Rainwater Infrastructure Building Typologies Pathways Study

FINAL REPORT

Lotus Water

Prepared for:

City of Vancouver
Sustainability Group

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Contents

Introduction & Background

The City of Vancouver is facing several challenges with respect to rainwater management. Population growth and climate change are straining the city's aging sewer system, leading to chronic water quality impacts on receiving waters such as False Creek and the Fraser River. Urban rainwater runoff discharges directly to the sewer and drainage system and contributes pollutants that are known to be toxic to fish and other aquatic species. Vancouver's prevalence of combined sewers and associated combined sewer overflows only exacerbate this issue, as does climate change which is causing more frequent, intense rain storms.

Water-related infrastructure comprises one of the costliest building blocks of modern cities. With the pressures to upgrade the systems to serve growth, increase water quality treatment, adapt to changing rainfall patterns due to climate change, and address the infrastructure renewal gap, the expected cost of integrated water infrastructure in Vancouver within the coming decades is in the billions of dollars. By 2041, the Metro Vancouver Regional Growth Strategy (2011) anticipates that Vancouver will have grown by more than 150,000 residents and close to 90,000 jobs, putting even more pressure on the existing water, sewer, and drainage system.

In response, the Citywide Integrated Rainwater Management Plan (2016, updated 2017) and the Rain City Strategy (November 2019) call for a shift in our urban water management strategies to include a more holistic and integrated approach to achieving the goals of improved water quality, increased resilience, and enhanced livability. This ambitious approach treats rainwater as a valuable resource and mimics the natural hydrologic cycle by capturing and treating rainwater where it lands using green rainwater infrastructure (GRI). This is an approach used by leading cities around the world and is a proven way to deliver multiple benefits while providing cost-effective stormwater management.

The Citywide Integrated Rainwater Management Plan (IRMP) and the Rain City Strategy (RCS) introduced specific performance targets and design standards in both the "public realm" (streets, public spaces, parks) and "private realm" (private property, City-owned property). To date, the City has reviewed a variety of GRI approaches to achieve the design standards for the private realm, including green roofs, rainwater harvesting, and bioretention. However, on some sites applicants have expressed difficulty in meeting the RCS design standards. In addition, some stakeholders have expressed concern regarding barriers to GRI implementation such as cost, potential liability, and warranty issues. It is therefore critical to better understand how GRI can be used on different building types to meet the RCS targets, including the costs and benefits of doing so. This information will help the City advance fair, effective rainwater management requirements for the private realm.

Executive Summary

The Rainwater Infrastructure Building Typologies Pathways Study ("Pathways Study") was undertaken to better understand what GRI tool combinations (compliance pathways) can be used at a site level to meet the rainwater management design standards (capture, clean, discharge) for a range of representative building-site 'typologies'. Typologies range from single family homes to large dense developments. As part of this work, the City is also seeking to better understand the cost of these green rainwater infrastructure "compliance pathways", the co-benefits that they offer, and the barriers and solutions to implementation. This work produced a preferred set of GRI tool pathways for each building-site typology as well as commentary and recommendations to help inform the development of new and/or improved rainwater management policies for the City that will help achieve the goals of the Rain City Strategy in a fair and consistent manner.

The Pathways Study includes a series of tasks organized to progressively identify the problem statement, fill data gaps, and provide recommendations. Each of these tasks (except for the administrative Task 1) is summarized below and discussed in greater detail in the associated Task memo deliverables included in this report.

Task 1 – Confirm Work Plan
Task 2 – Representative Building Site Typologies
Task 3 – Rainwater Management Tools
Task 4 – GRI Design Methodology
Task 5 – Performance Modeling and Pathway Development
Task 6 – Costing
Task 7 – Rainwater Management Co-Benefits
Task 8 – Rainwater Management Barriers and Solutions
Task 9 – Policy Considerations

Task 2 - Representative Building Site Typologies

A building site typology is a generic description of a building development project, as defined by the combination of its various physical characteristics including building footprint, building height, current and allowable use, parcel size, and parkade size. The Pathways Study developed seven representative building site typologies to be used in the subsequent modeling and analysis of rainwater management compliance approaches.

Methodology

To identify representative building site typologies, the following available relevant data sources were collected, evaluated, and aggregated to provide a comprehensive picture of the existing conditions and future development in the City.

Building Permit Database

The "Issued Building Permits" database analyzed consisted of over 25,000 entries for building permits issued by the City from January 2017 through July 2021. This included permits issued for new construction as well as retrofits and other uses. These were grouped into sub-categories based on the specific use category field and then further distilled into the following new building use types:

- Single Family Residential (SFR) – Small parcel single family homes, duplexes, laneway homes
- Multi-Family Residential (MFR) – Small-to-mid scale multi-family residential, typically 6 stories or less, such as townhomes and apartment buildings.
- Mixed-Use Residential (MUR) – Large scale multi-family residential, typically greater than 6 stories, with a commercial or institutional use type included.
- Commercial (COM*)* – Commercial buildings of all scales that typically contain office space
- Institutional (INST) – Schools, Hospitals, Community Care Facilities, etc
- Industrial (IND) – Industrial, Manufacturing
- Other (OTHER) – Not Stated, Public Utilities, Parks, Marinas, Agriculture, etc

Impervious Surface Area Database

The Impervious Surface Area database, created in 2014, served as the primary data source for the existing conditions of the buildings and land use in the City. The database contained data on all City parcels for the entire city. The impervious surface area data were separated into their own databases for further analysis. A statistical analysis was performed to determine the distribution of parcel sizes, impervious area percentage, and relationship between parcel size and impervious area.

Building Footprint Database

The Building Footprints 2009 database contained data on area, type, and height of the roofs in the City in 2009. GIS software was used to spatially join the Building Footprints 2009 database with the Property Parcels database, to associate building footprint / roof areas with zoning categories and land use typology. The resulting Building Footprints database was broken out into the same land use types as the Impervious Area Database and analyzed.

Rainwater Management Plan (RWMP) Database

Rainwater Management Plans (RWMP) are the submittals to the City that document the size, location, and configuration of proposed GRI that will be utilized to meet the rainwater management requirements. The City provided 101 RWMP submittals that were reviewed in detail and analyzed. A RWMP database was created by reviewing the select documents and extracting relevant project information including, but not limited to, address, existing land use, proposed land use, building height in stories, lot size, existing impervious area, proposed impervious area, pre- and post-project runoff peak flow, require rainwater management volume, and the number and type of GRI facilities proposed at the site. The projects in the RWMP database were separated by proposed land use and analyzed for minimum, maximum, and average parcel size, along with the pre- and post-project average impervious areas. The RWMP database was compiled and distilled to document new development building site typologies.

Representative Building Site Typologies

All data and analysis were combined to create the following seven representative building site typologies, which were reviewed and approved by the City for subsequent use in modeling compliance pathways. Illustrative example graphics for each typology are included in Appendix B of the Task 4 Memo.

Table ES 1 – Representative Building Site Typologies

Building Site Typology	Representative Typology Characteristics					
	Total Parcel Area (sq. m.)	Impervious Area (% of parcel) [1]	Building / Roof Area		Building Stories	Parkade
			(% of parcel)	(sq. m.)		
Small Lot Residential – Low Massing	375	45%	30%	113	2	no
Small Lot Residential – High Massing	375	70%	50%	188	2	no
Low-Rise Residential & Mixed-Use	2,500	90%	40%	1,000	3	yes
Mid-Rise Residential & Mixed-Use	3,000	95%	65%	1,950	6	yes
High-Rise Residential & Mixed-Use	1,200	90%	70%	840	20	yes
Low/Mid-Rise Non-Residential	2,500	100%	40%	1,000	3	yes
High-Rise Non-Residential	8,000	100%	55%	4,400	14	yes

Typology Descriptions:

- Small Lot Residential – Low Massing: primarily single-family residential development with one building (representative of the character of much of the historic existing residential lots)
- Small Lot Residential – High Massing: lower density residential typically with multiple buildings, such as a single-family home with laneway house, duplex, or rowhouse; also covers smaller multi-unit development such as character 4- and 6-unit buildings
- Low-Rise Residential & Mixed-Use: medium density development such as a stacked townhouse or low-rise apartment building, including those with a commercial component
- Mid-Rise Residential & Mixed-Use: medium density development such as mid-rise apartment buildings
- High-Rise Residential & Mixed-Use: larger high-rise apartment buildings and similar
- Low/Mid-Rise Non-Residential: lower density commercial and industrial buildings
- High-Rise Non-Residential: higher density commercial and industrial buildings

These typologies do not necessarily cover all potential building or project configurations that may be encountered, but rather are intended to represent a broad range of building types (and especially those where compliance is known to be challenging) to provide an understanding of rainwater management challenges and opportunities at different scales.

[1] Impervious Area represents the area onsite that will not be available for infiltration into the subgrade. This includes the roof area, all surface level impervious surfaces (e.g. paved parking, pathways, etc), and also subsurface structures (such as a parkade, which may extend nearly lot line to lot line) that could have planting above it.

Task 3 - Rainwater Management Tools

An early task in this study focused on defining the set of potential rainwater management tools, including both GRI tools and grey (non-GRI) tools, that could be used by developers to meet the City's rainwater management design standards. These tools are the basis for compliance pathway development and are analyzed further in subsequent tasks to determine performance, costs, and co-benefits. Typically, these tools facilitate the following key processes, either individually or in combination: retention, detention, and water quality improvement. For the purposes of the GRI Pathways Study, "retain/retention" is defined as captured runoff permanently removed through evapotranspiration, reuse, or infiltration (reduces peak flow and volumes) and "detain/detention" is defined as runoff that is captured and drains slowly back to combined sewer or stormwater collection system (reduces peak flow only).

Since there are many types of GRI and non-GRI tools available, the first step was to establish the proposed list of rainwater management tools to be included in this study. This list was developed based on existing City guidance, review of recent Rainwater Management Plans submitted to the City, practical design experience, and City input. Proposed tools were selected due to their ability to be:

- collectively applied across a range of hydraulic and hydrologic processes;
- applicable for the range of building-site typologies; and
- tested across the anticipated range of benefits, costs, and barriers likely to be encountered during implementation by developers.

Starting with tools identified in the project charter, an initial tool list was developed, presented to City staff, and refined. These tools include primary types (e.g., permeable pavement) as well as sub-types (e.g., permeable pavers, pervious concrete, and pervious asphalt) that may provide different siting applications, performance, cost, and/or co-benefits. The list of primary tool types are presented below.

- GRI Tools:
    - Resilient (green) roof
    - Bioretention planter
    - Tree trench
    - Permeable pavement
    - Subsurface infiltration gallery
    - Rainwater harvesting system (non-potable reuse)
- Non-GRI Tools:
    - Detention tank
    - Proprietary water quality treatment device

Two primary categories of information were compiled for each tool: siting considerations and design parameters. Siting considerations included applicable building-site typologies, maximum contributing drainage areas, minimum soil infiltration rates, minimum groundwater separation, and other setback criteria. Design parameters compiled included minimum and maximum dimensions, component characteristics, outlet and discharge requirements, and other design considerations.

Task 4 - GRI Design Methodology

Since the City introduced new rainwater management requirements for privately-owned redevelopment questions have arisen regarding how the regulatory program is implemented and what measures the City can take to simplify the rainwater management requirements and streamline the compliance process. Developers, proponents, and City staff have also identified data gaps and the need for guidance regarding the interpretation of the City's rainwater management design standard and target requirements, where they apply, and how GRI can be designed to meet those requirements. To address this, the GRI Design Methodology task:

- summarized the current state of the overall regulatory environment, applicability, and GRI design requirements related to successful submittal of a RWMP;
- recommended an updated GRI design methodology to standardize the design process;
- developed recommendations for revisions or modifications to City rainwater management regulations, policy, and guidance that would simplify the compliance process and enable private sites to meet the City's requirements in a more streamlined fashion; and
- created a GRI design tool to develop and size compliance pathways for the building typologies.

Current State Assessment

The current state assessment includes review and summaries of key, relevant sections of the Vancouver Building By-Law (VBBL), Zoning & Development By-Law (ZDBL), the Engineering Design Manual, and the Rainwater Management Bulletin. It should be noted that the Sewer and Watercourse Bylaw, which set requirements for sewer connection permits and sewer capacity review, was not included in this assessment. However, it is related to and, in some cases, part of the RWMP process. The project team noted the following conclusions:

1) Applicability for when rainwater management in redevelopment is required is not explicitly stated. There is no citywide standard (or threshold) for rainwater management applicability and performance.[2]
2) Overlaps exist between different rainwater policies. For example, some policies have conflicting instructions such as the City of Vancouver Engineering Design Manual, the Integrated Rainwater Management Plan, and the Rain City Strategy.
3) Multiple locations for drainage and rainwater management information and requirements. The VBBL provides basic information on some specific elements of design and all codes necessary for plumbing and drainage. However, this by-law provides only a portion of information needed

[2] Subsequent to the completion of the Task 4 memo the City updated rainwater requirements, moving them out of the ZDBL and into the VBBL. This change applies mandatory rainwater management requirements throughout the City to new Part 3 construction. The substantial expanded scale and applicability of the VBBL requirements will enhance rainwater management in Vancouver and sets the stage for improved, city-wide, enforceable private-property rainwater management requirements. However, mechanisms for incentivizing the use of green infrastructure tools for rainwater management through the review process may be weakened by this change.

by designers for rainwater management, which can result in wide range of design approaches. Subsequent bulletins seek to clarify parts of the VBBL and provide addition resources but fail to provide a detailed rainwater management methodology or to consolidate most of the required information for successful RWMPs.

