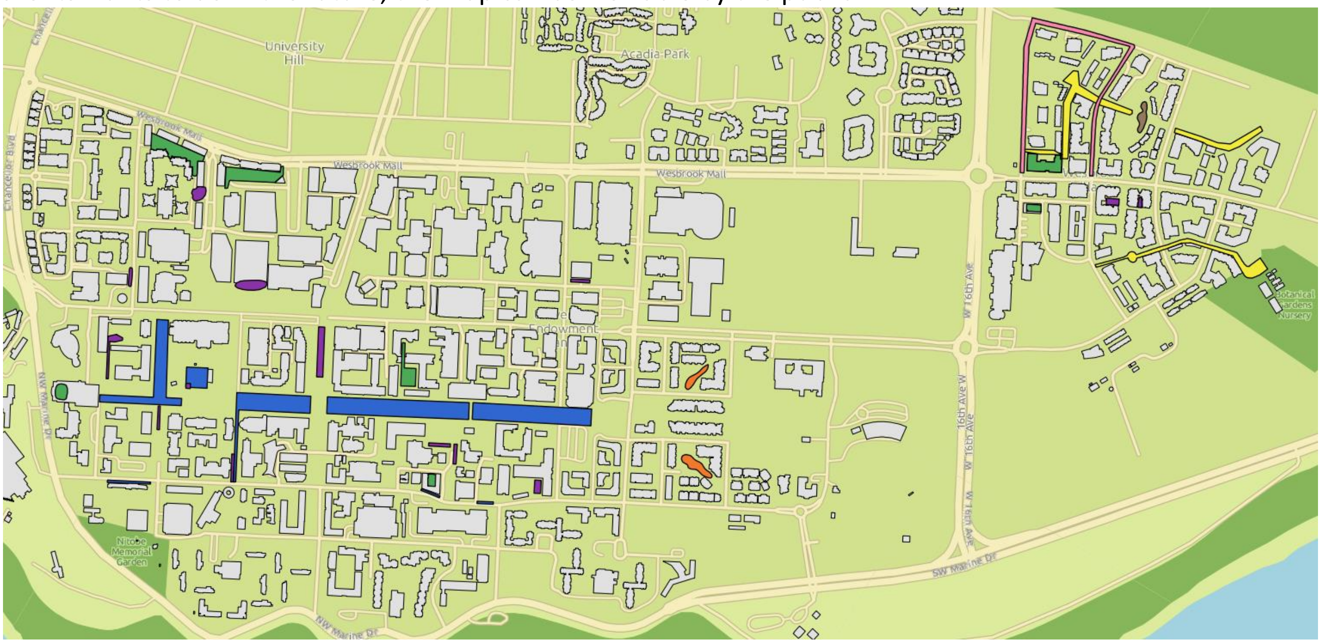
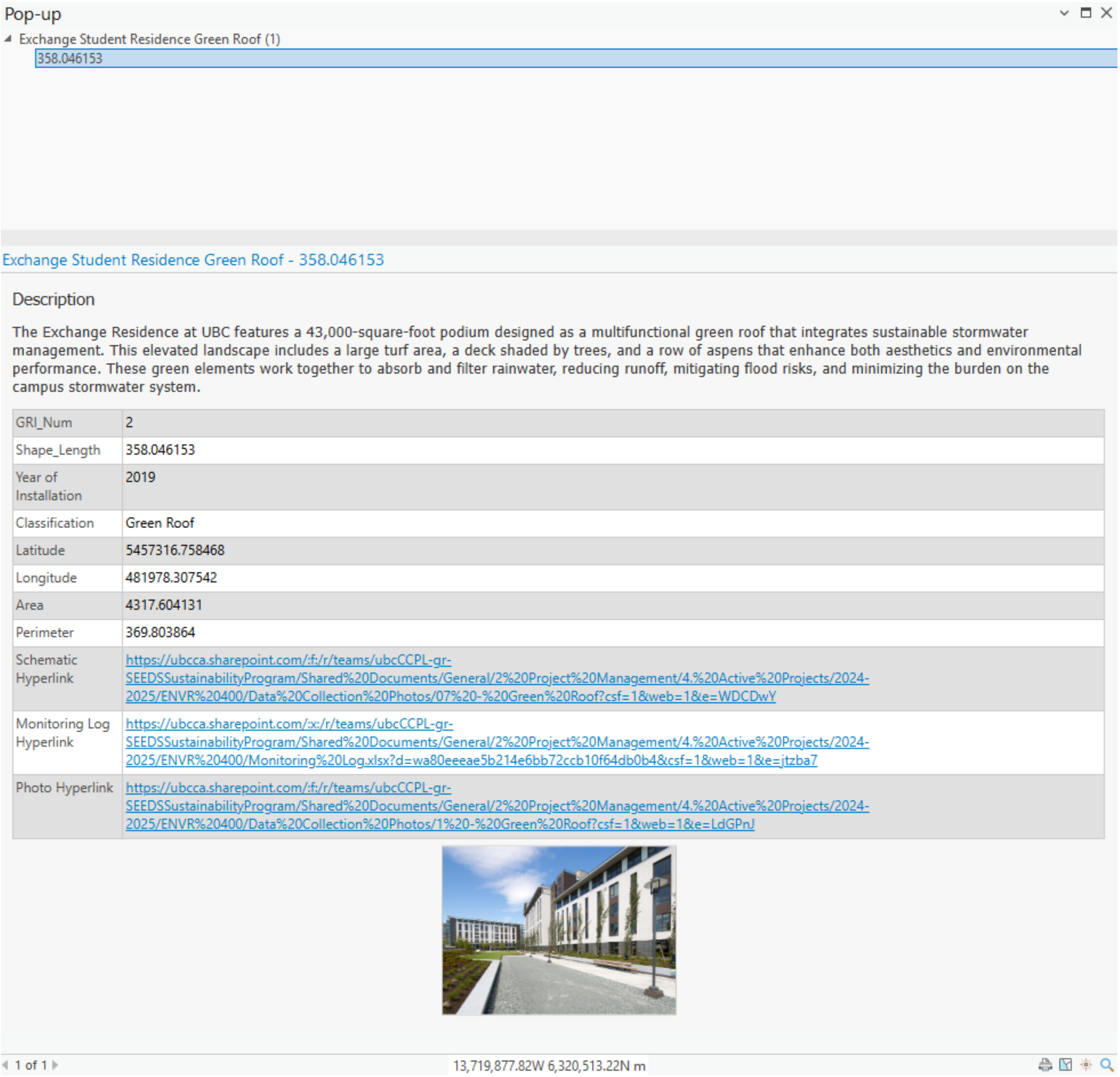


