UBC Social Ecological Economic Development Studies (SEEDS) Sustainability Program

Student Research Report

Redesign of 16th Avenue / SW Marine Drive Intersection

Final Design Report

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Executive Summary

The intersection of W 16th Ave. and SW Marine Dr. serves as a critical transportation hub facilitating access to the UBC Point Grey campus. In response to the identified challenges of speeding, pedestrian safety, campus arrival experience, and traffic capacity, our team has developed a comprehensive redesign plan aimed at enhancing intersection performance.

Our redesign strategy targets future traffic demands projected for 2050, aiming for a 25% increase in capacity while optimizing traffic flow and safety through strategic lane configurations and turning radii. Emphasizing cost-effectiveness and environmental sustainability, our design preserves existing features while integrating essential enhancements.

The redesigned roadway layout reduces lanes on SW Marine Dr. and W 16th Ave., incorporating turning and bicycle lanes to manage traffic speed effectively and enhance cyclist safety. Signal phasing is optimized into three phases to simplify configurations and accommodate all road users. Additionally, rainwater management features, such as rain gardens and detention tanks, mitigate stormwater runoff and enhance sustainability.

Our construction plan is structured across three phases to minimize traffic disruption, focusing on stakeholder engagement and safety. Anticipated construction challenges, including soil quality, underground utilities, and weather conditions, are addressed through proactive mitigation strategies to ensure project success and minimize impacts on the community.

The total project cost estimate of $2.12 million covers consultation, permitting, and construction expenses. Construction is scheduled to commence on May 1st, 2024, with completion by July 19th, 2024. Detailed cost breakdowns and considerations, including consulting fees, permitting fees, and annual costs, are provided to ensure transparency and budgetary control.

This comprehensive redesign proposal reflects our commitment to enhancing transportation efficiency, safety, and sustainability at the W 16th Ave. and SW Marine Dr. intersection, aligning with the objectives of the UBC SEEDS Sustainability Program.

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1. Introduction

The intersection of W 16th Avenue and SW Marine Drive is the primary transportation artery, facilitating access to the UBC Point Grey campus. The functioning of the intersection needs to incorporate with the growth of UBC. The current intersection, shown in Figures 1 and 2, has four lanes on each SW Marine Dr. and W 16th Ave., with wide right turns on the east side of the intersection. Vehicles entering W 16th Ave from north of SW Marine Dr. or turning left from W 16th Ave to head south on SW Marine Dr. will encounter the current traffic signal. It currently provides limited priority for buses, no cycling path, and a big reroute for pedestrians.

Our objective is to upgrade facilities at the intersection to solve key issues of speeding, pedestrian safety, sense of arrival to the campus, and traffic flow while minimizing negative impacts. The revised traffic signal design is the appropriate solution to improve all the key issues mentioned above. The intersection redesign mainly decreases the radius of two ramps for the right turn to slow down the vehicles coming to the intersection. This preliminary design report contains conceptual design ideas, detailed redesign information, drawings of the preferred design, a schedule, and a cost estimate.

Figure 1. Intersection Overview

Figure 2. Intersection Overview

Table 1 below outlines the team members and their contributions to the project.

Table 1. Team Member Contributions

Team Member	**Roles, Responsibilities and Tasks**
Isabella Chen	Gateway Design, Structural Analysis, Issue and Criteria
Gretchen Chen	Bike Lane Design, Pedestrian Crossing Design
Xiao Han	2D/3D CAD Drawings, Synchron Analysis
Jiwon (Evie) Hwang	Construction Work Plan, Traffic Management Plan Scheduling, Cost Estimate, Quality Control, Memo of Transmittal, Executive Summary
Rankin Sun	Team Lead, Roadway Design, 2D and 3D CAD Drawings
Lilian Ouyang	Construction Work Plan, Traffic Management Plan Scheduling, Cost Estimate, Quality Control, Memo of Transmittal, Executive Summary
Zijun Zhu	Stormwater Management, Introduction

2. Issues and Criteria

In accordance with the client's main concerns and requirements regarding the intersection redesign, our team encompassed various key issues and objectives. This section elaborates on the identified concerns, objectives, and the associated design criteria to show sufficient investigation and an in-depth understanding of the project. The main objective is to design an intersection that will meet BC Ministry of Transportation and Infrastructure design requirements while resolving these key issues.

2.1 Key Issues and Objectives

The key issues and design objectives are closely related. Our team clearly defined the project's key issues and objectives to better understand targets and the client's expectations, and provide direction in the design process. Table 2 summarizes the concerns that will be addressed.

Table 2. Key Issues and Objectives

Key Issues	**Key Objectives**
Speeding	Reduce vehicle travel speeds approaching the campus to avoid possible collisions
Pedestrian & Cyclist Safety	Create a safe and supportive environment for all road users
Designed and used as a highway, not an urban roadway	Higher preference for alternatives to single-occupant vehicles, including public transit busses, walking, cycling, and rolling
No sense of arrival to UBC	Include an obvious visual "gateway" feature located at the roadway

2.2 Design Criteria

In addition to the fundamental issues and objectives, several design criteria are also taken into consideration from technical, economic, construction planning, regulatory, environmental, and societal aspects. This section incorporates the design criteria from these six aspects with descriptions and strategies for each criterion. The design criterion and respective descriptions and methodologies are shown in Table 3 on the following page.

Table 3. Summary Table of Design Criteria

Design Criteria	Description and Methodology
Technical	The viability of the new intersection is proven to meet the level of service, enhance road performance, and have adequate rainwater management by professional transportation and hydrology simulation software, including EPASWMM, Sidra, and Synchro. Design constraints are strictly imposed and recognized for most recent code requirements, space limitation (i.e., road width) and resource availability.
Economic	The design and construction of the new intersection will be very cost-effective based on the Class C cost estimation provided in the section below. The design will involve a minimum change to the current site, leading to a shorter construction period, higher ease of construction, and lower overall costs.
Construction Planning	The procedures and stages of the construction will be meticulously planned to ensure a smooth and efficient process. Possible strategies include critical path scheduling analysis and a temporary traffic plan during the construction period to minimize the disturbance to the local traffic.
Regulatory	The design adheres to all policies and requirements from the BC Ministry of Transportation and Infrastructure and UBC, with referrals to multiple local and provincial guidelines to realize the most applicable design.
Environmental	The design orients the concept of sustainability, which minimizes land usage to preserve natural vegetation and the buffer zone of the nearby UBC Botanical Garden property. Rainwater retention management will promote water reservations and reduce erosion.
Societal	As the site is located on the traditional, ancestral, and unceded territory of the Musqueam people, the voices from indigenous communities have been heard, respected, and taken into consideration during decision-making. Other related stakeholders are also engaged with their opinions and have been integrated with our design. The gateway design is aesthetically appealing with the combinations of indigenous and UBC elements.

Our design stands on the premise of prioritizing the safety of all land users and construction staff. All design criteria have been addressed and applied to the new intersection design. The following sections describe the components of the design in detail.

3. Proposed Final Design

This section presents the proposed preliminary design, detailing the intended features and layout of the new intersection. It comprehensively outlines the key elements and components integral to the proposed design. A detailed technical analysis of the proposed design will be elaborated upon in the following sections, providing proof of the design's capability, feasibility, functionality, and alignment with the project objectives.

3.1 Proposed Preliminary Design Details

Our design addresses the anticipated increased 2050 traffic demands due to campus growth, forecasting a 25% increase in traffic volume and capacity. It includes optimized lane configurations, turning lanes, and radii to enhance traffic flow and safety. Traffic control devices are also implemented for both construction and permanent use. Key innovations include a new traffic signal phasing based on synchronization analysis, integrated bike lanes, pedestrian pathways, and a stormwater management system. These implementations emphasize ease of use, efficiency, and environmental sustainability. This approach is cost-effective and ensures a practical and budget-friendly execution plan, aligning with our commitment to efficient and sustainable infrastructure development.

3.1.1 Road Design

There are notable changes in our design for SW Marine Drive to streamline traffic in order to enhance safety and accessibility. Southbound traffic on SW Marine Drive will be reduced from four lanes to two, and northbound roads will be modified from three lanes to two. These modifications aim to balance traffic flow and allocate space for additional infrastructure improvements, including bike lanes and vegetation.

On W 16th Avenue, the existing right-turn and left-turn lanes are merged into combined lanes, reducing the number of separate lanes required for turning and thus simplifying the intersection's layout for road users. This change will facilitate smoother transitions between directions. Furthermore, the traditional slip lanes, previously designed for exclusive turning, are replaced with 90-degree turning lanes, subjected to slow-down turning vehicles, thereby increasing safety for both pedestrians and cyclists. Moreover, the turns are expected to reduce the frequency of accidents, further improving safety and traffic management. This design change aligns with the overarching goals of speed control and facilitating seamless transitions to and from campus areas, thereby proving to be a positive adjustment for all road users.

To accommodate traffic flow and prepare for the subsequent intersection, additional lanes are introduced approximately 100 meters before reaching the next junction. These lanes are designed to merge with the upcoming intersection, ensuring a smoother transition and reducing bottlenecks.

Pedestrian and cyclist infrastructure are paid significant attention in the new design as well. The original southern crosswalk is eliminated, and a new shared crosswalk accommodating both pedestrians and cyclists is established. This will be introduced in detail in the following section. Figures 3 and 4 show the overview of the proposed final design.