4) The Engineering Design Manual is a robust document that provides information covering a variety of engineering design issues, particularly servicing and streetscape design. While it provides the technical information needed for these designs, as well as methodology for a variety of calculations, it does not provide a comprehensive summary of all the key information to be considered when designing a rainwater management system specific to a redevelopment scenario.

5) The RWM Bulletin provides much of the required performance criteria to be met for rainwater management but only briefly touches on elements of GRI design. This document, together with the Engineering Design Manual, could provide most information needed for the design of a rainwater management system. However, the Manual is general and does not provide specific guidance on how to integrate GRI into site and development plans. The Team recommends a standalone and comprehensive manual for meeting stormwater management requirements that clarifies applicability, performance standards, and design guidance.

6) The by-laws and policies reviewed successfully provide most of the information required for design but lack the needed consolidation and completeness for successful implementation of all policies. Various policies and bulletins serve as appendices to many of the by-laws, and designers are expected to evaluate all these documents to obtain the required information. This can be quite time consuming as some of these by-laws, policies, and bulletins can be difficult to find if a designer is not aware they are relevant.

7) Performance requirements are unclear. The RCS is an aspirational document that proposed the capture and treatment of the first 48mm of rainfall during a rainfall event; however, most of the documents reviewed, containing similar information, require the capture and treatment of the first 24mm of rainfall during a rainfall event. If the goal of these documents is to assist in the fulfillment of these strategic goals, that needs to be reflected in the documents themselves through more stringent requirements.

8) Broader policy goals justifying the rainwater management requirements are unclear. The benefits to the drainage system and receiving waters from scaled implementation for the 48mm requirement have not yet been quantified. Completing this analysis would give the City's policies grounding and direction to align with the Vancouver Plan and Healthy Waters Plan as redevelopment occurs over the next 30 years.

Overall, the project team recommends that the City of Vancouver revise and consolidate the codes, by-laws, and bulletins behind a clear policy goal, and then translate that goal to rainwater management at the project-scale through a single guidance manual that is easy to navigate and use for both developers and City staff.

Review of Rainwater Management Plans

To understand how applicants are complying with the Rainwater Management Bulletin, the project team was provided RWMPs prepared by a range of consultants and reviewed by the City of Vancouver. The City initially provided 100 RWMPs, which were reviewed in detail and analysed to provide an overview of the current state, potential concerns, and whether the objectives presented in the Rainwater Management Bulletin were achieved. The City subsequently provided another 192 RWMPs, which were used to validate the findings from analysis of the original 100. Note this assessment does not represent final accepted RWMPs; rather, they were reviewed in various stages of submittal and acceptance for this exercise.

RWMP Data Analysis

To meet the volume reduction criteria provided in the Rainwater Management Bulletin, a proposed development must manage 24mm of rainfall, ideally through retention-based Tier 1 GRI practices (e.g., infiltrating bioretention, green roofs, or rainwater reuse). If a project meets acceptable exemptions for using Tier 1, they may then pursue either Tier 2 GRI (e.g., non-infiltrating bioretention, absorbent landscape on slab), which will provide some limited retention along with detention, or the Tier 3 practice of detention with treatment.

The data highlights that:

- Only 13% of the projects analyzed met the rainwater management criteria using retention-based GRI tools, and only 2% using only the preferred Tier 1 GRI methods.
- Though 94% of projects provided some retention with either a Tier 1 or Tier 2 GRI tool, over half of the projects were not able to provide retention for even half of the depth requirements (i.e., 30% retained less than 6mm and an additional 24% retained between 6 and 12 mm) - for all of these projects, the remainder of the volume capture requirement is met with Tier 3 detention (e.g., 9% of projects had some combination of Tier 1 and Tier 3, and 62% of projects had some combination of Tier 1, Tier 2, and Tier 3).

In addition to documenting what facilities were used to meet the design targets, the team looked at the range, and average, performance achieved for retention-based practices. Though some projects are achieving high levels of retention, and others almost none, the average depth retained is about:

- 71% of the standard for projects using only Tier 1 methods (17 mm),
- 54% for projects using only Tier 2 methods (13 mm), and
- 77% for projects using both Tier 1 and 2 methods (18.5 mm).
- The remainder of the 24 mm capture target is being addressed by Tier 3 detention facilities.

Rainwater Management Tools Used

- The most frequently proposed Tier 1 GRI tool was absorbent landscaping, which is often just the natural landscape areas included around the edges of properties where the parkade is located. Absorbent landscaping often represents a small portion of the site and typically does not manage significant impervious runoff.

- Out of the 100 RWMPs examined, 47 included some type of higher performing Tier 1 GRI (i.e., other than absorbent landscaping). Green roofs were the most common and were often encouraged by the City during the review process. Infiltrating Tier 1 GRI methods, such as bioretention, infiltration galleries, or permeable pavement, were much less common and found primarily on large sites with institutional land uses. Rainwater harvesting and reuse was not commonly used, with only two instances proposed.
- About half of the RWMPs examined utilized some form of Tier 2 GRI, which primarily consist of absorbent landscaping on slab and lined planter boxes. Rainwater is infrequently directed towards these GRI and their performance is limited.
- Tier 3 practices, primarily detention tanks and proprietary treatment devices, were by far the most common method of managing rainwater with nearly all projects (93%) utilizing a detention facility of some kind.

Rationale For Limited Use of GRI

In reviewing the City's response comments to the RWMPs, justification for lack of Tier 1 methods is typically requested and the review comments usually strongly encourage a higher proportion of Tier 1 approaches.

- Infiltration is commonly rejected by the applicant as a viable method based on lack of space, by citing the On-site Infiltration Systems Bulletin and the need to maintain required setbacks from building foundations.
- Suggestions to utilize a green roof on a project are often countered with a letter from a structural engineer citing that it would be structurally infeasible, for instance due to a wood frame structure.
- Developers did not have sufficient design tools and standards to deliver GRI efficiently in development applications.

Jurisdictional Scan

The jurisdictional scan collected key information on municipalities with relevant rainwater management policies, recommended design methodology, and successful mechanisms for achieving compliance, such as:

- Integration of green roofs as an acceptable GRI tool for stormwater compliance, as well as noting overlapping policies for green roofs.
- Success and maturation of the policies and programs for stormwater compliance.
- Distinguish the various drivers for each jurisdiction's policies and requirements.
- Strengths and weaknesses as they relate to the GRI Pathways Study goals.

The scan focused on municipalities with both separate and combined drainage systems, highlighting the goals and drivers for the respective stormwater management regulations as well as the specific standards established. In addition, it provides a comprehensive and detailed description of each program, including links directly to the legal authority and codes/bylaws enabling each jurisdiction to enforce the stormwater regulations in new and redevelopment.

The scan covered the following municipalities:

1. Toronto, Ontario
2. City of North Vancouver, British Columbia
3. Portland, Oregon
4. Seattle, Washington
5. San Francisco, California
6. Philadelphia, Pennsylvania
7. Washington, D.C.

The team reviewed published reports that analyzed the cities of North Vancouver, Portland, and Washington, D.C. Other source documents were the publicly available rules, guidelines, codes and/or plans for each jurisdiction, as well as team experience in the jurisdictions. The team collected consistent data points across each municipality to provide comparable results, to the extent possible. Each jurisdiction also includes a description of key findings, best practices, and innovative ideas.

Jurisdictional Scan Key Takeaways

The scan found that all jurisdictions had clear standards for where and how the stormwater regulations were applied. It also found that all jurisdictions had some form of alternative or modified compliance or variance built into its codes and manuals.

All jurisdictions had guidance manuals specifically written for stormwater compliance in new and redevelopment projects that meet the stated thresholds or applicability. While these vary in quality and comprehensiveness, the manuals lay out the background and purpose, design criteria and standards, submittal requirements, exceptions, and other critical details to ease the compliance process for the applicant and the regulating agency. The scan also noted where site-scale modeling is required and if sizing tools are provided by the jurisdiction for the applicants. As much as possible, the scan noted how long the stormwater management regulations for new development have been in place.

In the relevant findings for each jurisdiction, the scan includes additional programmatic efforts by the jurisdiction to encourage or require green roof installation, either as an optional tool to meet the stormwater regulations or for other sustainable building/urban greening goals. It also notes other city-sponsored programmatic efforts to retrofit existing buildings and residential properties using GRI. Links are provided throughout the jurisdictional scan for reference whenever available.

For the US jurisdictions, there are clear similarities driven by the Clean Water Act, as summarized below.

- Stormwater codes for development were primarily enacted as result of federal and state requirements pursuant to the Clean Water Act. While the CWA regulates combined systems and separate (MS4) systems differently, the MS4 permits specifically require "post-construction" compliance for regulated sites. Due to this:
  - Applicability of the requirement is standard and clearly defined in all US jurisdictions and often dictated by the MS4 permit language (e.g., disturbance area thresholds), however

some jurisdictions choose to broaden applicability to achieve greater benefits beyond MS4 minimum requirements.
    - Detailed guidance manuals specific to meeting the stormwater management requirements in development are ubiquitous in the US jurisdictions, as are local codes establishing authority, permitting, and enforcement of the requirements.
    - The technical tools and requirements for sizing and designing the stormwater management practice vary, but the manuals all provide detailed instructions and expectations for how to complete the calculations and often provide design standards. Often these are provided by the state stormwater manual.
- In recent years, some jurisdictions with both types of drainage systems have decided to regulate their whole service area under the same rules and provide benefits for both CSO and separately sewered areas.

For the two Canadian jurisdictions, the respective provinces directed the jurisdictions to produce either a liquid waste management plan or a wet weather management plan, which resulted in rainwater management requirement for new development. Like the US cities, these plans are driven by watershed health and receiving water quality as well as drainage and flooding. There does not appear to be a standardized permitting and reporting process similar to the one the US EPA administers and it's unclear how that influences the Canadian Provinces and smaller jurisdictions in pushing them to achieve highest outcomes. However, Toronto's example of the Toronto Green Standard achieves the integration of high standards for green building and climate goals, including stormwater and reuse, as a cohesive policy. This implementation strategy allows the city to avoid the siloed processes and requirements that many US cities struggle with in complying with the CWA.

Current GRI Design Methodology[3]

Current GRI design methodology is outlined in the City of Vancouver's Engineering Design Manual, which was developed as a comprehensive guide to the typical design processes and criteria to be used. Chapter 5 of the manual contains the information currently required for the design of a functional stormwater management system, including GRI, as part of a development. This includes design flow information, methods of calculation, runoff coefficients, rainfall data, and component design guides. Current GRI design follows the design information and procedures outlined in the manual to meet the design standards and performance targets.

Evaluation of Current GRI Design Methods

There are several areas where the current approach to rainfall-runoff calculations and GRI design methods based on the current methodology can be improved. A few of them are identified below.

- There is no conversion of rainfall to runoff for volume calculations. Current methodology assumes 100% of the 24mm of rainfall becomes runoff, which is an overly conservative approach and makes compliance more difficult.

[3] Note that at the time of this evaluation the current approach was based on the ZDBL, prior to the shift of rainwater management requirements into the VBBL.

- The criteria and guidance state that a proposed project must manage the 24mm rainfall in 24 hours, but this time component is not included in the design process. Volume reduction and water quality treatment volumes are determined based on a static rainfall depth rather than a dynamic rainfall pattern. By not distributing the rainfall depth across a full storm duration or using variable rainfall intensities, the rainwater runoff patterns are over-simplified and resulting GRI designs are often oversized.
- The current methodology uses basic storage calculations, such as media volume times media porosity, for natural landscapes and other retention-based GRI. This is a good starting point but does not allow for time-variable accounting of dynamic processes such as infiltration into the media, infiltration into the subsurface, temporary ponding of GRI due to peak runoff, or release from detention to the sewers during the storm event. The result is either oversized GRI or, more typically, the opportunity for applicants to justify the use of detention-based GRI to meet the onsite rainwater management requirements.
- Though not common in current development projects, driveways and parking lots are considered "high-pollutant" areas and have an additional 24mm of water quality treatment volume associated with them. Varying rainwater management targets across a single project complicates the design process, and in this case most pollutants will be captured by the smaller and more frequent rainfall events which produce the first 24 mm of runoff, reducing the value and effectiveness of this additional treatment volume requirement.
- Volume reduction and water quality treatment calculations use simplified, time-independent methods of single rainfall depth while release rate is determined using various design storms and time-dependent calculations. This results in a more complicated evaluation of compliance and ensures that the results are not directly comparable.
- Release rate of water quality treatment volume is initially set at the design release rate based on an intense, short duration, 5-year storm event, then adjusted down to use the required storage volume more efficiently. This results in a high release rate that tends to produce limited peak discharge reduction for longer duration or less intense storms, such as those with 24mm to 48mm of rainfall, where GRI can be more impactful.
- There is little discussion or consideration of standard orifice sizes when setting the design release rate. Designing the outlet control component of a facility using orifices at minimum and/or standard sizes could potentially lead to larger storage volumes (i.e., a standard orifice size may be slightly smaller or larger than a specific calculated size, which in turn would influence storage volume). Though the City is now requiring optimization of orifice size to increase detention for longer duration or less intense storms occurs during the design review process, this optimization should be built into the GRI design process from the start to allow for clarity, consistency, and overall better design.