Figure 5. A zoomed-out image from the final GIS map. Bioswales are in blue, green roofs are in green, rain gardens are in purple, infiltration channels are in yellow, recirculation channels are in orange, French drains are in pink, the stormwater pond is in brown, and the detention pond is not in this figure.



Pop-up

Exchange Student Residence Green Roof (1)

358.046153

Exchange Student Residence Green Roof - 358.046153

Description

The Exchange Residence at UBC features a 43,000-square-foot podium designed as a multifunctional green roof that integrates sustainable stormwater management. This elevated landscape includes a large turf area, a deck shaded by trees, and a row of aspens that enhance both aesthetics and environmental performance. These green elements work together to absorb and filter rainwater, reducing runoff, mitigating flood risks, and minimizing the burden on the campus stormwater system.

GRI_Num	2
Shape_Length	358.046153
Year of Installation	2019
Classification	Green Roof
Latitude	5457316.758468
Longitude	481978.307542
Area	4317.604131
Perimeter	369.803864
Schematic Hyperlink	https://ubcca.sharepoint.com/:f:/r/teams/ubcCCPL-gr-SEEDSSustainabilityProgram/Shared%20Documents/General/2%20Project%20Management/4.%20Active%20Projects/2024-2025/ENVR%20400/Data%20Collection%20Photos/07%20-%20Green%20Roof?csf=1&web=1&e=WDCDwY
Monitoring Log Hyperlink	https://ubcca.sharepoint.com/:x:/r/teams/ubcCCPL-gr-SEEDSSustainabilityProgram/Shared%20Documents/General/2%20Project%20Management/4.%20Active%20Projects/2024-2025/ENVR%20400/Monitoring%20Log.xlsx?d=wa80eeeae5b214e6bb72ccb10f64db0b4&csf=1&web=1&e=jtzba7
Photo Hyperlink	https://ubcca.sharepoint.com/:f:/r/teams/ubcCCPL-gr-SEEDSSustainabilityProgram/Shared%20Documents/General/2%20Project%20Management/4.%20Active%20Projects/2024-2025/ENVR%20400/Data%20Collection%20Photos/1%20-%20Green%20Roof?csf=1&web=1&e=LdGPnJ

1 of 1

13,719,877.82W 6,320,513.22N m

Figure 6. This figure shows the interactive pop-up associated with UBC's Exchange Residence Green Roof, as displayed in the ArcGIS-based GRI map. The pop-up includes a detailed description of the system's design and environmental function, along with additional metadata such as the year of installation, GRI number, classification, latitude and longitude, area, perimeter, schematic hyperlink, monitoring log link, and photo hyperlink.

ASSESSMENT OF GRI CORE AND SECONDARY SERVICES

Detailed core and secondary services provided by each type of GRI are included in the appendix under section title "Level of Service" (Appendix A).

Table 2. Core service matrix for Infiltration Channels. Core services refer to ecological benefits derived from the GRI.

Core Services - Infiltration Channel

Service Attributes that Matter to Customers or Elected Leaders	External LoS Performance Indicator	Internal LoS Performance Indicator
Rainwater Diversion	Walkability of pathways during rainfall	Percent rainfall diverted to channel
Flood prevention	Channel over/under capacity	Lack of blockage and debris in channel
Filtration of pollutants	Water in channel does not appear murky	Functionality of filters and health of vegetative buffer

Table 3. Secondary service matrix for Infiltration Channels.