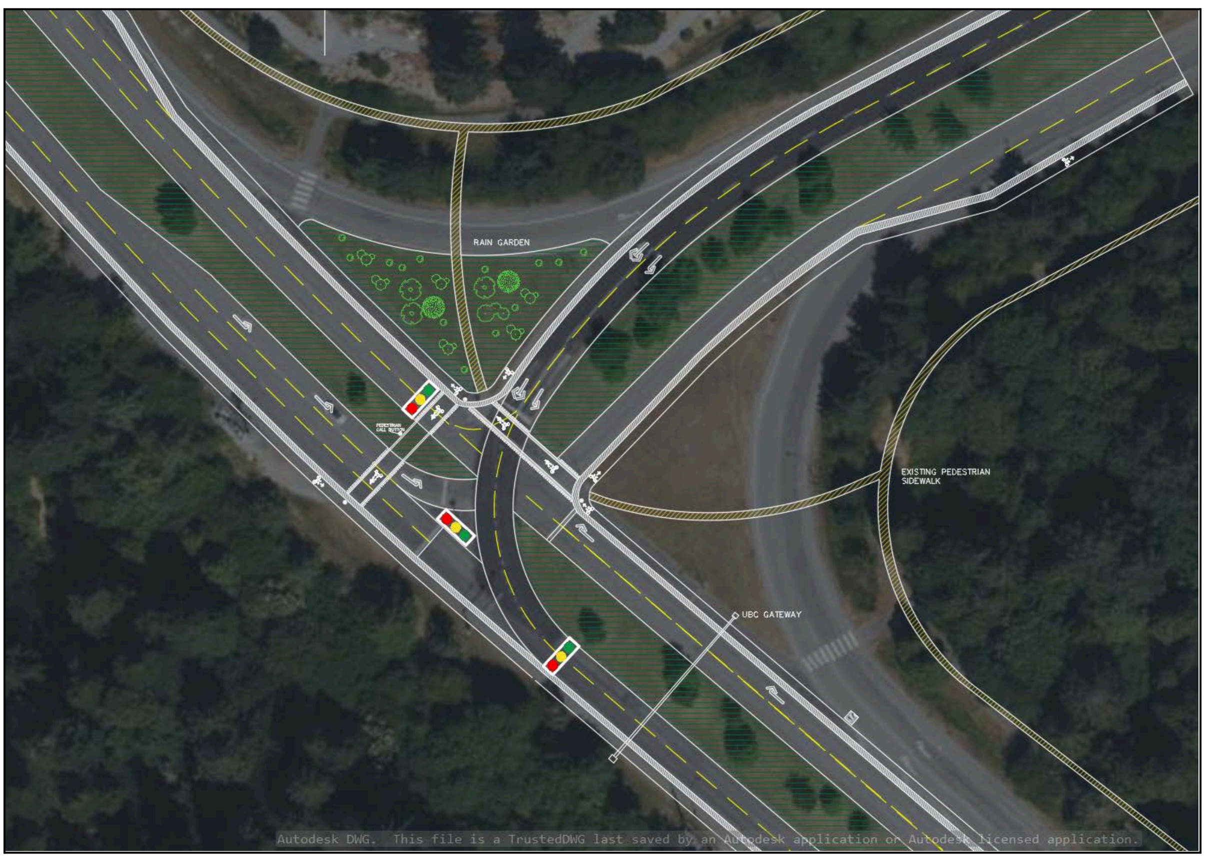


Figure 3. Overview of Intersection

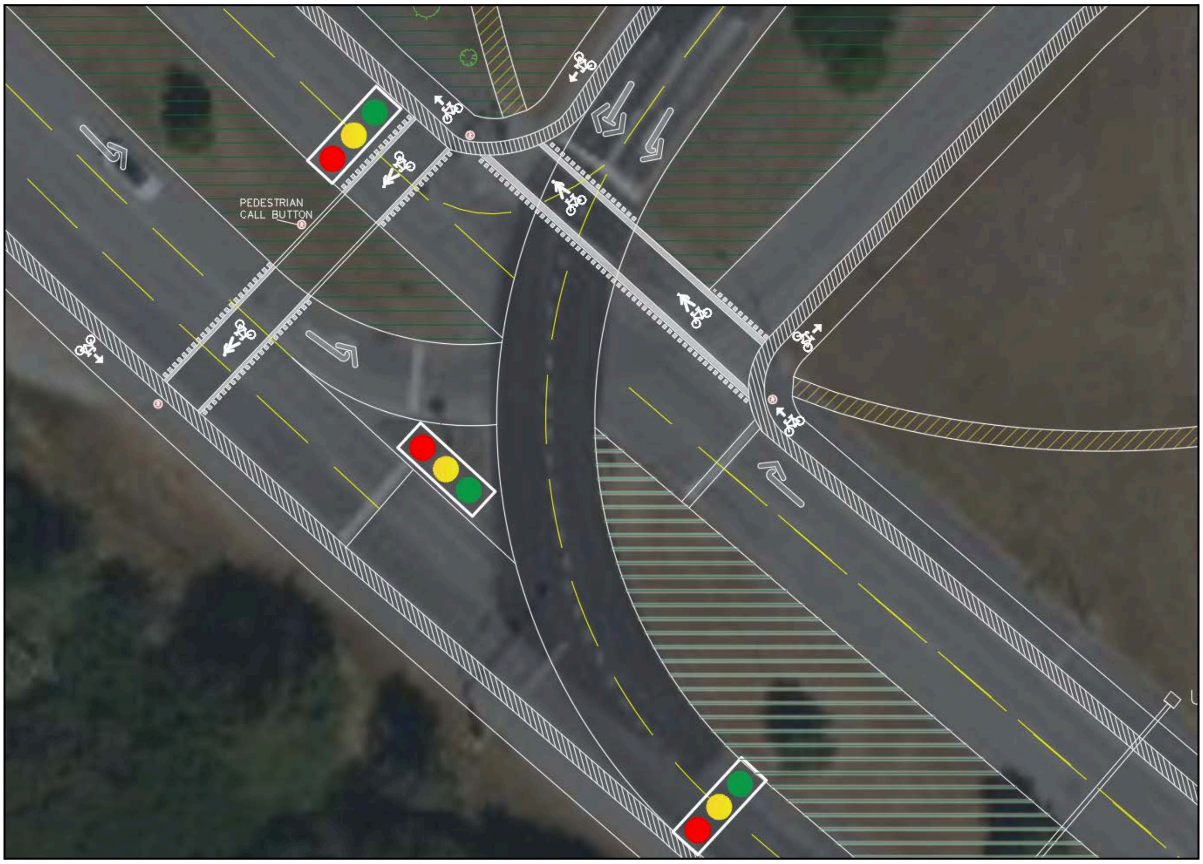


Figure 4. Close View for Intersection with Dimensions

3.1.2 Detailed Shoulder and Bike Lane Design

In alignment with our objective to promote active transit modes and safe transportation, dedicated bike lanes will be constructed along both SW Marine Drive and W 16th Avenue. The design of these bike lanes adheres strictly to the standards outlined in the British Columbia Active Transportation Design Guide, as seen in Figure 5, ensuring a high level of safety and accessibility for cyclists.

The proposed bike lanes will be established on the existing road shoulders, maximizing the use of the current infrastructure and minimizing the requirement of extensive roadwork and plant removal. Each lane will be 2 meters wide, accompanied by a 1-meter buffer zone, depicted in Figure 6, specifically incorporated to enhance safety by providing a protective space between the bikes and vehicles.

Furthermore, to ensure clear visibility and guidance for cyclists, the bike lane symbol (Figure 7) will be painted on the road surface at regular intervals of 2 kilometers, following the design code. Each symbol will be 1.0 meters by 2.0 meters, offering a clear and consistent visual cue for all road users.

FACILITY BY DESIGN SPEED	DESIRABLE (M)	CONSTRAINED LIMIT (M)
Rural ≤50 km/h	1.8	1.5
Rural < 70 km/h	2.5	1.5
Rural > 70 km/h	3.0	2.0
Buffer (between shoulder and motor vehicle lane for higher posted speed and/or higher motor vehicle volumes)	1.2	0.9

Figure 5. Spacing Requirement (Table D-19) from BC Active Transportation Design Guide

