PermeaPath

Nelson Creek Watershed
Green Infrastructure Solution

Prepared by

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List of Acronyms

AMF	Adaptive Management Framework
BCWWA	British Columbia Water and Waste Association
BMP	Best Management Practices
B-IBI	Benthic Index of Biotic Integrity
CAPEX	Capital Expenditure
CO_2	Carbon Dioxide
DO	Dissolved Oxygen
EPT	Ephemeroptera, Plecoptera, Trichoptera
GHG	Greenhouse Gases
GI	Green Infrastructure
IDF	Intensity Duration Frequency
I/P	Impervious-to-Pervious Ratio
LCA	Life Cycle Assessment
LID	Low Impact Development
NPV	Net Present Value
NTU	Nephelometric Turbidity Unit
OPEX	Operating Expense
QGIS	Coquitlam's online interactive, geographic information systems map, QTheMap
TP	Total Phosphorus
TN	Total Nitrogen
TSS	Total Suspended Solids
WDM	Weighted Decision Matrix

Abstract

Increasing rainfall intensity and ongoing urban densification in the Nelson Creek Watershed of Coquitlam, British Columbia, have amplified the need for sustainable stormwater management. PermeaPath is a strategy aimed at improving stormwater quality, reducing runoff through infiltration, reducing drawdown times, and enhancing ecological resilience. The design utilizes Green Infrastructure at upstream, midstream and downstream sites to address distinct stormwater challenges. Lebleu Street is a steep residential area with fast runoff, Edgar Avenue is a flat residential zone with limited infiltration, and Mackin Park is a public green space with high community use and ponding concerns. Each design exceeds criteria by treating 90% of rainfall and runoff, removing 90% TSS, and reducing excess nutrients and other contaminants.

Alternative technologies were evaluated and ranked by economic feasibility, constructability, environmental performance, and community benefit. The final design includes vegetated swales with check dams on Lebleu Street, tree trenches and permeable pavers for Edgar Avenue, and a rain garden in Mackin Park that incorporates educational signage on Indigenous knowledge and stream health. Cost estimates were derived from vendor quotes and comparable case studies, totaling $1.17M USD. PermeaPath offers a resilient, sustainable framework for stormwater management, while enhancing urban livability and strengthening community-environment connections.

Acknowledgements

Our team is incredibly grateful to our Faculty Advisor, Dr. Zeina Baalbaki, for her insightful guidance and support throughout this project. Dr. Baalbaki dedicated time out of her busy schedule to help us understand concepts, provide additional resources, and spark meaningful discussions. Her expertise and encouragement not only helped us to navigate challenges, but also inspired us to think critically beyond the scope of this work. We truly appreciate her dedication and the invaluable impact she has had on our team and our project.

We also thank Trevor Cheung, Lauren Lee, and Katie Patrao for coordinating site visits and for their prompt and thorough responses to any questions we had. We hold immense gratitude to BCWWA and their sponsors for providing this invaluable opportunity to work on such an impactful project.

Land Acknowledgement

This project takes place on the traditional, ancestral and unceded lands of the *kʷikʷəƛ̓əm* (Kwikwetlem First Nation). The *kʷikʷəƛ̓əm* have been stewards of Nelson Creek and its surrounding lands and water bodies since time immemorial. Their deep-rooted connection to this land is reflected through generations of traditional teachings and ecological wisdom. We thank *kʷikʷəƛ̓əm* for their advice and consultation during the development of PermeaPath.

We recognize that any meaningful solution in this region is not complete without respectful consultation and active engagement with *kʷikʷəƛ̓əm* and the honouring of traditional ecological knowledge.

Team Overview

Student Team

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Responsible for the design of Mackin Park, social and environmental assessments, and water balance calculations.

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Project Support

Dr. Zeina Baalbaki — **Ph.D., P. Eng., Lecturer,** *The University of British Columbia*
Faculty advisor for the student team.

Katie Patrao — **Corporate and Events Professional**, *BC Water and Waste Association*
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Trevor Cheung — **Engineering Technologist**, *City of Coquitlam*
Lauren Lee — **Engineer in Training**, *Urban Systems*
Representatives on behalf of the City of Coquitlam who provided the proposed project and problem statement, as well as supporting the students by clarifying competition-related questions.

1.0 Background

The Nelson Creek Watershed is a 600 acre urban catchment in Coquitlam, British Columbia, Canada, within the country's third largest metropolitan area of Vancouver. This subwatershed drains into Nelson Creek through a network of ditches and uncombined storm sewers before discharging to the south, into the Fraser River (*Figure 1*). In recent years, rapid urban densification has replaced natural and permeable surfaces with buildings and other impervious areas, reducing infiltration and significantly increasing runoff [3]. This has led to concerns of flooding risks, Creek water quality, and overall stream health. The City of Coquitlam has been monitoring various water parameters of the Creek, including turbidity, temperature, pH, dissolved oxygen concentration, conductivity, and water levels. Efforts to assess Nelson Creek date back to 2020, when the City retained Tetra Tech Inc. to conduct an Adaptive Management Framework (AMF) [5]. The report revealed that the creek did not meet all the AMF water quality guidelines and watershed health for the Nelson Creek catchment.

Given Coquitlam's temperate coastal climate, with an average rainfall of 78 in/year [5], and the proven success of green infrastructure (GI) in neighbouring municipalities, GI presents an effective approach to manage urban runoff. This is achieved through diverting contaminated runoff from the storm system that directly discharges into Nelson Creek. These systems help to remove pollutants, reduce peak flows, and promote groundwater recharge, therefore contributing to the restoration of the natural hydrological cycle within the watershed.

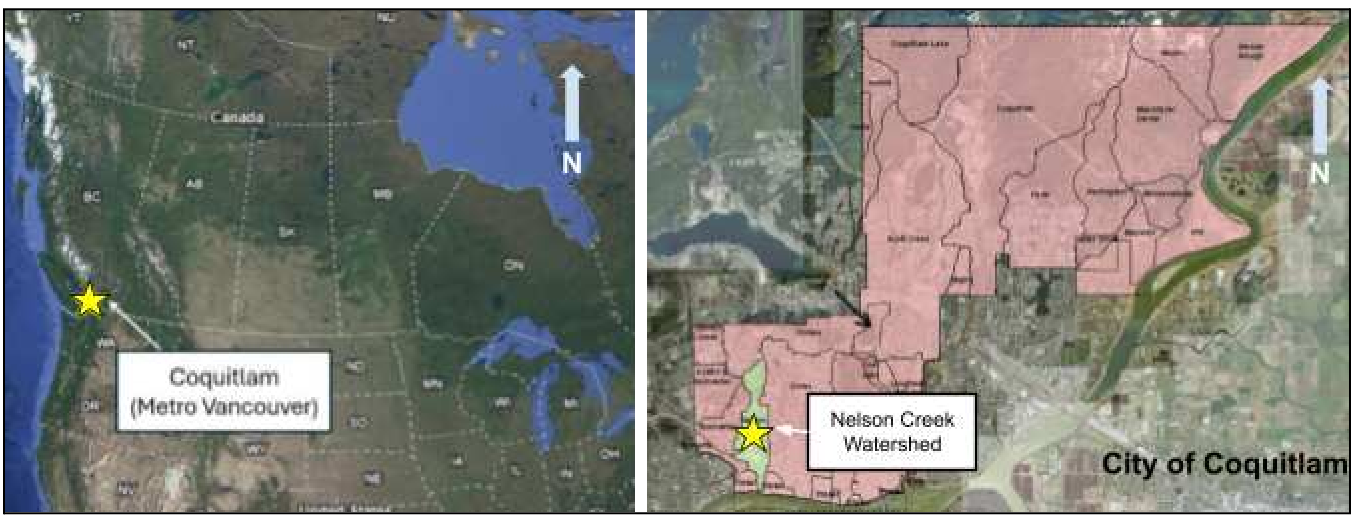

Figure 1: *Map of Coquitlam, British Columbia with Nelson Creek watershed highlighted in green.*

1.1 Objective

This project aims to develop an innovative and sustainable stormwater management strategy that integrates GI solutions to improve the water quality, mitigate flooding, and enhance ecological resilience in the Nelson Creek Watershed. The project will identify opportunities to incorporate GI elements in alignment with the City of Coquitlam's Stormwater Management Policy while accounting for the effects of climate change and densification [1]. This project targets three locations within the Nelson Creek Watershed, each representative of typical directional streets and greenways found in Coquitlam: Edgar Avenue and its laneway (East to West), Lebleu Street (North to South), and Mackin Park (urban public green space) as shown in (*Figure 2*). These locations were identified by the City of Coquitlam with flexibility granted in magnitude and placement of the design solution.

Figure 2: *Map of proposed sites within target locations outlined by the City of Coquitlam. The Nelson Creek Watershed boundary is outlined in red.*

1.2 Alternatives Evaluation

Water quality assessments from the Adaptive Management Framework (AMF) were analyzed to identify types and amounts of contaminants present in Nelson Creek [5]. Using QGIS, contours were mapped to determine flow direction and inform appropriate site evaluations [26]. QGIS was also used to identify specific catch basins that contribute to these drainage-deficient areas. These catch basins were flagged as target points for green infrastructure retrofits.

Various GI technologies were assessed and narrowed, with selected solutions highlighted in *Table 6.4.1, Appendix 6.4*. The assessment considered the GI's ability to treat site-specific contaminants, spatial constraints, and existing and future land uses [8]. *Table 6.4.7, Appendix 6.4* compares a matrix of pollutant sources from various land use types to appropriate treatment strategies.

A Weighted Decision Matrix (WDM) was utilized to select the most suitable option for each site in *Appendix 6.9*. The evaluation criteria remained consistent across all sites, with factors encompassing social, environmental, economic and operational factors. Weightings were adjusted based on land use and site-specific conditions, with a rationale for each weighting shown in the side column of each matrix. Each option was scored on a scale from 1 to 5, where 5 represented optimal performance under each constraint. Final scores were totalled, with the highest scoring solution being selected. Engineering judgement and GIS review were used to re-validate feasibility.

PCSWMM modelling was performed with the current IDF curves to assess local pipe capacity under a 1:10 storm event. It was assumed that the maximum flow rate from the pipe nearest to the culvert of interest represented the peak discharge at that location into Nelson Creek. These values provided a baseline for identifying areas along project sites with insufficient drainage capacity. To improve model accuracy and better understand runoff contributions to the selected designs, site-specific subcatchments were delineated to represent the areas draining into each system. Delineations were based on site visit observations (including road grading and drainage) and topographic data available through Coquitlam's QGIS database (*Appendix 6.1* and *Appendix 6.5*).

The Rational Method was applied to the selected sites using runoff coefficients provided in Coquitlam's Stormwater Management Policy and Design Manual [1]. A time of concentration of zero was assumed for simplicity, as contributing areas were small and runoff either landed directly on the proposed GI or flowed from immediately adjacent impervious surfaces such as roads. Due to the short flow paths and minimal pervious area, the effects of infiltration and soil saturation on flow timing were considered negligible. This approach allowed for a streamlined estimation of inflow into the proposed GI designs. *Tables 6.4.2* and *6.4.3 in Appendix 6.4* illustrate the current and future (2050) rainfall intensities for the Nelson Creek Watershed, which were used to perform this analysis. Incorporating both sets of rainfall data ensures that the design is resilient and responsive to both current and future scenarios associated with climate change.

2.0 Design Criteria and Basis

The design basis outlines the design criteria and research guiding the design and development approach. Key considerations for PermeaPath are criteria pertaining to hydrology, soils, water quality and stream health, and that all solutions comply with relevant municipal, provincial and federal regulations as shown in Table 1 below.

2.1 Regulatory and Policy Constraints

Table 1: *Summary of regulatory and policy frameworks used to approach and model designs.*

Design Element	Description and Key Frameworks
Right-of-Way (ROW) Constraints	The proposed designs remain within the City's property and right-of-ways, adhering to local Best Management Practices (BMPs) for setback distances [22, 24].
Existing Utilities	Confirm the proposed designs do not interfere with existing utilities, maintaining adequate setback distances and appropriate mitigations aligning with local BMPs. Perform a QGIS Coquitlam utility review to confirm that the design will not interfere with existing underground infrastructure.
Stormwater Design Compliance	All designs should comply with the City of Coquitlam's Stormwater Management Policy and Design Manual [1].
Riparian Setback	A 90 ft setback from the top of the bank of Nelson Creek is required. In instances where encroachment is necessary, measures should be taken to ensure no negative impact, including maintaining physical barriers, such as roads to protect the stream.
Additional Policies and Frameworks	Ensure the design is in alignment with the following sources: ● Metro Vancouver's Monitoring and Adaptive Management Framework for Stormwater [5] ● Best Management Practices for the Protection of Fish and Fish Habitat [4]

2.2 Soils Criteria and Site Hydrology

To meet minimum performance standards, pervious and hard surfaces draining into them require at least 11.8 in of absorbent topsoil [2]. This applies to all land uses, ensuring effective water management. While current classifications meet this criteria, a detailed geotechnical and hydrogeological assessment is strongly recommended to fully characterize existing subsurface conditions. The Nelson Creek Drainage Study [3] provides soil characteristics and watershed data critical for assessing GI feasibility. Without adequate infiltration, runoff cannot drain efficiently, rendering many GI designs ineffective. *Table 6.4.4 in Appendix 6.4* outlines soil infiltration characteristics for different soil types within the watershed. These soil classifications were used as assumptions to inform this current preliminary design. Soils along Lebleu Street, Edgar Avenue and Mackin Park consist of sand to gravel, offering high saturated conductivity (4.74 in/h) and strong infiltration potential [3].

2.3 Flow and Storage Criteria

The following flow and storage performance criteria in *Table 2* were defined through assessment of Coquitlam's Stormwater Management Policy and Design Manual [1] and by referencing their BMPs [24]. These values ensure design safety and establish an adequate level of service to maximize the overall impact and resilience of the proposed systems.

Table 2: *Summary of flow and storage criteria*

Design Element	Criteria/Performance Target
Water Retention	Retain the first 1.34 in of rainfall over a 24-hour period. Infiltrate, evapotranspirate, and re-use rainwater to the greatest extent possible.
Volume Reduction	Treat and retain 90% of receiving average annual runoff volumes
Surface Ponding Drainage	Ponded water drains within 24 hours post-rainfall
Subsurface Storage Drainage	Subsurface volumes within the GI system drain within 72 hours
Native Soil Infiltration/Characteristics	Must have a high infiltration capacity (e.g. greater than 0.59 in/hr), or a perforated underdrain may be required.
Peak Flow and Runoff Volume Control	Limit post-development peak flows to that of the pre-development peak flows as far as possible.

2.4 Water Quality Criteria and Assessment

Water quality criteria are based on Metro Vancouver's Monitoring and Tetra Tech AMF [5] which employs priority indicators to assess compliance with regulatory guidelines, as shown in *Table 3*.

Table 3: *Summary of water quality criteria*

Design Element	Criteria/Performance Target
Water Quality	Treat 90% of receiving average annual runoff volumes
Turbidity	<25 NTU under normal conditions; <100 NTU during significant rainfall events measured at final discharge location

The Tetra Tech AMF study of the Nelson Creek Watershed analyzes water quality samples from the creek collected during both wet and dry seasons in 2020 [5]. Each sample was evaluated using Tetra Tech AMF [5] and parameters were classified as “good”, “satisfactory”, or “needs attention” (see Table 6.4.5, Appendix 6.4). While no parameters fell into the “needs attention” category, copper, iron, and zinc exceeded allowable thresholds, posing risks to the aquatic ecosystem. Elevated E. coli levels suggest fecal contamination, potentially from urban wildlife or pet waste. These exceedances are exacerbated by increased runoff associated with urban densification, which accelerates pollutant transport through the watershed and amplifies the risk of contaminants entering Nelson Creek.

2.5 Stream Health Criteria and Assessment

Table 4: *Stream health criteria*

Design Element	Criteria/Performance Target
Urban Biodiversity Enhancement	Biotic Index of Benthic Invertebrates (B-IBI) score of 28-36

The water quality assessment in the TetraTech AMF [5] used the B-IBI to evaluate and quantify stream health by measuring EPT (Ephemeroptera, Plecoptera, Trichoptera) taxa abundance, which are a pollution sensitive species, suitable for evaluating urban environments. The report found Nelson Creek’s EPT (%) was 21% with a B-IBI score of 20, indicating poor stream health, similar to other Coquitlam streams [5]. Table 6.4.6 in Appendix 6.4 summarizes the issues at each of the three Nelson Creek sampling locations. Key factors impacting B-IBI scores include conductivity, total phosphorus and total nitrogen [6]. A U.S. Department of the Interior study found that urban land use, habitat conditions, and nutrient concentrations predominantly affect stream indices [7], underscoring the need to treat stormwater runoff before it reaches streams and guiding priorities for GI implementation.

3.0 Green Infrastructure Solution

3.1 Considerations

In addition to meeting project goals and regulatory requirements, three considerations further guided StormWise’s design approach:

1) **Resilient Design –** The solution should be economically and operationally feasible. Future land use and planning considerations emphasize the implementation of small-scale, non-intrusive stormwater management initiatives at strategic locations to minimize environmental disruption.
2) **Community –** The solution should aim to enhance communities and draw awareness and appreciation of watershed health. The solution should showcase the contributions of local and Indigenous communities, traditional ecological knowledge and stewardship practices, and foster a collaborative approach to watershed protection.
3) **Ecology –** Enhance the movement of people, water, and wildlife while prioritizing sustainable urban development and biodiversity.

3.2 Conceptual Design

3.2.1 Upstream Solution Overview – Lebleu Street Vegetated Swale

Lebleu Street (Brunette Ave to Madore Ave) is a priority site for stormwater improvements due to steep grades (8–11%) and increasing urbanization. This accelerated runoff mobilizes higher loads of pollutants (heavy metals, nitrates, and sediments) and strains the drainage system. Existing catch basins collect runoff but discharge untreated water directly into Nelson Creek. To address these challenges, the design targets a minimum 1.34-inch retention over 24 hours to ensure adequate erosion control and capacity. In addition to these functional considerations, improving local aesthetics and maximizing the use of available greenspace were high priorities. These enhancements not only contribute to community wellbeing, but also support a higher level of service by promoting infiltration, evapotranspiration, and long-term system performance.