Secondary Services - Infiltration Channel		
Service Attributes that Matter to Customers or Elected Leaders	External LoS Performance Indicator	Internal LoS Performance Indicator
Aesthetics	Benefits to mental health and satisfaction with architecture	Landscape quality index and local feedback
Recreational uses	Supporting communal gathering	Consistency of usage over time

Measurement of Services

Table 4. The number of water pooling events per GRI type from January 30th, 2025 to March 3rd, 2025. Data was collected once a week during rainfall events, over 5 separate days.

GRI Type	GRI Number	Number of Water Pooling Events	Total Number of Water Pooling Events
Bioswale	# 8: Buchanan Bioswale	2	6
	# 10: Indian Residential School History and Dialogue Centre Bioswale	0	
	# 12: Main Mall Bioswale	3	
	# 18 Centre Interactive Research on Sustainability Bioswale	1	
	# 19 UBC Coal and Mineral Processing Laboratory Parking Lot Bioswale	0	
Green Roof	# 1: sɫewət̓leləm̓ (Herring House) Green Roof #2: # 7: Rose Garden Green Roof # 16: Beaty Biodiversity Museum Green Roof # 17: Centre Interactive Research on Sustainability # 24: Granite Terrace Green Roof # 25: Tapestry North Green Roof	0	0

Rain Garden	# 3: Walter Gage Student Residence Rain Garden	0	5
	#4:	0	
	#5:	0	
	#6:	0	
	#9: Frederic Lasserre Building Rain Garden	0	
	# 11: Indian Residential School History and Dialogue Centre	1	
	# 13: Geography Building	1	
	#14:	0	
	# 15 Frank Forward Building Rain Garden	0	
	# 20: Campus Energy Center Rain Garden	0	
	#21:	1	
	# 29: Wesbrook Apartments Rain Garden	1	
	#30: Birney Ave Rain Garden	1	
Infiltration Channel	# 22 Eagles Park Infiltration Channel # 23 Hawthorn Park Infiltration Channel	0	0
Recirculation Channel	#26: Wesbrook East Recirculation Channel #28: Wesbrook West Recirculation	0	0
Stormwater Pond	#27: Michael Smith Park Stormwater Pond	0	0
Detention Pond	#32: Detention Pond	0	0
French Drain	#31: 16^{th} Ave French Drain	0	0

Condition rating

Each GRI was scored according to the condition rating criteria (Appendix C). The distribution of the results are summarized in Figure 5. GRI #4, 24, and 25 are listed as NA as they were inaccessible.

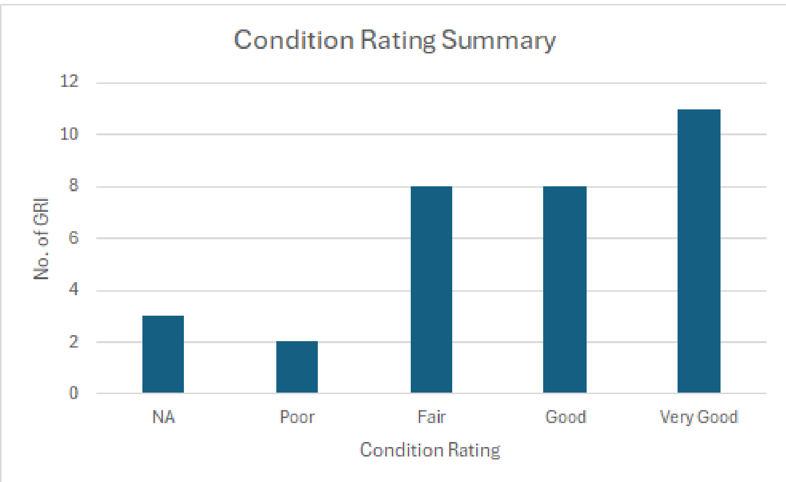


Figure 7. Distribution of condition rating across 33 GRI around UBC campus.

Discussion

ARCGIS MAP

In discussion with SEEDS and client, as well as Paul Young (UBC Properties Trust Director, Planning & Design), Wegland Sit (UNA Operations Manager), and Dean Gregory (UBC Municipal Landscape Architect), we highlighted a primary need to centralize information in a way that facilitates easy communication between design, installment, and maintenance of green rainwater infrastructure. Much of the history and nuance of GRI is captured only in the experience and memory of these experts without a formalized mechanism to collect this experience and inform future development and management of GRI.

SEEDS initially flagged inclusion of schematics and design notes pertaining to UBC GRI as a key function for the GIS map. Conversations with experts reinforced the importance and usefulness of this feature. Presently, around 25% of the 33 GRI on campus have some schematics included in the GIS map. Some of these were provided by SEEDS at the beginning of the project and some were found via UBC blog posts. In discussions with Dean Gregory, it was suggested that Records Management at UBC may hold a more complete set of schematics. They were initially unable to assist with this project and cited concerns over the potential for public access to these schematics for GRI. Subsequent follow-ups reiterating that the GIS map will be made for and only be accessible by SEEDS have not found a response as of yet.