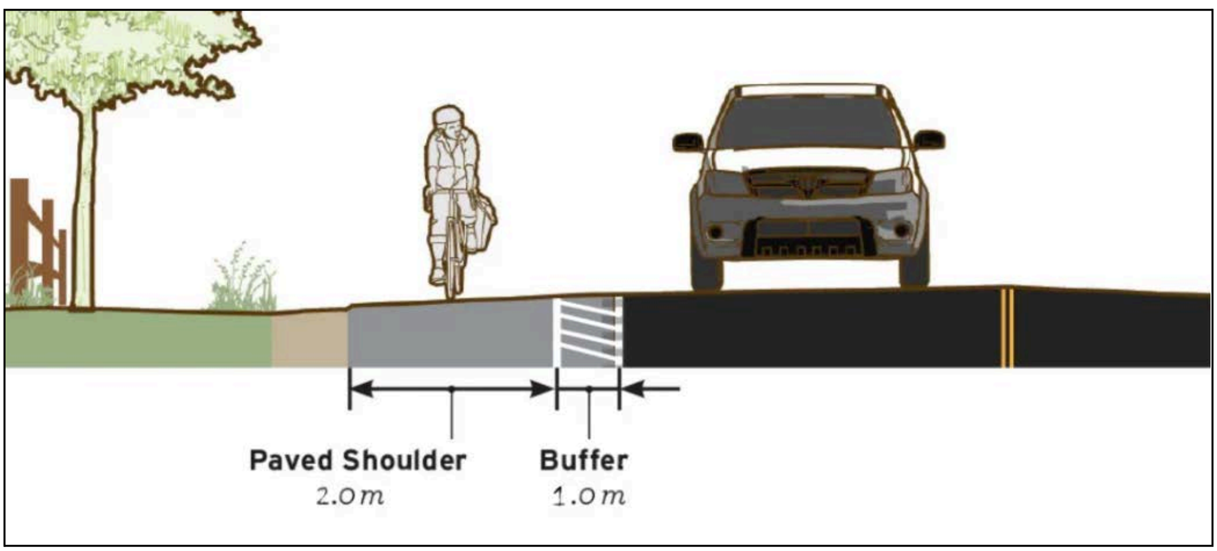


Figure 6. Bike Shoulder Design

Figure 7. Elongate Bicycle Symbol and Hatched Zone

3.1.3 Land Usage

The roadways are designed with a focus on retaining existing features, ensuring a generous buffer between the road and the botanical garden. Our design aims to safeguard all surrounding vegetation while also generating extra planting areas through the removal of the independent right-turn lanes. A rain garden is introduced to replace the trees on one side with shrubs and aquatic plants to enhance rainwater retention and expand green spaces. A subsurface detention tank will be installed within the rain garden. Refer to Appendix A for additional AutoCAD design drawings.

3.1.4 Traffic Light & Crossing Signals

The traffic signal design at the intersection is divided into three 40-second phases, specifically designed to prioritize pedestrian and cyclist crossings, enhancing safety and reducing waiting times. This segmentation helps to extend the vehicle queue lengths, inherently slowing down traffic speeds and creating a safer environment for all road users. By managing vehicle speeds and prioritizing non-motorized traffic, the system aims to improve the overall safety and efficiency of the intersection, balancing the incoming traffic from each direction.

The crosswalk design for our intersection prioritizes both functionality and safety, set up on the east side and the northbound of the intersection. To facilitate the shared use by pedestrians and cyclists, the crosswalks are designed to be 3 meters wide, ensuring enough space for navigation and the crossing comfortably. This design decision is supported by detailed traffic and pedestrian flow analyses, which indicate that the proposed dual crosswalks will suffice the peak hour traffic of both pedestrians and cyclists.

To improve the user-friendliness of the northbound crosswalk, especially in scenarios where crossing times may be insufficient, a push-button has been incorporated at the northern crossing. This feature allows pedestrians who are unable to cross the road within the given signal time to request an extended crossing period. This system not only prioritizes pedestrian safety but also enhances the accessibility of the crossing, making it more responsive to the needs of all road users. This approach reflects a thoughtful consideration of creating a safe, inclusive, and efficient urban transportation environment.

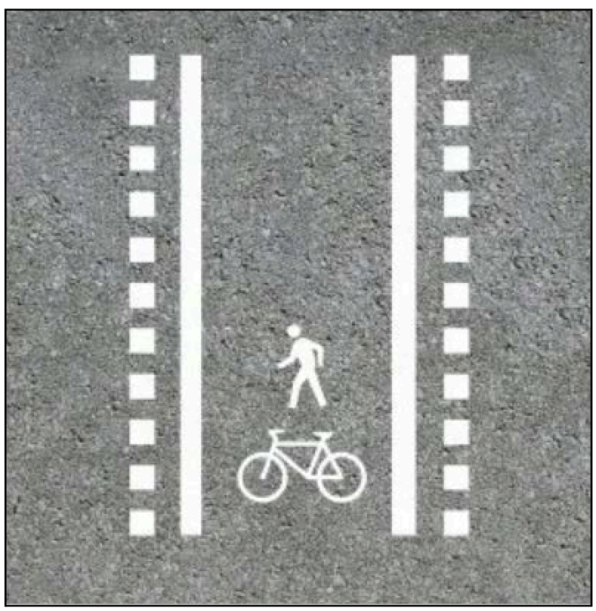


Figure 8. Crossbike Symbol[1]

[1] https://vancouver.ca/streets-transportation/signs-signals-regulations.aspx

Figure 9. Crossing Signal Existing Example

3.2 Synchro Analysis

Based on a 10-year traffic volume projection, we estimated that the total traffic volume will increase by 25 percent. The design traffic volume was calculated using 80 percent of the peak traffic volume. The newly designed road has reduced lanes to lower the LOS from A to D, thus reducing speed at the intersection.

An in-depth Synchro analysis was conducted to evaluate the level of service (LOS) at a particular intersection, as presented in Figure 10 and Figure 11. The analysis utilized the identical methodology outlined in Section 3.1.1 of our comprehensive study.

Following the Highway Capacity Manual standards, the designed traffic flow will be 80% of the peak hour flow. The insights gathered from transportation reports were collated to make a prudent forecast, projecting a moderate demand surge of 10% over a decade. This strategic choice is based on the expectation that public transportation will remain a popular commuting mode, poised for expansion and enhancement in the future. The estimate of a 125% increase is a pragmatic approach designed to accommodate growing demand while mitigating the risk of unwarranted over-investment in the project. The design traffic flow data and Synchro are presented in Table 4 on the next page.

Table 4. Design Traffic Flow for Synchro Analysis

	→ EBT	↘ EBR	↙ WBL	← WBT	↰ NBL	↱ NBR
Peak Hour Data	300	350	150	650	600	100
Design (80%)	240	280	120	520	480	80
25% Increase	360	420	180	780	720	120

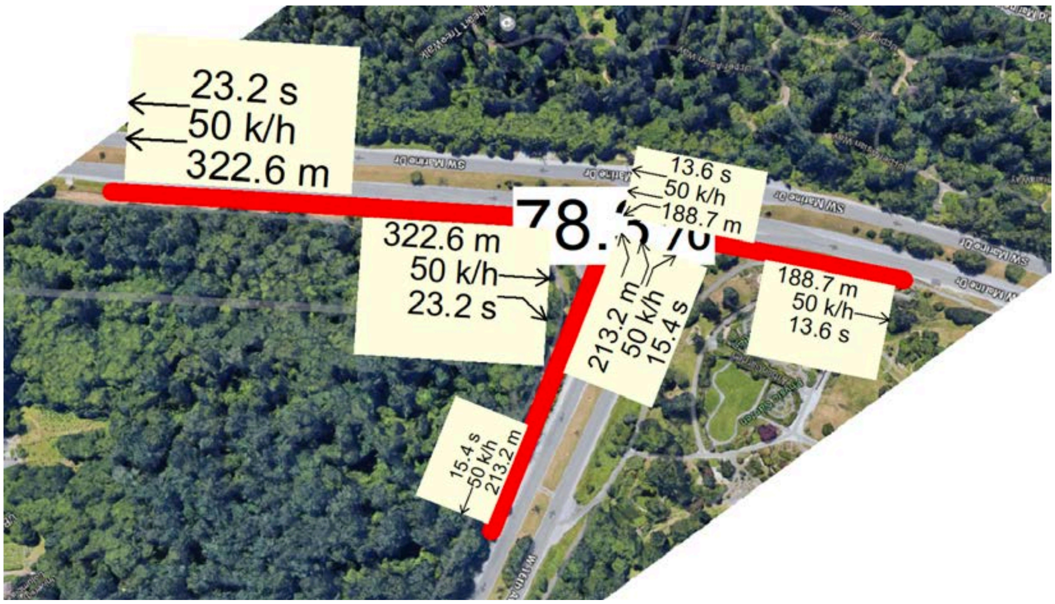


Figure 10. Synchro Data Input

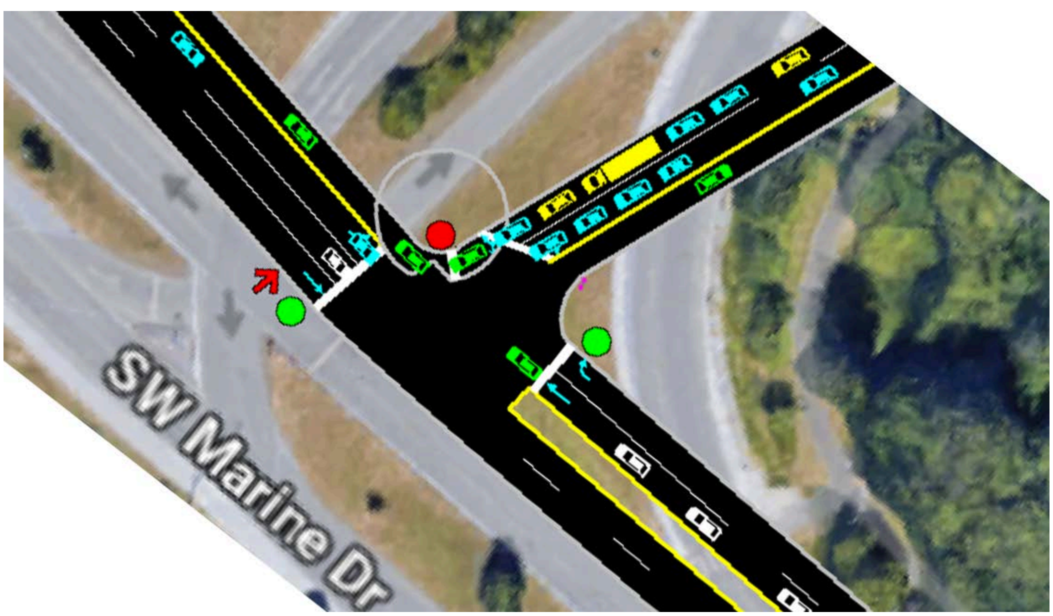


Figure 11. Model for Designed Intersection

The analysis was performed by considering an 80% threshold of peak flow, and the results are presented in Figure 12 and Figure 13. The Synchro analysis indicates that the intersection will likely achieve a Level of Service D, equivalent to a maximum delay of 23 seconds per vehicle. This suggests a condition characterized by light congestion while effectively avoiding the less desirable LOS F.