Recommended GRI Design Methodology

An updated GRI design methodology is recommended that would use a single design storm, distributed over 24 hours, with a unit hydrograph approach to routing that allows for the evaluation of GRI performance in terms of rainwater runoff volume and peak discharge rate. The method proposed is consistent with industry standards and approved methods at other municipalities and will result in a simplified and streamlined GRI design process to meet rainwater management requirements.

Rainfall-Runoff Methodology

The Rational Hydrograph Method is an acceptable method for calculating rainwater runoff from a study area; it allows for time-variable account of dynamic processes in GRI design and is similar to the current approach used by developers in Vancouver. However, the Rational Hydrograph Method is a simplistic approach to runoff calculations that is only appropriate for small sites, typically less than 0.5 ha, that employ simpler approaches to GRI design and compliance. Also, it is based on the Rational Method, which was developed to determine peak flow rates rather than total rainwater runoff from storm events, so evaluating runoff volume requires determining a storm duration and rainfall intensity. This results in a peak flow rate that is highly dependent upon the chosen storm duration and does not vary across that duration. This could potentially lead to GRI design and rainwater management compliance that is inconsistent across projects.

One of the overall purposes of this study is to evaluate and develop potential pathways that proposed projects can use to comply with the City's onsite rainwater management requirements. Additionally, the stated goal of this task is to simplify and streamline rainwater management criteria and the GRI design process. The Santa Barbara Unit Hydrograph (SBUH) Method is standard industry practice for runoff calculations and GRI design and has been used in multiple jurisdictions for decades. Coupled with an appropriate rainfall distribution, the SBUH Method allows for the evaluation of both peak flow rate and total runoff volume from rainfall patterns that mimic real-world conditions. Additionally, the SBUH Method results in better design, as the rainfall distribution typically allows for higher efficiency GRI by minimizing area or volume while still capturing the required runoff and peak flows. Therefore, it is recommended that the Pathways Study use the SBUH Method with a fixed rainfall distribution that will allow for a simple, but not simplistic, evaluation of rainwater runoff and GRI design.

Design Storms and Performance Targets

This Study assumes that the 24mm and 48mm design standards are the performance targets and appropriate depths to capture 70% and 90% of the average annual rainfall. However, our team's understanding is that the City is currently undertaking a separate study to examine rainfall patterns and depths across the city. At the conclusion of that rainfall study, the assumptions that a 6-month, 24-hour storm has a total depth of roughly 48mm and that 48mm depth is equal to the capture of 90% of the average annual storms should be confirmed. The results of the modeling and pathway development in this study provide guidance on feasible approaches to retaining the two design standard depths at developments with varying building and site characteristics. Based on these results, and the results of the rainfall study, a retention depth design standard that differs from either 24mm or 48mm should be considered.

Unlike the volume reduction and water quality treatment depths, the required release rate from a project is not based on the targets established in Volume 1 of the IRMP. The short duration and high intensity of the 5-year or 10-year, 5- or 10-minute storm used for release rate calculations results in a high pre-development release rate target which, in effect, means that systems with orifices sized to that standard produce no attenuation of peak discharge during smaller or less intense storms. A longer duration design storm matching the high rainfall intensities from the 5-year, 5-min or 10-min storms would require a much larger distributed storm event than has previously been proposed. As the 2-year, 24-hour design storm has a peak rainfall roughly equivalent to the 5-year storms and a total depth that is easily compared to the 24mm and 48mm design standards, this design storm could potentially be used to model both runoff volume and peak discharge. For example, a capture of 25% of the runoff volume would be equivalent to 100% capture of the 24mm storm and 50% runoff capture be equivalent to 100% capture of the 48mm storm. Alternatively, a synthetic 24-hour storm distribution that distributes 48mm of rainfall across 24 hours while also having a brief peak intensity that more closely mimics the 5-year, 5- or 10-minute peak intensity could be developed for use in GRI design.

Preliminary Recommendations for Additional Technical Analyses

- Quantify benefits of the performance targets and design standards compared to the broader water quality goals for the City's receiving waters.
- Quantify benefits of potential changes to the rainwater management requirements for combined sewer overflow and drainage capacity issues during wet weather.
- Quantify benefits of potential changes to the rainwater requirements on total loadings discharged to receiving waters in areas with separate storm drainage.
- Assess impacts of existing stormwater infrastructure draining the property as it relates to various release rates, as well as local watershed constraints that should be considered in GRI design.
- Verify that 24/48mm volume retention is equivalent to 70-90% of annual runoff.
- Develop a synthetic storm to capture 24/48mm depth (or other design standard depth) PLUS the 5- or 10-year peaks (or other peak rate).
- As described in Task 9: consider a more restrictive detention tank release rate target, below the pre-development condition, to simulate the benefits of on-site retention.

GRI Design Tool

The GRI Design Tool is an excel-based calculator that can be used to evaluate potential onsite rainwater management compliance pathways using different types of GRI along with the methodology and design storms discussed above. Modeling of various compliance pathways for the representative building site typologies using this GRI Design Tool was completed in Task 5 Modeling.

The GRI Design Tool is fully contained within an excel workbook, but it spread over many worksheets. Some of the worksheets are merely informative, such as those providing tabular and graphic views of design storm distribution. Two of the worksheets are provided for input while the remaining majority include the models and calculations used to evaluate rainfall runoff and GRI performance.

Task 5 - Performance Modeling & Pathway Development

The next step in the study was to assemble and test a set of potential compliance pathways that meet the rainwater management design standards (retention, water quality, and peak flow release rate) for each building-site typology. This involved developing relevant modeling variables and an overall modeling approach, performing the performance modeling, preparing results and observations, and determining recommendations for further pathway development.

MODELING VARIABLES

The primary purposes of the performance modeling task were to determine the viability of various rainwater management tools and compliance pathways for the building-site typologies. The rainwater management tools used to build compliance pathways for each typology were defined in Task 3. The design standards, site conditions, and development conditions represent additional modeling variables that were developed in consultation with the City over a series of working group meetings in Task 5.

Compliance Standards

The City is seeking to test two different compliance design standards for rainwater management in the City under this study. The first represents the 24-mm daily retention standard defined in the Zoning and Development By-law (ZDBL). The second represents the aspirational goal of 48-mm daily retention as defined in the 2019 Rain City Strategy. Both include the same release rate and water quality requirements.

Site Conditions

Two separate variables representing site conditions were determined to be critical for evaluating performance of compliance pathways. These were pre-development conditions and existing soil conditions. These are described further below.

Pre-Development Conditions

The two compliance standards to be tested include a release rate component. Compliance with the release rate standard requires that post-construction peak flow rates not exceed the pre-construction peak flows (using specified intensity-duration-frequency (IDF) curves). Determination of pre-construction flows requires an evaluation of pre-development conditions. Since the typologies are hypothetical sites without an established pre-development state, a set of three pre-development conditions were initially proposed to represent the range of potential values encountered in a real-world development scenario, ranging from 0% impervious to 100% impervious.

Soil Conditions

Soil conditions are a key variable to determine selection and performance of rainwater management tools for a particular site. One of the primary considerations for soil condition is infiltration capacity, which has a direct bearing on the performance of infiltrating GRI tools (Tier 1). A range of infiltration rates were proposed to reflect potential real-world conditions— ranging from high (50 mm/hr) to moderate (20 mm/hr) to low infiltration (5 mm/hr). A no infiltration (0 mm/hr) value was also included to represent very poor infiltration conditions, as well as other site conditions where runoff infiltration is not possible or not recommended. These other site conditions could include high groundwater, steep sloped areas, and areas with soil or groundwater contamination.

Upstream and Downstream Context

For this study, upstream and downstream context could include a number of conditions, including large developments and/or upzonings, increased impervious cover upstream in the watershed, the presence of ecologically sensitive zones downstream, a combined sewer or otherwise capacity constrained pipe, or floodplain with potential for backwatered conditions.

While these are all important contexts, assessment of these conditions would require watershed- scale modeling, which is not part of this study. However, the team highly recommends carrying out watershed-scale modeling based on Task 9 policy recommendations to assess its aggregated impact on the broader conveyance system over a specific timeframe (e.g., aligned with the Healthy Waters Plan's and Vancouver Plan's planning horizon). This would allow the City to quantify the potential system benefits from those policy recommendations, and course correct as needed.

Development and Policy Conditions

Three development-specific conditions that are reflective of decisions made by the developer or influenced by City policy were identified as potential variables of interest. These were roof area managed by rainwater management tools, infiltration area available at ground level as a result of setback requirements and parkade extent, and degree of non-potable reuse. Each of these three variables is described further below.

Roof Area Managed by Roof GRI

Several rainwater management tools (i.e., resilient roofs and blue roofs) require sufficient flat or mildly-sloped roof area to meet or contribute to meeting the standards. The availability of roof area for resilient roofs or blue roofs is highly varied amongst developments given the competition for roof space for bulkheads, egress, and mechanical equipment. Note that roof area programed for public access and amenities space or play areas can be integrated into resilient roof systems and designs and can be included in the managed roof area. These are not mutually exclusive uses.

Therefore, while "roof area available" (i.e., within which the actual resilient roof system managing rainfall would be located) is the primary variable impacted by space constraints, for modeling purposes, "roof area managed" was the variable used to simplify the analysis (acknowledging that a resilient roof system can be designed to manage runoff from adjacent roof area). To capture a range of areas that might be available in a real-world application, a range of values for roof area managed was used from 0% of total roof area up to 100%.

Infiltration Area Available

The availability of space for siting infiltrating GRI tools determines the extent to which these Tier 1 tools are utilized to meet the performance standards. For many of the denser building-site typologies, there is very little, if any, ground-level non-impervious surface available. Even when some ground-level pervious area is available, the ability to site infiltrating GRI tools can be limited by City policies including parking and infiltration setback requirements and by developer decisions around site layout. The available infiltration area considers these two factors:

- Setback Requirements
- Parkade Extent

While these are not the sole limiting factors of infiltration area availability, the values considered for each variable do reflect the potential outcome of a range of future policies and development decisions, which is an increase in available infiltration area.

Setback Requirements

The Vancouver Building By-law (VBBL) requires a 5-meter setback from building foundation for any infiltration system. In addition to this existing requirement, the setback assumption variable used in the modeling includes two additional setback assumptions: a modified 3-meter setback (which could be achieved via the Alternatives Solutions submission or some equivalent policy change), and a no setback assumption (0-meter setback). The modeling of reduced foundation infiltration setbacks was done as a sensitivity analysis step, and any actual policy change to the foundation infiltration setback will require additional study/discussion by the City.

Parkade Extent

The parkade extent variable includes two extremes which represent the range of impacts expected due to parkade structures located beneath the parcels:

- Full Impervious Footprint Parkade: suggests that the parkade extends to the full limit of the defined impervious area for a typology (i.e., the parkade is much larger than the building footprint, occupying 90-100% of the parcel). This is the maximum value, resulting in the greatest reduction to site area available for an infiltrating GRI footprint. This is the standard development practice assumed in the representative site typologies characteristics.
- Building Footprint Parkade: suggests that the parkade does not extend beyond the defined building footprint for a typology. This is the minimum value, resulting in the parkade having no impact on the site area available for infiltrating GRI footprint.

Non-Potable Reuse

The VBBL, Book II, Plumbing Systems contains the current requirements for non-potable water systems and onsite reuse, including the allowable alternative water sources and the allowable uses for non-potable water. Differing approaches to permitted water sources were explored with the rainwater management tools variable, with "rainwater harvesting systems (rooftop runoff)" capturing only roof runoff and "rainwater harvesting systems (all impervious runoff)" including rainwater runoff from other impervious surfaces (i.e., including ground-level stormwater). The non-potable reuse variable had two values focused on different levels of non- potable demand: typical non-potable demands (flushing and irrigation) and expanded non-potable demands (typical demands plus clothes washing and cooling makeup). While both fall under currently permitted uses, they represent two ends of plausible reuse scenarios.

A summary of the variables used is included below.

Table ES 2 – Summary of Modeling Variables

Retention Compliance Standard	Site Conditions		Development and Policy Conditions	
	Pre-Development Condition	Soil Infiltration Rate	Infiltration Area Available	Non-potable Reuse
• 24 mm • 48 mm	• No pre-development (Natural conditions, 0% impervious) • Less than post-development (50% of typology impervious) • Equivalent to post-development (100% of typology impervious)	• High (50 mm/hr) • Medium (20 mm/hr) • Low (5 mm/hr) • None (0 mm/hr)	Foundation Setback • Typical (5 m) • Reduced (3 m) • No setback (0 m) Parkade Extents • Parkade minimum - occupies only the building footprint • Parkade maximum – occupies portion of parcel equal to total impervious area (i.e., 90-100% of parcel)	• Typical non- potable demands (flushing + irrigation) • Expanded non-potable demands (including clothes washing and cooling makeup)

MODELING APPROACH

Testing and development of compliance pathways for each of the typologies and design standards being considered were performed using the GRI Design Tool developed in Task 4. The modeling process involved the creation of different modeling scenarios that represent distinct combinations of typologies, compliance standards, rainwater management tools, and all the other site, development, and policy condition variables discussed in the previous section.