Similarly, maintenance logs were not available to be included within the GIS map. Comprehensive costs associated with past management activities were not available. Accordingly, in the “Life Cycle Costing” section of the Asset Management plan, costs have been sourced from literature and especially considering analysis done by the City of Vancouver.

Some GRI were not accessible during the project. The rain garden outside the Student Recreation Centre, shown as asset #4 in Figure 1, was not accessible due to renovation of the building. It is assumed for the GIS map that this rain garden will remain after construction. Two green roofs (asset #24 and 25) are located within private apartment housing within UNA. These green roofs were never visited for data collection.

ASSET MANAGEMENT

Only rain gardens and bioswales exhibited water pooling, though even in these GRI types, pooling was infrequent. Water pooling indicates a decrease in infiltration performance and may suggest issues such as soil compaction, or insufficient storage capacity in GRI systems. Water pooling may inhibit accessibility of pathways and cause runoff across impervious services, depositing sediment in vegetation (Davis & McCuen, 2005).

Strong integration with large, catchment-level gray infrastructure helps to capture excess rainwater beyond the infiltration capacity of the lawn. The main mall bioswale (Figure 8), for instance, implements drains intermittently spread across each segment of the lawn to increase infiltration capacity of the system. The actual depression gradient of the bioswale is rather shallow. The amount of green space on campus (even beyond GRI) and the connectivity of these spaces also contributes to vegetative and soil health even without a coordinated management plan specific to GRI.

These same mechanisms likely explain the frequency of high condition ratings across the board. Sites ranked “Good” or “Fair” typically reflect lower biodiversity sites without clear service issues. Sites ranked “Poor” lack vegetative cover or have been taken over by invasive species.

Lack of water pooling in some sites is not necessarily an indication of proper performance. Recirculation channels and stormwater ponds, for instance, are aquatic features that inherently do not allow water pooling. For infiltration channels, the layer of rock and gravel above the soil is intended to create pooling water during heavy rainfall that slowly seeps through this gravel layer into the soil. Green roofs, on the other hand, did not show any water pooling despite the potential for it. This may be the result of higher management care due to the high criticality of these GRI or higher infiltration capacity due to improved drainage compared to bioswales and rain gardens.

Individual site assessments highlighted other potential mechanisms that could be useful indicators for performance where pooling water is not applicable. For recirculation channels and stormwater ponds, deposition of detritus or algal growth in the water periodically blocks flow or disrupts filters. For infiltration channels, blockage of the terminal filter can be monitored. The apparatus of the French drain lies below the ground and monitoring for this specific GRI is not possible without specialized instruments.

Figure 8. A section of the bioswale on Main Mall.

Management of GRI at UBC follows the same procedures as generalized vegetative areas. In preparation for snowfall, several larger GRI were extensively trimmed, including the drainage channel leading from the Beaty Biodiversity Museum green roof (Figure 9). This trimming serves no ecological purpose. In fact, fast-growing invasives may gain a foothold as these plots regenerate.

Figure 9. Beaty green roof, showing trimming of wetland vegetation in drainage channel on left.

Recommendations

These recommendations aim to inform planning and practices in order to increase the performance of GRI at the UBC Vancouver campus. Future research recommendations are included to find ways to quantitatively analyze the performance of existing GRI to better inform maintenance practices.

RECOMMENDATIONS FOR ACTION

Immediate Action

- Remove weeds and invasive plants from GRI
    - This is important since weeds can outcompete the desired vegetation that can best help with mitigating rainwater runoff.
    - Areas that are most at risk for weed proliferation and therefore need the most attention are the GRI with only understory planting since they receive more sunlight which allows for rapid weed growth (Mullaly, 2019).
    - Responsible party: UBC Facilities
    - Timeline: Once a year

Mid-term Action

- Establish a centralized maintenance log for all GRI across UBC
    - Gather all the maintenance/monitoring logs for each GRI if there are any
    - Create a standardized maintenance log so that C + CP are up to date about the status of each GRI.
    - Responsible party: UNA, UBC Facilities, and UPT

- Timeline: Gather documents over the next couple of months, then create a standardized maintenance log.

RECOMMENDATIONS FOR FUTURE RESEARCH

Performance

- Analyze the infiltration rate and performance of GRI that experienced water pooling during rainfall events such as the bioswale along Main Mall.
- This is to ensure that UBC remains prepared for increased severe rainfall events and to minimize the possibly of flooding.
- Timeline: Begin planning over the summer, begin data collection in the fall during heavy rainfall event season (October to December).

Species Analysis

- Identify the species currently at each GRI and compare them to the species originally planted to check for invasive species that could impact the performance of the GRI.
- This is important since different species have different water uptake rates; therefore, some species are better than others for increasing infiltration. Additionally, invasive species can harm the surrounding environment and overtake the important species.
- Timeline: Preliminary research to begin within the next year.