Moreover, even when subjected to a heightened demand scenario with a 25% increase, the intersection exhibits remarkable resilience by maintaining a LOS of D. In this case, the maximum delay per vehicle extends to 33 seconds. This resilience underscores the effectiveness of the design and reaffirms the intersection's capability to handle increased demand without compromising its operational efficiency.

Additionally, Synchro further optimizes the time phases at the intersection, as shown in Figure 14, maximizing traffic capacity while enhancing pedestrians' and vehicles' safety and efficiency. Overall, Synchro plays a pivotal role in orchestrating traffic movements and fostering safety and efficiency at this intersection.

TIMING WINDOW	EBT	EBR	WBL	WBT	NBL	NBR	PED	HOLD
Lanes and Sharing (#RL)							—	—
Traffic Volume (vph)	250	320	124	540	520	84	—	—
Turn Type	—	Free	custom	—	—	—	—	—
Protected Phases	2		3	6	5	—		
Permitted Phases		Free	7		1	—	—	—
Detector Phases	2	None	3	6	5	—	—	—
Minimum Initial (s)	4.0	—	4.0	4.0	4.0	—	—	—
Minimum Split (s)	30.0	—	30.0	30.0	30.0	—	—	—
Total Split (s)	40.0	—	40.0	40.0	40.0	—	—	—
Yellow Time (s)	3.5	—	3.5	3.5	3.5	—	—	—
All-Red Time (s)	0.5	—	0.5	0.5	0.5	—	—	—
Lead/Lag	Lag	—	—	Lag	Lead	—	—	—
Allow Lead/Lag Optimize?	Yes	—	—	Yes	Yes	—	—	—
Recall Mode	Max	—	Max	Max	Max	—	—	—
Actuated Effct. Green (s)	36.0	120.0	36.0	36.0	36.0	—	—	—
Actuated g/C Ratio	0.30	1.00	0.30	0.30	0.30	—	—	—
Volume to Capacity Ratio	0.23	0.22	0.23	0.50	0.59	—	—	—
Control Delay (s)	32.3	0.3	33.0	36.5	37.6	—	—	—
Queue Delay (s)	0.0	0.0	0.0	0.0	0.0	—	—	—
Total Delay (s)	32.3	0.3	33.0	36.5	37.6	—	—	—
Level of Service	C	A	C	D	D	—	—	—
Approach Delay (s)	14.4	—	—	35.8	37.6	—	—	—
Approach LOS	B	—	—	D	D	—	—	—
Queue Length 50th (m)	24.5	0.0	23.1	57.9	63.8	—	—	—
Queue Length 95th (m)	35.6	0.0	39.4	75.5	83.1	—	—	—
Stops (vph)	182	0	91	434	490	—	—	—
Fuel Used (l/hr)	18	10	7	35	41	—	—	—

Figure 12. Design Flow

TIMING WINDOW	EBT	EBR	WBL	WBT	NBL	NBR	PED	HOLD
Lanes and Sharing (#RL)							—	—
Traffic Volume (vph)	300	350	150	650	600	100	—	—
Turn Type	—	Free	custom	—	—	—	—	—
Protected Phases	2		3	6	5	—		
Permitted Phases		Free	7		1	—	—	—
Detector Phases	2	None	3	6	5	—	—	—
Minimum Initial (s)	4.0	—	4.0	4.0	4.0	—	—	—
Minimum Split (s)	30.0	—	30.0	30.0	30.0	—	—	—
Total Split (s)	40.0	—	40.0	40.0	40.0	—	—	—
Yellow Time (s)	3.5	—	3.5	3.5	3.5	—	—	—
All-Red Time (s)	0.5	—	0.5	0.5	0.5	—	—	—
Lead/Lag	Lag	—	—	Lag	Lead	—	—	—
Allow Lead/Lag Optimize?	Yes	—	—	Yes	Yes	—	—	—
Recall Mode	Max	—	Max	Max	Max	—	—	—
Actuated Effct. Green (s)	36.0	120.0	36.0	36.0	36.0	—	—	—
Actuated g/C Ratio	0.30	1.00	0.30	0.30	0.30	—	—	—
Volume to Capacity Ratio	0.28	0.24	0.28	0.60	0.69	—	—	—
Control Delay (s)	32.9	0.4	33.8	38.6	40.2	—	—	—
Queue Delay (s)	0.0	0.0	0.0	0.0	0.0	—	—	—
Total Delay (s)	32.9	0.4	33.8	38.6	40.2	—	—	—
Level of Service	C	A	C	D	D	—	—	—
Approach Delay (s)	15.4	—	—	37.7	40.2	—	—	—
Approach LOS	B	—	—	D	D	—	—	—
Queue Length 50th (m)	29.8	0.0	28.4	72.2	77.0	—	—	—
Queue Length 95th (m)	42.1	0.0	46.6	92.5	98.5	—	—	—
Stops (vph)	222	0	113	541	590	—	—	—
Fuel Used (l/hr)	22	11	9	43	49	—	—	—

Figure 13. Increase 25%

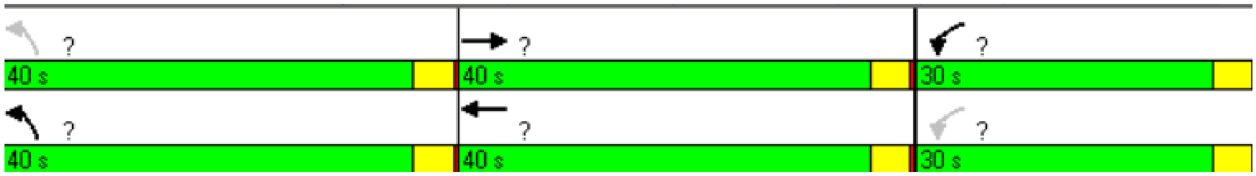


Figure 14. Time Phasing with Pedestrian

Figure 15. Time Phase without Pedestrian

4. Stormwater Management

To manage stormwater, a detention tank and a rain garden in addition to the existing sewage system will be implemented. The detention tank will retain stormwater on-site, avoid flooding, and assist in drainage. Green infrastructure, median strip, and roadside area will be utilized as a rain garden for retention and bio-retention.

4.1 Geological & Hydrological Analysis

The study area soil consists of 40% sand, 40% clay, and 20% silt with a Wilt Point of $0.221m^3$ water/m^3 of soil, the field capacity of this soil is $0.338m^3$ water/m^3 of soil. This would give $0.117m^3$ water/m^3 of soil available for water retention. In addition, water evaporates at a rate of 0.001m/day and infiltrates at a rate of 0.0015 m/hour. The software analysis is shown in Figure 16 on the following page.

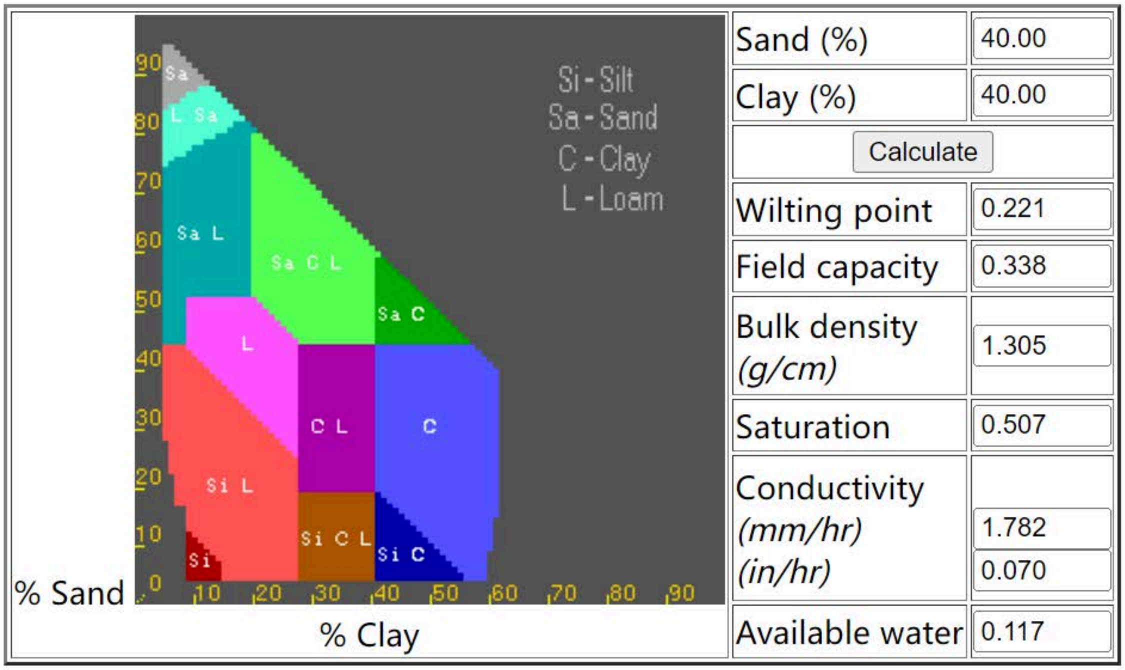


Figure 16. Soil Hydraulic Properties Calculator

The area designed for water runoff on the non-permeable pavement covers a total of 12000m^2 as indicated in Figure 18 on the next page, which sums up to 24000m^2 of coverage when considering the comprehensive study area that includes the roadways and green spaces. The determination of the study area is based on the local slope. In Figure 17, a snippet from EPASWMM provides critical insights into the intersection, aiding in the configuration of the pipeline system.