The most complicated component of this modeling analysis was pairing the many rainwater management tools with the many typologies and additional variables that influence tool siting and performance. This is compounded by the hypothetical nature of this exercise, where true site conditions and context are not known. To navigate these complexities, the modeling approach required multiple phases.

In Phase 1, as described below, the high-level viability and scale testing was performed to isolate each primary rainwater management tool type to help determine its performance and viability towards meeting overall typology compliance. The collective results of Phase 1 modeling facilitated the identification of tools and variables that were critical for pathway compliance and informed the recommended pathways.

Phase 2 of the modeling occurred during Task 9 where the tools' performance, cost (Task 6), and co-benefits (Task 7) were brought together to develop pathway tool sets for each typology.

Phase 1 Modeling Approach

As noted above, the intent of Phase 1 of the pathway modeling effort was to isolate rainwater management tool performance and determine their viability towards meeting overall typology compliance. The modeling was focused primarily on determining viability of pathways that achieve the 24-mm and 48-mm volume reduction requirements through retention.

To develop modeling scenarios, each building-site typology was broken into distinct relevant land covers (roof area and ground area) that were paired with logical sets of associated Tier 1 GRI tools. These paired rainwater management tools were then modeled individually for all seven building-site typologies, both compliance retention design standards, and all the relevant site, development, and policy condition variable values. This resulted in over 73,000 distinct scenarios that were modeled in Phase 1. Each scenario was modeled with the GRI Design Tool to evaluate the rainwater management tool viability and performance.

The modeling accounted for siting considerations (e.g., maximum contributing drainage areas, setback criteria) and design parameters (e.g., average dimensions, component characteristics) for each Tier 1 rainwater management tool. Because of the significant complexity of sizing each tool to exactly manage the required retention volume given the set of site variables, each tool was tested with the maximum footprint based on the available space on the land cover on which it was sited and the drainage area to footprint ratio established for each tool in Task 3. In this way, the modeling results represent the full potential for a particular tool to manage runoff. While this may be unrealistic in real world applications, it is helpful to understand the viability of a particular tool and site context. More precise sizing was then completed during Task 9 with a smaller subset of defined pathways.

MODELING RESULTS

The output from the modeling yielded a significant amount of data, including a full water balance of how much design storm runoff volume was generated from each surface, directed to each rainwater management tool, and processed in each tool (i.e., infiltrated, evapotranspired, stored, reused, and bypassed). Since the focus of the modeling was on retention, the results of interest represented the percentage of the runoff that was retained within each tool. From the modeling, the retention percentage was calculated for each of the over 73,000 scenarios that represent different rainwater tools paired with typology land covers and the range of associated site, development, and policy variables. Because of the significant amount of data to review and report, the data was further simplified and a dashboard was created for viewing results.

Key Observations

Reviewing modeling results through the dashboards illuminated a number of key general observations on pathway compliance. While compliance with the 24-mm and 48-mm retention standards was possible for many of the scenarios tested, especially those representing more favorable site conditions (e.g., less impervious area, higher infiltration potential), the focus of the observations below is related to non-compliance and the factors that contribute to it.

With few exceptions, most site-typologies have at least some conditions where compliance is not feasible for the 24-mm and/or 48-mm retention standards. There are two general conditions that were found to have the greatest influence on the potential for available tools to meet the retention standard at a particular site-typology:

- Site Conditions – These are the factors that are inherent in the geography of the site. The most important site-related feasibility factor is the "soil conditions" variable and associated infiltration capacity, which has a direct bearing on the performance of ground-level Tier 1 infiltration tools.
- Current Development and Policy Conditions – These are the factors that dictate the resulting character of the development. Some are influenced by City policy and some are influenced by the purpose and economics of a particular development. The most important of these factors are the impervious extent of the development, which is hard- coded into the typology definition, and the "infiltration area available" variable, which includes infiltration setbacks set by City policy and the extent of the subsurface parkade dictated by developer decisions. Like the soil conditions variable, the infiltration area available variable has a direct bearing on the feasibility and performance of ground-level Tier 1 tools.

Site Conditions

The following observations were made about the influence of the soil conditions variable:

- The "no infiltration" condition is the most common variable that limits compliance potential; when a site has no infiltration potential there are two typologies (Low-Rise Residential & Mixed-Use and Low/Mid-Rise Non-Residential) that cannot achieve 24-mm (or 48-mm) retention and two others (Mid-Rise Residential & Mixed-Use and High-Rise Non-Residential) that cannot achieve 48-mm retention.
- While rainwater harvesting and resilient roofs are critical tools in these "no infiltration" scenarios to achieve some rainwater retention, they are often not able to facilitate compliance on their own and when they are, they must be deployed at very high levels to achieve compliance.
- While increasing infiltration potential (from "low infiltration" to "high infiltration") intuitively aligns with a greater potential to meet retention standards, there are three typologies (Mid-Rise Residential & Mixed-Use, Low/Mid-Rise Non-Residential and High-Rise Non-Residential) where it is very difficult or impossible to meet 48-mm retention under existing development and policy conditions with even the "high infiltration" condition due to the parkade and infiltration setback resulting in little to no space for infiltrating tools.

Current Development and Policy Conditions

The following observations were made about the influence of these variables:

- Assuming the infiltration setbacks (5 meters), impervious extents, and the existing practice of extending parkades past the building footprint, two typologies (Low-Rise Residential & Mixed-Use and Mid-Rise Residential & Mixed-Use) have very limited pathways to 48-mm and even 24-mm compliance, while two other typologies (Low/Mid-Rise Non-Residential, High-Rise Non-Residential) had no compliant pathways.
- Changing the infiltration setback to 3 meters and/or reducing the parkade extent provided enough space for infiltration for all typologies to meet the 48-mm standard in all but the least

favorable "no infiltration" conditions. It should be noted that changing the infiltration setback to 0 meters offered limited to no improvement in terms of compliance potential.

- Changing the infiltration setback and/or reducing the parkade extent reduced the dependency on rainwater harvesting and resilient roofs for compliance by improving the viability of ground-level infiltrating tools (e.g., bioretention, permeable pavement).

Based on the observations above, it is apparent that pathways with lower retention requirements will be an important consideration for sites with no or limited infiltration potential. Likewise, exceptions to infiltration setbacks in certain situations and consideration for reducing site impervious area and parkade extents will also be important. As noted, there are numerous pathways to compliance with both the 24-mm and 48mm retention standards depending on the chosen typology, site conditions, and development conditions. There are also numerous site and development constraints that contribute to non-compliance with these retention standards, which suggests the need for revised or clarified standards, policy exceptions, and alternative development approaches.

Task 6 - Costing

The primary objective of enacting stormwater management requirements for new and re-development projects is to reduce the quantity and/or improve the quality of stormwater flowing from private parcels into the city sewer system. A supporting objective is to administer the requirements in a fair and equitable manner that does not place undue burden on the development community. Costing is critical for understanding the financial impact of rainwater management on development projects, and this Study sought to better understand the cost of implementing the GRI compliance pathways. The scope of the costing task included:

- Develop planning-level unit capital costs, appropriate for construction in the City of Vancouver, for the rainwater management tools,
- Calculate planning-level total capital cost estimates for the compliance pathways identified for each building-site typology,
- Estimate total capital costs for each pathway as a percentage of the overall building construction cost, and
- Provide a qualitative evaluation of the operation and maintenance (O&M) cost for each pathway.

Unit Cost – Rainwater Management Tools

Capital costs (including the materials and labor for construction as well as the soft costs associated with planning, design, and delivery) are a challenge to estimate, and especially so in the highly theoretical context of these representative typologies and pathways. The first step in this task was to gather available rainwater management tool costing data, standardize the data to currency (CAD) and year (2022), and establish a set of unit costs for the tools used in this Study. Costing data for rainwater infrastructure were gathered from many sources including capital planning and project costs (from Vancouver and similar municipalities), private sector planning and project costs, vendor pricing, previous costing studies, and agency cost estimating tools.

Table ES 3 - Baseline and Range of Rainwater Management Tool Construction Unit Costs (2022 CAD) [4]

Rainwater Management Tool		Unit	Baseline Construction Unit Cost ($ per unit)	Const. Unit Cost Range ($ per unit)	
				Low	High
Resilient Roof	Green roof - Extensive	$ / Area	$220 per sq. m.	$154	$330
	Green roof - Intensive	$ / Area	$430 per sq. m.	$301	$645
	Blue-green roof	$ / Area	$340 per sq. m.	$238	$510
Bioretention	Raingarden	$ / Area	$160 per sq. m.	$112	$240
	Sloped-side w/o underdrain	$ / Area	$1,500 per sq. m.	$1,050	$2,250
	Sloped-side w/ underdrain	$ / Area	$2,000 per sq. m.	$1,400	$3,000
	Full-walled w/o underdrain	$ / Area	$2,100 per sq. m.	$1,470	$3,150
	Full-walled w/ underdrain	$ / Area	$2,600 per sq. m.	$1,820	$3,900
Tree Trench	Soil cells	$ / Area	$400 per sq. m.	$280	$600
	Structural soils	$ / Area	$900 per sq. m.	$630	$1,350
Permeable Pavement		$ / Area	$250 per sq. m.	$175	$375
Subsurface Infiltration		$ / Volume	$2,200 per cu. m.	$1,540	$3,300
Absorbent Landscape		$ / Area	$17 per sq. m.	$12	$26
Non-GRI	Detention tank	$ / Volume	$900 per cu. m.	$630	$1,350
	Proprietary water quality treatment device	$ / Flow Rate	$34,000 + $1,900 per Lps	-30%	50%

Overall Building Construction Cost

Limited data was available to estimate the costs to construct the full building and parkade structures and non-GRI sitework for each typology (i.e., everything else that would comprise the typology development project other than the rainwater management tools). Data was used from a "Canadian Cost Guide" prepared by the Altus Group that had construction unit cost data for the Vancouver area for a variety of residential and commercial building types. Costs for the total building project were calculated by multiplying these unit costs by the square footage of building structure for each typology.

Cost Estimates for Rainwater Management Pathways[5]

The unit costs were then applied to the modeled size of each compliance pathway rainwater management tool to calculate pathway construction cost estimates. Costs for each pathway, including total building cost and cost of rainwater infrastructure, are included in the Task 4 memo and Task 9 pathways appendices.

[4] These unit costs and subsequent cost estimates are of a conceptual pre-planning level, equivalent to a Class 5 Estimate by AACE Estimate Classification standards. Class 5 estimates are based on very limited information, with project definition from 0 to 2%, and subsequently have a wide accuracy range of -20% to -30% on the lower end and +30 to +50% on the higher end. Considering the building typologies and associated rainwater infrastructure are entirely conceptual and representative in nature, the outer bounds of the accuracy range are appropriate for these estimates and a range of costs is provided based on those (i.e., -30% and +50% of the baseline).

[5] This task focused on capital and O&M costs. It did not include impact on revenue or return on investment, as that is too dependent on the individual building design and marketing to be able to provide a general estimate.

Task 7 - Rainwater Management Co-Benefits

An assessment of the co-benefits of rainwater infrastructure is critical for developing a more holistic framework when considering financial impact of GRI on the development industry and public, for undertaking comparative pathway assessments, for informing development of effective policy options, and for increasing the probability of successful policy implementation.

This task developed a framework and methodology for evaluating and measuring the other ancillary value and co-benefits provided by the rainwater management tools that comprise each compliance pathway. The framework for this analysis uses two related, but subtly distinct terms ("value" and "co-benefit") to describe the additional advantages gained and services provided by the utilization of rainwater management tools. These advantages and services are intended to go beyond fulfillment of the primary objectives associated with the City's rainwater quality, quantity, and peak flow rate design standards.

The term "value" refers to an intrinsic characteristic of a rainwater management tool that provides a particular advantage over another tool. Examples of values include increased reliability, implementability, feasibility, and resiliency. Values are not typically thought of as co-benefits but are nonetheless important considerations when weighing the performance of a tool against its cost. This is especially critical in the absence of a full life-cycle cost analysis that is beyond the scope of this project.

The term "co-benefit" refers to an additional benefit beyond the prime water management objectives that is generated by utilizing a rainwater management tool. A co-benefit may be received by individual or multiple parties, including the tenant, property owner, developer, and/or the broader public. Co-benefits typically refer to economic, social, and other environmental benefits. It should be noted that water quality and quantity performance and capital costs were not considered in the co-benefits since these components are considered separately in the comparison of compliance pathways.

Approach

The approach for developing a framework includes the following key steps explained further below: identification and development of criteria and metrics that will be used to represent key values and co-benefits, development of a scoring and weighting scheme to evaluate individual rainwater management tools, and development of a scoring scheme for full compliance pathways.

Criteria and Metric Development

An initial list of value and co-benefit criteria and metrics were compiled from the project charter and from other projects in the region that consisted of rigorous internal review processes. The project team specifically leveraged the results from the Cambie Corridor Integrated Water Management Plan (Herrera, 2019), or "Cambie Project", to augment the criteria. The Cambie Project was specifically leveraged because the value and co-benefit criteria and metrics for that project were developed iteratively with multiple City stakeholders through a series of workshops to ensure they were aligned with the City's values and broader water management objectives.