Conclusion

The main objective of this study was to evaluate and enhance the functionality and management efficiency of Green Rainwater Infrastructure (GRI) at UBC's Vancouver campus. Some examples of enhancements include real-time monitoring systems for rainfall, runoff, and water quality, as well as increased optimizing GRI layout using GIS to ensure that they are strategically placed in areas most at risk for flooding. Our research methodology combined on-site observations and qualitative assessments of 33 GRI sites with the development of an interactive GIS map to support campus rainwater management and infrastructure maintenance.

Our findings indicate that most GRIs perform effectively under typical rainfall conditions. While some bioswales and rain gardens exhibited occasional water pooling, it's important to note that these systems are specifically designed to manage frequent, small-to-moderate storm events rather than extreme rainfall occurrences. The observed pooling during infrequent, high-intensity precipitation events therefore represents expected performance parameters rather than system failures. These observations do highlight opportunities for improving maintenance protocols and implementing a centralized information management platform.

This study offers three key contributions:

- Data and Visualization Tools: A campus-wide GIS map that supports sustainable rainwater infrastructure planning and maintenance.
- Operational Recommendations: Targeted strategies such as enhanced inspection protocols and a centralized digital maintenance log to optimize GRI upkeep.
- Transferable Management Framework: A standardized GRI evaluation method and best practice guide that can inform future implementations.

While the study's findings are robust, we acknowledge certain limitations including constrained observation periods and incomplete historical maintenance records. These limitations not only highlight the need for more comprehensive data collection systems but also present valuable opportunities for future research directions, particularly in long-term performance monitoring and climate-resilient GRI design.

This research successfully achieved its objectives by providing both a detailed assessment of current GRI performance and practical tools for infrastructure management. The findings contribute significantly to our understanding of sustainable water management in campus environments while establishing a foundation for continued improvements in infrastructure resilience and operational efficiency.

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Appendices

APPENDIX A. LEVEL OF SERVICE

Green Roof

Core Services - Green Roof		
Service Attributes that Matter to Customers or Elected Leaders	External LoS Performance Indicator	Internal LoS Performance Indicator
Reduce rainwater runoff	Percentage of pedestrians satisfied with the performance	Volume of runoff diverted from walking paths
Filter out pollutants	Vegetative health in and around area	Percentage of target pollutants removed
Restore and recharge the groundwater system	Vegetative health after dry period	Percentage of water that infiltrates the soil

Secondary Services - Green Roof		
Service Attributes that Matter to Customers or Elected Leaders	External LoS Performance Indicator	Internal LoS Performance Indicator
Habitat provisioning	Local biodiversity	Immigration of new species over time
Aesthetics	Benefits to mental health and satisfaction with architecture	Landscape quality index and local feedback
Recreational uses	Supporting communal gathering	Consistency of usage over time

Rain Garden

Core Services - Rain Garden		
Service Attributes that Matter to Customers or Elected Leaders	External LoS Performance Indicator	Internal LoS Performance Indicator
Reduce rainwater runoff	Percentage of pedestrians satisfied with the performance	Volume of runoff diverted from walking paths
Filter out pollutants	Clearness of water	Percentage of target pollutants removed
Restore and recharge the groundwater system	Greenery of surrounding vegetation	Percentage of water that infiltrates the soil

Secondary Services - Rain Garden		
Service Attributes that Matter to Customers or Elected Leaders	External LoS Performance Indicator	Internal LoS Performance Indicator
Increase biodiversity	Visible health and greenery through enhanced ecosystem function	Number of new plant or animal species (native)
Aesthetically pleasing	Percent of residents, students, and faculty satisfied with the appearance of the garden	Percentage of weed cover Frequency of trash removal

Bioswale

Core Services - Bioswale		
Service Attributes that Matter to Customers or Elected Leaders	External LoS Performance Indicator	Internal LoS Performance Indicator
Directs rainwater into swales	Usability of surrounding paths	Pooling water
Reduce flooding	Usability of surrounding paths	Pooling water
Recharge aquifers	Health of vegetation	Temporal stability of plant community in dry conditions

Secondary Services - Bioswale		
Service Attributes that Matter to Customers or Elected Leaders	External LoS Performance Indicator	Internal LoS Performance Indicator
Aesthetics	Frequency of use of surrounding spaces	Vegetative health

Infiltration Channel

Core Services - Infiltration Channel		
Service Attributes that Matter to Customers or Elected Leaders	External LoS Performance Indicator	Internal LoS Performance Indicator
Rainwater Diversion	Walkability of pathways during rainfall	Percent rainfall diverted to channel
Flood prevention	Channel over/under capacity	Lack of blockage and debris in channel

Filtration of pollutants	Water in channel does not appear murky	Functionality of filters and health of vegetative buffer

Secondary Services - Infiltration Channel		
Service Attributes that Matter to Customers or Elected Leaders	External LoS Performance Indicator	Internal LoS Performance Indicator
Aesthetics	Benefits to mental health and satisfaction with architecture	Landscape quality index and local feedback
Recreational uses	Supporting communal gathering	Consistency of usage over time

Recirculation Channel

Core Services - Recirculation Channel		
Service Attributes that Matter to Customers or Elected Leaders	External LoS Performance Indicator	Internal LoS Performance Indicator
Rainwater diversion	Usability of pathways	Flow rate in channel