After conducting a thorough analysis, it was determined that the sewer system within the southern catchment area can completely manage stormwater within a 50-year period based on a 24-hour estimation. This attests to the robustness of the sewer infrastructure and highlights its resilience and capacity to handle extreme weather conditions while safeguarding against potential flooding issues. According to the UBC Integrated Stormwater Management Plan, the stormwater model identifies that under a 10-year return storm, there will be small areas with light surface flooding, in keeping with typical municipal practice, which can be assumed that 95% of stormwater can be drained through the outfall of Botanical Garden Creek.

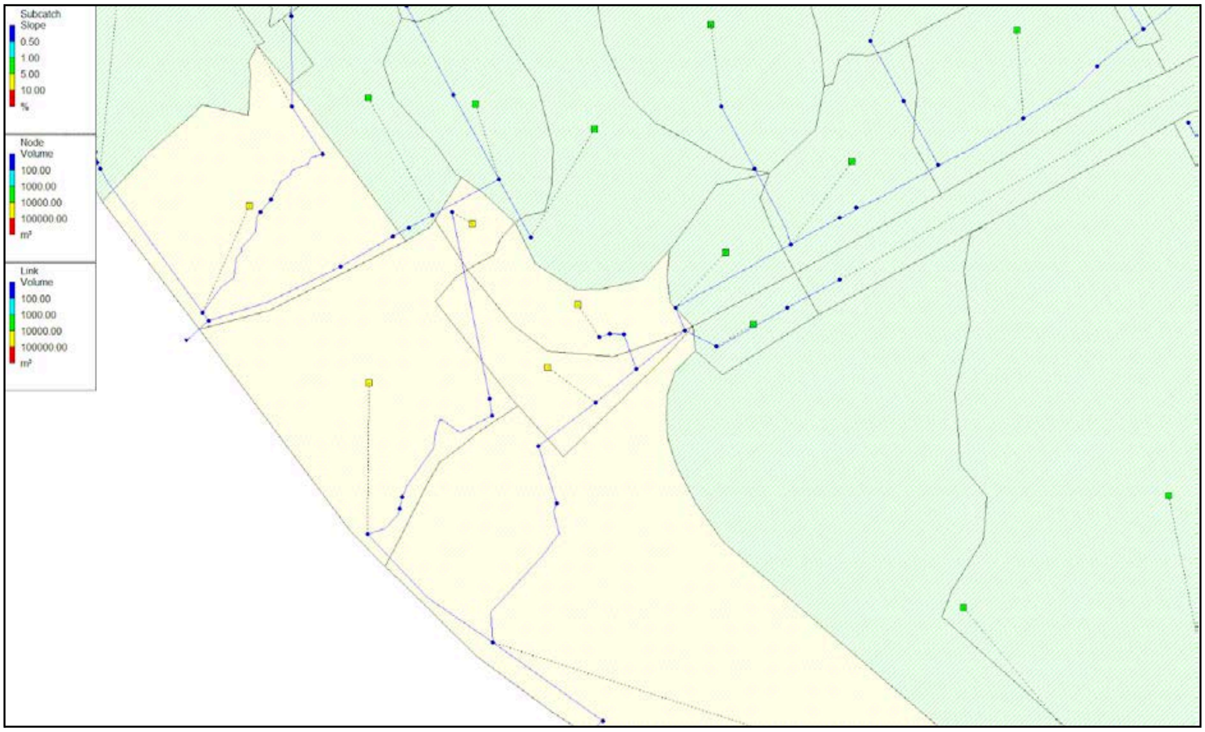
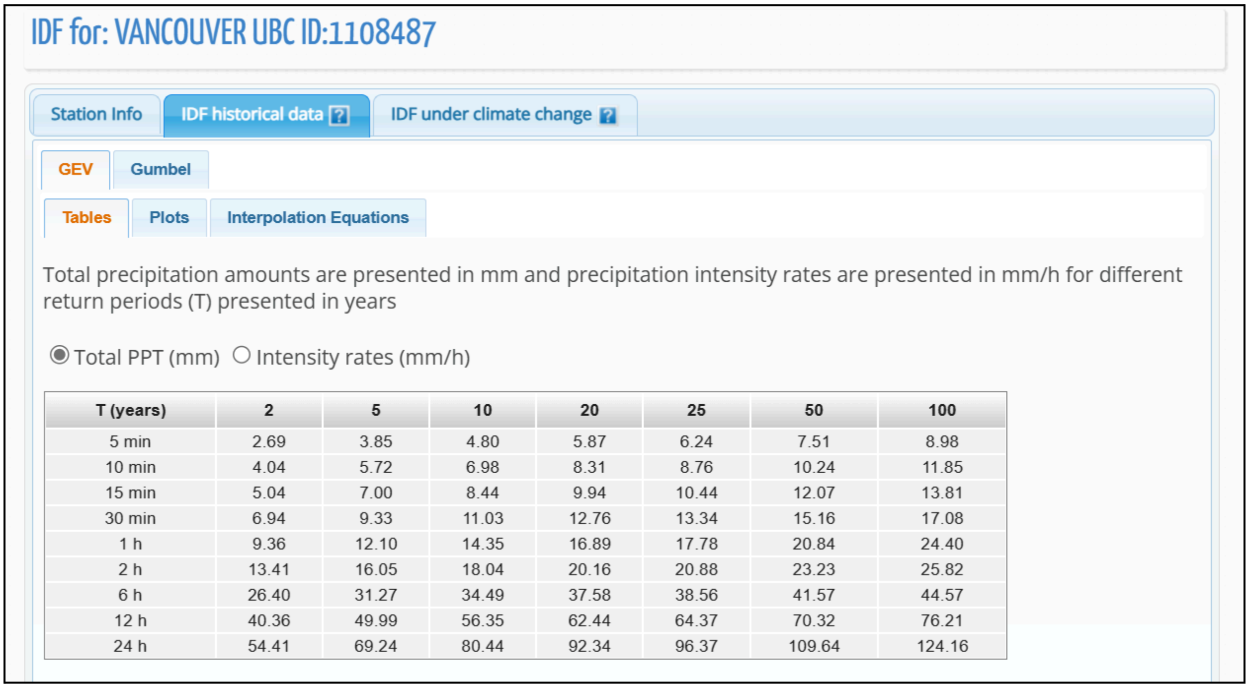


Figure 17. EPASWMM Details

Figure 18. Stormwater Study Area

The IDF_CC Tool, developed by Western University, is a resource instrumental that is able to obtain precipitation data within the vicinity of UBC, as shown in Figure 19. This tool guides the estimation of the maximum stormwater volume generated by the pavement, not accounting for draining to the ocean. The maximum stormwater volume is determined as 398.4m^3. Detailed stormwater calculations are provided in Appendix B.



T (years)	2	5	10	20	25	50	100
5 min	2.69	3.85	4.80	5.87	6.24	7.51	8.98
10 min	4.04	5.72	6.98	8.31	8.76	10.24	11.85
15 min	5.04	7.00	8.44	9.94	10.44	12.07	13.81
30 min	6.94	9.33	11.03	12.76	13.34	15.16	17.08
1 h	9.36	12.10	14.35	16.89	17.78	20.84	24.40
2 h	13.41	16.05	18.04	20.16	20.88	23.23	25.82
6 h	26.40	31.27	34.49	37.58	38.56	41.57	44.57
12 h	40.36	49.99	56.35	62.44	64.37	70.32	76.21
24 h	54.41	69.24	80.44	92.34	96.37	109.64	124.16

Figure 19. IDF Estimation for Precipitation

The northeast corner of the intersection is used as a 1000m^2 rain garden to retain water, with 0.45m topsoil and 0.4m drain rock depth implemented. The capture volume for these rain gardens in 24 hours is 293m^3.

4.2 Rain Garden Design

The management of stormwater volume in urban areas is a critical concern for urban planners and environmental engineers. In light of this, a 147.26 m^3 (38903 gallons) precast detention tank model W38000 from Wieser Concrete with dimensions of 12.192m x 4.2672m x 3.556m(40′ x 14′ x 140″) will be installed as shown in Figure 20. The location of this proposed tank would be at the northeast corner of the intersection situated 1m below the geomembrane of the rain garden. The detention tank will collect any water overflows emanating from the rain garden. The drainage system would be managed by an automated control device and a suction pump with a 15HP motor. The system employs an 8-inch split case suction water pump, and the total length of the 8-inch diameter pipes employed spans 5 meters. For a comprehensive understanding of the detention tank system, Table 5 below provides detailed specifics of the system.