The initial list of criteria and metrics was refined to ensure applicability and that information was available to perform a qualitative assessment for the rainwater management tools used in the Pathway study. The rainwater management tool types considered for this project are general and developed for broad application. Therefore, the value and co-benefit criteria and metrics needed to be general enough to be applied to conceptual tools and scenarios and have measurable characteristics that allow for qualitative scoring. The team intentionally avoided criteria/ metrics that depended on spatial location and avoided including too many specific interests in separate metrics, which can result in non-differentiating results.

The proposed criteria and metrics are organized into four overarching value and co-benefit categories. These overarching categories consist of 11 individual criteria and 14 qualitative metrics that were used in the value and co-benefit evaluation.

Table ES 4 – Value and Co-benefit Criteria and Metrics

Category	Criteria	Metric
Economic	Life Cycle Considerations	Ease of O&M
		Replacement frequency
	Property Values	Property value uplift
	Energy Efficiency	Energy savings
	Other Cost Implications	Other costs
Environmental	Ecosystem Health	Biodiversity and habitat enhancement
	Water Preservation	Potable water savings
	Water Resource Restoration	Groundwater recharge
	Climate	Carbon sequestration
Community	Community Health	Air quality improvement
		Urban heat island mitigation
		Provides or enhances access to nature
Resiliency	Long-Term Stresses (e.g., Climate Change)	Adaptability
	Short-Term Stresses & Shocks (e.g., Earthquake and Other Disasters)	Service disruption potential

Metric Scoring and Weighting for Rainwater Management Tools

For each rainwater management tool, a value and co-benefit score was developed for each metric on a measurement scale of 0 to 5, with 0 representing no to low value or benefit and 5 representing the highest value or benefit. To combine metric scores and calculate a composite "total value and co-benefit score" for each tool, each metric was weighted to reflect its relative overall importance to the City. Metric scoring for each tool was initially completed based on the average scores assigned by members of the consultant team, based on best professional judgement and experience planning, designing, constructing, and maintaining each tool. These scores were further adjusted by City staff following review of the initial draft. The metric weighting for criteria and total value and co-benefit score for each tool is presented in Table ES 5.

Overall Scoring for Compliance Pathways

Additional analyses of values and co-benefits were completed for each pathway developed in Task 9. Each pathway is comprised of one or more rainwater management tools necessary to meet the City's rainwater quality, quantity, and peak flow rate design standards. The total value and co-benefit score for each pathway are included in the pathways appendices attached to the Task 9 memo.

Table ES 5 – Preliminary Value and Co-benefit Score Results

Benefit Category	Economic					Environmental				Community			Resiliency		Total Value and Co-Benefit Score (0 - 5 scale)
Category Weight	28%					28%				28%			16%		
Metric	Lifecycle Considerations – Ease of O&M	Lifecycle Considerations – Replacement Frequency	Property Values – Property Value Uplift	Energy Efficiency – Energy Savings	Other Cost Implications – Other Costs	Ecosystem Health – Biodiversity and Habitat	Water Preservation – Potable Water Savings	Water Resource Restoration – Groundwater Recharge	Climate – Carbon Sequestration	Community Health – Air Quality Improvement	Community Health – Urban Heat Island Mitigation	Social Equity & Community – Nature Access	Long-Term Stresses – Adaptability	Short-Term Stresses – Service Disruption	
Metric Weight	8%	8%	4%	4%	4%	7%	7%	7%	7%	8%	10%	10%	10%	6%	
Green Rainwater Infrastructure (GRI) Tools															
Resilient roofs	2	3	4	4	0	3	0	0	3	3	4	3	0	3	2.3
Bioretention	3	3	4	2	3	4	3	5	4	4	3	4	3	4	3.5
Tree trenches	4	4	3	3	3	3	3	4	4	4	3	4	1	3	3.3
Permeable pavement	4	4	0	0	3	0	2	3	0	0	0	0	2	3	1.5
Subsurface infiltration	5	5	0	0	3	0	3	5	0	0	0	0	3	3	2.0
Non-potable water systems	1	4	1	0	4	0	5	0	0	0	0	0	4	0	1.4
Grey Rainwater Infrastructure (Non-GRI) Tools															
Detention tanks (w/o reuse)	3	5	0	0	3	0	2	0	0	0	0	0	2	2	1.2
Proprietary treatment devices	3	2	0	0	3	0	2	0	0	0	0	0	2	2	1.0

Task 8 - Rainwater Management Barriers and Solutions

Successful implementation of the Rain City Strategy will require understanding existing barriers and developing solutions to remove those barriers wherever possible. The purpose of this task was first to identify, prioritize, and evaluate the key barriers for implementing GRI in new development (under current policies and regulations) in the City of Vancouver. After identifying barriers, potential solutions were explored for wider adoption of GRI. The solutions were further developed in Task 9 as policy recommendations, as appropriate.

Starting early in the Pathways Study, the team focused on identifying and sorting the barriers for GRI implementation into five key categories: Physical, Regulatory, Economic, Procedural, and Cultural. The team then completed a Current State Assessment and Jurisdictional Scan as part of Task 4 and held two public workshops to gain input from external stakeholders. The observations, analysis, and feedback from these efforts were synthesized to narrow down the extensive initial list of barriers into a more focused list to highlight the issues most frequently faced when determining if and how to implement GRI on a specific site. The following table lists the barrier categories, with their corresponding barriers and solutions. This information is summarized below and described in greater detail in the Task 8 memo.

Table ES 6 – Barriers & Solutions Summary

Category	Barriers	Solutions
Physical	▪ Steep Topography ▪ Soil or Groundwater Contamination ▪ High Groundwater or Bedrock ▪ Low or Zero Infiltration Capacity ▪ Existing Trees (Root Protection Zones) ▪ Inadequate or Shallow Municipal Service Connection	▪ GRI Design Standards and Manual ▪ Alternative Compliance Program
Regulatory	▪ Rooftop Space Constraints and Competition ▪ Building Envelope Certification and Building Insurance ▪ Maximizing Development within Zoning By-law, Parking, and Other Policies ▪ Building Integrity Concerns ▪ Challenges with Managing Runoff Across Property Lines ▪ Rainwater Harvesting Feasibility and Cost Effectiveness ▪ Limited GRI Design Standards to Support Current Regulation and Policy	▪ GRI Design Standards and Manual ▪ Align By-Laws, Bulletins, and Other Policy and Guidance Documents ▪ Resilient Roofs Policy ▪ GRI Design Standards and Manual ▪ Expanding Green Building Policy for Rezonings ▪ Expand Alternative Water Sources Allowed for Onsite Reuse ▪ Alternative Compliance Program
Procedural	▪ Lack of Departmental Coordination ▪ Unclear RWMP Submission Process ▪ Lack of GRI Maintenance Plan Enforcement	▪ GRI Design Guidance Coordination ▪ GRI Maintenance Standards and Enforcement
Economic	▪ Added Incremental Costs ▪ Affordability of Housing	▪ GRI Design Standards and Manual ▪ Alternative Compliance Program
Cultural	▪ Limited Local GRI Design Expertise ▪ Insufficient GRI Construction Standards and Expertise ▪ Limited Understanding of Benefits and Costs ▪ Perception of Higher Risk	▪ GRI Engagement and Training ▪ Providing Leadership

Physical Barriers

At the site scale, physical site characteristics require the design professional to make a set of decisions in order to achieve desired and/or required goals. Depending on the type of constraint, a solution can often be found through the site assessment and design process and then by selecting the appropriate GRI type to achieve the goal (e.g., compliance with rainwater management targets).

Physical constraints range in severity from high groundwater to challenging site topography and poor soils. Some physical constraints can be prohibitive to overcome, especially for infiltrative GRI tools, which would lead the designer to choose more traditional gray/detention solutions instead of GRI solutions.

With the complexity and variety of site conditions, it would be impractical to have a one-solution-fits-all approach for GRI design and sizing. A specific guideline or manual, with a set of standard details and specifications, to assist developers in implementing GRI is recommended as a solution for meeting rainwater management goals despite a site's physical constraints.

Regulatory Barriers

Regulatory barriers arise when potential GRI tools are determined to be unfeasible due to constraints or conflicts that emerge from existing regulations or policies. The solutions to these barriers would be revisions to existing regulations and guidance, and/or the creation of new regulations and guidance documents.

The regulatory barriers fall into two general categories, the first being those that are related to the at-grade configuration of the new development including setbacks, building over slab construction, integration with the public realm, private-to-private rainwater management, and so on. The second category is related to the building itself such as internal plumbing and reuse, and rooftop uses, loading, programming, and the quality of the building envelope.

The key regulatory solutions are focused on coordination across different strategies, policies, and departments to meet both site level and city-wide rainwater management goals. Other solutions address a need for new collaboration between developers/owners and the City whereby rainwater can be managed collaboratively and more efficiently across property lines or within offsite GRI facilities.

Procedural Barriers

Procedural barriers include challenges involved in the progression of a project from early concept design to building permit, including the development and submittal of the Rainwater Management Plan (RWMP). These types of barriers can have a substantial impact on a project timeline and therefore the cost of the project. Barriers to the inspection and maintenance of GRI systems have the potential to render them ineffective. There is a strong correlation between regulatory and procedural barriers as procedural guidelines are usually laid out in regulatory or guidance documents.

The solutions to the procedural barriers will largely rely on the regulatory solutions discussed above. In general, the alignment of rainwater management regulations and policies should streamline much of the RWMP submittal, design, and permitting process and provide a simpler method for City plan reviewers.

Addressing the issue of enforcement of existing maintenance & inspection to ensure the longevity of GRI is critical to programmatic success, but also necessitates a broader discussion around staffing resources or third-party options and costs.

Economic Barriers

Economic barriers are described from the perspective of the developer in terms of cost to design and implement the GRI as part of a new development i.e., "economic factors" that relate directly to individual projects. It should be noted that rainwater management is a small percentage of total development soft and hard costs, particularly in the context of large residential, commercial, or mixed-use developments.

Assuming that the majority of projects required to comply with rainwater management requirements are privately funded, profitability will typically remain a developer's key concern as well as ensuring the viability of the project overall. Single-family homes and co-ops will have far less financial backing than big developers, increasing the importance of keeping costs down for residents and workers.

The current economic factors affecting the widespread application of GRI in new development are related to the aspirational goals of the Rainwater Management Bulletin and the less costly pre-development release rate policy. Under typical circumstances, economic forces will push developers to build the least expensive solution, including cost for design and permitting.

Assuming regulatory changes are enacted, the City would work with stakeholders to review the changes, the potential incremental costs, and work to educate residents on the benefits of GRI to their properties and for the City's system. In addition, engagement with the design and engineering community about procedural changes to reduce time and costs for permitting should be highlighted and promoted.

Cultural Barriers

In this context, cultural barriers are a reluctance to accept changes to conventional rainwater management approaches unless it is absolutely required. Cultural barriers can be based on direct experience but are often based on anecdotal evidence. These barriers are perpetuated by those with limited experience in the design, construction, review, and maintenance of GRI. The identified cultural barriers were derived from stakeholder input, the team, and the City's current experience in GRI implementation.

The solutions to cultural barriers are intended to address misconceptions around various forms of GRI and educate the various stakeholder groups on the rainwater management benefits and co-benefits of GRI implementation. Solutions for the advancement of the design community should involve training programs to address gaps in knowledge, skills, and experience that currently exist.

It is also critical for the City to provide leadership in this area to get ahead of misconceptions, reduce regulatory and procedural barriers, and lead by example. This would likely have the greatest impact on cultural barriers.

Task 9 – Policy Considerations

The objectives of this task are to develop a prioritized pathway tool set, provide policy recommendations to support the identified pathways, and make recommendations for general policy development. The policy considerations are presented in the current context of the recent changes to the Vancouver Building By-Law (VBBL) for rainwater management in new development and the advancement of the Healthy Waters Plan (HWP) analyses, both of which were either unknown or undeveloped at the time this Pathways Study was initiated in 2021.

In summary and given the above, this task provides:

- insights and information concerning the feasibility for certain private developments to meet either the 24mm or 48mm retention design standard (i.e., a set of compliance pathways),
- general recommendations for policies, guidance, and tools that the City could develop to support the implementation of GRI and overcome barriers, and
- general recommendations for streamlining and simplifying the design, submission, review, and approval of rainwater management plans.

SECTION 1 - PATHWAY SOLUTION SETS AND RELEASE RATE ANALYSIS

Pathway Solution Set Development

This first phase of pathway identification completed in Task 5 (Modeling) was high-level feasibility and scale testing, performed to isolate each primary rainwater management tool type to help determine its performance and viability towards meeting the compliance standard for each typology. The collective results of this modeling facilitated the identification of tools and variables that were critical for pathway compliance and informed the recommended pathways for each typology.

The identified pathways are organized into five categories. These pathway categories are characterized by specific modeling variable values used for the pathways in each. Pathway categories 1, 2, and 3 all meet a 24-mm retention standard but are differentiated by the infiltration potential assumed for the building site; category 1 assumes no infiltration is possible, category 2 assumes the soils have a low infiltration potential, but typical foundation infiltration setbacks and large parkades limit the available space on site, and category 3 assumes that the setbacks and/or parkades are reduced to create some space for infiltrating GRI. Pathway category 4 meets the aspirational Rain City Strategy standard of 48-mm retention. Pathway category 5 is a detention-only approach (i.e., a gray infrastructure "Tier 3" detention tank and water quality treatment device) that is included to provide a basis of comparison with the various GRI pathways.