Secondary Services - Recirculation Channel		
Service Attributes that Matter to Customers or Elected Leaders	External LoS Performance Indicator	Internal LoS Performance Indicator
Aesthetics	Benefits to mental health and satisfaction with installation	Landscape quality index and local feedback
Recreational uses	Communal gathering, walking, cycling	Usage over time

Detention Pond

Core Services - Detention Pond		
Service Attributes that Matter to Customers or Elected Leaders	External LoS Performance Indicator	Internal LoS Performance Indicator
Flood control	Percent of residents satisfied with Detention pond installation	Percentage reduction in flood incidents or flood damage in the service area
Erosion control	Reduction in costs associated with repairing erosion damage	Percentage reduction in soil erosion rates in the service area

Water quality improvement	Decrease in water quality-related complaints from residents or businesses	Pollutants removed by the detention pond

Secondary Services - Detention Pond		
Service Attributes that Matter to Customers or Elected Leaders	External LoS Performance Indicator	Internal LoS Performance Indicator
Recreational Value	More park visitors	Maintenance frequency of recreational features
Habitat Creation	More biodiversity	Health and coverage of vegetation
Community Safety	Less complaints about community safety	System reliability during storm events

Stormwater Pond

Core Services - Stormwater Pond		
Service Attributes that Matter to Customers or Elected Leaders	External LoS Performance Indicator	Internal LoS Performance Indicator
Stormwater management	Percent of residents satisfied with stormwater pond installation	Rate of water discharged downstream
Stormwater pond is managed in cost-effcetive way	Average maintenance cost per square meter of stormwater pond	Stormwater pond maintenance completed on schedule
Clean receiving water	Number of fish species present in the water body	Percent of the community with sufficient stormwater quality control

Secondary Services - Stormwater Pond		
Service Attributes that Matter to Customers or Elected Leaders	External LoS Performance Indicator	Internal LoS Performance Indicator
Improve biodiversity	More visitors in this area	Percent of features of native species
Aesthetics	Area of stormwater pond that are naturalized	Average median age of stormwater pond

APPENDIX B. CURRENT STATE OF ASSETS

Field	Description
Site Description	Situated between Herring House and Walter Gage Residence, the green roof features culturally significant plants to the xʷməθkʷəy̓əm (Musqueam) people. These plants include Western Red Cedar, Kinnikinnick, Sword Fern, and Salal.
Asset ID	# 1: sɬewət̓ leləm̓ (Herring House) Green Roof
Classification	Green Roof
Location	1945 Wesbrook Mall, Vancouver, BC V6T 1Z4
Size	3593 m^2
Year Installed	2022
Ownership	UBC
Management responsibility	UBC Student Housing and Community Services
Unit replacement cost	Depending on soil depth, replacement costs can range from $10 to $20 per square foot. Total: ~ $580,120.95
Replacement value	Helps manage stormwater, improve air quality, reduce urban heat, and support biodiversity
Expected useful life	30-50 years if maintenance is continued
Remaining useful life	Approximately 47 years with maintenance
Condition rating	Very good

Field	Description
Site Description	Sitting atop the Rose Garden Parkade, with an elevated view of the Pacific Ocean and North Shore Mountains, the public garden features over 4,500 rose bushes of 400 different varieties. The roses bloom from June to September.
Asset ID	# 7: Rose Garden Green Roof
Classification	Green Roof
Location	6301 Crescent Rd, Vancouver, BC V6T 1Z2

Size	837 m^2
Year installed	1994
Ownership	UBC
Management responsibility	• UBC Campus and Community Planning • UBC Municipal Landscape Services: Responsible for ensuring that the Rose Garden is adhering to the sustainable landscape management practices
Unit replacement cost	Depending on soil depth, replacement costs can range from $10 to $20 per square foot. Total: ~ $135,140.85
Replacement value	• Serves as a peaceful retreat for students, faculty, and visitors, reducing stress and promoting mental well-being • Frequently used for social interactions
Expected useful life	30-50 years if maintenance is continued
Remaining useful life	Approximately 9 years left
Condition rating	Very Good

Field	Description
Site Description	The rain garden consists of two main sections, one next to the EOS building and the other next to the Frank Forward Building. Plants in the rain garden will need to be pruned regularly to ensure that they maintain their normal function.
Asset ID	# 15: Frank Forward Building Rain Garden
Classification	Rain Garden
Location	6339 Stores Road, Vancouver, BC V6T 1Z4
Size	22m^2
Year installed	2022
Ownership	UBC Properties Trust
Management responsibility	UBC Campus & Community Planning
Unit replacement cost	Depending on soil depth, replacement costs can range from $10 to $20 per square foot. Total: ~ $396

Replacement value	Temporarily store rainwater to relieve pressure on drainage systems during heavy rains, filter pollutants, and reduce urban heat island effects
Expected useful life	10-30 years if maintenance is continued
Remaining useful life	Approximately 27 years of useful life
Condition rating	Very good