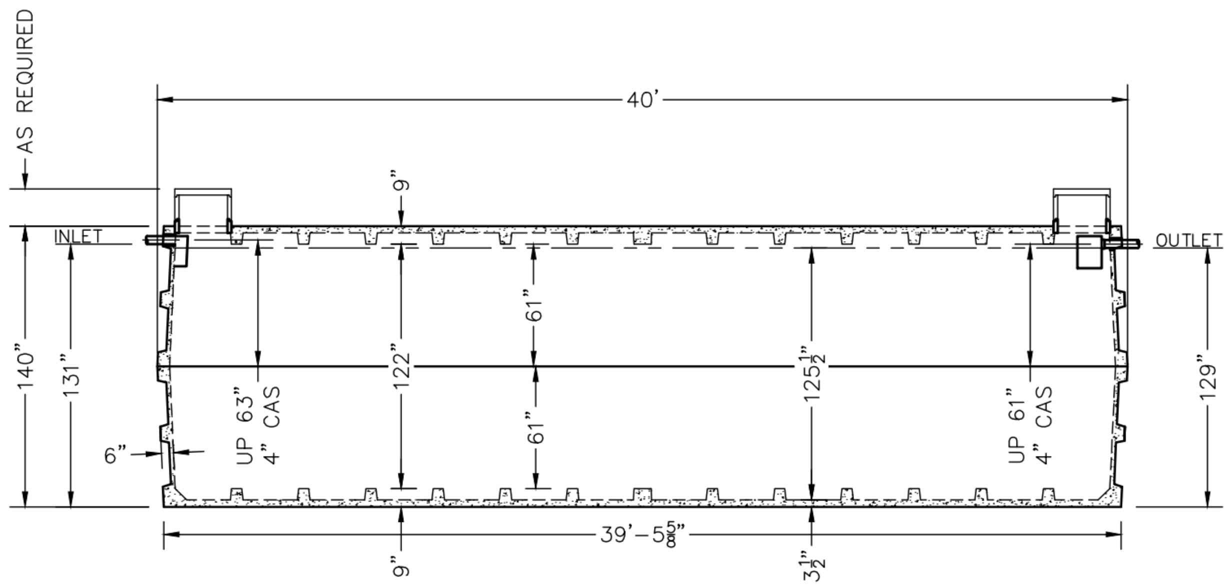


Figure 20. Detention tank Cross Section

Table 5. Stormwater System Formation Details

Detention Tank Parts	**Quantity**	**Units**
8-inch diameter pipe	5	m
8-inch centrifugal industrial dewater pump	1	N/A
3 phase, 15HP 1200RPM cast iron motor	1	N/A
Automated stormwater detention control device	1	N/A
Detention tank	1	N/A
Rain Garden Parts	**Quantity**	**Units**
Topsoil	400	m^3
1/4" Drain 28mm rounded washed rock	300	m^3
Geotextile Membrane	1000	m^2
Planting (shrubs and aquatic plants)	1000	m^2

The diagram presented in Figure 21 below provides a detailed illustration of the cross-sectional layout of the rain garden and detention tank system. Other detailed drawings are provided in Appendix A. The rain garden, with a depth of approximately 0.4m, is a vegetated area consisting of shrubs and aquatic plants supported by a 0.3m thick layer of soil. The soil is sandwiched between two geotextile membranes, which provide crucial functions such as filtration, reinforcement, and protection.

A 0.3m deep layer of rounded rocks is placed on top of the geotextile membrane. In the northeastern corner where the rain garden overlays the detention tank, an intervening stratum of soil, 0.3m in depth, is present. This soil layer plays a significant role in ensuring the proper functioning of the entire system.

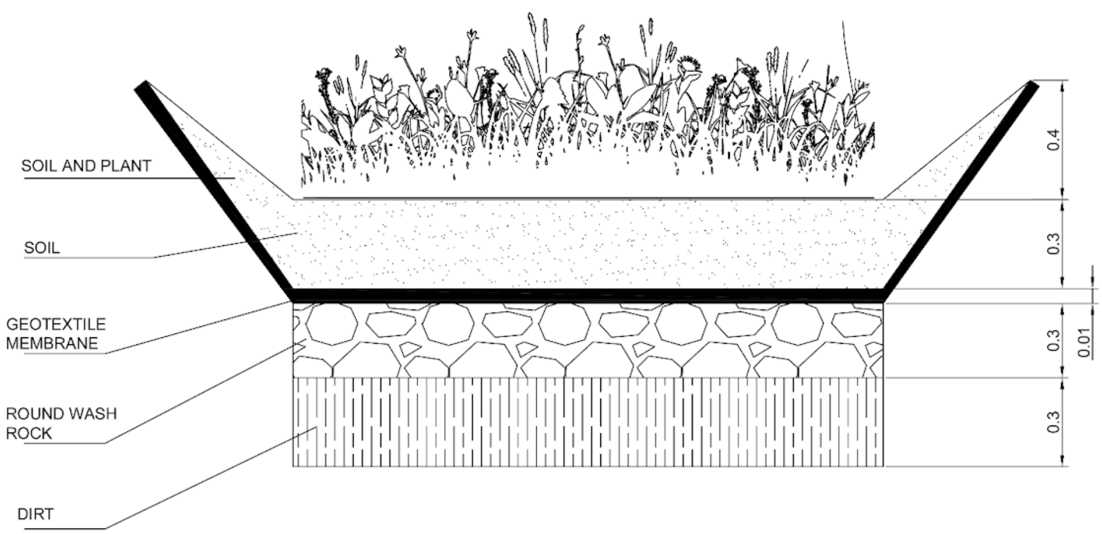


Figure 21. Rain Garden Cross Section

4.3 Detention Tank Design

The concrete detention tank will be located beneath the northeast rain garden and is connected to an existing municipal sewer as the entry point for rainwater, as shown in Figure 22. During periods of heavy precipitation, the detention tank efficiently accumulates water. Once the pre-existing sewer system's water level recedes after intense rainfall, a sophisticated Automated

Stormwater Detention Control Device[2] is activated to facilitate the discharge from the detention tank. This device acts as an automated control mechanism, ensuring optimal timing and volume control to prevent overload of the drainage system. It is equipped with advanced sensors and programmable logic controllers, enabling dynamic response to water levels and automatic dewatering.

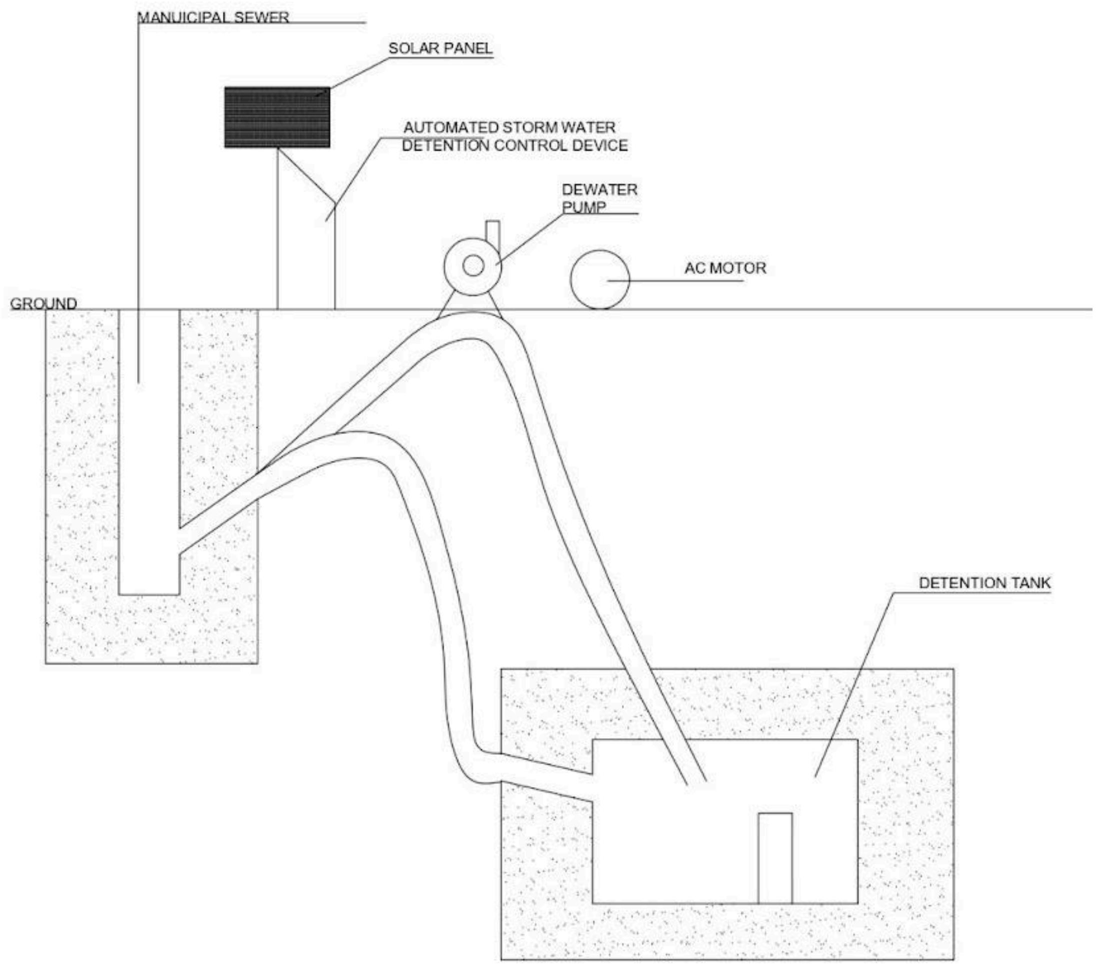


Figure 22. Detention Tank Details

The detailed drawings of the stormwater system are provided in Appendix A.