Pathway Solution Set

The pathway tool sets that were identified with the Task 5 (Modeling) analysis were evaluated individually using the GRI Design Tool to confirm their viability and to size each GRI tool component to manage the total site rainfall. These pathways are summarized in Table ES 7 below. Additional information on performance, co-benefits, and costs is included in the detailed Pathway Solution Set tables in the Task 9 appendix.

Table ES 7 – Pathway Solution Set Summary Table

Pathway Category:	1	2	3	4	5
Retention Standard:	*24 mm*			*48 mm*	*n/a (Tier 3)*
Soil Conditions:	*No Infiltration*	*Low Infiltration (5 mm/hr)*			*n/a*
Setback/Parkade:	*n/a*	*Typical (Full)*	*Reduced*		*n/a*
Small Lot Residential – Low Massing *Stories: 2* *GFA: 225 m²*	*No viable pathway*	• Bioretention	• Bioretention	• Bioretention	• Detention & Treatment device
Small Lot Residential – High Massing *Stories: 2* *GFA: 375 m²*	*No viable pathway*	• Green roof • Bioretention • Permeable pavement	• Bioretention	• Green roof • Subsurface infiltration	• Detention & Treatment device
Low-Rise Residential & Mixed-Use *Stories: 3* *GFA: 3,000 m²*	*No viable pathway*	• Green Roof • Bioretention	• Bioretention	• Bioretention • Permeable pavement	• Detention & Treatment device
Mid-Rise Residential & Mixed-Use *Stories: 6* *GFA: 11,700 m²*	• Green roof • Rainwater harvesting	• Green roof • Rainwater harvesting • Bioretention	• Bioretention • Permeable pavement	• Green roof • Subsurface infiltration	• Detention & Treatment device
High-Rise Residential & Mixed-Use *Stories: 20* *GFA: 16,800 m²*	• Rainwater harvesting	• Green Roof • Bioretention	• Bioretention	• Bioretention • Permeable pavement	• Detention & Treatment device
Low/Mid-Rise Non-Residential *Stories: 3* *GFA: 3,000 m²*	*No viable pathway*	*Not applicable (parkade occupies entire site)*	• Bioretention • Permeable pavement	• Green roof • Bioretention • Permeable pavement	• Detention & Treatment device
High-Rise Non-Residential *Stories: 14* *GFA: 61,600 m²*	• Green roof • Rainwater harvesting	*Not applicable (parkade occupies entire site)*	• Bioretention • Permeable pavement	• Green roof • Bioretention • Permeable pavement	• Detention & Treatment device

GFA = Gross Floor Area

Key Takeaways

- In the most restrictive "no infiltration" soil condition:
  - Larger building typologies met the 24-mm retention standard (through a combination of green roofs and rainwater harvesting for reuse)
  - In the other typologies, incorporating lined non-infiltrating bioretention in addition to green roofs still achieved approximately half of this retention standard (see Task 9, Section 1.6 for more info).
- With at least "low infiltration" site soils:
  - Nearly all typologies met the 24-mm retention standard.

  - Small Lot and High-Rise Residential typologies met the 48-mm retention standard.
  - Three typologies (Mid-Rise Residential and both the Non-Residential) are defined with parkades that occupy nearly the entire site, eliminating any infiltration potential.
- Though only low infiltration soils were used for the selected pathways, in situations where soil infiltration rates are medium or high:
  - The reliance on building-based tools could expect to be reduced or eliminated.
  - It typically is feasible for most typologies to achieve a 48-mm retention standard using a combination of building-based and infiltration tools.
- Changing the foundation infiltration setback to 3 meters and/or reducing the parkade extent:
  - All typologies met both the 24-mm and 48-mm retention standards.
  - Reduced the dependency on rainwater harvesting and green roofs for compliance by creating additional opportunity for ground-level infiltrating tools (e.g., bioretention, permeable pavement).
- Compliance with the 24-mm retention compliance standard:
  - Category 1 - With no infiltration soils, compliance was only possible for the large dense typologies (GFA>10,000 m^2) with pathways composed entirely of building-based rainwater management tools (i.e., rainwater harvesting and green roofs).
  - Category 2 - With low infiltration soils, compliance was possible for all typologies with pathways composed of a combination of building-based tools and ground-level infiltrating tools (e.g., bioretention planters).
  - Category 3 - With infiltrative soils and reduced foundation infiltration setback and/or parkade condition, compliance was possible for all typologies with pathways composed of ground-level infiltrating tools only.
- Compliance with the 48-mm retention compliance standard:
  - With either no or low infiltration soils (and a standard foundation infiltration setback/parkade) compliance with a 48 mm retention standard was typically not feasible (and thus there is no category for this condition).
  - Category 4 - With low infiltration soils and a reduced foundation infiltration setback and/or parkade condition, compliance was possible for all typologies with a combination of building-based tools (green roofs and rainwater harvesting) and infiltration tools.
- Cost implications [6]:
  - For both Categories 1 and 2, the project capital costs increased by 1-3% using the GRI tool pathway compared to the conventional approach (detention tank and water quality treatment).
  - For Category 3, project capital costs increased by less than 1% over the conventional approach.
  - For Category 4, the project capital costs increased by 1-3% over the conventional approach.

[6] The cost increase with reduced foundation infiltration setbacks assumed that the building design is able to account for the reduced setback without requiring additional waterproofing/structural costs.

Key Observations

Based on the analysis and results from the pathway development, Lotus has the following observations with policy implications:

1. The typologies with the most potential to meet the retention requirements are the larger residential buildings, mid-rise residential and high-rise residential. These three typologies can achieve compliance under all categories (most critically, Category 1 with no infiltration and Category 2 with low infiltration but no reduced setbacks). This is because they:

    - have enough non-potable demand to utilize rainwater harvesting as a retention method (critical if infiltration is not possible),
    - were defined with a parkade that did not occupy the entire site (90% vs 100% for the larger commercial typologies) therefore when infiltration is possible there is space onsite to incorporate at-grade infiltrative facilities (and the space can be increased with a reduced foundation infiltration setback alone, rather than a reduced parkade size), and
    - have a larger proportion of the site occupied by the building (65-70% versus 40-55% for the larger commercial typologies) therefore green roofs are able to manage more of the overall site runoff (flexibility if at-grade GRI tools are challenging to incorporate).

    The other typologies (Small Lot Residential and Low/Mid-Rise Non-residential) cannot meet the retention target under Category 1 because they do not have sufficient non-potable demand to utilize rainwater harvesting.

2. The development/policy practice that would most facilitate implementation of cost-effective GRI and thus an increased feasibility of meeting retention targets would be allowing a reduction in the foundation infiltration setback requirement (e.g., 3-m, with additional criteria established to further reduce in certain situations) and/or policy that would facilitate a reduction in the parkade extents (e.g., reducing parking requirements). The effect of either of these is simply to create more space on site to locate infiltrative GRI facilities. It is worth noting that currently a special case can be made to reduce the current 5m foundation infiltration setback requirements (i.e., through the Alternative Solutions process), however the potential uncertainty of an approval encourages developers toward Tier 3 detention instead of designing for Tier 1 without a certain outcome. There may also be additional costs for a developer to achieve an Alternative Solution for reducing the foundation infiltration setback, in order to provide mitigation to the building foundation (for example, partial sealing of building foundation).

3. Meeting retention targets is most challenging and expensive if a site does not have the ability to infiltrate because rainwater harvesting would be required (a green roof can manage above-ground runoff, but cannot manage the runoff from at-grade impervious area, so retaining this requires capturing it in a rainwater harvesting system if there is no place to infiltrate it). Only larger/denser buildings (mid-rise residential, high-rise residential, and high-rise non-residential) have sufficient daily indoor non-potable demand to make rainwater harvesting a feasible tool to meet a 24 mm retention

requirement. Note that the Pathways tables included in the Task 9 memo appendices do show the benefit provided for other typologies if GRI is used that doesn't meet the retention target.

4. Pre-development release rates for all of the typologies are around 20-25 L/s/HA assuming the site has no existing development (i.e., no imperious surfaces) and up to 150 L/s/HA if the site had an equivalent amount of development (i.e., the same impervious surface coverage)[7]. The City's release rate standard requires that projects do not exceed that pre-development rate (i.e., post-development rate be equal or less than the pre-development rate). Said another way, the release rate requirement is that a project must achieve a post-development peak flow reduction of 0% or greater (less than 0% would be a peak rate increase). Projects that meet the 24mm (or higher) retention standard achieve a significantly higher rate reduction than 0%, i.e., for all GRI retention pathways the release rate reduction is at least 95% (as discussed previously, this is due to the retention tools typically eliminating all discharge during the release rate design storm). Even typology categories that can't meet the retention requirement, such as in Category 1 pathways, can use non-infiltrating GRI (e.g., bioretention with an impermeable liner and an underdrain) to achieve a release rate reduction of around 90% for the short duration release rate design storm. This is in comparison to the standard Tier 3 detention tank approach (sizing a tank based on 24 mm rainfall depth and a minimum orifice of 50 mm) that typically only results in a release rate reduction of 50% or less.

5. Green roofs are typically necessary to achieve the retention targets when there are space or site (infiltration) constraints at-grade. Green roofs are a component of all Category 1 pathways (24 mm retention with no infiltration) and nearly all Category 2 pathways (24 mm retention with standard foundation infiltration setback/parkade). They are also a component of about half of the Category 4 (48 mm retention) pathways. However, no green roofs are included in any of the Category 3 pathways (24 mm retention with reduced foundation infiltration setback/parkade) since there is more space onsite to located at-grade infiltration facilities as a result of the reduced setback/parkade. The Task 5 Modeling memo, and specifically the "Performance Modeling Results Summary" tables, can provide the City with more detailed guidance concerning where the modeling analysis observed that green roofs were critical for meeting the retention standard and where they were optional. It should also be noted that Vancouver's asynchronous peaks of evapotranspiration and rainfall have implications for green roofs in meeting retention targets. The single-event modeling for this study (i.e., performance in meeting the 24-hour retention target or design storm release rate target) assumed that all rainwater management facilities were empty and dry at the start of a storm event. However, for rainfall on a green roof with saturated soil (i.e., during periods of frequent rainfall) there will be little to no available storage capacity in the soil and the rainwater retention benefits would be greatly decreased. On an annual basis, it is still likely that these systems will meet the retention performance basis of 70% annual rainfall removed. However, to provide peak flow attenuation in the "saturated" condition a green roof would need to be designed with a detention component that slowly drains through an orifice (e.g., ponding on the surface or a storage layer below the soil media).

[7] Variation in pre-development release rates across typologies given the same pre-development condition (e.g., no impervious surface) are due to slight differences in time of concentration for different sized sites, along with the use of 5-yr storm for residential and 10-yr storm for commercial sites.

6. In terms of influence on overall building construction cost, if infiltration is not feasible (or if setbacks/parkade are not reduced) the impact on initial capital cost to implement GRI to retain 24 mm of rainfall (compared to a traditional Tier 3 detention tank approach) is likely around a 1-3% increase in total project construction costs. If infiltration is feasible and foundation infiltration setbacks/parkades are reduced then the incremental cost increase is only around 1% or less for 24 mm retention, or up to 2% for 48 mm retention.[8] More detail on all pathway costs and impact on overall project cost can be found in the Task 6 Costing memo and the detailed Pathway tables in the Task 9 appendices.
7. Our observation from reviewing Rainwater Management Plans and discussion with staff is that most developments have complied with the ZDBL rainwater management requirements via Tier 3 detention rather than Tier 1 retention. Our opinion is that this is because the RWMB allows detention and implementing traditional Tier 3 approach is more familiar to developers and designers, is likely estimated and bid as a much more affordable option compared to GRI due to this familiarity and common deployment, and due to lack of local design and construction the Tier 3 approach is perceived as a more straightforward design and implementation step compared to implementing GRI. A more detailed assessment of how building design and rainwater management has been approached on existing sites (and specifically why retention practices have been employed so infrequently and if there were practical opportunities to achieve a higher level of retention) would be a worthwhile exercise, however this was beyond the scope of the study. Such work would be a critical prerequisite to policy and regulatory development and would inform next steps. We'd speculate (based on the outcomes of the modeling work and our experience in other similar jurisdictions) that in many cases the level of retention achieved on these projects could feasibly have been much higher, and the use of GRI may have been more prevalent, if regulations required it.

POLICY RECOMMENDATIONS OVERVIEW

As a result of the Pathways Study, the policy recommendations fall under two key sequential steps:

First, articulate the city-wide watershed management and water quality objectives (or targets) so that new private property development requirements can be linked to and compatible with those objectives.

The City is encouraged to advance the HWP, specifically for drainage system and receiving water benefits resulting from updated new development rainwater management by-laws, and build upon this work to develop:

- a quantifiable understanding of the city-wide system benefits of the current or future rainwater management regulations (e.g., 24 mm detention, 24 mm retention, 48 mm retention),

[8] As noted previously, the cost increase with reduced foundation infiltration setbacks assumed that the building design is able to account for the reduced setback without requiring additional waterproofing/structural costs. Also, the costing exercise in this study was focused on capital and O&M costs. It did not include impact on revenue or return on investment, in part because those aspects are too dependent on the individual building design and marketing to be able to provide a general planning-level estimate.