Field	Description
Site Description	Situated at the ground level above the underground museum, it features a central meadow composed of various BC native grasses and herbal plants.
Asset ID	# 16: Beaty Biodiversity Museum Green Roof
Classification	Green Roof
Location	Vancouver Campus, 2212 Main Mall, Vancouver, BC V6T 1Z4
Size	1698 m^2
Year installed	2009
Ownership	UBC Properties Trust
Management responsibility	UBC Building Operations and a volunteer from the Beaty Biodiversity Museum
Unit replacement cost	Depending on soil depth, replacement costs can range from $10 to $20 per square foot. Total: ~ $274,156.8
Replacement value	• Green roofs provide natural insulation, reducing heating and cooling costs over time. • This green roof is frequented by researchers, visitors, and students who utilize it for passive activities such as eating and relaxing
Expected useful life	30-50 years if maintenance is continued
Remaining useful life	Approximately 24 years of useful life
Condition rating	Very good

Field	Description
Site Description	Was once planted with local (now overgrown with unknown plants, shrubs, weeds, etc.), well-adapted native species, which covered the

	auditorium structure below it. The Green roof was also formed in a courtyard-like garden for the offices that overlook it.
Asset ID	# 17: Centre Interactive Research on Sustainability
Classification	Green Roof
Location	2260 West Mall, Vancouver, British Columbia, Canada
Size	91 m^2
Year installed	2011
Ownership	UBC Properties Trust
Management responsibility	UBC Building Operations
Unit replacement cost	Depending on soil depth, replacement costs can range from $10 to $20 per square foot.
Replacement value	Green roofs provide natural insulation, reducing heating and cooling costs over time.
Expected useful life	If well maintained the green roof could last around 40-50 years
Remaining useful life	Approximately 31 years of useful life but judging by accelerated deteriorated state, a more accurate approximation would be <15 years.
Condition rating	Poor

Field	Description
Site Description	This bioswale is a shallow, vegetated channel near the CIRS building. The plants and rocks help remove sediments and pollutants before the water percolates into the ground or flows to nearby drainage.
Asset ID	# 18: Centre Interactive Research on Sustainability Bioswale
Classification	Bioswale
Location	2260 West Mall, Vancouver, BC V6T 1Z4
Size	172 m^2
Year Installed	2011
Ownership	UBC Properties Trust
Management responsibility	UBC Properties Trust

Unit replacement cost	Depending on soil depth, replacement costs can range from \$10 to \$20 per square foot. Total: ~ \$2580
Replacement value	• Slow down the flow of rainwater, relieve the pressure on urban drainage systems, and reduce the risk of urban waterlogging. • Provide habitats for insects and birds, and promote the recovery of urban ecosystems.
Expected useful life	20-50 years if maintenance is continued
Remaining useful life	Approximately 36 years of useful life
Condition rating	Good

Field	Description
Site Description	The green roof consists of low-maintenance plants such as grasses, sedum, and other resilient species well-suited to Vancouver's climate. Note: GRI Asset IDs 24 and 25 are on private property and were not visited on site for data collection.
Asset ID	# 24: Granite Terrace Green Roof
Location	3233 Wesbrook Mall, Vancouver, BC V6S 0B4
Size	674 m^2
Year installed	2009
Ownership	UBC Properties Trust
Management responsibility	Wesbrook Properties
Unit replacement cost	Depending on soil depth, replacement costs can range from \$10 to \$20 per square foot.
Replacement value	Green roofs provide natural insulation, reducing heating and cooling costs over time.
Expected useful life	If well maintained the green roof could last around 40-50 years
Remaining useful life	Approximately 29 years of useful life
Condition rating	NA

Field	Description

Site Description	The green roof covers over 50% of the building's roof area. This green roof requires minimal maintenance while enhancing energy efficiency and reducing rainwater runoff. Includes a garden terrace, providing residents with outdoor spaces for relaxation and socialization. Note: GRI Asset IDs 24 and 25 are on private property and were not visited on site for data collection.
Asset ID	# 25: Tapestry North Green Roof
Location	3382 Wesbrook Mall, Vancouver, BC V6S 2L2
Size	2393 m^2
Year installed	2010
Ownership	Seasons Retirement Communities • Previously owned by Concept Properties and managed by Origin Active Lifestyle Communities
Management responsibility	Seasons Retirement Communities
Unit replacement cost	Depending on soil depth, replacement costs can range from $10 to $20 per square foot. Total: ~ $386,370
Replacement value	Provides residents with outdoor spaces for relaxation and socialization.
Expected useful life	30-50 years if maintenance is continued
Remaining useful life	Approximately 15 years with maintenance
Condition rating	NA

Field	**Description**
Site Description	This recirculation channel snakes through the University Neighborhoods between Burton and Gray Avenues, eventually feeding into the stormwater pond in Michael Smith Park. The channel collects runoff from parallel pathways and periodically experiences blockages from detritus entering the channel. A long-standing blockage of dirt and sediment stops water from the recirculation channel from dispensing into the stormwater pond except for during heavy rainfall events, when the channel reaches a higher water level. There is no risk of spillover from the channel onto walkways during heavy rainfall.
Asset ID	# 26: Wesbrook East Recirculation Channel