[2] https://www.fergusongss.com/product/smartpond/

5. Gateway Design

At the core of this design lies a sense of welcome and inclusivity, symbolized prominently by the display of the UBC title. This gateway proudly signifies the University of British Columbia entrance, creating a compelling visual narrative that encapsulates the institution's ethos. The accompanying dimensions of this thoughtfully crafted gateway design, articulated in meters, demonstrate our commitment to seamlessly blending cultural homage with architectural finesse.

The gateway has been meticulously crafted, employing a structural analysis while simultaneously ensuring resilience against collapse, cracking, and any structural failure. The design of the gateway entails poles on each side spanning all lanes while ensuring smooth passage for all vehicles, accommodating varying heights. Considerations for optimal visual distance have been taken into account, resulting in an appropriately sized structure. The gateway design minimizes material usage while ensuring the visibility of signage for passersby.

The texture of the pole incorporates layered stone walls and brick textures, enhancing aesthetic appeal. At the apex, a lighting fixture has been incorporated to illuminate the gateway during nighttime, enhancing both visibility and aesthetics. Figure 23 displays a 2D drawing of the gateway design.

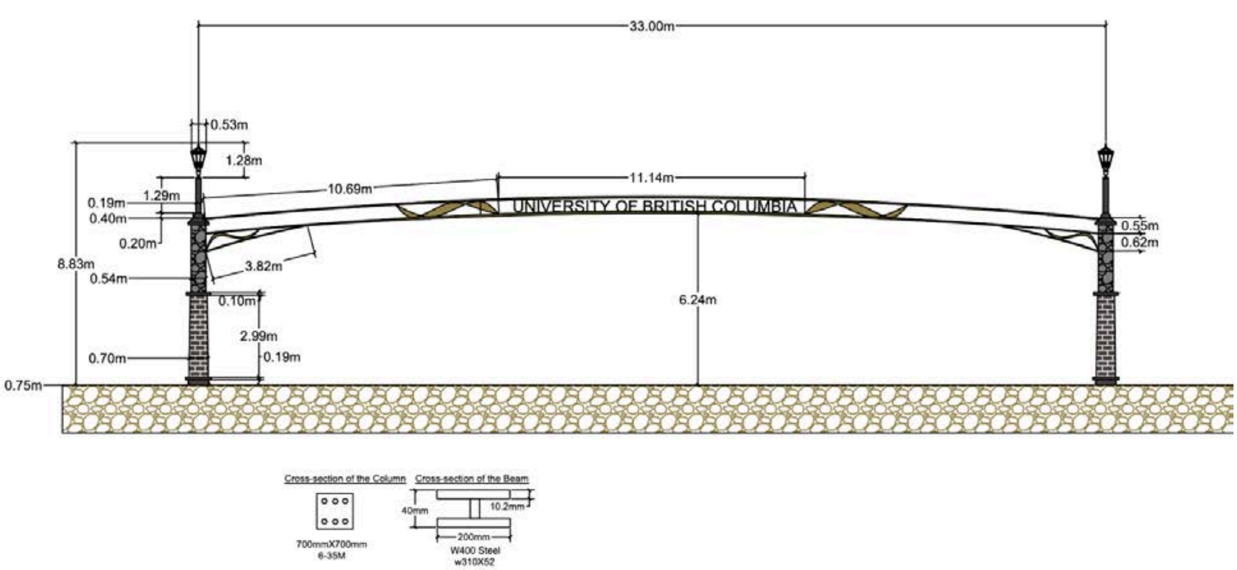


Figure 23. Gateway AutoCAD Drawing with Dimensions

5.1 Gateway Materials

Reinforced concrete serves as the primary material for the gateway, while the lighting fixture is constructed of steel and the UBC signage utilizes aluminum. Column design incorporates big bars measuring 4x20M with a 30mm clear over, and beam design utilizes bars of W400 steel. Structural analysis has been conducted to ensure the integrity of the gateway design. Figure 24 shows the gateway structure labelled with corresponding materials.

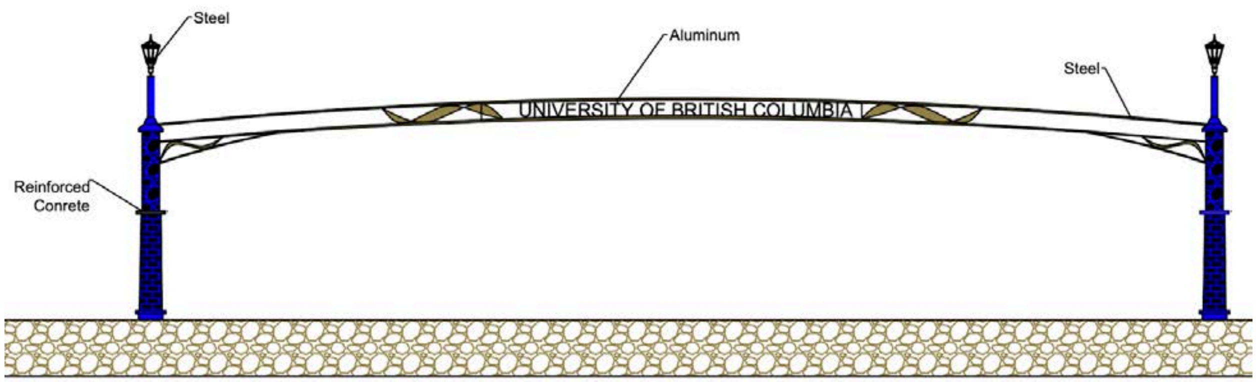


Figure 24. Gateway Material Overview

5.2 Location

The gateway is to be positioned 74 meters from the intersection of SW Marine Drive and 16th Avenue, as shown in Figure 25, strategically chosen to enhance visibility for individuals approaching UBC via SW Marine Drive while avoiding obstruction of the traffic lights. Additionally, the design prioritizes minimizing the necessity for tree removal. Figure 25 illustrates the satellite view of the gateway location.

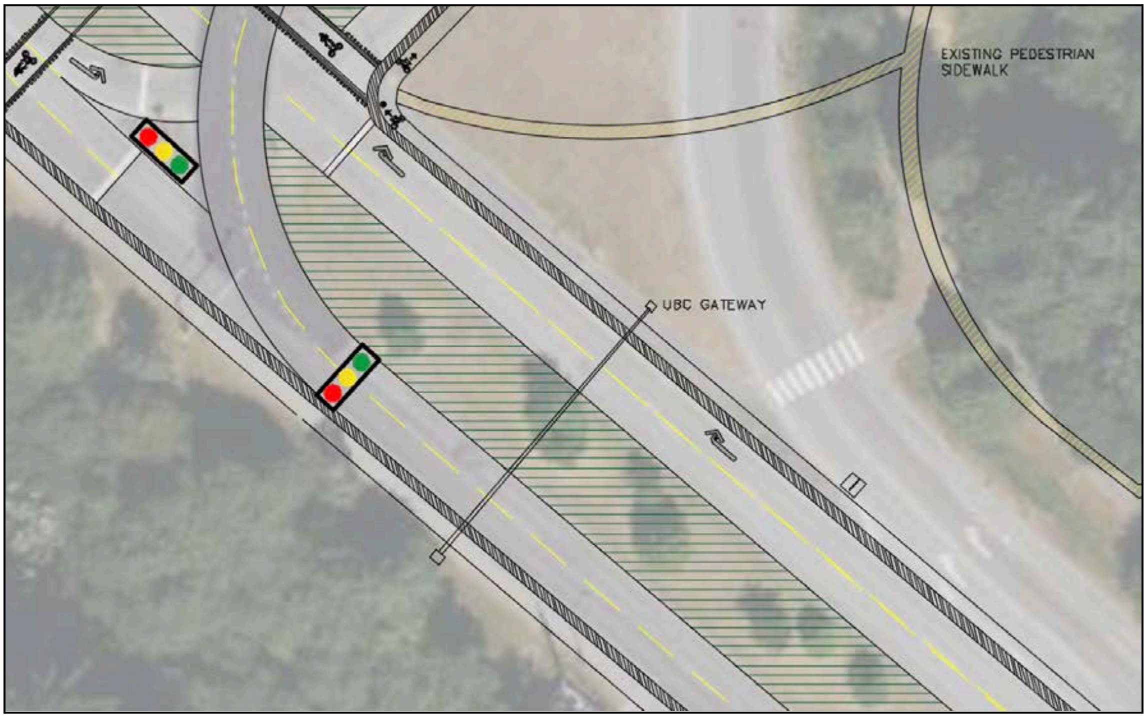


Figure 25. Close View of Gateway Location

6. Construction Work Plan

This section delineates the construction specifications and considerations, detailing the preliminary construction plan with it's sequential phases. Additionally, it identifies anticipated site-specific challenges and presents corresponding mitigation strategies.