- a defensible technical basis for a 48 mm (or 24 mm) retention standard, which would require a more thorough analysis of potential drainage system and receiving water benefits (e.g., reduced flow to drainage systems with capacity challenges, reduction in pollutant levels discharged to receiving bodies, reduction in CSO events),
- an evaluation of the cost and benefits of changing regulations, outside of site-level criteria such as GRI tool feasibility and construction cost comparisons for representative projects, or
- a numerical recommendation for the City's VBBL Phase 2 design standards (i.e., retention depth, flow rate reduction) that links back to the City's water quality goals.

Second, based on the city-wide objectives and the Pathways Study work, establish an administrative process for new development that provides clear and specific technical resources, and certainty and predictability for the professional design and development communities. Both would decrease time and costs for rainwater management compliance and increase the likelihood of the City achieving its goals for parcel-based GRI.

The Pathways Study highlights many elements of this process, including the following recommendations:

- Provide a performance-based design standard.
- Evaluate and modify parkade and set-back requirements.
- Clarify green roof design standards aligned with Building Envelope Inspection process and certifications.
- Provide a dedicated design manual and technical resources, such as sizing tools, to assist applicants and standardize submittal format and information presentation.
- Create a "prescriptive" or standard process and steps to allow developers to estimate the time and effort for rainwater management planning and implementation more accurately.
- Develop a simple alternative compliance hierarchy for challenging site conditions and/or to incentivize certain outcomes.

SECTION 2 - POLICY OPTIONS AND RECOMMENDATIONS

Alignment with Healthy Waters Plan Performance Measures

The Healthy Waters Plan has defined draft objectives and performance measures for healthy waterways, healthy watersheds, adaptation to risk, and affordability. It has also identified specific options, or tools, that the City can utilize to achieve these performance measures over time. One of those tools is a policy option for new development, based on the current and proposed Rain City Strategy performance standards of 24 mm and 48 mm rainwater capture, respectively. The GRI Pathways Study outlines clear methods and conditions for meeting the on-site rainwater management goals outlined in the Healthy Waters Plan.

The HWP goals and objectives will become the foundation for the overarching city-wide policy for rainwater management and specifically on parcels and in redevelopment. Once finalized, several of the options will be combined and optimized leading to HWP Phase 3 implementation planning. Given the high proportion of land area and impervious cover within the realm of private parcels and the potential for low costs and high benefits to the City over time, its highly likely that the option related to rainwater management in redevelopment will be included in HWP Phase 3.

As revealed in the pathway costing evaluation, the portion of total development costs for retaining 24 mm or 48 mm depending on the typology did not exceed 3%. Therefore, it is likely that streamlining and strengthening the rainwater management requirement itself will not result in negative impacts to private redevelopment. However, the opportunity to streamline the administrative process (e.g., timeline for submittals, reviews, approvals, and/or clear alternative compliance mechanisms) could have material benefits for private redevelopment in terms of time and cost savings. Clear technical design guidance in the form of standard drawings and sizing procedures would also assist in simplifying the delivery of GRI solutions.

When linking overarching city policy with specific requirements or incentives, a jurisdiction will need to revise and iterate scenarios until they achieve the right balance of supporting city objectives, meeting regulatory expectations, and ensuring that the requirement is reasonable and technically feasible. This is where the HWP and the GRI Pathways Study intersect.

This memo will not cover the scope of the HWP and its modeling and performance analysis, but once the HWP quantifies the outcomes needed to meet these goals and objectives, the City will be able to define the specific goals for rainwater management across several land use types and/or within the various basins. Then HWP Phase 3 and the list of specific options to be implemented can be applied toward that numeric goal. Using the output developed from the HWP (i.e., the Mass Balance Model) and the GRI Pathways Study, the City will have the tools to begin a performance analysis for the redevelopment policy options.

Even at its early development stage, using the results of the Mass Balance Model (MBM) analyses can provide some context at the basin-scale and an initial direction for near term policy decisions. The combined results of the MBM and the GRI Pathways Study can provide the City with a basis for initial reasonable expectations for site-level retention or detention that are feasible and can be used in the implementation of the VBBL Phase 2 effort.

Determine Performance-Based Design Standard

The City is interested in recommendations as to whether some specific building-site typologies should have "prescriptive" or "performance-based" policies, Lotus does not recommend typology specific "prescriptive" policies for rainwater management in redevelopment in Vancouver. Instead, Lotus recommends a "performance-based" compliance policy.

Given the City's current challenges with capacity, variation in submittals, permit approval timelines, and uneven application of the ZDBL rainwater management requirements, a performance-based standard would better support the City's goals to streamline the permit submittal and approval process and to accommodate modified or alternative compliance frameworks where compliance is not feasible.

Ideally, the HWP modeling and analysis will determine an initial minimum design standard that can be applied to all redevelopment and extrapolated over time to assess the cumulative benefits. Once the standard is determined, it would be applied universally to all parcels over a fixed area (e.g., parcels of 0.25

hectares or larger). Basing rainwater management compliance on building mass (e.g., total floor area) is not recommended for a rainwater management requirement as one of the main inputs for all the calculations for runoff volumes are surface areas and types. The amount of runoff that a new development project is going to create and discharge offsite (absent any rainwater management interventions) is directly associated with the amount of impervious surface on that site. In our experience, jurisdictional requirements for rainwater management are essentially always tied to this metric as opposed to building massing. Building mass, if considered along with building type (e.g., commercial or residential), can be a reasonable proxy for onsite non-potable water demand and thus be indicative of the potential to implement a rainwater harvesting system.

A "performance-based" standard relies on clear standards for how to successfully meet the performance goals. As mentioned, developers will need step-by-step guidance to design and size the GRI systems. The proposed standards below would seek to address the issue of uneven applications in the requirements, which impacts the permit submittal and approvals, and would result in higher quality submissions from developers. The below bullets are two proposals for a viable approach to a performance-based standard.

In the absence of the HWP modeling, we can see in the results of the GRI Pathways Study that a true retention standard provides greater than 90% reduction in the release rate for all typologies. That is significant and is a clear basis for two options of performance-based standards:

- Maintaining but clarifying and strengthening the requirements in the current RWMB (August 2022), or
- Creating a 90% release rate reduction requirement from the current pre-/post-, to mimic and achieve benefits similar to the retention standard without a prescriptive bylaw.

Recommendation for Release Rate Reduction

The results of the release rate analysis showed a strong argument for the benefits of substantial reduction in the release rates for a detention-based design standard and requirement to achieve close equivalent benefits as compared to the retention-based design standard and requirement. A post-development peak flow rate of no more than 10% of the pre-development peak flow rate is recommended.

A significant release rate reduction would align efficiently with the recent Phase I VBBL changes for the following reasons:

- It’s a detention-based standard that allows retention; therefore, a dramatic increase in the total detention volume would incentivize more retention where feasible in order to reduce the detention volume because large grey tanks can cost more than bioretention.
- A maximum release rate would allow developers to determine the scale of the retention and detention features within the site based on the site plan, programing, parkades, and other factors.
- The detention-based standard can be refined over time as the City develops more modeling tools for system-wide benefits of redevelopment requirements.

- Once the HWP modeling is complete, it will be possible for the City to transition to a standard maximum release rate L/s/ha that would be applied to all redevelopment parcels exceeding a certain size or impervious cover threshold.

Without the modeling to confirm which categories of buildings would be subject to this new maximum release rate, the City can set an initial reduction ratio based on the result of this study, which showed that all retention pathways reduced release rates by over 90%.

SECTION 3 - RECOMMENDED IMPLEMENTATION STEPS

There are two sets of recommendations presented in this section: the recommended steps for increasing the use of specific GRI tools, and recommendations for broader policy to advance the Pathways Study purpose and align this work with related City initiatives and policies.

Recommendations for Specific GRI Types

The GRI Pathways Study looked at various constraints and limitations to GRI implementation in Task 8 (Barriers and Solutions). Regulatory constraints arise when potential GRI tools are determined to be infeasible due to real and perceived conflicts that emerge from existing regulations or policies. The solutions to these constraints are policy recommendations to revise existing regulations and guidance, and/or the creation of new regulations and guidance documents.

Develop Resilient Roofs Policy

Based on the Pathways Solution Sets modeling and analysis, it's clear that resilient roofs in redevelopment will be critical to successful GRI implementation in Vancouver. While the solutions to the related constraints would be covered in the regulatory revisions described above, it is important to note that resilient roof policy could proceed forward on its own track and could allow for earlier adoption, especially in multi-family residential scale or larger buildings.

Intensive green roofs are typically sold as systems and mostly modular to install. This allows a jurisdiction to set basic standards and/or performance metrics and allow the designer to specify which system to procure for a project.

The rollout of standards, guidance, or performance metrics around resilient roofs for rainwater management would help alleviate the issue of space constraints at ground-level. New guidance could also clarify and show examples of resilient roofs incorporated into amenity space while not significantly impacting space for bulkheads, egress, and mechanical equipment. Other regulatory changes, such as allowing mechanical floors to be excluded from the maximum floor space ratio calculation could also be explored.

Insurance barriers related to green roofs and the building envelope certification were discussed at the Green Roof Workshop. A review of the insurance challenges (e.g., concerns with leaking or maintenance) and the City's building envelope certifications will need further attention to determine how the City's regulations or policies would need to be revised. This would be done in coordination with green roof professionals, building envelope professionals, and insurance representatives.

Expand Alternative Water Sources Allowed for Onsite Reuse

The VBBL (Book II, Section 2.7) only allows onsite reuse systems to use rainwater and stormwater and prohibits the reuse of groundwater, greywater, and blackwater. Without these additional alternative sources (which are allowed in many jurisdictions with onsite reuse policies), the seasonal nature of rainwater supply often means that a system either incorporates large storage tanks to capture enough rainfall during the rainy season that the system can continue to operate into the dry season (this is exacerbated by the relative lack of irrigation demand during the rainy season for systems that supply non-potable water to irrigation) or that, without the large tanks, the system ends up offsetting a relatively low portion of potable demand and has a long period of supplemental potable water purchases throughout the dry season. Either of these approaches can challenge the cost effectiveness of constructing and operating an onsite non-potable reuse system.

Allowing additional sources that have a more consistent year-round supply, such as greywater, often provides the opportunity for an onsite reuse system to achieve a much greater level of potable water offset. For some projects, particularly larger residential typologies, the long-term avoided costs (i.e., reduced municipal utility fees) resulting from a much higher level of onsite non-potable reuse can balance out the increased initial construction and ongoing operation costs associated with treating the additional alternative water sources and benefit the overall cost-effectiveness (in addition to greatly enhanced potable water savings, if that is a City goal).[9]

Lotus recommends that the City develop additional standards and requirements around the design, treatment, approval, commissioning, and ongoing testing/operation of systems that use these additional sources (greywater and/or blackwater) to provide additional opportunities and flexibility for projects that wish to implement more ambitious onsite reuse systems.

Increase Retention Opportunities within Parcels

Zoning by-laws set the building form requirements within areas of the City. Meeting all of the zoning requirements can result in limited space specifically in determining structure setbacks from the property line.

The parking requirements in the Parking By-Law often result in projects constructing large parkades under buildings to provide the required parking spaces. These subsurface parkades regularly extend to property lines, reducing opportunity for GRI at ground level.

The VBBL contains 5-meter foundation infiltration setback requirements from building foundations for infiltrating GRI that are intended to limit harm to people and damage to buildings from excessive moisture loading on foundations and footings. The foundation infiltration setbacks are intended to avoid short-circuiting that could occur by infiltrating water adjacent to a structure (which could enter the foundation

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[9] In our experience, diversifying the available alternative water supplies (e.g., using greywater in addition to rainwater) will increase the initial capital and operating costs of an onsite reuse system, but the economies of scale that can be gained from a larger system can sometimes provide a better overall life-cycle cost (resulting from a significant increase in annual potable water savings). However, this is very dependent on local requirements around treatment and testing/monitoring, as well as the size and function of the building.

drains that lead to the sewer)[10]. Setback distance from the street, lane, and utilities are at the discretion of the City.

As described in Section 1, the foundation infiltration setback and parkade requirements are key limitations for expanding the application of GRI and retention in redevelopment. Lotus recommends addressing those requirements to allow for more opportunities onsite to incorporate at-grade/infiltrating GRI. Specifically:

- Remove or drastically reduce parking requirements for buildings near public transit, for example handicap parking and building service areas only.
- Reduce the minimum foundation infiltration setback requirement for retention GRI from buildings (e.g., to three meters). Provide design standards for below-grade structure sealing and waterproofing, along with structural soils, and other resources. Additional engineering analysis and evaluation would be necessary to determine an appropriate lowered standard setback.[11]
- Create clear guidance for foundation infiltration setbacks from streets, lanes, and utilities for GRI retention to eliminate or drastically reduce discretionary approvals. Develop reasonable, allowable minimums and allow for variances upon request and review. In addition, the City can create standard design details to protect streets and lanes adjacent to retention facilities and share them with the professional design community for redevelopment projects.

Recommendations for Implementation of Policy

Looking ahead to the VBBL Phase 2 revisions and future HWP performance measures coordination, Lotus has developed the following key steps for new policy implementation to achieve the larger policy goals of healthy waters, increased retention and drainage management with parcels, and increased certainty for developers in the rainwater management approval process.