Location	3382 Wesbrook Mall, Vancouver, BC V6S 2L2
Size	778 m^2
Year installed	2005
Ownership	UBC Properties Trust
Management responsibility	UNA
Unit replacement cost	Masonry of channel roughly equates to $80-200/square meter. Average cost: ~ $108,920
Replacement value	Provides residents with outdoor spaces for relaxation and socialization.
Expected useful life	50 years
Remaining useful life	30 years
Condition rating	Very good

Field	Description
Site Description	This stormwater pond situated within Michael Smith Park in the University Neighbourhoods collects runoff from the park as well as water dispensed from a recirculation channel (Asset ID 26). The pond serves to recharge groundwater during dry spells, through a thin filter installed at the bottom of the pond, which helps to keep the park green. Algae periodically block filters as well as fountain elements of the pond.
Asset ID	# 27: Michael Smith Park Stormwater Pond
Location	3382 Wesbrook Mall, Vancouver, BC V6S 2L2
Size	2154 m^2
Year installed	2004
Ownership	UBC Properties Trust
Management responsibility	UNA
Unit replacement cost	Calculation assumes concrete lining. This GRI has some specialized functionality that is more difficult to find effective comps for. Total: ~ $179,475
Replacement value	Provides residents with outdoor spaces for relaxation and socialization.
Expected useful life	50 years if maintenance is continued

Remaining useful life	Approximately 29 years
Condition rating	Very good

Field	Description
Site Description	This recirculation channel connects larger water features in the University Neighbourhoods and collects runoff from pathways. The channel adds aesthetic value to the surrounding area and a vegetative buffer separates much of the channel from these walkways. The channel ultimately feeds into Mundell Park.
Asset ID	# 28: Wesbrook West Recirculation Channel
Location	3382 Wesbrook Mall, Vancouver, BC V6S 2L2
Size	10842 m^2
Year installed	2005
Ownership	UBC Properties Trust
Management responsibility	UNA
Unit replacement cost	Depending on soil depth, replacement costs can range from $10 to $20 per square foot. Total: ~ $1517880
Replacement value	Provides residents with outdoor spaces for relaxation and socialization.
Expected useful life	50 years
Remaining useful life	30 years
Condition rating	Very good

Field	Description
Site Description	Rain garden situated in courtyard of apartment complex in Wesbrook Place. Serves primarily as a communal space with water feature, buffer vegetation, and several benches.
Asset ID	# 29: Wesbrook Apartments Rain Garden
Location	3479 Wesbrook Mall, Vancouver, BC V6S 2L2
Size	389 m^2
Year installed	2011

Ownership	UBC Properties Trust
Management responsibility	UNA
Unit replacement cost	Depending on soil depth, replacement costs can range from $10 to $20 per square foot. Total: ~ $5835
Replacement value	Provides residents with outdoor spaces for relaxation and socialization.
Expected useful life	30 years
Remaining useful life	16 years
Condition rating	Very good

Field	Description
Site Description	Rain garden situated within courtyard of apartment complex in Wesbrook place. Water recirculation within water feature. Buffer zone around the water feature serves as the rain garden. Primarily serves as aesthetic feature for the apartment complex.
Asset ID	# 30: Birney Ave Rain Garden
Location	5928 Birney Ave, Vancouver, BC V6S 2L2
Size	629 m^2
Year installed	2010
Ownership	UBC Properties Trust
Management responsibility	UNA
Unit replacement cost	Depending on soil depth, replacement costs can range from $10 to $20 per square foot. Total: ~ $9435
Replacement value	Provides residents with outdoor spaces for relaxation and socialization.
Expected useful life	30 years
Remaining useful life	15 years
Condition rating	Very good

APPENDIX C. CONDITION RATING

Rating	Water management	Vegetation health	Structural integrity	Management Action
Very good	Water is accurately diverted to reservoirs and surrounding areas are usable.	Vegetation is healthy, high local biodiversity and habitat provisioning.	High integrity in all conditions.	None needed.
Good	Water is diverted but may overflow reservoirs in particularly high rainfall intensity.	Region is healthy and relatively diverse.	Sound integrity in most conditions.	None needed.
Fair	Rainwater is mostly diverted and may occasionally disrupt use of surrounding space.	No factors that would deter growth, but low levels of diversity.	Sound integrity in normal conditions.	Periodic monitoring of site, baseline management by type of GRI.
Poor	Water is not often diverted but the impact on surrounding spaces is not large.	Signs of poor conditions for growth, presence of invasives.	Integrity is maintained in optimal condition.	Baseline management should be carried out quickly. Establish frequent monitoring to ensure revival of services.
Very poor	Water frequently disrupts use of surrounding space.	Lack of vegetation or domination of invasives.	Low integrity with minimal external pressure.	Active restoration and deliberate removal of negative externalities is necessary by management teams. Activities must be designated according to specific sites.