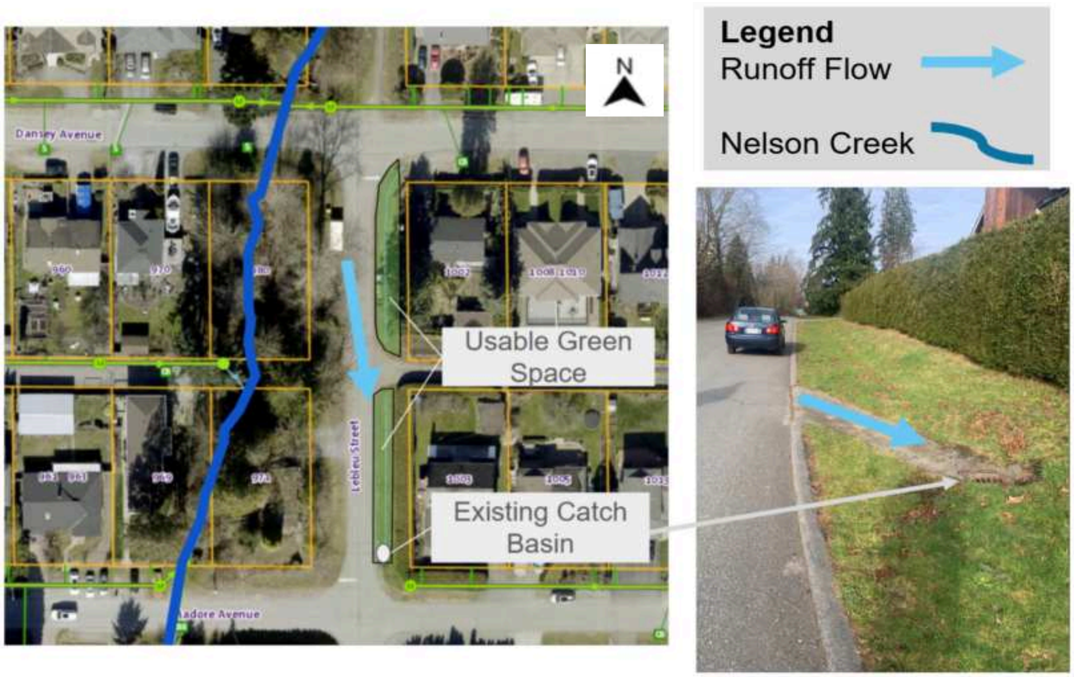

Figure 3: *Site layout of the Lebleu Street corridor between Dansey Avenue and Madore Avenue.*

A feasible stormwater treatment site exists along Lebleu Street, between Madore Avenue and Dansey Avenue (*Figure 3*). The road's eastward cross-grade directs runoff to a catch basin at the northeast corner of Lebleu and Madore, 6 ft east of the curb. This grading is advantageous for GI, as it facilitates runoff flow into the proposed treatment area. While efficient at channelling runoff, this basin lacks any treatment capabilities and drains directly into the storm sewer system, which leads into Nelson Creek (see *Figure 6.5.1, Appendix 6.5*). A 115 ft long green space directly north of the catch basin remains underutilized due to a lack of upstream drainage entry points. Further north, an alley separates this area from another 115 ft long green space, creating an opportunity for a dual-section stormwater design. The area provides ample space, with 14 ft between the curb and existing vegetation, while remaining in the road right-of-way. A utility review via Coquitlam's QGIS confirms no underground utilities in this green space, supporting additional feasibility.

Lebleu Street Design and System Narrative

A vegetated swale with check dams is proposed to slow, treat, and infiltrate stormwater, diverting contaminants from the storm system and Nelson Creek (*Figure 4*). As outlined in *Appendix 6.2*, the Lebleu Street Vegetated Swale design calculations ensure treatment performance meets criteria. Runoff will enter the swale through five strategically placed (2.3 ft-wide) cutouts along the roadside for retention and treatment. The cross-graded roadway will ensure that stormwater continues flowing toward the swale cutouts.

The swale will have two sections: a 98 ft long North section (upstream of the alleyway) and a 115 ft long South section (downstream), both with check dams to control ponding and manage the rapid runoff. A 20 ft long 6" PVC culvert will be installed beneath the alley, which is sized to ensure uninterrupted flow (see *Appendix 6.2.1*). As stormwater enters the North section, check dams will slow the flow, allowing sediments and pollutants to settle while supporting infiltration. Water then flows through the culvert to the South section, where additional filtration will occur before infiltrating into the subsurface. During intense storm events, excess runoff that exceeds the system's capacity will enter the elevated drain grate, which is connected to the storm sewer system. The swale's 7.9 ft bottom width provides a treatment area of 1679 ft^2, while the crest-to-crest width of 12.9 ft ensures a 1.2 ft or greater buffer from all existing vegetation (including bushes and trees). Ponding will remain shallow (below 0.40 ft), even during heavy rainfall, protecting existing vegetation and mitigating the risk of localized flooding. The proposed vegetated swale achieves the volume reduction and treatment objectives of capturing and treating 90% of annual rainfall, based on a 1.34-inch, 24-hour design storm (see *Appendix 6.4.10*). On an annual basis, this translates to a diversion of 110,000 ft^3 of stormwater, significantly reducing runoff volumes (see *Appendix 6.8.6*). Given the steep terrain, extra care was taken in the layout to manage runoff safely, while maximizing the available green space. This enables the design to achieve a greater level of service, being capable of fully treating the first 3.6 inches of runoff in 2050 scenario 1:2 year, 24-hour storm event (see *Appendix 6.4.11*). Using native plants, the swale enhances transpiration and healthy vegetation by restoring natural water flow patterns to reduce runoff.

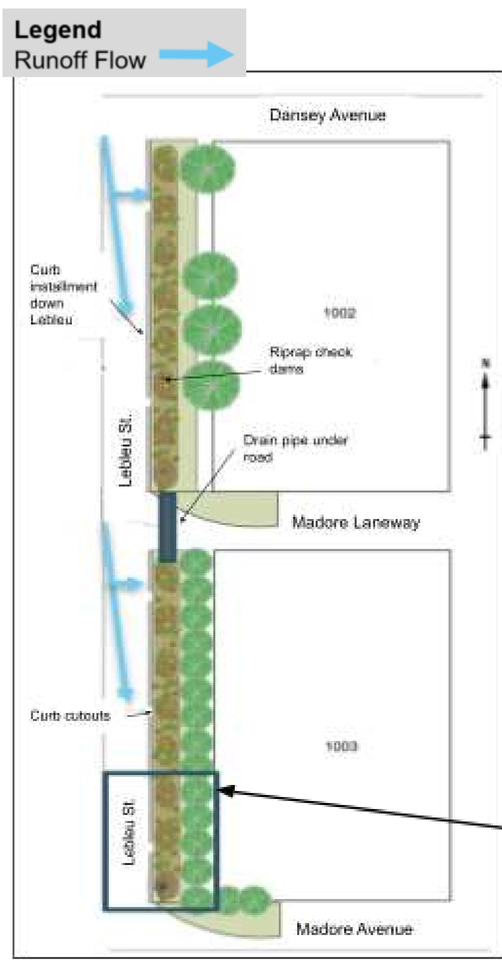

Table 5: *Lebleu Street design measurements*

Section	Value
Total Treatment Area (ft^2)	1679
North Section Length (ft)	98
South Section Length (ft)	115
Check Dam Spacing (ft)	4.1
Swale Bottom Width (ft)	7.9
Crest-to-Crest Width (ft)	12.9
Curb Cutout Width (ft)	2.3

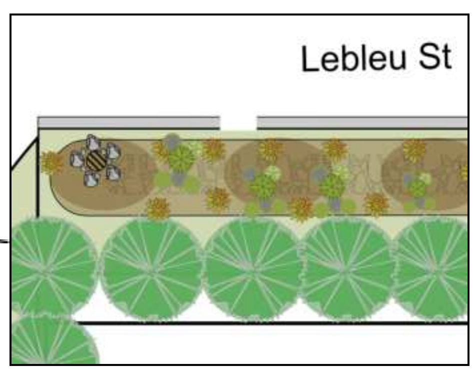

Figure 4: *Plan view of Lebleu Street Vegetated Swale with check dams between Dansey and Madore Avenue.*

Alternative Evaluation

Due to the steep topography of the design location on Lebleu Street, careful consideration was given to design specifications to ensure resilience against system erosion and localized flooding. An alternative design proposed using only the land south of the alleyway with a 115 ft vegetated swale (see *Table 6.9.1, Appendix 6.9*). The main advantage of this option was a reduction in earthworks and the elimination of a culvert, as it functions as a single-stage design. However, this reduced the effective treatment area by 46% (down to 872 ft^2), causing the alternative to not meet the 1.34 in over 24-hour (90% annual treatment) target. Due to its reduced treatment capacity, this alternative scored lower because of increased risks of flooding and maintenance from more frequent system overflows. In addition, this alternative limits the opportunity to improve local aesthetics by not making full use of the available space on site. Another alternative considered involved reducing the swale capacity to 805 ft^3 to accommodate a 4-foot sidewalk east of the vegetated swale. While this design improves pedestrian access, this corridor was rated a low priority for sidewalk installation in the City's *Strategic Transportation Plan Update* [13]. Additionally, the reduced swale volume would limit stormwater treatment capacity, preventing the design from meeting the 90% annual rainfall capture target achieved by the preferred alternative.

3.2.2 Midstream Solution Overview – Edgar Avenue Permeable Pavers and Laneway Tree Trenches

Edgar Avenue and the adjacent laneway resemble a typical Coquitlam neighbourhood, with paved roads, gravel walkways, and several front-facing driveways (*Figure 5*). The street is flat with a 0–3% slope, draining directly eastward into Nelson Creek (*see Figure 6.5.2, Appendix 6.5*). Coquitlam's long-term vision for this area includes improved transport accessibility [13], as reflected in new residential developments and expanded sidewalk infrastructure. PermeaPath aligns with these plans, accommodating residential parking, curbside pickup, and driveways. The laneway north of Edgar is a narrow, low-traffic, dead-end road, bordered by Nelson Creek's steep bank to the east. It is currently about 70% impervious and is projected to reach 90% imperviousness by 2050 due to larger driveways replacing vegetation [3].

Figure 5: *Key site characteristics of Edgar Avenue and the laneway directly north of Edgar Avenue*

Edgar Avenue Design and System Narrative
Both sides of Edgar Avenue will feature 4 ft × 8 ft tree trenches totalling 44 trees within the City right-of-way that are interwoven between strategically placed permeable parking pockets, which will support residential parking (*Figure 6*). Tree selection will prioritize narrow, native species, such as Hornbeam, to avoid conflicts with overhead utilities and remain in line with Coquitlam's Streetscape Guidelines [14].

Each tree trench will include structural soil to support tree growth to a depth of 4.9 ft while bearing surface loads. Beneath this, a 1 ft layer of crushed gravel will promote infiltration, with overflow directed to the storm sewer network. The proposed design achieves the volume reduction and treatment objectives of capturing and treating 90% of annual rainfall, based on a 1.34-inch, 24-hour design storm. An estimated water volume of 163 ft^3 can drain into each tree trench along Edgar Street. The tree trenches will collect water running off from properties and the road. The water will then infiltrate into the tree trenches and pass through structural soil then gravel to drain, or excess will be conveyed by a pipe connected to the storm sewer network (see *Figure 6.7.1, Appendix 6.7*). The permeable parking pockets will provide further infiltration capabilities.

Edgar Laneway Design and System Narrative
The north side of the laneway (*Figure 6*) will include a 900 ft x 3.3 ft x 2.4 ft deep section of permeable pavers to capture, treat, and infiltrate runoff from current and future driveways, likely to carry contaminants from construction, vehicles, and yard fertilizers. Given the area's high subsoil conductivity [3], a full infiltration model was selected to maximize stormwater absorption. The laneway currently consists of ditches that span down most of the laneway between property lines and the road, with open drainage culverts (see*Figure 6.1.2, Appendix 6.1*).

The proposed design achieves the volume reduction and treatment objectives of capturing and treating 90% of annual rainfall, based on a 1.34-inch, 24-hour design storm. Moreover, the laneway is expected to infiltrate up to 330 ft^3 of precipitation through the engineered media which is integrated into the existing drainage pipes, allowing excess clean water to support baseflows in the creek. This design mitigates streambank erosion by lowering discharge velocity, volumes and the drainage outfall. Only an additional 2 ft of depth is required in the existing trenches, which makes excavation smoother, and avoids the 3 ft deep water main down the laneway's centre.

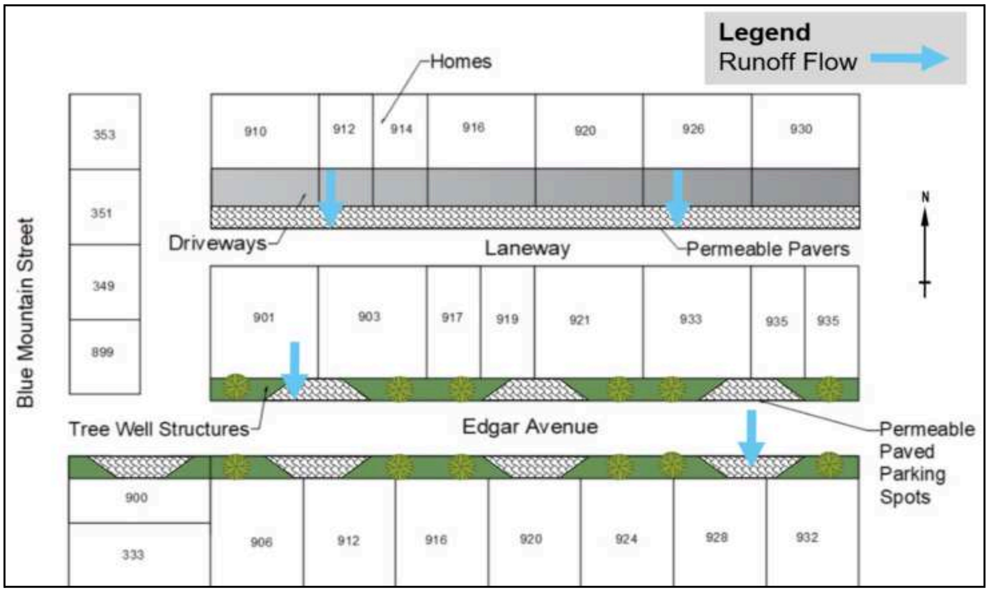

Figure 6: *Plan view of the Edgar and laneway design.*

Alternative Evaluation

Alternative solutions considered for Edgar Avenue included rain gardens and vegetative swales (see *Figure 6.9.2, Appendix 6.9*). Constraints such as flat grade, parking needs, future sidewalk installation, and maintenance requirements limited their suitability. Vegetative swales are not ideal on flat terrain due to the risk of poor infiltration rates and which increases mosquito breeding grounds [32]. For the rain garden, frequent maintenance is required for neighbourhood aesthetics. If expanded to more streets, this would significantly increase operational costs.

Alternative solutions for the laneway included vegetated swales, porous asphalt, and a modified version of Vancouver's Country Lanes concept (see *Figure 6.1.3, Appendix 6.1* for Country Lane, and *Figure 6.9.2, Appendix 6.9* for WDM). Vegetated swales would have enhanced greenspace by replacing topsoil with engineered media and native plants to manage runoff. However, given Coquitlam's development goals, this option was deemed impractical due to potential damage from ongoing construction and the likelihood of replacement with concrete for construction access. Porous asphalt also offered a structurally sound option but required significant disruption, including breaking existing concrete and extended laneway closures. Finally, the Country Lane concept emerged as a balanced alternative, using concrete wheel paths with vegetated strips between and beside them. However, the central water main limited soil depth, and previous studies reported poor public reception of the model due to muddy conditions in wet seasons which required high maintenance demands [33].

3.2.3 Downstream Solution Overview – Mackin Park Rain Garden

The City of Coquitlam has identified Mackin Park, a community park located on the southern end of the study site, as a potential location for GI. The 15 acre park is frequently visited by residents, featuring a playground and sports field. With nearby sites experiencing up to an 89% increase in imperviousness by 2050, this area is quickly urbanizing and requires scalable GI strategies to accommodate projected runoff volumes.

Nelson Creek flows through Mackin Park (light blue line in *Figure 7*), which includes delicate salmon-bearing flows in this naturalized area of the park. Due to the vulnerable nature of this riparian habitat, the Mackin Park Rain Garden solution is proposed on 1046 Brunette Avenue, an adjacent parcel to Mackin Park. As shown in *Figure 7*, developing GI across Nelson Street ensures a physical barrier between any construction disruption and Nelson Creek's riparian habitat, while maintaining a high visibility, urban green area for residents to socialize and enjoy. This location presents an excellent opportunity to capture and treat runoff along Brunette Ave, a high-traffic thoroughfare, where contaminants such as nitrates, copper, oils, and sediment runoff pose threats to Nelson Creek.

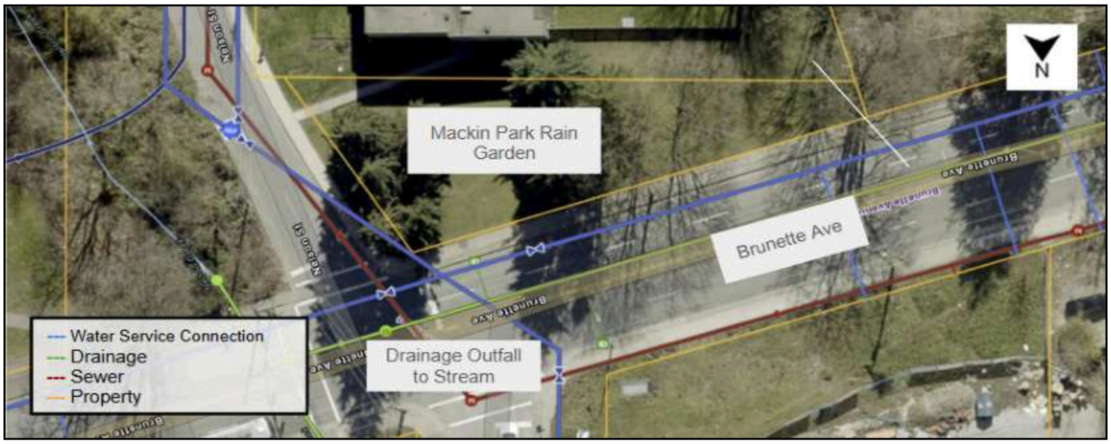

Figure 7: *Mackin Park and utilities, currently with one outfall.*

Mackin Park Design and System Narrative

A rain garden is proposed for Mackin Park. The Mackin Park Rain Garden will span 904 ft^2 at a 2.6 ft depth alongside the sidewalk on Brunette Avenue's south side. Rain gardens are capable of capturing high runoff flows and volumes in an area with ample space. This is effective for infiltrating and treating runoff before recharging groundwater and before discharge of excess water to the drainage outfall and fish-bearing streams (see*Figure 6.5.3, Appendix 6.5*). Rain gardens provide additional greenery in urban/gray areas and support inhabitants such as bees and insects. Finally, they promote groundwater recharge and the regrowth of plants effectively due to the sufficient water supply and pooling within the garden.

Mackin Park, a popular pedestrian area, offers an ideal location for community engagement. The proposed rain garden will feature educational signage on native plants, traditional history of Nelson Creek, and Indigenous relations in British Columbia. A walkway will lead to a community bench surrounded by Indigenous living art created by local Indigenous artists and culturally significant plant displays. This curation will enhance public awareness of *kʷikʷəƛ̓əm* recognition and the role of all beings in protecting the natural environment.

The proposed rain garden achieves the volume reduction and treatment objectives of capturing and treating 90% of annual rainfall, based on a 1.34-inch, 24-hour design storm (see *Table 6.4.12, Appendix 6.4*). On an annual basis, this translates to a diversion of approximately 60,000 cubic feet of stormwater, significantly reducing runoff volumes (see *Table 6.8.6, Appendix 6.8*). The ample sizing of the rain garden, making optimal use of the available green space, allows it to also capture the first 2.27 inches of rainfall during a 1:2 year, 24-hour storm (2050 scenario), demonstrating its resilience to higher-intensity events (see *Table 6.4.13, Appendix 6.4)*. Two curb cutouts on Brunette Avenue's south side will direct runoff down slope, where it will pass through 44.3 ft of grass filter strips, riprap, native vegetation, and stone into the rain garden subsurface [15]. Stormwater will infiltrate through sandy loam and coarse sand into native sand-gravel soil, promoting groundwater recharge and maintaining the site's water balance. The site's existing contours and steep grade already accumulate significant puddles, making the central, flatter area suitable for treating greater runoff containing vehicular pollutants such as metals, nitrates, and sediments.