The City's leadership and advocacy for GRI and innovative rainwater management provides an overarching tone as these policies are implemented. City-led changes to regulations and procedures would reflect the commitment to GRI as well as broader drainage and water quality issues facing the City. Having a clear overarching policy framework from the HWP will show continuity with the RCS and ground the new regulations in clear outcomes.

Finalize HWP Performance Measures and Complete Performance-Based Modeling Analysis

As stated above, confirming the city-scale performance measures with numeric targets is on the critical path for creating a beneficial redevelopment policy. As part of that effort, the modeling analysis to confirm the performance-based design standards at the parcel level can also begin. The City can then

[10] It should be noted that the model National Building Code contains a 5 m setback, reaffirmed in the 2020 edition in Division B, Sentence 9.14.5.3.(2). The Province has reaffirmed this requirement in the 2024 BC Building Code, and this will be carried through into the next edition of the Vancouver Building By-law. Should there be appropriate technical documentation supporting a reduction of this setback, staff in Development, Buildings & Licensing would submit a formal "Code Change Request" to the Canadian Board for Harmonized Construction Codes.

[11] The modeling leading to this recommendation for the reduced foundation infiltration setback was done as a sensitivity analysis step, and any actual policy change to the foundation infiltration setback will require additional study/discussion by the City.

use those modeling outputs for both city-scale or basin-scale and parcel-scale to develop the VBBL Phase 2 rainwater requirements while simultaneously developing a design manual and accessible technical resources to link the city-wide policy and the redevelopment policy.

Completing this modeling will provide the City with the opportunity to perform a cost/benefit analysis to present to the development community, i.e., showing where potential costs for compliance and co-benefits can vary depending on the proportion of retention and detention systems and, if applicable, alternative compliance options.

Rainwater Management Design Manual and Technical Resources

Regardless of the ultimate details for the performance-based design standard and specific requirements, Lotus recommends a dedicated design manual and accompanying technical resources (e.g., sizing calculator) be developed specifically for rainwater management in redevelopment and new development scenarios, including GRI. Ensuring certainty and predictability will equate to lower costs and less time in developing rainwater management submittals and will streamline the approval process. The more ambiguity surrounding rainwater management requirements, submittals, and approvals, the more likely the development community will take the path of least resistance (which currently is resulting in more tanks and less GRI).

Several of the recommendations made for the GRI design methodology fall under the umbrella of creating certainty and predictability. For example:

- Standardizing the land use application of the rainwater management requirement for redevelopment parcels is key.
- Providing clear design and sizing guidance with examples for how to meet the priority goals, including what will not be approved.
- Communicating that an alternative compliance option is available, or will be developed.
- Creating enhanced engagement with stakeholders, professionals, and developers, including regularly scheduled workshops covering the manual and sizing tool, and "open hours" with City staff for questions and problem solving.

Creating the recommended specific guidance and technical resources will build capacity and help manage risk within the development community. These resources allow for all participants from the professional design community, developers, reviewers, and contractors as well as City management to be aligned about requirements and reduce the need for special exceptions or discretionary reviews and approvals.

With the complexity and variety of site conditions demonstrated through the pathways development, prescriptive pathways are not recommended for GRI design and sizing. A specific guideline or manual, with a set of standard details and specifications, to assist developers in implementing GRI is recommended as a solution for meeting rainwater management goals despite a site's physical constraints.

The rainwater management standards and manual should provide stepwise guidance for each category of site constraints including site assessment requirements. Once site assessments are completed, a design approach can be developed. The manual should illustrate design approaches for commonly encountered site constraints and provide guidance on how to overcome or integrate them into the site.

Over the course of the GRI Pathways Study, Lotus identified several sources and documents including by-laws, policies, bulletins, and the engineering design manual that all contribute to the design of rainwater management systems in Vancouver. Navigating these documents individually presents designers with a complex and time-consuming task to align with multiple resources that may lack consistency. A single design manual that considers all of these inputs and creates a simplified and common language and set of units will support a more efficient design process. During the majority of this study the rainwater management regulations were within the ZDBL, but then were moved into the VBBL. With this change, a period of transition will take place with the City engaging heavily with applicants, responding to questions, and clarifying expectations. Especially during policy transitions, manuals and technical resources (such as sizing tools) are fundamental to providing consistency, leadership, risk management, capacity building, and reinforcing certainty and predictability.

It is recommended that the City draft concise language within the new by-law and reference a detailed manual for stepwise guidance for compliance. This is common practice among North American jurisdictions. The outcome would be a single document that contains all the regulatory requirements, related procedures, standard details, and any of the sizing tools. It could be updated as needed without revisions to the by-law itself.

This manual should describe the following topics at a minimum:

- Applicability: Applicability for when rainwater management in redevelopment is required should be very clear and based on a total parcel area, total proposed impervious area, and/or disturbance area. Lotus recommends a standalone and comprehensive manual for meeting stormwater management requirements that clarifies applicability, performance standards, and design guidance. The manual would provide a single location for rainwater management compliance information and all requirements.
- Precise Audience: The Engineering Design Manual is a robust document that provides information covering a variety of engineering design issues, particularly servicing and streetscape design. While it provides most of the technical information needed for these designs, as well as the methodology for a variety of calculations, it does not provide a comprehensive summary of all the key information to be considered when designing a rainwater management system specific to a redevelopment scenario.
- Sole Technical Resource: The ZDBL, and related RWM Bulletin, provides much of the required performance criteria to be met for rainwater management but only briefly touches on elements of GRI design. This document, together with the Engineering Design Manual, could provide most information needed for the design of a rainwater management system. However, the Engineering Design Manual is general and does not provide specific guidance on how to integrate GRI into site and development plans.
- Clear, Predictable Standards: The RCS is an aspirational document that proposed the capture and treatment of the first 48mm of rainfall during a rainfall event; however, most of the

documents reviewed, containing similar information, require the capture and treatment of the first 24mm of rainfall during a rainfall event. The manual recommended here would clarify these two documents and statements and give guidance on exactly which performance standard must be met.

The Jurisdictional Scan completed in Task 4 (GRI Design Methodology) provides several leading examples of manuals and the underlying performance standards they achieve.

Develop Alternative Compliance Options

Based on this study, it's clear that not all sites will be able to retain 24 mm (or 48 mm) of rainfall given real physical constraints. In these cases, the allowance for detention facilities (i.e., detention tanks and treatment devices) provides a pathway for compliance with the intent of the rainwater management requirements. The current policy does not include any specific options for alternative (i.e., offsite, fee-in-lieu, credit trading) or modified (i.e., adjusted capture/treat/flow targets) compliance approaches for highly constrained sites.

The City does provide an Alternative Solutions process to allow for flexibility in design or "to employ design methods that are different from the prescriptive Building Bylaw requirements" however there is no guidance on acceptable alternative approaches specific to stormwater management (i.e., no certainty and predictability). Developing a more formalized program around potential alternative or modified compliance options, with clear guidance and submittal requirements, may create incentive and opportunity for constrained sites and the City to meet the intent of the RCS.

Given the shift in the VBBL Phase 1 approach toward only requiring detention facilities, the City may not necessarily need an alternative compliance option in the near term. However, if the VBBL Phase 2 requirements look to reinstate a compliance hierarchy with retention as the priority, then an alternative compliance option may be a detention system with a significantly reduced release rate to attain almost similar performance.

Once the final performance-based design standard is determined, alternative compliance options can be developed. There are several general approaches to alternative compliance including:

- Fee-In-Lieu options can be a last resort and per discretion only, or broadly utilized to create a new revenue stream for the jurisdiction to use in the funding of capital projects toward Healthy Waters Plan goals. Examples of these projects include building large green facilities, tree planting, urban greening and watershed health initiatives, or distributed GRI assets within the public right-of-way – all within the same basin as the proposed development. Fee-in-lieu programs can be shaped to fit the specific needs and goals of the jurisdiction and can be tailored to meet the City's goals using the magnitude of the fee and eligibility criteria to drive participation accordingly.
- Credit Trading options create a buyer/seller marketplace for GRI credits as public and private parcel-based projects are developed. The jurisdiction regulates a market-based unit price per credit and develops the software and reporting to facilitate the trading system of rainwater credits when needed. Some projects can sell GRI credits where they have more space and can build a larger GRI facility, and other projects are very constrained and need to purchase credits

for compliance. The most well-established stormwater credit trading program is in Washington, D.C. and was covered in the Task 4 (GRI Design Methodology) Jurisdictional Scan.

- Off-Site Compliance options typically require the developer to build an equivalent GRI facility somewhere else within the watershed or subcatchment. Often these off-site projects can be banked, or consolidated, to install more meaningful projects that are targeted in areas of a higher need. Off-site compliance could be combined with credit trading programs.
- Due to the difficulty of meeting retention targets using green infrastructure systems on some building typologies, the City may want to consider incentivizing "green" detention systems such as non-infiltrating bioretention planters that could be incorporated into site landscaping plans, could provide many of the co-benefits of green retention systems and could offset the size of on-site detention tanks.

Facilitate GRI Engagement and Training

The correct design, installation, and maintenance of GRI systems is necessary for long-term performance. With any new regulation change, the City should provide training courses for designers, contractors, and maintenance crews to ensure correct design, installation, and longevity of these systems. Once current contractors and maintenance workers are trained, the knowledge will be passed on to newer staff as GRI becomes commonplace around the City.

In general, the alignment of HWP and rainwater management requirements should streamline much of the submittal, design, and permitting process and provide a simpler method for City plan reviewers. Addressing the issue of enforcement of existing maintenance & inspection to ensure the longevity of GRI is critical to programmatic success, but also necessitates a broader discussion around staffing resources or third-party options and costs.

The development of a design manual is also a solution to administrative and training challenges, as well as serving as an engagement tool. The manual would support coordination across City departments and their respective policies and guidelines and provide a single document for all policies related to rainwater management in redevelopment as a training resource.

GRI Maintenance Standards and Enforcement

Successful GRI policy and programs depend on adequate inspection and maintenance of these systems. The City currently has a team of maintenance staff who are responsible for the upkeep of GRI in the public realm. Currently, there are limited requirements for inspection and maintenance for most GRI in the City.

To combat any deficient maintenance operations by Strata or other property or building management, new inspection and maintenance requirements should be included with the updated rainwater management regulations and procedures. This should allow City staff, or third parties on behalf of the City, to inspect GRI on private sites and request maintenance and repairs as required. A financial analysis would be required to assess the effort needed to meet the City’s expectations for maintenance of private GRI.

There are many variables to consider on this topic. In the US, many of the on-site GRI implemented as part of new or redevelopment is required to be inspected and an annual reported submitted per Municipal Separate Storm Sewer System (MS4) Permits. While these inspections may not be perfect, it has forced jurisdictions into some frequency of inspection cycle, self-reporting or self-certification, or other systems. The frequency and level of inspection depends on the amount of assets, parcels, and resources. Enforcement tools such as random inspections, fines, and liens can also be effective tools for this purpose. Routine building inspections are not a new challenge however and there are likely several models that would fit the scale and needs for the City to consider.

Interim Steps To Consider

At this time, the VBBL updates are being finalized and the HWP is ongoing. If the City wanted to advance any of the recommendations included in this memo, there are some interim steps that may be taken. These were also presented to the City on March 7, 2024.

- Advance the expansion of policy for specific GRI types (City and Provincial Level)
- Start alignment of City-wide policies and goals (HWP Performance Measures)
    a. Using the MBM and VSA modeling analyses can provide an initial direction for near term policy decisions at the basin-scale.
    b. Combined results of modeling and GRI Pathways Study can provide the City with a basis for initial reasonable expectations for site-level retention or detention that are feasible and can be used in the implementation of the VBBL Phase 2 effort.
    c. Release an RFP or change order for HWP to further refine appropriate city-wide performance standard that meets HWP goals
- Create resources to support GRI on private sites and simplify review process for City staff
- Provide an interim performance-based standard
    a. Modify Release Rate Reduction in VBBL Revisions, Phase 2
    b. Can be updated/revised after further study

Workshops

The Pathways Study included three public-facing workshops to engage with stakeholders in order to gain feedback and better understand their perspectives, especially as related to the barriers and potential solutions.

Workshop #1: Typologies, Tools, & Implementation Barriers

The workshop had the following objectives:

- Introduce the GRI Pathways Study project and the representative building typologies and rainwater management tools we will be using in the study;
- Introduce the barriers to GRI implementation on private property collected to date; and
- Hear participant feedback and input on the tools, assumptions, typologies, and barriers to meeting the City's rainwater management design standards and performance targets.

Workshop #2: Barriers and Solutions for Green Roofs

The workshop had the following objectives:

- Hear from subject matter experts, industry leaders, advocates, and stakeholders about implementation barriers and, particularly, implementation solutions related to green roof installation in the City; and
- Learn from and understand the perspective of different actors involved in green roof policy, design, installation, maintenance, and regulation.

Workshop #3: Findings, Policy Considerations, and Next Steps

The workshop had the following objectives:

- Provide an overview of all work to date and ask participants for feedback on the identified GRI pathways,
- Provide an overview of the identified GRI co-benefits; and
- Present and discuss preliminary policy considerations to support the implementation of GRI.

See attached WORKSHOP #1, #2, and #3 ENGAGEMENT SUMMARIES for further information.