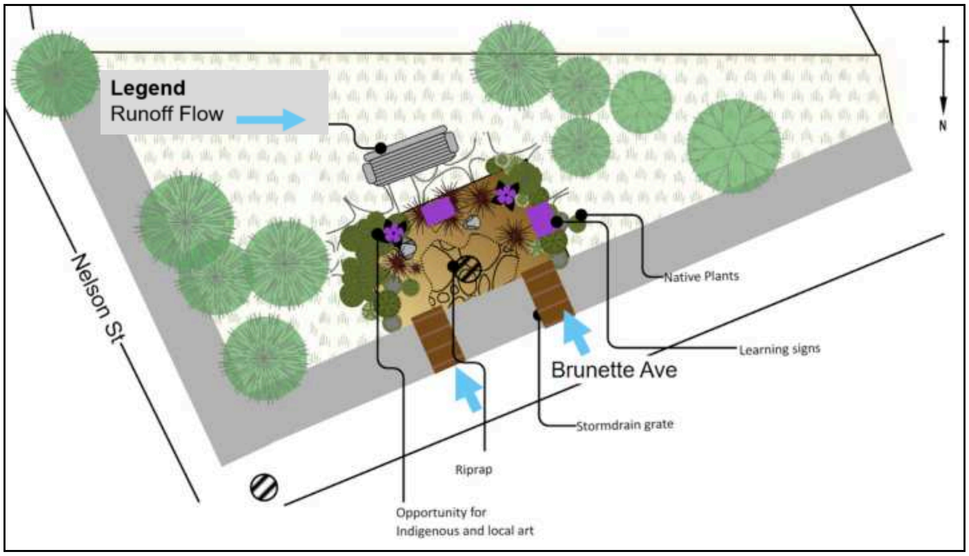

***Table 6:** Measurements for the Mackin Park rain garden*

Section	Area
Total Rain Garden Area (ft^2)	1238
Bottom Width (ft)	23.0
Bottom Length (ft)	39.4
Crest-to-Crest Width (ft)	27.9
Crest-to-Crest Length (ft)	44.3

***Figure 8:** Plan view of Mackin Park Rain Garden and summary of key design measurements for the rain garden.*

Alternative Evaluation

Alternative LID solutions considered for Mackin Park included infiltration swales along public parking lots and tree boxes as a meridian in public parking lots (see *Table 6.9.3, Appendix 6.9*). These concepts were developed with inspiration from other urban LID projects seeking to directly treat roadway contaminants from parking lots. However, due to constraints such as high capital costs, little space available in city right-of-ways, and impeding parking at Mackin Park during construction, the infiltration swales and tree boxes provided the least opportunity for biodiversity enhancements and water quality improvements. These constraints also stemmed from flat terrain and spatial limitations. Contrastingly, the rain garden concept allowed for substantial space to be used, which could sufficiently meet and exceed the outlined water quality targets, as well as reducing runoff velocity and enhancing biodiversity. Moreover, the rain garden could be maximized on the unused, public parcel of land to include interactive community spaces and feature cultural recognition of *kʷikʷəƛ̓əm* traditional ecological knowledge. The proximity of the rain garden area to Brunette Avenue and an existing catch basin draining into Nelson Creek additionally offered an ideal opportunity to intervene with an LID solution that could treat and infiltrate contaminated runoff that is currently draining directly into Nelson Creek, untreated. This area could also intake multiple points of runoff entry with sidewalk curb cutouts, allowing greater volumes of captured runoff. Ultimately, choosing the rain garden allowed for all environmental and social criteria to be met, while offering the exciting opportunity for Indigenous collaboration to build a new, accessible, and educational urban green space at Mackin Park.

3.3 Design Specifications and Efficacy

This section outlines media composition, sizing decisions and pollutant removal percentage for the design solutions. Calculations are outlined in *Appendix 6.2*. The Mackin Park and Lebleu Street designs use a water balance approach to guide ponding depth and sizing decisions (see *Tables 6.4.9, 6.4.10 in Appendix 6.4*).

3.3.1 Lebleu Street Key Design Parameters and Materials

The proposed design incorporates a multi-stage vegetated swale with a total area of 1679 ft^2 with riprap check dams every 4.1 ft. Check dams are critical for managing rapid runoff from Lebleu Street, which has a steep 10% grade, ensuring this runoff is slowed and efficiently infiltrated through the engineered soil and vegetation. The swale's capacity and retention features allow it to effectively treat the first 1.34 in of rainfall in a 24-hour period, achieving the 90% treatment of receiving runoff criteria. The swale is designed to accommodate a maximum ponding depth of 0.39 ft, a value that aligns with BMPs [22], ensuring that the risk of localized flooding is mitigated. Given the steep grade of the receiving catchment and its proximity to residential properties, the proposed design integrates a series of engineered controls that enhance stormwater flow management, minimize long-term maintenance requirements, and ensure the overall resilience of the system. In addition to the mentioned riprap check dams, the use of strategically sized curb cutouts and carefully graded channel slopes will help control runoff, reduce erosion, and maintain compatibility with existing and future infrastructure while remaining a cost-effective solution. *Table 6.3.3 in Appendix 6.3* describes these engineering controls in further detail.

Bioretention Sizing and Materials

The proposed vegetated swale utilizes sandy loam as the primary growing media [17], targeting a hydraulic conductivity of 1-1.2 in/h with an underlayer of coarse sand. The topsoil conductivity ensures that water draws down efficiently while maintaining strong treatment performance. Moreover, the swale consists of three vegetated regions – a wet zone within the ponding depth, a moist zone within the 3.2:1 catchment slope, and a dry zone surrounding the site. Using local, native plants in vegetation is a key focus in all solutions, and a selection of plants specific to Coquitlam can be found in *Table 6.6.3, Appendix 6.6*. Below the system, the native subsoil's high conductivity (4.74 in/h) ensures rapid drainage [3], preventing prolonged water retention and system clogging. This will likely eliminate the need for a perforated underdrain, relying instead on natural infiltration [8]. Ponded water is expected to draw down within 4.8 hours, well below the 24-hour design requirement (see Appendix 6.2.2).

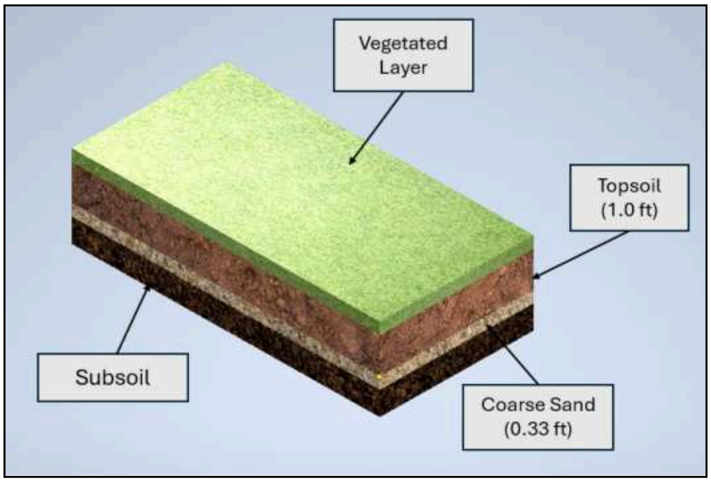

Figure 9: *Sectional drawing to represent the proportionally scaled thicknesses of layered media beneath the surface of the vegetated swales.*

Table 7: *Media composition and depths for the vegetated swale at Lebleu Street.*

Layer Description	**Thickness (ft)**	**Conductivity Rate (in/h)**
Topsoil (Sandy Loam)	1.0	1.0-1.2
Transition Layer (Coarse Sand)	0.33	~ 3.94
Native Subsoil	-	~ 4.74

Performance in Pollutant Removal

The proposed multi-stage vegetated swale is designed to effectively remove key stormwater pollutants by utilizing a sandy loam bioretention system, whose effectiveness is well-supported by research. A Monash University study concluded that bioretention areas, like vegetated swales and rain gardens, can significantly improve water quality by removing critical pollutants when utilizing sandy loam at a depth of 11.8 in and covering at least 2% of the catchment area [18]. With a treatment area that is 6.8% of the catchment area, this design exceeds this target. By utilizing engineered soil media and coarse sand, the swale is expected to achieve the following:

- 96–99% Total Suspended Solids (TSS) removal,
- 46–63% Total Nitrogen (TN) removal, effectively reducing nitrates and other nitrogenous compounds, including nitrate, and
- 82–91% Total Phosphorus (TP) removal, which is strongly correlated with the reduction of E. Coli and fecal coliforms due to their association with phosphorus-rich organic matter [19].

3.3.2 Edgar Avenue and Laneway Key Design Parameters and Materials

This design is composed of tree trenches connecting along each side of the length of Edgar Avenue, alternating trees and areas for parking and driveway access. Structural soil will be used to be able to support trees, as well as the ability for infrastructure such as parking to be supported above. A base of crushed stone will allow water to drain naturally, along with a storm pipe to convey excess water. Small trees will be used, so as to not overwhelm the street.

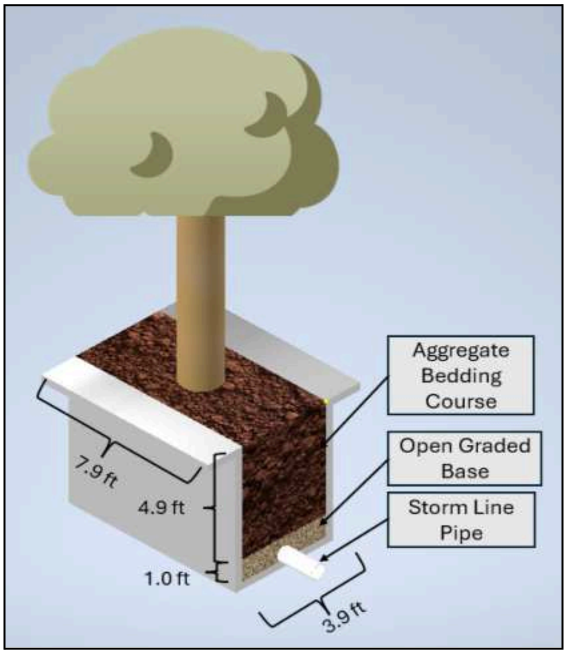

Table 8: *Media composition and dimensions of tree trenches.*

Layer Description	Thickness (ft)	Material
Aggregate Bedding Course	4.9	Structural Soil
Open Graded Base	1.0	Clear crushed stone 20 mm in diameter, including a mixture of sand and gravel
Overall Dimensions (ft)		
Length = 7.9	Width = 3.9	Total Depth = 4.9

Figure 10: *Sectional drawing to represent the proportionally scaled thicknesses of layered media.*

The permeable pavers design consists of materials which filter sediment and contaminants, and provide storage for large water volumes. A geotextile layer is also included to help reinforce structural integrity due to the vehicles driving over the pavers. For subsoils with conductivity above 1.77 in/h, (measured at 4.74 in/h in this location), the reservoir depth is limited to 6.6 ft to prevent compaction and permeability loss due to the overhead weight. [16]. The depth and layer thickness, and infiltration calculations can be found in *Appendix 6.2*, while *Table 9* below outlines the media composition.

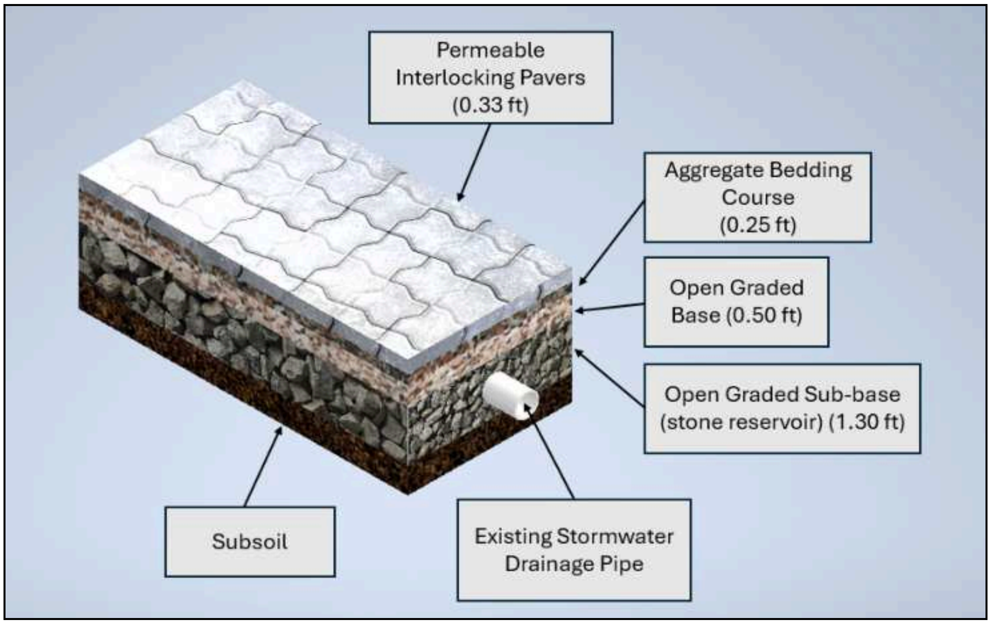

Figure 11: *Sectional drawing to represent proportionate layering of media beneath the pavers.*

Runoff Reduction, Storage and Infiltration

Full infiltration permeable pavers, with an underdrain, are estimated to reduce runoff volumes by 45% [16]. The projected increases in the 5-year storm rainfall rates will increase from 0.14 in/h in 2021 to 0.20 in/h in 2050, which is about a 43% increase in intensity and volumes. This system will manage the future storm volumes while reducing post-development peak flows to pre-development levels. Surface infiltration rates on permeable pavers have shown to be consistently high even at 90% clogged with sediment, and maintain effective water throughput when using ASTM #8 aggregate sizes [34, 35]. However, more importantly, the overall capacity of this system as well as its ability to store and infiltrate water through the engineered media is imperative, with the subsurface media providing an infiltration rate of 10.8 in/h (see *Appendix 6.2.2*).

Table 9: *Media composition and dimensions for permeable pavers in laneway.*

Layer Description	**Thickness (ft)**	**Material**
Permeable Interlocking Pavers	0.33 (vehicle applications)	PIPC - Belgard's Aqualine Pavers
Aggregate Bedding Course	0.25	Clear crushed stone 5 mm in diameter (US ASTM #8)
Open Graded Base	0.50	Clear crushed stone 20 mm in diameter, including a mixture of sand and gravel
Open Graded Sub-base	1.30	Clear crushed stone 50 mm in diameter, void space ratio of 0.4
Geotextile Filter Cloth surrounding excavated area	N/A	Nonwoven geotextile
Overall Dimensions (ft)		
Length = 902	Width = 3.3	Total Depth = 2.38

Proven Performance in Pollutant Removal

Beyond runoff reduction, the system improves water quality by capturing and infiltrating contaminants. Permeable pavers are able to reduce TSS in runoff by about 90%, as evaluated during a 5 year study across three permeable paver surfaces [12]. Studies showed that tree trenches are also effective in meeting 85% TSS reduction, as well as approximately 50% reduction in TN, TP, and Zn, and 40% in Cu [11]. Additionally, these two designs work hand-in-hand, as permeable pavers installed around tree planting zones help provide water and air to the roots of nearby trees, which contribute to healthier and longer lasting trees by requiring less manual irrigation [12].

3.3.3 Mackin Park Key Design Parameters and Materials

The Mackin Park Rain Garden utilizes two curb cut-outs with storm drain grates in the existing sidewalk, directing Brunette Avenue runoff from sloping gradients into the garden, with a total treatment area of 904 ft^2. This design ensures efficient infiltration and treatment by reducing flow velocities using a series of rocks, ripraps, and grass filter strips. The rain garden treats the first 1.34 in of rainwater in a 24-hour period, achieving the 90% treatment of annual receiving runoff criteria (see *Table 6.4.12, Appendix 6.4*). The design includes a central raised catch basin in case of overflow above 5.91 in of ponding, which connects to the municipal drainage system via the existing drainage system. Due to nearby steep slopes and proximity to residential properties, a series of engineered controls to mitigate risks is outlined in *Table 6.3.4, Appendix 6.3*. Key measures and BMPs, including strategically-placed riprap, permeable native sand-to-gravel soil, and carefully selected vegetation and soil compositions will work together to control runoff, reduce erosion, and maintain compatibility with existing and future infrastructure.

Bioretention Sizing and Materials
Similar to the Lebleu Street Vegetated Swale, this design will use a 1 ft depth of sandy loam for primary growing media and topsoil, and 1.6 ft of coarse sand below the topsoil, as a treatment and transition layer above the pre-existing subsoil. The subsoil in the design location, identified as Sand-to-Gravel shown in *Table 10*, has a high hydraulic conductivity of 4.74 in/h, therefore acting as an extremely favourable drainage soil in lieu of drainage rocks. The rain garden will consist of three vegetated regions, similar to the Lebleu Street Vegetated Swale, and each region will feature local, native plants, selected in partnership with *kʷikʷəƛ̓əm,* as outlined in *Table 6.6.3 in Appendix 6.6*. The system is designed to meet key drawdown time requirements, ensuring efficient stormwater infiltration. Ponded water will draw down within 6 hours, and subsurface volumes within 17 hours, well below the 24-hour and 72-hour maximum requirements, respectively (see *Appendix 6.2.2*).

Proven Performance in Pollutant Removal
See *Section 3.3.1 Lebleu Street Key Design Parameters* for discussion on pollutant removal success. The Mackin Park Rain Garden satisfies the same criteria as the Lebleu Street Vegetated Swale for the outlined pollutant removal success, due to utilizing the same dimensions of engineered soil media and coarse sand. With a designed coverage of 8.3% of the catchment area, this design similarly exceeds the target of covering 2% of the catchment area with LID treatment area to achieve significant water quality improvements [18].

Table 10: *Media composition and depths for the Mackin Park Rain Garden.*

Layer Description	Thickness (ft)	Conductivity Rate (in/h)
Topsoil (Sandy Loam) [20]	1.0	1.0-1.2
Transition Layer (Coarse Sand) [20]	1.6	~ 3.94
Native Subsoil (Sand-to-Gravel)[3]	-	~ 4.74

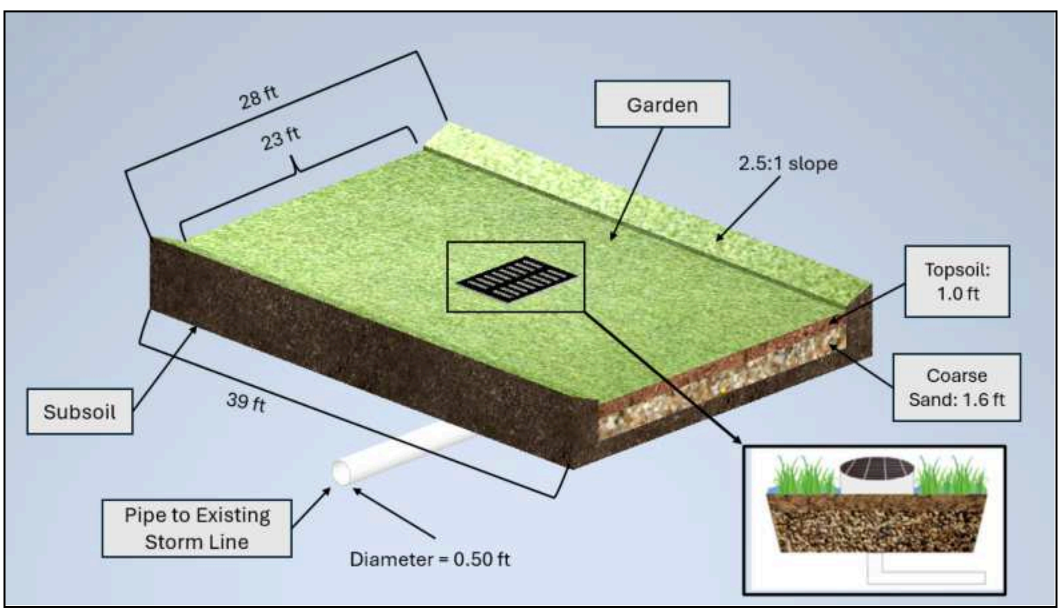

Figure 12: *Sectional drawing to represent the proportionally scaled thicknesses of layered media beneath the rain garden surface, and other components.*

3.4 Construction Strategy

Construction aims to have minimal community impacts, with strategic planning for safety and scheduling. Construction will occur throughout the dry seasons of the year (May to September) to allow proper material installation, prevent soil compaction, and allow vegetation to settle before heavy seasonal rainfall. We also strongly recommend the implementation of a comprehensive erosion and sediment control plan prior to all construction activities to minimize soil loss and prevent sediments from entering the storm sewer system. Edgar Avenue and the laneway should be implemented in phases to ensure minimal impact to residential parking and noise. On Lebleu Street, one-way traffic and no parking should be implemented to allow space for material storage and excavation. At Mackin Park, construction will minimally affect traffic along Brunette Avenue (a main road) due to utilizing Nelson Creek for basing construction needs. Construction vehicles will be instructed to park on Nelson Street. No utilities or businesses will be affected at any of the sites.

As per City of Coquitlam by-laws, construction can take place from 7 AM to 8 PM on weekdays and 9 AM to 6 PM on Saturdays. During these hours, noise management measures will be implemented to ensure activities are within the noise decibel thresholds. Additionally, residents will be notified in advance if the work will directly impact them.

4.0 Bottom Line Assessment

4.1 Social Assessment

Community engagement is at the centre of PermeaPath and should be incorporated into all stages of the project. Consultation with Kwikwetlem First Nation highlighted their wishes for initiating cultural recognition in projects, greater funding for engagement initiatives, and participation opportunities to support stormwater quality on their traditional lands. The inclusion of Indigenous artwork and traditional knowledge at Mackin Park Rain Garden is inspired by successful municipality and First Nations collaborations around Vancouver – such as featuring traditional *hən̓q̓əmin̓əm̓* pronunciation and knowledge of native plants on the City of Coquitlam's website, collaborating with Indigenous artists to design living art, and featuring signage of *kʷikʷəƛ̓əm* plant knowledge near the rain garden (see *Tables 6.6.1 and 6.6.2, Appendix 6.6*). This can raise awareness on the importance of protecting watersheds, water quality, and stream health for all living beings. Such opportunities for community involvement and Indigenous recognition will enhance public awareness, and support Coquitlam's commitment to reconciliation. Moreover, strengthening Indigenous partnership aligns with the recent Joint Flood Mitigation Project announced with *kʷikʷəƛ̓əm* and the City of Coquitlam to rebuild stronger, sustainable watersheds [21].

Furthermore, 117 social housing units are within 0.62 miles of a PermeaPath LID site (an average 7 minute walk), thereby creating access to new green spaces for approximately 132 residents. Moreover, the GI sites can increase local property values from 3.5% to 5%, benefitting local residents, while contributing to aesthetically-calming, accessible neighbourhood greenery that improves mental wellbeing of visitors while also strengthening watershed resilience. See *Table 6.6.4, Appendix 6.6* for a comprehensive social assessment of benefits that PermeaPath can offer to residents.

To minimize disruptions to local community members, the construction process will be phased, with multiple opportunities for community and Indigenous engagement before and during planning phases. During site visits and interactions with local residents, StormWise noted that residents were particularly excited about the prospect of GI being implemented. They were eager to learn more about the project and noted interest in being more involved with planning processes. Opportunities for consultation include city visioning workshops, public maintenance initiatives (building on the City of Coquitlam's "Adopt-A-Catch-Basin" program), and long-term stewardship programs (such as volunteer gardening at PermeaPath GI sites) [45].

4.2 Environmental Assessment

The primary ecological criterion is to improve the B-IBI score to a threshold of ≥ 28 [6]. This metric is sensitive to changes in taxa abundance, organism count and habitat quality within stream ecosystems. GI technologies directly enhance aquatic ecosystem function, contributing to improved salmonid habitat conditions, freshwater quality and biodiversity. Native plants have been selected based on City of Coquitlam-specific plant databases, ensuring suitability for wet, moist, and dry conditions (see *Table 6.6.3, Appendix 6.6*). Further benefits of implementing native plants include fire resistivity, pollinator support, nutrient uptake, and natural contribution to CO_2 capture [46]. Other key environmental benefits of PermeaPath include enhanced groundwater recharge and urban heat island mitigation. The integration of GI technologies facilitates subsurface infiltration of rainfall and runoff, supporting aquifer replenishment. In general, porous surfaces provide additional benefits and have the ability to reduce water temperature, which can support an increase in stream DO levels. This is primarily due to the lower outflow of volumes along with porous surfaces having less thermal conductivity than asphalt pavement [12].

Identifying the water quality parameters of highest concern were important to target. PermeaPath exceeds the design requirements by achieving around 90% TSS removal as well as being designed to retain and treat 90% of the rainfall and runoff volumes expected to contribute to its area. Rain gardens and vegetated swales are able to remove about 55% TN and 87% TP, and pavers and tree trenches also around 50% [11], [19].

4.3 Economic Assessment

4.3.1 Class D Cost Estimate

The purpose of the Class D cost estimate is to support strategic planning purposes for resource, budgeting and assessment of viability. Costs are broken into the following categories:

- Owner's Project Management and Administration Costs (owner oversight, permitting, legal costs)
- Engineering Design (engineering services, procurement of GI)
- Construction (construction installation materials, construction labour, equipment)

The estimate of PermeaPath is based on vendor quotes, online price sourcing, and articles on similar projects done in surrounding cities near Coquitlam. A 30% contingency is applied based on the current level of project definition. The total cost of PermeaPath is $1.17M USD. A full detailed cost breakdown can be found in *Appendix 6.8*.

Life Cycle Costs are based on a set of standard rates provided by the City of Coquitlam over a 50-year period, with an assumed cash flow of $100,000 USD per year for this project. Operation and Maintenance after Year 1 accounts for 3% of capital costs, with adjustments made based on frequency and level of effort needed to maintain certain GIs. Frequency of maintenance for the technologies proposed in PermeaPath are outlined in *Table 6.4.8, Appendix 6.4*.

Table 11: *Cost breakdown of each solution ($USD).*

Category	Lebleu Street	Edgar Avenue/Laneway	Mackin Park
Owner's PM and Administration Costs	$16,802	$121,553	$16,035
Engineering Design	$26,113	$188,906	$24,920
Construction	$55,651	$402,592	$53,108
Subtotal	$98,566	$713,051	$94,062
Contingency (30%)	$29,570	$213,915	$28,219
Total			**$1,177,383**

Table 12: *Life Cycle Costs ($USD).*

Escalation Rate	2%
Discount Rate	6%
Debt Financing Rate	5%

	Lebleu Street	Edgar Avenue/Laneway	Mackin Park	Totals
Operation and Maintenance after Year 1	$3,000	$10,000	$3,000	$16,000
Escalation of Cost (50 yrs)	$344,792	$2,495,102	$328,374	$3,168,268
NPV (50 yrs)				$57,252
Loan Payment (50 yrs)				$3,224,660

4.3.2 Cost Benefit Analysis

The table summarizes the annual runoff treated and the corresponding 50-year cost per cubic foot for each design. All designs are based on achieving 90% treatment of receiving runoff and a 50-year design lifespan. Annual runoff volumes were multiplied by the 50-year design lifespan to calculate lifetime treatment. Key assumptions and parameters for this assessment are outlined in *Table 6.8.6, Appendix 6.8*.

Table 13: *Annual runoff treated and cost per volume treated over the 50-year design life.*

Design	Volume of Runoff Treated per Year (ft^3/year)	Cost per Volume Treated over Design Life, 50 years ($/$ft^3$)
Vegetated Swale (Lebleu Street)	109,200	$0.035
Permeable Pavers (Edgar Avenue Laneway)	231,325	
Permeable Pavers and Tree Trenches (Edgar Avenue)	156,293	$0.059
Rain Garden (Mackin Park)	60,505	$0.062

5.0 Recommendations and Conclusion

5.1 Recommendations for Further Success

- To quantify the efficacy of PermeaPath, regular water quality testing at these designated sites is recommended. Ongoing sampling through the City's current water quality station located at Mackin Park should continue to assess the effectiveness of implemented measures.
- TN and TP levels should be assessed due to their significant impact on stream health. Despite being satisfactory in 2020, water quality should be reassessed every 5 years to monitor for changes [5].
- Expand PermeaPath concepts to other areas of Coquitlam. For this scope, the critical areas to capture runoff were identified by the City throughout the watershed. More blocks along Lebleu Street and Edgar Avenue could incorporate similar infrastructure.
- PermeaPath was constrained to remain within municipal property and right-of-ways. The City of Coquitlam can further reduce future runoff by encouraging and incentivizing residents to incorporate GI projects and increasing permeability on private property. During a site visit, one resident pointed out that their driveway would flood during rainfalls until they installed a catch basin and included more absorbent soils on their lawn. Currently, the City offers *Water Wise* tools such as rain barrels, but similar programs could incentivize other green GI projects for residents.

5.2 Conclusion

PermeaPath is a cohesive and strategically integrated GI system, targeting three key locations, to manage stormwater quality and quantity entering Nelson Creek. The most upstream location at Lebleu Street utilizes multi-staged vegetated swales to capture, treat, and decrease runoff velocity, thereby mitigating the current roadside contaminants brought into the Creek. Edgar Avenue incorporates tree trenches and permeable parking pockets to address residential runoff while balancing parking needs. Along the laneway, permeable pavers mitigate driveway runoff and reduce streambank erosion by controlling discharge into the outfall. The Mackin Park Rain Garden is effective in infiltrating and treating large amounts of roadside runoff from the busy Brunette Avenue and surrounding steep gradients. As a central, accessible public space, the design presents an opportunity for Indigenous collaboration and community engagement. PermeaPath is a robust treatment system that meets all outlined technical, environmental, and social criteria. Water always finds a way, and the implementation of PermeaPath provides a sustainable, permeable path for runoff to flow for years to come.

6.0 Appendices

6.1 Site Photos

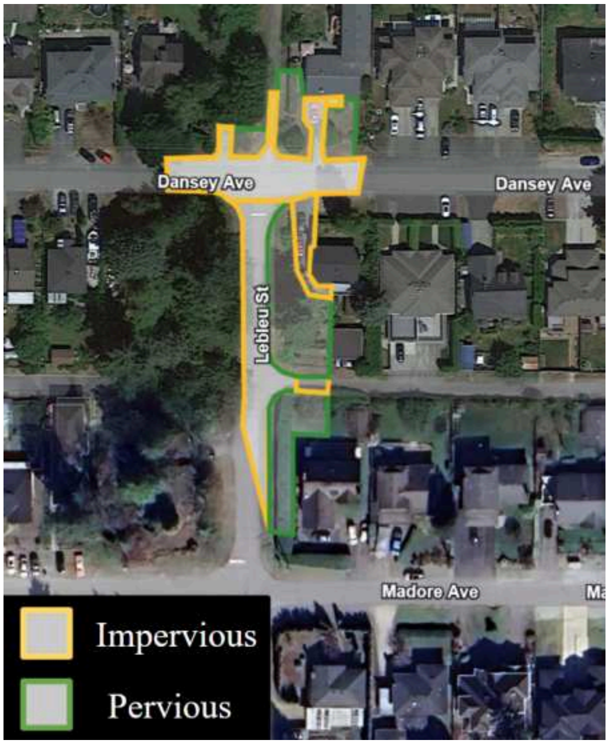

Figure 6.1.1: *Lebleu Street conceptual design catchment area. Green highlighted areas indicate pervious areas (0.25 acres) and yellow highlighted areas indicate impervious areas (0.33 acres). This image is used as one example and is representative of how the other sites approached their contributing impervious areas as well.*

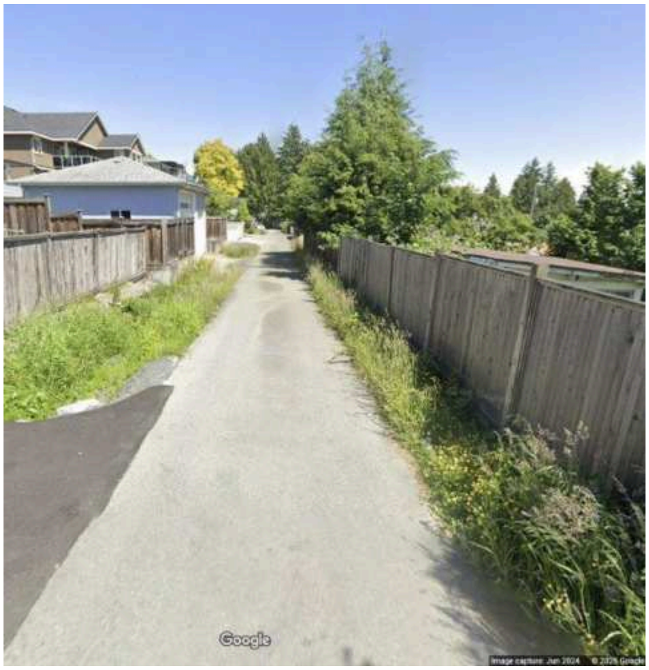

Figure 6.1.2: *View of the laneway directly north of Edgar Avenue [56].*

Figure 6.1.3: *Image of the City of Vancouver's Country Lane concept [47].*

Figure 6.1.4: *Edgar Laneway conceptual design catchment area. Homes on the lot include roof gutter lines directly connected to the storm sewer system, and therefore do not contribute to the pavers. Greater impervious contribution is anticipated by post-development driveways and any fugitive runoff.*

Figure 6.1.5: *Edgar Avenue conceptual design catchment area. Road, driveway and future sidewalk implementation contribute to runoff.*

Figure 6.1.6: *Mackin Park conceptual design catchment area. Green highlighted areas indicate pervious areas (0.17 acres) and yellow highlighted areas indicate impervious areas (0.17 acres).*

Areas north of this delineation – such as Parcel 1025 outlined in orange and Nelson Street – currently minimally contribute to current runoff volumes due to existing catch basins and favourably pervious areas along runoff paths. I/P ratios. However, incoming developments will convert those pervious areas into impervious contributions to this catchment area, and I/P ratios are expected to increase towards greater impervious areas by 2050. Post development driveways and any fugitive runoff are expected to infiltrate into the rain garden – therefore, the rain garden is designed to accommodate additional pervious area while managing the first 2.27 inches of rainfall during a 1:2 year 24-hour storm in a 2050 scenario (see *Table 6.4.13, Appendix 6.4*).

Figure 6.1.7: *Image of the open culvert at East end of Edgar Avenue during rainfall.*

Figure 6.1.8: *Image of the runoff drainage routes North-to-South across Edgar Avenue during rainfall.*

Figure 6.1.9: *Image of the Mackin Park Rain Garden proposed site [56].*

6.2 Sample Calculations

6.2.1 Sizing

Mackin Park Curb Cutout Sizing

- Inlet width for complete perpendicular linear flow capture: $W_T = 0.817 * Q^{0.42} * S_0^{0.3} * (\frac{1}{nS_x})^{0.6} \rightarrow$ W_T= 2.2 m = 7.2ft
  - W_T = Total width of inlet for complete capture (m)
  - Q = Design flow perpendicular to the inlet (m^3/s)
  - S_0 = Longitudinal slope ratio
  - n = Manning's 'n' (0.014 used for Brunette Avenue)
  - S_x = Cross slope ratio (0.0275)

Mackin Park Outflow Pipe Sizing [15]

- Maximum flow for outlet pipe: $Q_O = \frac{K_s * I}{360} \rightarrow Q_O = 0.023\ m^3/s = 303.6\ gpm$
  - Q_O = Orifice flow (m^3/s)
  - K_s = Saturated hydraulic conductivity of native soil (mm/hr)
  - I = Impervious area tributary to rain garden (ha)
- Area of the outflow pipe: $A_O = \frac{Q_{site}}{K*\sqrt{2gh}} \rightarrow A_O = 0.00979\ m^2,\ d_O = 111\ mm$ = 4.30 in
  - A_0 = Area of orifice opening (ft^2)
  - Q_{site} = Theoretical discharge through infiltration from impervious area (ft^3/s)
  - K = Orifice coefficient (typical value used of 0.6)
  - g = Gravitational constant (typical value used of 9.81 m/s^2)
  - h = Impervious area tributary to rain garden (ha)
  - **Although the calculations led to a 111 mm-diameter PVC pipe, the final diameter was sized for 150 mm to align with best management practices [15]**

Edgar Laneway Sizing

- Imperviousness coefficient = 0.95
- R = Ac/Ap: ration of contributing impervious area to the permeable pavers surface area
  - Impervious area: ~37,674 ft^2
  - Permeable paver area: 902 ft long * 3.28 ft wide = 2959 ft^2
  - R = Ac/Ap = 37,674/2959 = 12.72
- tf: time to fill the reservoir layer, typically 2 hrs
- P: Rainfall depth for the design storm = 34mm = 0.111549 ft
- i: infiltration rate (conductivity) of subsoils = 120.4mm/hr = 0.3950 ft/hr
- n: Porosity = 0.4

$Required\ Depth: dp = [0.95RP - (i/2) * tf] / n$

$= [0.95(12.72)(0.111549) - 0.3950] / 0.4$

$= 2.38\ ft$

Lebleu Street Swale Sizing

- Crest to Crest Width: $Wc = W + 2 * Dc * m = 3.94\ m = 12.93\ ft$
  - Bottom Swale Width: W = 2.4 m = 7.9 ft
  - Swale Side Slope (Run/Rise): m =3.2
  - Ponded Depth: D = 0.12 m = 0.39 ft
  - Swale Bottom to Crest Depth: Dc = 2*D = 0.24 m = 0.79 ft

- Number of Check Dams [16]: $z = L * (Si - Se)/Hc = 51.46\ Dams$ → Round up to 52 Dams.
- Check dam spacing: $= L / z = 1.25\ m = 4.10\ ft$
  - Design Area: A = 156 m^2 = 1679 ft^2
  - Ponded Depth: D = 0.12 m = 0.39 ft
  - Check Dam Height: Hc = 0.12 m = 0.39 ft
  - Swale Length: L = 65 m^2 = 700 ft^2
  - Existing Slope: Si = 0.10
  - Desired Effective Slope: Se = 0.005

- Cutout Width for 100% Capture [16]:

  $Wc = Wt/Nc = 0.817 * Q^{0.42} * S0^{0.3} * (1/(n * Sx))^{0.6} / (5\ cutouts) = 0.69\ m = 2.26\ ft$

  - Number of Cutouts: Nc = 5
  - Peak Flow Rate (2050 10-year 24 hour storm): Q = 0.0021 m^3 /s = 27.72 gpm
  - Longitudinal Slope: S0 = 0.1
  - Cross Section Slope: Sx = 0.0275
  - Manning's Coefficient: n = 0.014 (concrete)

6.2.2 Infiltration

Mackin Park

- Ponded water drawdown time = $d_p/C_{TS} = 5\ to\ 6\ hours$

- Subsurface drawdown time = $(d_{TS}/C_{TS}) + (d_{CS}/C_{CS}) = 15\ to\ 17\ hours$

  - Maximum Ponded Depth: d_p = 150 mm = 5.91 in

- Conductivity of Topsoil: C_{TS} = 25-30 mm/h = 1-1.2 in/h
- Conductivity of Coarse Sand: $C_{CS} = 100\ mm/h = 3.94\ in/h$
- Thickness of Topsoil: $d_{TS} = 300\ mm = 11.8\ in$
- Thickness of Coarse Sand: $d_{CS} = 500\ mm$ = 19.7 in

Lebleu Street

- Ponded water drawdown time = $d_p/C_{TS} = 4\ to\ 4.8\ hours$
- Subsurface drawdown time = $(d_{TS}/C_{TS}) + (d_{CS}/C_{CS}) = 11\ to\ 13\ hours$

  - Maximum Ponded Depth: d_p = 120 mm = 4.72 in
  - Conductivity of Topsoil: C_{TS} = 25-30 mm/h = 1-1.2 in/h
  - Conductivity of Coarse Sand: $C_{CS} = 100\ mm/h = 3.94\ in/h$
  - Thickness of Topsoil: $d_{TS} = 300\ mm = 11.8\ in$
  - Thickness of Coarse Sand: $d_{CS} = 100\ mm = 3.94\ in$

Edgar Laneway

This is the maximum allowable drain time to ensure that water in the sub-base does not take too long to infiltrate into the subgrade soil. The expected rainfall is based on the design requirement of retaining 34 mm of rainfall in a 24-hour period. The areas provided are for the contributing impervious area and the area of the permeable pavers. It was found that the expected volume over this total area is less than the infiltration capacity of the pavers over the same intensity and time period, yielding a positive result towards retention and treatment.

$$Subsurface\ Water\ Drawdown\ Time = (dp * n)/(0.5 * i) = (1.31 * 0.4) / (0.5 * 0.395)$$

$$= 2.65h < 72h\ requirement$$

$$Required\ Volume\ Drawdown\ Rate = (\ (1.34\ in/h) / 24\ h) * (1\ ft/12\ in) * (\ 37,674\ ft^2\ ) * (0.95)\ ] +$$

$$[\ (1.34\ in/h / 24h) * (1\ ft/12\ in) * (\ 2960\ ft^2\ )\ ] = 180.3\ ft^3$$

$$Maximum\ Infiltration\ Rate = Total\ Depth / Subsurface\ Drawdown\ Time$$

$$= 28.56\ in / 2.65\ h = 10.78\ in/h = 0.90\ ft/h$$

$$Maximum\ Volume\ Drawdown\ Rate = (0.90\ ft/h) * (2960\ ft^2) = 2664\ ft^3/h > 180.3\ ft^3$$

6.3 Design Specifications

Table 6.3.1: *Edgar Avenue Tree Trenches sizing summary, including permeable parking spots.*

Parameter	Value
Width Tree Trench [ft]	4.0
Length Tree Trench [ft]	8
Parking Space Length [ft]	18
Area of Total Sub-catchment [ha]	2.1
Depth Tree Trench [ft]	5
Length of Edgar Ave One Side [ft]	1165
Length of Tree Trench "unit" (2 box, 2 parking) [ft]	52
Number of Tree Trenches	44
Tree Well Bottom Width [ft]	3
Volume Per Rain Garden [ft^3]	7416
Total volume of all tree trenches [ft^3]	7416
Total surface area of all tree trenches [ft^3]	4944
Depth of structural soil [ft]	5
Depth of crushed gravel [ft]	1

Table 6.3.2: *Summary of key drainage features for Lebleu Street Vegetated Swale.*

Station	Feature	Category
0+000.00	Beginning of System	Boundary
0+030.00	6 m PVC Culvert (D = 0.1524 m)	Pipe
0+071.60	Overflow Catch Basin	Drainage
0+072.23	End of System	Boundary

Table 6.3.3: *Summary of key engineering controls for the Lebleu Street Vegetated Swale.*

Engineering Control	Design Benefit
Check Dams for Slope Reduction & Flood Control [16]	To significantly reduce the effective slope from 10% to 0.5%, check dams will be installed at regular 1.25-meter intervals throughout the length of the swale, helping to slow stormwater flow and enhance overall treatment efficiency by encouraging infiltration and sedimentation. These check dams will be constructed using riprap (D50 = 0.12 mm), a durable and permeable material that will facilitate the controlled dispersion of water,

	ensuring that smaller rainfall events can be effectively distributed throughout the entire rain garden while still providing sufficient structural integrity to handle larger storm events without causing excessive pooling or erosion.
Curb Cutouts for Efficient Stormwater Entry[16]	To allow stormwater to enter the swale system without requiring extensive modifications to the existing roadway infrastructure, 0.7-meter curb cutouts will be strategically placed along the right side of the road, ensuring that inflows are aligned with natural drainage patterns. By leveraging the existing right-side drainage configuration, the design avoids the need for costly roadway regrading or structural alterations, allowing for an efficient and minimally invasive stormwater management solution that remains both functional and economically viable.
Channel & Side Slopes for Flow Control & Erosion Prevention [8]	The swale channel will be graded to a controlled slope of 1.5%, a measure specifically implemented to limit excessive flow velocities and reduce the likelihood of erosion, ensuring that the system remains both effective and sustainable under varying storm conditions. To further enhance erosion resistance and minimize long-term maintenance requirements, side slopes will be graded at a 1:3.2 ratio, a slope profile that aligns with Metro Vancouver BMPs by striking a balance between hydraulic efficiency and structural stability, preventing excessive sediment displacement while maintaining an effective stormwater conveyance system.

Table 6.3.4: *Summary of key engineering controls for the Mackin Park Rain Garden.*

Engineering Control	**Design Benefit**
Curb Cutouts for Efficient Stormwater Entry	To ensure adequate inflow from stormwater runoff between catch basin leads STPC06803 and STPC06792 along the south side of Brunette Avenue, two 3.6 ft-long curb cutouts will be strategically placed to align natural drainage flow with the rain garden inlets (see *Appendix 6.2.1 Mackin Park Curb Cutout Sizing* for sample calculations). The location of these cutouts leverage the 5-15% downward slope in green from the street into the garden, and having two cutouts ensures flow from the 20-25% slope in yellow enters as well. Similar to Lebleu Street Vegetated Swale, this design leverages existing right-side drainage systems to avoid costly structural alterations.

Channel & Side Slopes for Flow Control & Erosion Prevention	As per Metro Vancouver BMPs [8], the side-slope for water inflow is designed to a 2.5:1 ratio – a slope profile that, similar to the Lebleu Street Vegetated Swale, boasts minimal maintenance requirements, reducing flow velocities, and enhancing erosion resistance. The 23 ft x 39 ft base area will be excavated to ensure the rain garden base is flat, but surrounding catchment areas strategically remain in their natural contours. The rain garden utilizes the 0-25% slope on the north end for runoff catchment, is stationed within the flatter 0-10% slope area, and maintains a 3.28 ft margin from the crest of 25-45% slope towards the Park Court residence building. This conservative margin ensures that no overflow water will flow downwards towards Park Court. Moreover, the design follows BMP for the remaining 9.8 ft downslope of building foundations.

6.4 Tables

Table 6.4.1: *GI Technologies Considered* [8]. *Selected technologies are highlighted in green.*

GI Method	Description	Purpose	Benefits
Bioretention Cells & Rain Gardens	Depressed, vegetated areas designed to capture and store rainwater.	Infiltrate, treat, detain	Reduces runoff volume, improves water quality, and conveys excess stormwater.
Infiltration Swales	Shallow, vegetated channels that capture and convey rainwater.	Infiltrate, treat, detain	Reduces runoff volume and improves water quality.
Pervious Pavers	Permeable paving materials that allow water to infiltrate through the surface.	Infiltrate	Reduces runoff volume, improves water quality, and maintains a usable road surface.
Roadside Ditches	Grass-lined ditches designed to capture and slow stormwater runoff.	Infiltrate, detain, treat	Detains, filters, and infiltrates runoff, reducing volume and flow rate.
Tree Trenches	Engineered tree pits that collect and filter stormwater.	Infiltrate, treat, detain, transpire	Reduces runoff, removes pollutants, and promotes healthy tree growth.
Natural & Engineered Wetlands	Constructed wetland systems that filter and treat stormwater.	Detain, habitat, treat, transpire	Reduces runoff, improves water quality, and mimics natural wetland treatment processes.

Table 6.4.2: *24-hour rainfall intensities for current design storm: Coquitlam, Zone 3, 2021.*

Zone 3 - 2021 IDF Curve (in/h)						
Rainfall Duration	**2-year**	**5-year**	**10-year**	**25-year**	**50-year**	**100-year**
5-min	1.51	2.05	2.45	3.01	3.42	3.85
10-min	1.1	1.48	1.76	2.14	2.43	2.73
15-min	0.91	1.22	1.44	1.76	1.99	2.23
30-min	0.66	0.88	1.03	1.25	1.41	1.58
1-hr	0.48	0.63	0.74	0.89	1	1.12
2-hr	0.35	0.45	0.53	0.63	0.71	0.80
6-hr	0.21	0.27	0.31	0.37	0.41	0.46
12-hr	0.15	0.19	0.22	0.26	0.29	0.33
24-hr	0.11	0.14	0.16	0.19	0.21	0.23

Table 6.4.3: *24-hour rainfall intensities for future design storms: Coquitlam, Zone 3, 2050.*

Zone 3 - 2050 IDF Curve (in/h)						
Rainfall Duration	**2-year**	**5-year**	**10-year**	**25-year**	**50-year**	**100-year**
5-min	2.02	2.93	3.59	4.54	5.24	5.97
10-min	1.47	2.11	2.57	3.23	3.72	4.24
15-min	1.22	1.74	2.11	2.65	3.05	3.47
30-min	0.89	1.25	1.51	1.88	2.16	2.46
1-hr	0.65	0.9	1.08	1.34	1.54	1.74
2-hr	0.47	0.65	0.77	0.95	1.09	1.24
6-hr	0.29	0.38	0.46	0.56	0.63	0.72
12-hr	0.21	0.28	0.33	0.39	0.45	0.51
24-hr	0.15	0.20	0.23	0.28	0.32	0.36

Table 6.4.4: *Soil characteristics and infiltration abilities [2].*

Soil Texture	Average capillary suction (in)	Saturated Hydraulic Conductivity (in/hr)	Initial Moisture Deficit
Sand to Gravel	1.95	4.74	0.34
Silt to Silt Clay Loam	1.15	0.06	0.23
Clayey Silt Gravel Sand	9.41	0.05	0.25
Peat Sandy Silt Loam	8.22	0.98	0.24
Sand Gravel Till Refuse	1.95	4.74	0.34

Table 6.4.5: *Summary of Water Quality Parameters. Green is "good" and yellow is "satisfactory" in requirements as per AMF [5].*

Parameter	Primary/ Secondary	Dry Season Average	Wet Season Average	Flowlink Average	Client Target	AMF Target (Good/Satisfactory)
Dissolved Oxygen (mg/L)	Secondary	9.35	11.42	7.68 (Dry)	-	6.5 to <11 (Satisfactory) ≥11 (Good)
Turbidity (NTU)	Primary	2.21	4.24	0.6 FNU (Dry)	≤ 25 under normal conditions ≤ 100 during significant rainfall events (final discharge)	>5 to 25 (Satisfactory) ≤ 5 (Good)

E.Coli (CFU/100 mL)	Secondary	153.79	223.14	-	-	Geomean between: 78-385 (Satisfactory) Geomean ≤77 (Good)
Fecal Coliforms (CFU/100mL)	Secondary	211.52	332.47	-	-	Geomean between: 201-1,000 (Satisfactory) Geomean ≤200 (Good)
Copper (ug/L)	Secondary	4.22	3.77	-	-	3 to 11 (Satisfactory) <3 (Good)
Zinc (µg/L)	Secondary	10.30	10.40	-	-	6 to 40 (Satisfactory) <6 (Good)
Conductivity	Secondary	181.94	112.44	256.8 (Dry)	-	50 to 200 (Satisfactory) <50 (Good)
pH	Primary	7.59	7.25	7.13 (Dry)	6.5 to 8.0	6.0 to <6.5 or >9.0 to 9.5 (Satisfactory) 6.5 to 9.0 (Good)

Table 6.4.6: *Summary table of values pertaining to stream health. Red cells indicate where the total number organisms do not meet the minimum of 400 objectives at each of the three sampling locations.*

Location: Nelson Creek	**Nelson 1**	**Nelson 2**	**Nelson 3**	**Aggregate**
B-IBI Score (Stream Condition)	10 (very poor)	14 (very poor)	16 (very poor)	20 (poor)
Total Number of Organisms	150	363	411	924
Total Number of Taxa	13	17	20	32

Table 6.4.7: *Water quality parameters that affect EPT diversity and abundance of benthic invertebrates, along with sources, impacts and solutions. Summary of significant water quality parameters. Contained in the table are design aspects to address these issues.*

Water Quality Parameter	**Source of Contamination or Issue**	**Ecological Impact / Effect on EPT**	**Solution**
Dissolved Oxygen	Decreases at high temperatures	Algal growth, Lowered number of invertebrates	Reducing water temperature is the main contributor. Green GIs contribute to dissolved oxygen. Provide shade for the stream using native plants. Stream aeration techniques are also impactful in creating more turbid flow, allowing air to better infiltrate through the water.
Turbidity	Erosion of stream banks, and sediment deposition	Stream bank steepens Disrupts habitats	Reduce discharge rates into the stream at insufficient culverts..
Conductivity	Urban runoff: road salt Increases with temperature	Increased salinity stresses freshwater organisms	GI treatment technologies
Microbial Parameters	Sewage / animal feces runoff	Decreases DO due to decomposition of organic matter	GI can address pathogens.
Nutrients (Nitrate / Phosphate)	Soil fertilizer (excess material not absorbed) Wastewater from sewer overflows Fossil fuel emissions from atmospheric deposition Sewage / animal feces runoff Yard waste	Excess nutrients can affect pH, water temperature, and cause rapid algae growth leading to reduced DO levels, harming the invertebrate community.	GI treatment technologies Introduce native plants to uptake excess nutrients.
Water Level / Flows	Temporal influence	Reduction of habitat area High flows destroy organisms and substrates form streambeds	Mitigate fluctuations by capturing rainwater to slowly infiltrate to the creek Retain stormwater to slow discharge

Vegetation	Invasive plants consume necessary nutrients Can block sunlight for native plants	Decreases taxa richness	Reintroduce native plants

Table 6.4.8: *Green Infrastructure best maintenance practices.*

GRI Technology	Establishment Period	Maintenance frequency	Landscape Care	Large Trash and Debris Removal	Sediment Removal and Cleaning	Plant Replacement
Pervious Paving Stones	In first year following construction, inspect contributing drainage area twice within 24 hr after storm events. Stabilize or repair as needed [15]	1-2 per year [27]		Surface Sweeping - Visual inspection monthly to remove organic debris [15]	Clean inlets to prevent clogging Leaf blow and dry vacuuming seasonally [28]	N/A
Rain Gardens and Infiltration Bulges	Within 6 months of construction, drainage area should be inspected after storm event that exceeds 1/2 inch of rainfall Water plants weekly during first 2-3 months after installation Fertilize once within 1-2 years of installation [29]	Quarterly maintenance inspection to ensure adequate filtration rate [27]	Weed seasonally, water plants during droughts, mow turf areas monthly [15]	Visual inspection on a regular basis Remove trash and animal waste, any dead or diseased plants [29]	As-needed if water is standing for long periods of time [28]	Replace plants as necessary Regular mulching to minimize weed growth [27] Prune trees and shrubs, remove invasive plants [29]
Tree Trenches	Water trees 25 gallons weekly via a slow release device in the first year 25 gallons bi-monthly in a slow release device in the 2nd and 3rd years [29]	Inspect annually for erosion, sediment buildup, proper vegetative conditions Inspect inlets and outlets Cleanouts annually (Van, 2016) Inspect trees for health and establishment three times during establishment period and every five years	Weeding seasonally	Remove litter and garbage as needed [29]	Subsurface maintenance (vacuum structure and pipes) annually [29]	Ensure plant survival and density Control evasive species Tree pruning annually Apply mulch annually [29]

		for life of the tree [29]				

__Table 6.4.9:__ Key parameters used in water balance and sizing calculations for the Lebleu Street Vegetated Swale and Mackin Park Rain Garden. The Lebleu Street parameters are applicable to Tables 6.4.10 and 6.4.11. The Mackin Park parameters are applicable to Tables 6.4.12 and 6.4.13.

Design Parameter	**Lebleu Street Vegetated Swale**	**Mackin Park Rain Garden**
Treatment Area (ft^2)	1679	904
Engineered Soil Infiltration Rate (in/hr)	1.18	1.18
Maximum Ponding Depth (ft)	0.39	0.49
Impervious Contributing Area (acres)	0.33	0.17
Pervious Contributing Area (acres)	0.25	0.17
Effective Runoff Coefficient	0.67	0.63

For the Lebleu Street swale solution, the proportion of impervious area was increased by 19% for the 2050 scenario, as determined from a PCSWMM assessment of the watershed under 2050 conditions to reflect anticipated densification. This adjusted imperviousness was then used in our spreadsheet-based water balance calculations to size the system appropriately. In contrast, no increase was applied to the Mackin Park rain garden, as its contributing area is limited to the adjacent roadway and the rain garden footprint itself, and therefore is not expected to be affected by densification. To calculate the effective runoff coefficient, a value of 0.3 was used for green spaces, 0.8 for general road right-of-ways, and 0.95 for roads [1]. This was calculated as a weighted value based on the size of the delineated subcatchments to help streamline system inflow calculations.

Table 6.4.10: *Lebleu Street Vegetated Swale Water Balance for 90% annual runoff treatment criteria (1.34 in over 24 hours).*

The "Overflow (Y/N)" column shows whether water has exceeded the system's maximum ponding depth of 0.39 ft. If marked "N," stormwater is still ponding within the swale. If marked "Y," the swale has reached capacity, and excess water is being directed into the storm sewer system. This water balance demonstrates the swale's ability to retain and manage the first 1.34 inches of rain over 24-hours, which is a key design requirement.

Hour	Cum. Rainfall (in)	Rainfall (ft^3/h)	Cum. Volume In (ft^3)	Ponded Volume at end (ft^3)	Vegetated Swale Area (ft^2)	Ponded Depth (ft)	Overflow (Y/N)	Max Outflow (ft^3)	Cum. Max Outflow (ft^3)
1	0.06	68.12	68.12	0	1679.17	0	N	165.27	165.27
2	0.11	68.12	136.25	0	1679.17	0	N	165.27	330.55
3	0.17	68.12	204.37	0	1679.17	0	N	165.27	495.82
4	0.22	68.12	272.50	0	1679.17	0	N	165.27	661.09
5	0.28	68.12	340.62	0	1679.17	0	N	165.27	826.36
6	0.33	68.12	408.74	0	1679.17	0	N	165.27	991.64
7	0.39	68.12	476.87	0	1679.17	0	N	165.27	1156.91
8	0.45	68.12	544.99	0	1679.17	0	N	165.27	1322.18
9	0.50	68.12	613.12	0	1679.17	0	N	165.27	1487.45
10	0.56	68.12	681.24	0	1679.17	0	N	165.27	1652.73
11	0.61	68.12	749.37	0	1679.17	0	N	165.27	1818.00
12	0.67	68.12	817.49	0	1679.17	0	N	165.27	1983.27
13	0.73	68.12	885.61	0	1679.17	0	N	165.27	2148.54
14	0.78	68.12	953.74	0	1679.17	0	N	165.27	2313.82
15	0.84	68.12	1021.86	0	1679.17	0	N	165.27	2479.09
16	0.89	68.12	1089.99	0	1679.17	0	N	165.27	2644.36
17	0.95	68.12	1158.11	0	1679.17	0	N	165.27	2809.63
18	1.00	68.12	1226.23	0	1679.17	0	N	165.27	2974.91
19	1.06	68.12	1294.36	0	1679.17	0	N	165.27	3140.18

20	1.12	68.12	1362.48	0	1679.17	0	N	165.27	3305.45
21	1.17	68.12	1430.61	0	1679.17	0	N	165.27	3470.72
22	1.23	68.12	1498.73	0	1679.17	0	N	165.27	3636.00
23	1.28	68.12	1566.86	0	1679.17	0	N	165.27	3801.27
24	1.34	68.12	1634.98	0	1679.17	0	N	165.27	3966.54

Table 6.4.11: *Lebleu Street Vegetated Swale Water Balance for 1:2 year 24-hour storm (2050 Scenario).*

The "Overflow (Y/N)" column shows whether water has exceeded the system's maximum ponding depth of 0.39 ft. If marked "N," stormwater is still ponding within the swale. If marked "Y," the swale has reached capacity, and excess water is being directed into the storm sewer system. This water balance demonstrates the swale's ability to retain and manage the first 3.63 inches of rainfall over a 24-hour period and resilience against the effects of future climate scenarios.

Hour	Cum. Rainfall (in)	Rainfall (ft^3/h)	Cum. Volume In (ft^3)	Ponded Volume at end (ft^3)	Vegetated Swale Area (ft^2)	Ponded Depth (ft)	Overflow (Y/N)	Max Outflow (ft^3)	Cum. Max Outflow (m^3)
1	0.15	184.66	184.66	19.38	1679.168	0.012	N	165.27	165.27
2	0.30	184.66	369.31	38.77	1679.168	0.023	N	165.27	330.55
3	0.45	184.66	553.97	58.15	1679.168	0.035	N	165.27	495.82
4	0.60	184.66	738.63	77.54	1679.168	0.046	N	165.27	661.09
5	0.76	184.66	923.28	96.92	1679.168	0.058	N	165.27	826.36
6	0.91	184.66	1107.94	116.30	1679.168	0.069	N	165.27	991.64
7	1.06	184.66	1292.60	135.69	1679.168	0.081	N	165.27	1156.91
8	1.21	184.66	1477.25	155.07	1679.168	0.092	N	165.27	1322.18
9	1.36	184.66	1661.91	174.46	1679.168	0.104	N	165.27	1487.45
10	1.51	184.66	1846.57	193.84	1679.168	0.115	N	165.27	1652.73
11	1.66	184.66	2031.22	213.22	1679.168	0.127	N	165.27	1818.00
12	1.81	184.66	2215.88	232.61	1679.168	0.139	N	165.27	1983.27
13	1.97	184.66	2400.54	251.99	1679.168	0.150	N	165.27	2148.54

14	2.12	184.66	2585.19	271.38	1679.168	0.162	N	165.27	2313.82
15	2.27	184.66	2769.85	290.76	1679.168	0.173	N	165.27	2479.09
16	2.42	184.66	2954.50	310.14	1679.168	0.185	N	165.27	2644.36
17	2.57	184.66	3139.16	329.53	1679.168	0.196	N	165.27	2809.63
18	2.72	184.66	3323.82	348.91	1679.168	0.208	N	165.27	2974.91
19	2.87	184.66	3508.47	368.30	1679.168	0.219	N	165.27	3140.18
20	3.02	184.66	3693.13	387.68	1679.168	0.231	N	165.27	3305.45
21	3.17	184.66	3877.79	407.06	1679.168	0.242	N	165.27	3470.72
22	3.33	184.66	4062.44	426.45	1679.168	0.254	N	165.27	3636.00
23	3.48	184.66	4247.10	445.83	1679.168	0.266	N	165.27	3801.27
24	3.63	184.66	4431.76	465.22	1679.168	0.277	N	165.27	3966.54

Table 6.4.12: *Mackin Park Rain Garden Water Balance for 90% annual runoff treatment criteria (1.34 in over 24 hours).*

The "Overflow (Y/N)" column shows whether water has exceeded the system's maximum ponding depth of 0.49 ft. If marked "N," stormwater is still ponding within the rain garden. If marked "Y," the system has reached capacity, and excess water is being directed into the storm sewer system. This water balance demonstrates the rain garden's ability to retain and manage the first 1.34 inches of rainfall over a 24-hour period, which is a key design requirement.

Hour	**Cum. Rainfall (in)**	**Rainfall (ft^3/h)**	**Cum. Volume In (ft^3)**	**Ponded Volume at end (ft^3)**	**Rain Garden Area (ft^2)**	**Ponded Depth (ft)**	**Overflow (Y/N)**	**Max Outflow (ft^3)**	**Cum. Max Outflow (ft^3)**
1	0.06	43.26	43.26	0	904.17	0	N	88.99	88.99
2	0.11	43.26	86.53	0	904.17	0	N	88.99	177.99
3	0.17	43.26	129.79	0	904.17	0	N	88.99	266.98
4	0.22	43.26	173.06	0	904.17	0	N	88.99	355.97
5	0.28	43.26	216.32	0	904.17	0	N	88.99	444.96
6	0.33	43.26	259.58	0	904.17	0	N	88.99	533.96
7	0.39	43.26	302.85	0	904.17	0	N	88.99	622.95

8	0.45	43.26	346.11	0	904.17	0	N	88.99	711.94
9	0.50	43.26	389.38	0	904.17	0	N	88.99	800.94
10	0.56	43.26	432.64	0	904.17	0	N	88.99	889.93
11	0.61	43.26	475.91	0	904.17	0	N	88.99	978.92
12	0.67	43.26	519.17	0	904.17	0	N	88.99	1067.92
13	0.73	43.26	562.43	0	904.17	0	N	88.99	1156.91
14	0.78	43.26	605.70	0	904.17	0	N	88.99	1245.90
15	0.84	43.26	648.96	0	904.17	0	N	88.99	1334.89
16	0.89	43.26	692.23	0	904.17	0	N	88.99	1423.89
17	0.95	43.26	735.49	0	904.17	0	N	88.99	1512.88
18	1.00	43.26	778.75	0	904.17	0	N	88.99	1601.87
19	1.06	43.26	822.02	0	904.17	0	N	88.99	1690.87
20	1.12	43.26	865.28	0	904.17	0	N	88.99	1779.86
21	1.17	43.26	908.55	0	904.17	0	N	88.99	1868.85
22	1.23	43.26	951.81	0	904.17	0	N	88.99	1957.84
23	1.28	43.26	995.08	0	904.17	0	N	88.99	2046.84
24	1.34	43.26	1038.34	0	904.17	0	N	88.99	2135.83

Table 6.4.13: *Mackin Park Rain Garden Water Balance for 1:2 year 24-hour storm (2050 Scenario).*

The "Overflow (Y/N)" column shows whether water has exceeded the system's maximum ponding depth of 0.49 ft. If marked "N," stormwater is still ponding within the rain garden. If marked "Y," the system has reached capacity, and excess water is being directed into the storm sewer system. This water balance demonstrates the swale's ability to retain and manage the first 2.27 inches of rainfall in this storm event, demonstrating resilience against the effects of future climate scenarios.

Hour	**Cum. Rainfall (in)**	**Rainfall (ft^3/h)**	**Cum. Volume In (ft^3)**	**Ponded Volume at end (ft^3)**	**Effective Drainage Area (ft^2)**	**Ponded Depth (ft)**	**Overflow (Y/N)**	**Max Outflow (ft^3)**	**Cum. Max Outflow (ft^3)**

1	0.15	117.27	117.27	28.28	904.17	0.03	N	88.99	88.99
2	0.30	117.27	234.54	56.56	904.17	0.06	N	88.99	177.99
3	0.45	117.27	351.81	84.84	904.17	0.09	N	88.99	266.98
4	0.60	117.27	469.09	113.11	904.17	0.13	N	88.99	355.97
5	0.76	117.27	586.36	141.39	904.17	0.16	N	88.99	444.96
6	0.91	117.27	703.63	169.67	904.17	0.19	N	88.99	533.96
7	1.06	117.27	820.90	197.95	904.17	0.22	N	88.99	622.95
8	1.21	117.27	938.17	226.23	904.17	0.25	N	88.99	711.94
9	1.36	117.27	1055.44	254.51	904.17	0.28	N	88.99	800.94
10	1.51	117.27	1172.71	282.78	904.17	0.31	N	88.99	889.93
11	1.66	117.27	1289.98	311.06	904.17	0.34	N	88.99	978.92
12	1.81	117.27	1407.26	339.34	904.17	0.38	N	88.99	1067.92
13	1.97	117.27	1524.53	367.62	904.17	0.41	N	88.99	1156.91
14	2.12	117.27	1641.80	395.90	904.17	0.44	N	88.99	1245.90
15	2.27	117.27	1759.07	424.18	904.17	0.47	N	88.99	1334.89
16	2.42	117.27	1876.34	452.45	904.17	0.49	Y	88.99	1423.89
17	2.57	117.27	1993.61	480.73	904.17	0.49	Y	88.99	1512.88
18	2.72	117.27	2110.88	509.01	904.17	0.49	Y	88.99	1601.87
19	2.87	117.27	2228.15	537.29	904.17	0.49	Y	88.99	1690.87
20	3.02	117.27	2345.43	565.57	904.17	0.49	Y	88.99	1779.86
21	3.17	117.27	2462.70	593.85	904.17	0.49	Y	88.99	1868.85
22	3.33	117.27	2579.97	622.12	904.17	0.49	Y	88.99	1957.84
23	3.48	117.27	2697.24	650.40	904.17	0.49	Y	88.99	2046.84
24	3.63	117.27	2814.51	678.68	904.17	0.49	Y	88.99	2135.83

6.5 Site Maps

All site maps in this section are sourced from the City of Coquitlam's QGIS Software [26].

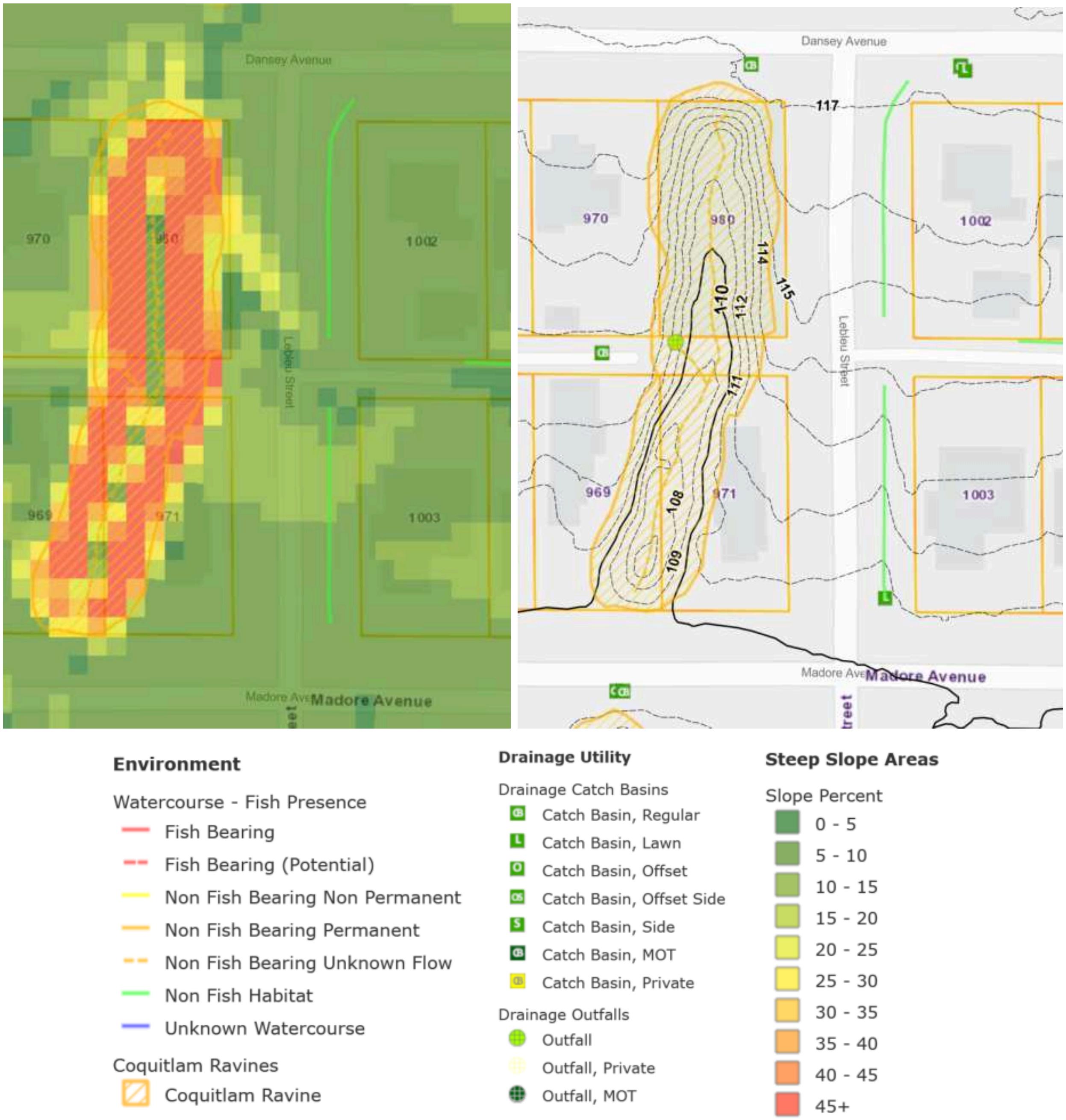

Figure 6.5.1: *Lebleu Street Elevation and Contour Map.*

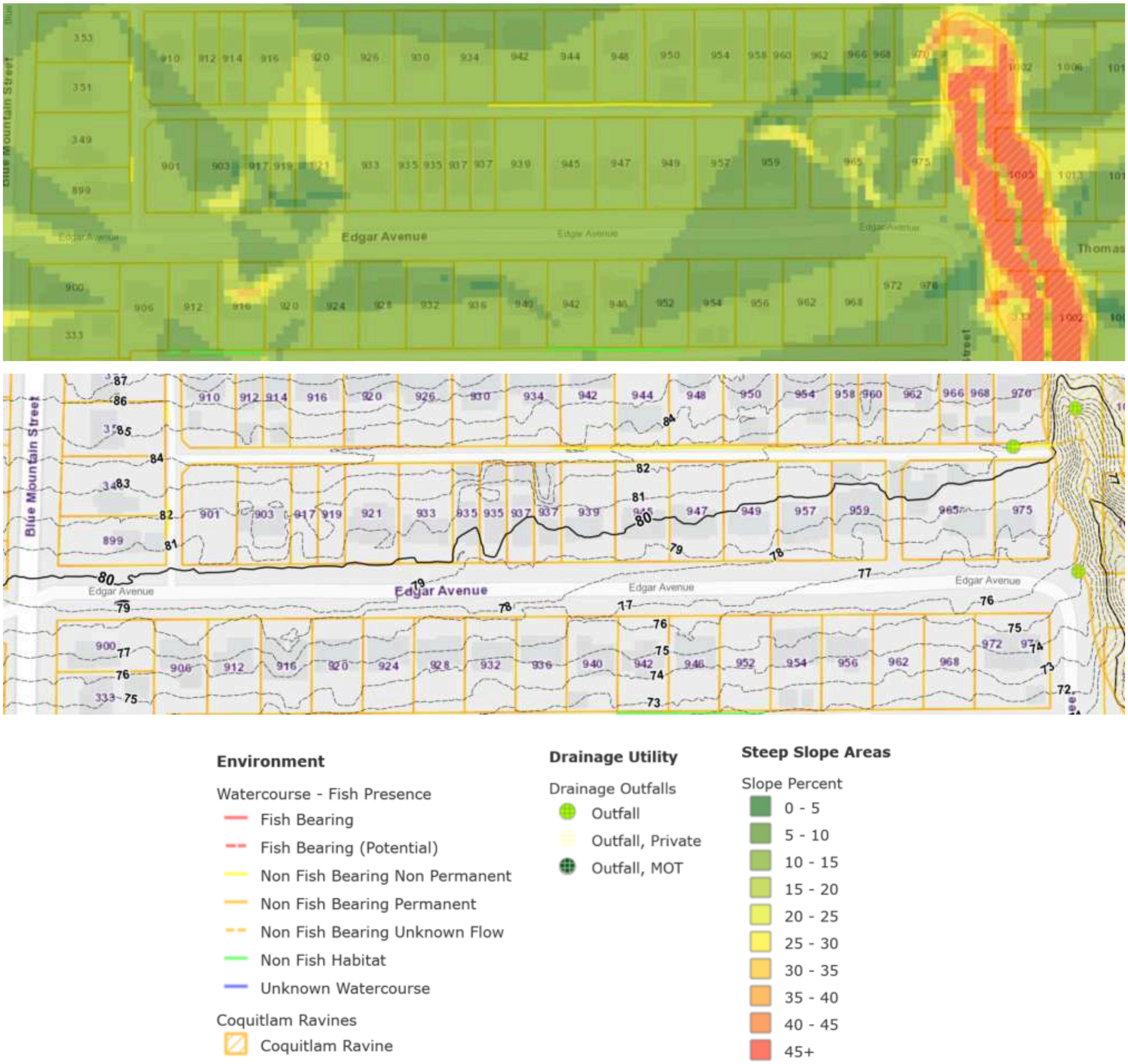

Figure 6.5.2: *Edgar Avenue and Laneway Elevation and Contour Map.*

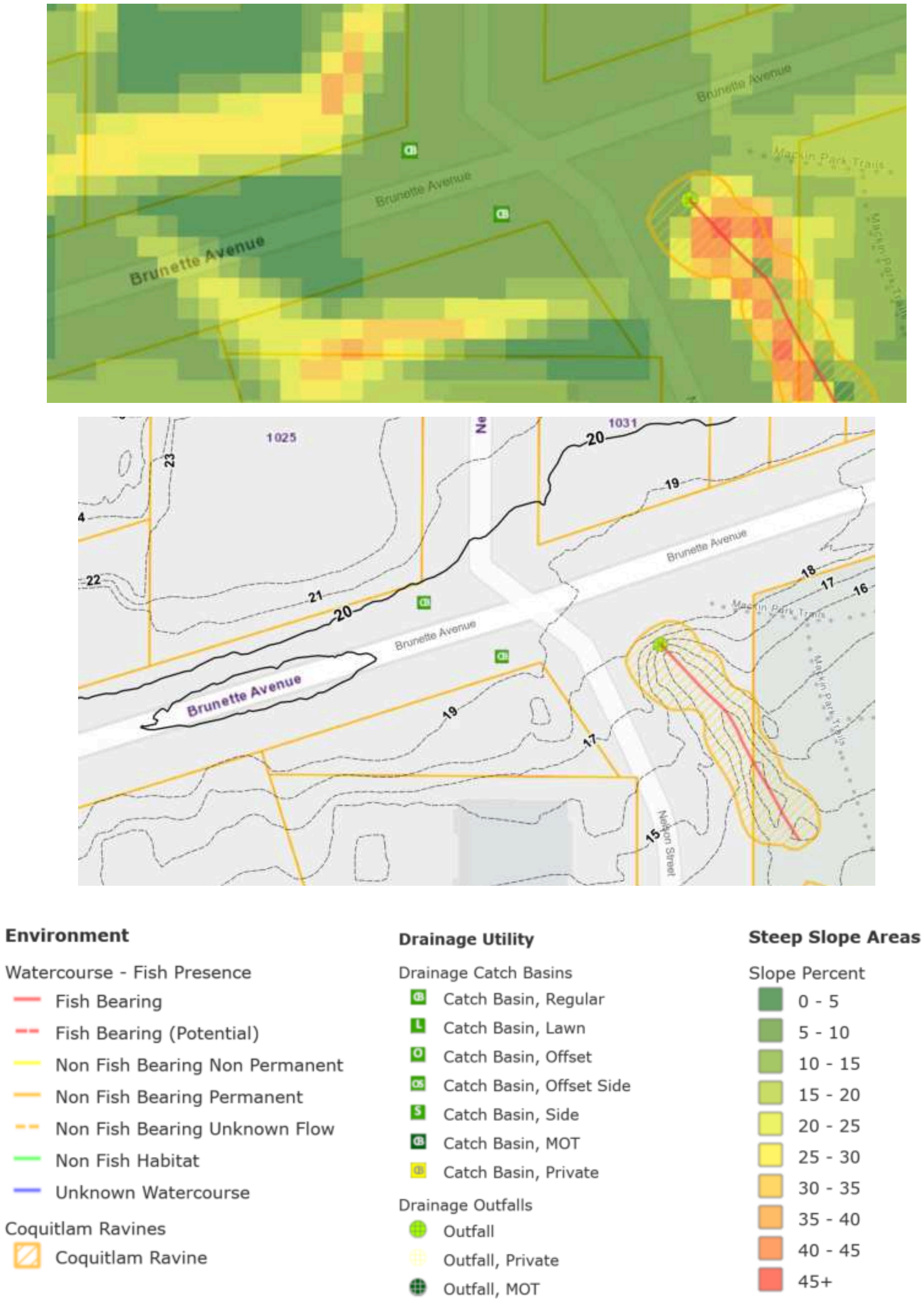

Figure 6.5.3: *Mackin Park Elevation and Contour Map.*

6.6 Social and Environmental Assessments

Table 6.6.1: *Concept Learning Space Signage and Webpage Learning for Native Plants.*

<table>
<tr><th>Description</th><th>Signage or Webpage Learning Opportunity</th></tr>
<tr><td>qeθəɬp (Ocean Spray)
xʷməθkʷəy̓əm (Musqueam) Nation</td><td>

</td></tr>
<tr><td>səniʔəɬp (Dwarf Oregon grape)
xʷməθkʷəy̓əm (Musqueam) Nation</td><td>

</td></tr>
<tr><td>Example webpage resources for City of Coquitlam to partner with kʷikʷəƛ̓əm to develop supplemental learning resources for plants used in GI solutions in addition to signage [48].

The website can feature traditional hən̓q̓əmin̓əm̓ pronunciation and further information of the traditional significance and usage of the plants.</td><td>

</td></tr>
<tr><td>Example webpage resources for City of Coquitlam to partner with kʷikʷəƛ̓əm to develop supplemental learning resources for plants used in GI solutions in addition to signage [48].

The website can feature a directory of plants used in green GI spaces, and hyperlink to the associated traditional hən̓q̓əmin̓əm pronunciation.</td><td>

</td></tr>
</table>

Table 6.6.2: *Concept art for Indigenous Living Art from Yukon and 63rd, Vancouver [30].*

These Indigenous living art pieces, featured in a Vancouver rain garden, are conceptual references for the Mackin Park rain garden. These art installations, created in collaboration and partnership with local Indigenous artists, tell a story of birds, fish, and life crucial to natural water cycles. Similarly, installation of Indigenous living art pieces and partnership with local Indigenous artists is proposed for Mackin Park Rain Garden to curate an educational, traditional experience for visitors.

Description	**Indigenous Living Art Piece**
Hummingbird Pia Bond, Nlaka'pamux Nation.	
Raven Madison Corkum-Gallon, Haida Nation.	
Spawning Salmon I Top: Madelyn Hourston-Baker, Squamish and Ojibway Nations Bottom: Katelynn Aquash, Squamish Nation	

Spawning Salmon II Top: Scarlett Sparrow-Felix, Musqueam Nation Bottom: Kaleigh Goetzinger, Musqueam and Haida Nations	

Table 6.6.3: *Database of Suitable Native Plant Species.*

*indicates native species [14], [18], [22]

Wet Zone	**Moist Zone**	**Dry Zone**
* Cornus Sericea / Red-Osier Dogwood	Chelone / Turtlehead	* Arctostaphylos uva-ursi / Kinnikinnick
* Cornus Sericea 'Kelseyi' / Dwarf Red-Twig Dogwood	* Blechnum spicant / Deer fern	* Symphyotrichum subspicatum / Douglas Aster
* Vaccinium Ovatum 'Thunderbird' / Evergreen Huckleberry	* Mahonia aquifolium / Oregon grape	Carex muskingumensis/ Palm Sedge
Carex Muskingumensis/ Palm Sedge	Carex Squarrosa / Squarrose Sedge	* Gaultheria shallon / Salal
Carex Squarrosa / Squarrose Sedge	* Tiarella trifoliata / Foamflower	* Symphyotrichum subspicatum / Douglas Aster
Chelone / Turtlehead	* Adiantum pedatum / Maindenhair fern	* Cornussericea 'Kelseyi' / Dwarf red-twig dogwood
Carex Appressa / Tall Sedge	Melaleuca Ericifolia / Swamp Paperbark	Carex muskingumensis/ Palm Sedge

__Table 6.6.4:__ Quantifiable Social Benefits of LIDs.

Benefit Category	Environmental Benefit
Physical Health	Reduction in Childhood Asthma**:** Green spaces can protect children aged 0-19 from a high risk of asthma development, and can be further protected by greater tree diversity [50]. Increasing street tree density by 888 trees / square mile) leads to: ● 24% lower asthma prevalence for general public, ● 26% lower risk of hospitalization resulting from asthma, and ● 29% lower prevalence of early childhood asthma Reduced Urban Heat Island Effec**t**: An LID with vegetated green space is assumed to reduce adjacent air temperatures by 3 to 4 ℉. Therefore, the implementation of LIDs in general can help decrease occurrences of heat-stress and heat-related illnesses, which are often exacerbated by the urban heat island effect in cities.
Equitable Access to Urban Green Spaces	117 social housing units are within 1 km of a PermeaPath LID site – an average 7 minute walk [51]. Therefore, the implementation of PermeaPath creates access to new urban green spaces for approximately 132 Coquitlam residents in underserved areas.
Property Values	When located on a street with LIDs, property values in certain Seattle neighbourhoods increased and sold for 3.5% to 5% higher [57]. It was concluded that a common theme was the introduction of LIDs. Therefore, residents along a PermeaPath LID site, such as Lebleu Street, Edgar Avenue, and Brunette Avenue, *may* discover an increase in property value. This is especially beneficial for residents looking to sell their property.
Mental Health and Well-being	Urban green spaces produce the greatest positive mood change within the first 30 minutes [52]. This is ideal given PermeaPath's solution sizing, as many users would likely spend up to 30 minutes at a site, and can experience improved moods within a short time frame. Moreover, a Pennsylvania study found that surgical patients with window views of trees used less painkiller medication and were discharged from hospital on average nearly 10% more quickly than patients who had views of a brick wall [58]. Therefore, the addition of new trees on Edgar Avenue may boost the mental well-being of residents receiving a greener view outside of their window. Furthermore, a Vancouver study found that for every 10 additional street trees added within a 328 ft radius, a 4% reduction is found in total psychotropic (antidepressants and anti-anxiety) prescriptions dispensed from community and outpatient pharmacies [54]. On this basis, the addition of 44 trees along over 0.18 miles of Edgar Avenue may similarly boost overall community well-being and mental health, resulting in fewer psychotropic prescriptions dispensed at local pharmacies over time.
Community Cohesion and Engagement	A Vancouver study found that per every 1% increase in publicly accessible green space within a 0.3 mile radius, social cohesion amongst the neighbouring population increased by 3 to 5%. This meant 3 to 5% more people getting to know their neighbours and becoming more involved in the community. Those with highest social

	cohesion reported an 86% decreased chance of major depressive disorder and 91% decrease in negative mental health [54]. Seeing as the Mackin Park Rain Garden offers interactive spaces for users – in addition to being a publicly accessible green space within 0.3 mile of a community – it can also offer a space for greater social cohesion and allow for stronger community connections through volunteer maintenance programs.
Noise Reduction	1 street tree can reduce roadway noise by a difference of 3.5 to 2.5 dB across a 16 ft distance from the road. Across a 32.8 ft distance, the reduction ranges from 3.5 to 4.5 dB. Based on similarity to the study conditions, a single Hornbeam tree from an Edgar Avenue tree trench is assumed to provide similar results in summer during full foliage and greater traffic noise. Moreover, a greater effect is anticipated with the planting of 44 trees across the full project site, due to effects of greater noise dampening through multiple trees [55].

6.7 Water Balance Diagrams

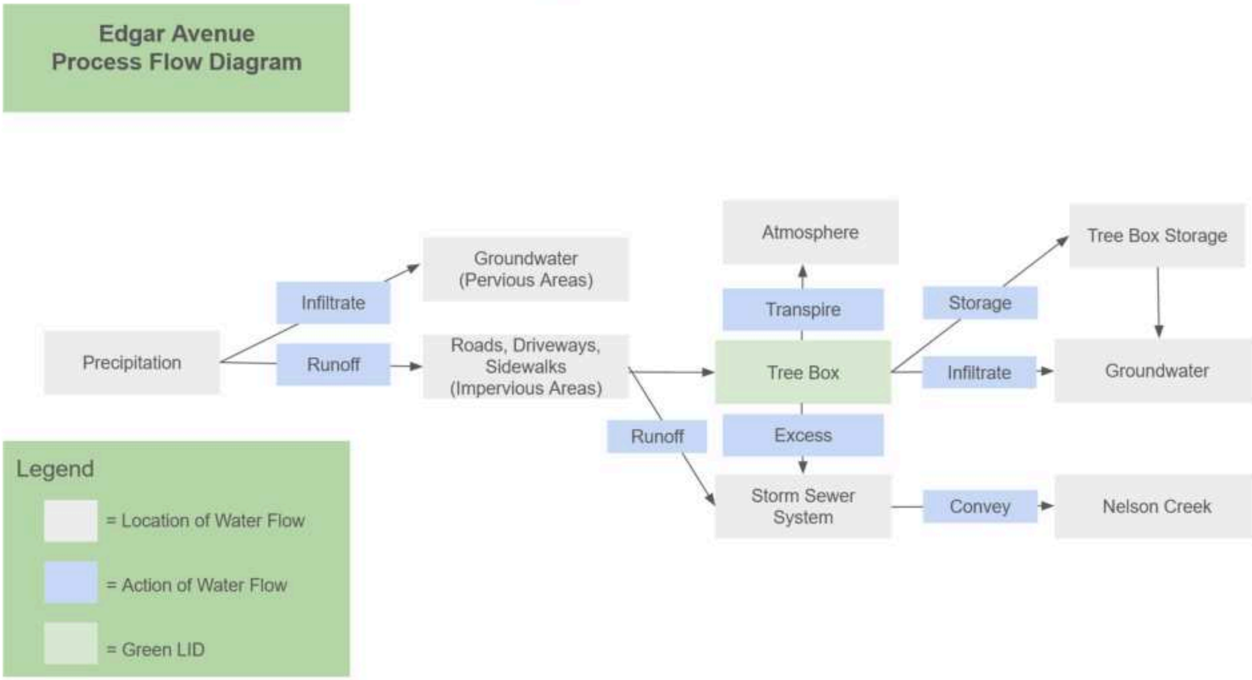

Figure 6.7.1: *Edgar Avenue Water Balance Diagram.*

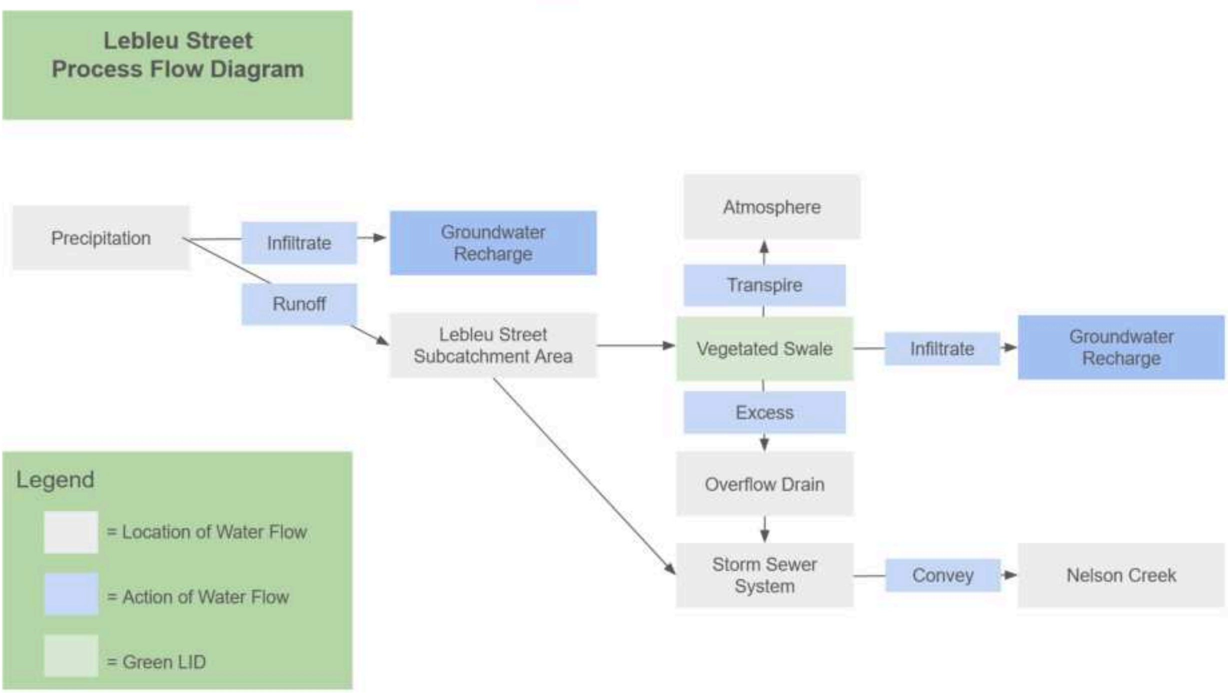

Figure 6.7.2: *Lebleu Street Water Balance Diagram.*

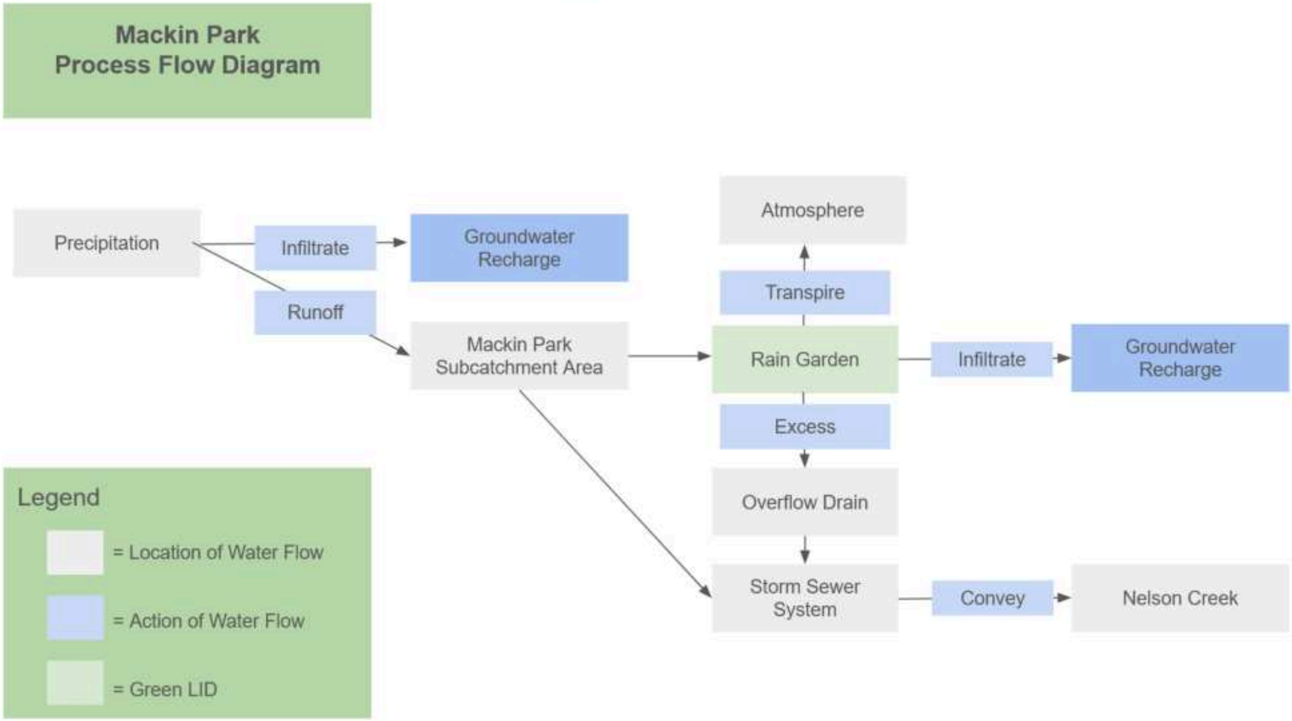

Figure 6.7.3: *Mackin Park Water Balance Diagram.*

6.8 Cost Tables

Table 6.8.1: *Class D Cost Estimate.*

	REVISED	Jul 2025			
	Project	PermeaPath			
	Client	City of Coquitlam			
	Consultant	StormWise Solutions			
	Cost Class	D			
	USD Conversion	**1.37**			
Item	**Category**	**Lebleu Street**	**Edgar Avenue and Laneway**	**Mackin Park**	**Total**
1	**Regulatory and Owner's PM Costs**				
	15%	$16,802	$121,553	$16,035	$154,390
2	**Design**	25%	25%	25%	
	Design Estimate	$26,113	$188,906	$24,920	
3	**Construction**				
	Labour	$38,744	$258,218	$11,809	
	Materials	$11,222	$129,989	$25,340	
	Equipment	$5,480	$13,700	$13,700	
	Overhead (permitting etc)	$206	$685	$2,258	
	Subtotal	*$98,566*	*$713,051*	*$94,062*	*$905,679*
3	**Design Contingency**				
	30%	$29,570	$213,915	$28,219	$271,704
	Total	$128,136	$926,966	$122,281	$1,177,383
	ROUNDED TOTAL	$128,100	$927,000	$122,000	$1,177,100
	Note: Estimates have been prepared with little or no site information and as such indicates the approximate magnitude of the cost of the capital tasks, for project planning purposes only. The estimate has been derived from unit costs for similar projects.				

Table 6.8.2: *Net Present Value Calculation.*

Escalation Rate	2%			
Discount Rate	6%			
Year	Cost (Escalated)	Cost (PV)	Revenue	NPV
0	-$1,177,383	-$1,177,383		-$1,177,383.14
1	-16000	-15094.33962	100000	$79,245.28
2	-16320	-14524.7419	100000	$74,474.90
3	-16646.4	-13976.63843	100000	$69,985.29
4	-16979.328	-13449.21811	100000	$65,760.15
5	-17318.91456	-12941.70045	100000	$61,784.12
6	-17665.29285	-12453.3344	100000	$58,042.72
7	-18018.59871	-11983.39725	100000	$54,522.31
8	-18378.97068	-11531.19358	100000	$51,210.04
9	-18746.5501	-11096.0542	100000	$48,093.79
10	-19121.4811	-10677.33517	100000	$45,162.14
11	-19503.91072	-10274.41686	100000	$42,404.34
12	-19893.98893	-9886.70302	100000	$39,810.23
13	-20291.86871	-9513.619887	100000	$37,370.28
14	-20697.70609	-9154.615363	100000	$35,075.48
15	-21111.66021	-8809.158179	100000	$32,917.35
16	-21533.89341	-8476.737116	100000	$30,887.89
17	-21964.57128	-8156.860244	100000	$28,979.58
18	-22403.86271	-7849.054197	100000	$27,185.32
19	-22851.93996	-7552.863472	100000	$25,498.44
20	-23308.97876	-7267.849756	100000	$23,912.62
21	-23775.15834	-6993.591275	100000	$22,421.95
22	-24250.6615	-6729.68217	100000	$21,020.83
23	-24735.67473	-6475.7319	100000	$19,703.99
24	-25230.38823	-6231.364658	100000	$18,466.49
25	-25734.99599	-5996.218822	100000	$17,303.64
26	-26249.69591	-5769.946414	100000	$16,211.06
27	-26774.68983	-5552.212587	100000	$15,184.58
28	-27310.18363	-5342.695131	100000	$14,220.32
29	-27856.3873	-5141.083994	100000	$13,314.59
30	-28413.51504	-4947.080824	100000	$12,463.93
31	-28981.78535	-4760.398529	100000	$11,665.09
32	-29561.42105	-4580.760848	100000	$10,914.98
33	-30152.64947	-4407.901949	100000	$10,210.72
34	-30755.70246	-4241.566026	100000	$9,549.59

35	-31370.81651	-4081.506931	100000	$8,929.01
36	-31998.23284	-3927.487801	100000	$8,346.59
37	-32638.1975	-3779.280714	100000	$7,800.04
38	-33290.96145	-3636.666348	100000	$7,287.22
39	-33956.78068	-3499.433655	100000	$6,806.12
40	-34635.91629	-3367.379555	100000	$6,354.84
41	-35328.63462	-3240.308629	100000	$5,931.60
42	-36035.20731	-3118.032831	100000	$5,534.71
43	-36755.91146	-3000.371215	100000	$5,162.59
44	-37491.02969	-2887.14966	100000	$4,813.76
45	-38240.85028	-2778.200616	100000	$4,486.81
46	-39005.66728	-2673.362857	100000	$4,180.42
47	-39785.78063	-2572.48124	100000	$3,893.35
48	-40581.49624	-2475.406476	100000	$3,624.43
49	-41393.12617	-2381.994911	100000	$3,372.57
50	-42220.98869	-2292.10831	100000	$3,136.73
NPV				**$57,251.69**

Table 6.8.3: *Lebleu Street detailed cost estimate.*

Location	Item	# TOTAL ($)	# Estimated Quantity	Unit Rate	Unit	Category	Sub-Category	Details
Lebleu St	Equipment	4000				Construction	Equipment	Excavator small (largest cost) ~1300/week [45]
Lebleu St	Gradation Testing	1200	24	50	hours	Design	Labour	
Lebleu St	Land Surveying	1920	8	240	Hours	Design	Labour	
Lebleu St	Geotechnical Survey and Study	5000	-	-		Design	Labour	
Lebleu St	Planting and Soil Installation	20160	1680	12	sf	Construction	Labour	[36]
Lebleu St	Topsoil	5590	130	43	cu yd	Construction	Materials	1.25 swell factor, includes delivery [37][38]
Lebleu St	Course Sand	3036	44	69	cu yd	Construction	Materials	1.25 swell factor [39]
Lebleu St	Riprap	490	10	49	tonnes	Construction	Materials	Smaller particles will be used for velocity dissipation and larger particles will be used for check dams. [40]
Lebleu St	Round Grates	14	1	14	item	Construction	Materials	
Lebleu St	Curb Cuts	2032	4	508	ft	Construction	Materials	[41]
Lebleu St	Culvert Materials	60	1	60	Item	Construction	Materials	[42]
Lebleu St	Road & Sidewalk Closure	150				Construction	Permit	

Table 6.8.4: *Edgar Avenue and Laneway detailed cost estimate.*

Location	Item	TOTAL ($)	#	Estimated Quantity	Unit Rate	Unit	Category	Sub-Category	Details
S+L	Equipment	10000					Construction	Equipment	Excavator small (largest cost) ~1300/week [45]
Street	Trench Excavation	22400		32	700	100 lin ft	Construction	Labour	[43]
Street	Tree box installation	7200		48	150	Item	Construction	Labour	north side of Edgar only 2Crew,8LH, 3days
Street	Paver installation	34800		1160	30	sf	Construction	Labour	1Crew,8LH
Street	Planting and soil installation	12360		1030	12	sf	Construction	Labour	[36]
Street	Land Surveyance	1920		8	240	hours	Construction	Labour	
Laneway	Paver installation	88800		2960	30	sf	Construction	Labour	
Laneway	Trench Excavation	21000		30	700	100 lin ft	Construction	Labour	1.25 swell factor, includes delivery [37][38]
Street	Trees under 10 ft	5250		15	350	Item	Construction	Materials	north side of Edgar only
Street	Infill for Drainage	800		160	5	cu yd	Construction	Materials	[39]
Street	Perforated Pipe	120000		1000	120	20 ft	Construction	Materials	
Street	Pavers	171.25		125	1.37	Item	Construction	Materials	assumes 7 permeable pavement pockets with each pocket parking 4 cars width = 9ft total length of 128.82 ft total area = 1160 ft^2 Paver area = 9.36 ft^2
Street	Soil cell structures	1620		90	18	cu ft	Construction	Materials	[44]
Laneway	Pavers	548		400	1.37	Item	Construction	Materials	
Laneway	Infill for Drainage	1600		320	5	cu yd	Construction	Materials	
Street	Road & Sidewalk Closure Perm	150					Construction	Permit	
Laneway	Road & Sidewalk Closure	150	-		-	-	Construction	Permit	1.25 swell factor [36]
Laneway	Conservation Permit	200	-		-	-	Construction	Permit	Smaller particles will be used for velocity dissipation and larger particles will be used for check dams. [39]

Table 6.8.5: Mackin Park detailed cost estimate.

Location	Item	# TOTAL ($)	# Estimated Quantity	Unit Rate	Unit	Category	Sub-Category	Details
Mackin Park	Equipment	10000				Construction	Equipment	Excavator small (largest cost) ~1300/week [45]
Mackin Park	Gradation Testing	900	6	150	hours	Design	Labour	
Mackin Park	Geotechnical Survey	5000	-	-		Design	Labour	
Mackin Park	Land Surveyance	2000	8	250	Hours	Design	Labour	
Mackin Park	Grounds Installation	720	24	30	Hours	Construction	Labour	
Mackin Park	Planting and Soil Installati	13500	900	15	sf	Construction	Materials	[36]
Mackin Park	Topsoil	1720	40	43	cu yd	Construction	Materials	1.25 swell factor, includes delivery [37][38]
Mackin Park	Course Sand	4485	65	69	cu yd	Construction	Materials	1.25 swell factor [36]
Mackin Park	Riprap	49	1	49	tonnes	Construction	Materials	Smaller particles will be used for velocity dissipation and larger particles will be used for check dams. [39]
Mackin Park	Round Grates	14	1	14	item	Construction	Materials	
Mackin Park	Curb Cuts	2032	4	508	ft	Construction	Materials	[40]
Mackin Park	Culvert Materials	3540	60	59	Item	Construction	Materials	[41]
Mackin Park	Zoning Permit	1648.5	-	-	-	Permit	Permit	based on 3.75% of Construction Costs
Mackin Park	Public Art Installation	2000	-	-	-	Design		

Table 6.8.6: *Cost Benefit Analysis shows the annual runoff treated and cost per volume treated over the 50-year design life.*

Key Assumptions and Parameters:

- All contributing areas include both pervious and impervious surfaces.
- In general, use a runoff coefficient of 0.3 for green spaces, 0.8 for general road right-of-ways, and 0.95 for roads [1].
- All solutions achieve the 90% treatment of receiving runoff criteria. Although some designs may exceed this level of service (vegetated swale on Lebleu Street), this approach represents the closest practical approximation to the treatment goal.
- The net present value (NPV) for each site was calculated based on a design lifespan of 50 years, including annual maintenance costs of $3,000 for Lebleu Street and Mackin Park, $10,000 for Edgar Avenue, and the capital costs (including contingency) listed in Appendix 6.8.1.
- The Edgar Avenue cost was estimated assuming it includes both the Edgar Avenue laneway permeable pavers and the Edgar Avenue pavers/tree trenches; for the purpose of this assessment, these are considered together.

Design	Contributing Area (Acres)	Weighted Runoff Coefficient	Volume Treated per Year (ft^3)	Volume Treated over Design Life (ft^3)	NPV ($)	Cost per Volume Treated, 50 years ($\$/ft^3$)
Vegetated Swale (Lebleu St)	0.58	0.67	109,200	5,457,907	-$192,177.29	$0.035
Permeable Pavers (Edgar Avenue Laneway)	0.86	0.95	231,325	19,380,933	-$1,140,435.63	$0.059
Permeable Pavers and Tree Trenches (Edgar Avenue)	0.69	0.80	156,293			
Rain Garden (Mackin Park)	0.34	0.63	60,505	3,025,226	-$186,321.46	$0.062

6.9 Weighted Decision Matrices

Table 6.9.1: *Weighted decision matrix for Lebleu St.*

Location	**LeBleu**						
		Ratings					
		1	2	3	4	5	
		5 = Optimizes constraint 1 = Does not optimize constraint		vegetated swale, two stage design	vegetated swale, single stage design	vegetated swale, two stage design with sidewalks	**Rationale for Weightings**
Category	**Criteria**	**Description**	**Weighting**	**op1**	**op2**	**op3**	
Economic							
Operational Cost		Maintenance cost is low long-term	12%	0.48	0.12	0.12	Long-term maintenance should be low, with considerations for applying solutions to other neighbourhoods
Capital Cost	Cost	Capital cost is low	8%	0.16	0.32	0.24	Capital cost should be in city budget limits for medium sized projects such as this
Operational							
	Phase implementation	Can the solution be implemented in phases to optimize capital expenditures	4%	0.04	0.04	0.04	Solution should consider extension down Lebleu, it is crucial to phase solution
	Risk of Design Failure	Accounts for the likelihood of the solution remaining effective and operable in its lifetime	13%	0.65	0.26	0.26	Solution should have a long lifespan
	Maintenance	Design takes maintanence in consideration esp in high use/traffic areas	14%	0.56	0.28	0.28	Long-term maintenance should be low, with considerations for applying solutions to other neighbourhoods
Social							
	Engagement	Opportunity to incorporate community/indigenous aspects	6%	0.24	0.18	0.18	Design should incorporate community input and follow landscape practices for City of Coquitlam
	Public accessibility	Design takes accessibility and visibility in consideration esp in high use/traffic areas	2%	0.06	0.06	0.1	This is a neighbourhood roadway. It is important to ensure the designs do not impede traffic or parking constraints
	Public impact	Serves to benefit the community in terms of traffic calming, increasing green space, enhancing overall community aesthetic	8%	0.4	0.24	0.4	Design should be appealing
Environmental							
	Water Quality	Offers further improvement to water quality than just the constrints	15%	0.75	0.6	0.6	Design should improve water quality before discharge into Nelson Creek
is related to water quality	Erosion	Stream protection and velocity reduction	10%	0.4	0.3	0.2	Steep slope, velocity reduction is needed
	Biodiversity	Improves/enhances surrounding biodiversity (plants/animals)	8%	0.32	0.24	0.24	Should serve to enhance the community space
		TOTAL	100%	**4.06**	2.64	2.66	

Table 6.9.2: *Weighted decision matrix for Edgar Ave. and the laneway.*

Location	Edgar + Alley											
Main Problems	Localized flooding in back alley + along street		Ratings									
	Runoff ifrom construction, trash, and cars in alleyway		1	2	3	4	5					
	Runoff from cars on road											
	Runoff from roofs - organics, feces, metals											
	Very impervious - alley and street											
				Avenue				Laneway				
		5 = Optimizes constraint 1 = Does not optimize constraint		Permeable Pavement Lining Road	Tree Boxes Lining Sidewalk Right-of-Way	Tree Boxes with Permeable Pavers Parking	Rain Garden Curb Bulges	Pervious Asphalt	Vegetated Swales	Country Lane	Permeable Pavers	Rationale for Weightings
Category	**Criteria**	**Description**	**Weighting**	**op1**	**op2**	**op3**	**op4**	**Option 1**	**Option 2**	**Option 3**	**Option 4**	
Economic												
Operational Cost		Maintenance cost should be minimized long-term	10%	0.3	0.2	0.3	0.4	0.4	0.3	0.1	0.4	Long-term maintenance should be low, with considerations for applying solutions to other neighbourhoods
Capital Cost	Cost	Capital cost should be minimized	8%	0.32	0.16	0.24	0.4	0.24	0.24	0.16	0.24	Capital cost should be in city budget limits for medium sized projects such
Operational												
	Phase implementation	Can the solution be implemented in phases to optimize capital expenditures	8%	0.16	0.32	0.24	0.32	0.08	0.16	0.08	0.16	Solution extends the length of Edgar, it is crucial to phase solution
	Risk of Design Failure	Accounts for the likelihood of the solution remaining effective and operable in its lifetime	12%	0.36	0.48	0.48	0.36	0.24	0.36	0.24	0.36	Solution should have a long lifespan
	Maintenance	Design takes maintanence in consideration esp in high use/traffic areas	15%	0.45	0.45	0.45	0.6	0.6	0.6	0.15	0.6	Long-term maintenance should be low, with considerations for applying solutions to other neighbourhoods
Social												
	Engagement	Opportunity to incorporate community/indigenous aspects	6%	0.06	0.12	0.12	0.3	0.12	0.24	0.18	0.12	Design should incorporate community input and follow landscape practices for City of Coquitlam
	Public accessibility	Design takes accessibility and visibility in consideration esp in high use/traffic areas	12%	0.6	0.36	0.6	0.24	0.6	0.24	0.24	0.48	This is a neighbourhood roadway. It is important to ensure the designs do not impede traffic or parking constraints
	Public impact	Serves to benefit the community in terms of traffic calming, increasing green space, enhancing overall community aesthetic	8%	0.08	0.4	0.4	0.4	0.16	0.16	0.24	0.16	Design should be appealing
Environmental												
	Water Quality	Offers further improvement to water quality than just the constrints	14%	0.28	0.56	0.7	0.42	0.42	0.56	0.42	0.56	Design should improve water quality before discharge into Nelson Creek
is related to water quality	Erosion	Velocity reduction	0%	0	0	0	0	0	0	0	0	Grade is relatively flat so velocity reduction is not needed
	Biodiversity	Improves/enhances surrounding biodiversity (plants/animals)	7%	0.07	0.28	0.28	0.21	0.14	0.28	0.21	0.14	Should serve to enhance the community space
		TOTAL	100%	2.68	3.33	**3.81**	3.65	3	3.14	2.02	**3.22**	

Table 6.9.3: *Weighted decision matrix for Mackin Park.*

Location	Mackin Park						
		Ratings					
		1	2	3	4	5	
		5 = Optimizes constraint 1 = Does not optimize constraint		Rain Garden in unused greenspace off Brunette	Infiltration swale along parking edges	Tree boxes as meridian in parking lot	Rationale for Weightings
Category	Criteria	Description	Weighting	op1	op2	op3	
Economic							
Operational Cost		Maintenance cost is low long-term	12%	0.36	0.36	0.24	Long-term maintenance should be low, with considerations for applying solutions to other neighbourhoods
Capital Cost	Cost	Capital cost is low	8%	0.32	0.24	0.16	Capital cost should be in city budget limits for medium sized projects such as this
Operational							
	Phase implementation	Can the solution be implemented in phases to optimize capital expenditures	4%	0.08	0.16	0.12	Mackin Park solution does not need to be phased due to the size of the solution
	Risk of Design Failure	Accounts for the likelihood of the solution remaining effective and operable in its lifetime	8%	0.24	0.24	0.32	Solution should have a long lifespan
	Maintenance	Design takes maintenence in consideration esp in high use/traffic areas	11%	0.44	0.33	0.44	Long-term maintenance should be low, with considerations for applying solutions to other park spaces in Coquitlam
Social							
	Engagement	Opportunity to incorporate community/indigenous aspects	10%	0.5	0.4	0.2	Since Mackin Park is a community space, design should engage aspects of community and Indigenous features
	Public accessibility	Design takes accessibility and visibility in consideration esp in high use/traffic areas	10%	0.5	0.4	0.4	This is a neighbourhood park. It is important to ensure the designs do not impede traffic constraints and should be accessible for public use
	Public impact	Serves to benefit the community in terms of traffic calming, increasing green space, enhancing overall community aesthetic	10%	0.5	0.4	0.4	Design should be appealing and enhance community wellbeing
Environmental							
	Water Quality	Offers further improvement to water quality than just the constrints	15%	0.6	0.3	0.45	Design should improve water quality before discharge into Nelson Creek
is related to water quality	Erosion	Stream protection and velocity reduction	6%	0.24	0.18	0.12	Grade is relatively flat so velocity reduction is not needed
	Biodiversity	Improves/enhances surrounding biodiversity (plants/animals)	6%	0.24	0.18	0.12	Should serve to enhance the greenspace
		TOTAL	100%	**4.02**	3.19	2.97	

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