6.1 Construction Requirements and Consideration

The scope of construction work includes the intersection geometry redesign, installation of rain gardens, construction of gateway, and road resurfacing and signage. The construction requirements are listed in Table 6 below:

Table 6. Construction Requirements and Considerations

Design Specifications Ready for Construction	Detailed intersection layout and dimensions.
	Rain Garden specifications, such as size, depth, and plant types.
	Gateway detailed design and materials.
	Road resurfacing details.
Traffic Management Plan	Each way of the intersection will remain open during construction.
	Clear signage for drivers and pedestrians.
	Implement efficient communication strategies to manage traffic, inform the public of construction schedules, and minimize disruption.
Environmental Considerations	Protection of existing trees and greenery and minimize tree loss.
	Use of sustainable materials.
	Utilize pollution control measures to prevent construction-related pollution.

6.2 Construction Phases

The scope of construction work includes the intersection geometry redesign, installation of rain gardens, construction of gateway, and road resurfacing and signage. The construction work is separated into three phases as shown in Table 7 below:

Table 7. 3 Phases of Construction

Phase 1	- Site preparation and clearing - Existing utility removal and adjustments - Excavation and grading - Pavement removal and reconstruction - Installation of new road markings and signage
Phase 2	- Excavation and shaping of rain garden areas - Installation of detention tank - Landscaping and installation of permeable surfaces - Planting of appropriate vegetation - Foundation and structural work for the gateway - Installation of gateway
Phase 3	- Quality control checks - Installation of final road markings and signage - Cleanup and restoration of the construction site

Figure 26 illustrates the construction zones for Phases 1 and 2. Phase 3 encompasses the entirety of the intersection for road markings and signage, however, the phase does not cause disturbance or inconvenience to the traffic flow within the intersection.

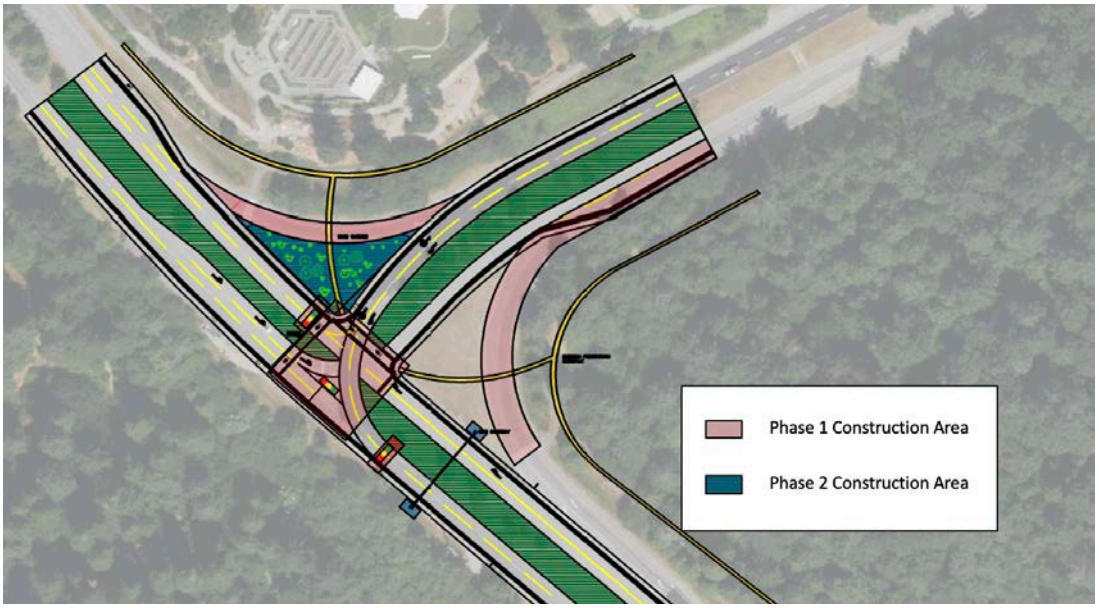


Figure 26. Construction Area

6.3 Anticipate Issues and Mitigation Strategies

Table 8 below describes the anticipated issues regarding construction work and mitigation strategies to combat these issues.

Table 8. Anticipated Issues and Strategies for Construction

Topic	**Issue**	**Mitigation Strategy**
Site Conditions	Soil Quality	Conduct soil tests before rain garden and gateway installation to ensure proper drainage and foundation.
	Underground Utilities	Coordinate with utility companies to accurately locate and adjust any underground utilities necessary.
Weather Conditions	Rainy Weather	Plan for weather-related delays, especially during rain garden installation. Implement proper erosion control measures.
Stakeholder Communication	Community Engagement	Keep the local community informed about construction schedules and progress through regular updates and meetings.

7. Traffic Management Plan

A goal during construction is to minimize traffic disturbance and limit the intersection closure, particularly because this intersection serves as one of the entry points to UBC from SW Marine Drive. The construction is scheduled during the UBC summer terms when traffic volume is reduced, and there's less demand for entry into UBC. The construction process is divided into phases to minimize the overall impact on traffic flow and maintain accessibility to alternative routes for vehicles and users. Effective communication with public transit authorities, the public, and local communities will involve informing them about construction schedules, expected disruptions, and available alternate routes to manage traffic flow during construction. Safety precautions will include maintaining clear visibility of the construction site, adequate lighting, and clear instructions for users.

A Traffic Management Plan is essential to maintain uninterrupted intersection access during construction phases 1 and 2, particularly when work is conducted near roads. Clear signage and traffic controllers will be strategically placed at appropriate distances, adhering to guidelines outlined in the MoTI Traffic Management Manual for Work on Roadways (2020), to ensure the safe and continuous operation of each intersection approach.

8. Project Schedule

The project's consultation and design phase commenced on September 8, 2023. Following a comprehensive process encompassing conceptualization, preliminary design, and final design stages, construction is scheduled to begin on May 1, 2024. The construction schedule delineates the three phases, specifying tasks within each phase. The intersection construction is projected to reach completion by July 19, 2024. For further information, refer to Appendix D for the construction schedule Gantt Chart.

9. Class A Cost Estimate

The total initial Class A cost estimate is $2.12 million. The cost estimate encompasses engineering consultation, permitting processes, and construction expenses. A summary breakdown of initial costs is provided in Table 9. The proposed design's yearly operational and maintenance cost, shown in Table 10, is estimated at $83,879.70. Yearly costs may increase throughout the lifespan due to inflation.

Table 9. Summary Table of Initial Cost Estimate Breakdown

Cost Section		Cost ($)
	Consulting and Permitting	**$333,055.77**
Construction	**Phase 1**	**$1,048,478.33**
	Phase 2	**$240,880.75**
	Phase 3	**$20,698.97**
	Subtotal	**$1,643,113.82**
	Total Cost Estimate (with Tax and Contingency)	**$2,116,330.59**

Table 10. Yearly Operational and Maintenance Cost

Yearly Operation and Maintenance Cost Subtotal	**$66,061.18**
Total Cost Estimate (with Tax and Contingency)	**$83,897.70**

The cost estimate process involved deriving unit costs from RS Means Data, online sources, and publications. 12% tax was applied to the costs. To ensure accuracy, Consumer Price Indices (CPIs) were applied to historical data, and a 15% contingency was factored into the cost estimate to address potential risks and uncertainties. A 15% contingency was added to the total cost estimate to factor in risks and uncertainties. For an extensive breakdown of the cost estimate and any assumptions made, please refer to Appendix E.

10. Conclusion

Our design adequately addressed the design issues and objectives and fulfilled the specifications provided by the client. The intersection design prioritizes safety and speed control, and promotes active transit. Sustainability is integral in guaranteeing the design's resilience to peak traffic demand. After evaluating three conceptual designs, we opted for the Revised Traffic Signal design while incorporating elements from the U-Turn design. The new layout introduces bike lanes, sharper right-turn lanes, and enhances green spaces. A rainwater management system detention tank and rain garden will be implemented. Additionally, a clear, aesthetic gateway designed with clear UBC lettering will welcome all road users onto the UBC campus.

Our team is confident that this new intersection design will largely benefit the community by providing a more efficient and sustainable transportation system. We are hopeful to seeing our design's successful implementation and its positive impact on the community.

Appendix A:

Detailed Drawings and Construction Specifications

GENERAL NOTES:

1. THE METRIC SYSTEM OF MEASUREMENT IS USED ON ALL DRAWINGS. ELEVATIONS AND STATIONS ARE SHOWN IN METRES AND ALL OTHER DIMENSIONS ARE SHOWN IN MILLIMETRES UNLESS NOTED OTHERWISE.

2. READ THE STRUCTURAL DRAWINGS IN CONJUNCTION WITH ALL OTHER PERTINENT CONTRACT DOCUMENTS.

3. REFER TO THE CIVIL, MECHANICAL AND ELECTRICAL DRAWINGS FOR DIMENSIONS OF OPENINGS, SLEEVES AND OTHER COMPONENTS NOT SHOWN ON THE STRUCTURAL DRAWINGS. CONTRACTOR TO CONFIRM EQUIPMENT DIMENSIONS AND ALL OTHER CRITICAL DETAILS PRIOR TO CONSTRUCTION. REPORT DISCREPANCIES AND OBTAIN APPROVAL PRIOR TO PROCEEDING WITH CONSTRUCTION.

4. NOTIFY THE STRUCTURAL DESIGNER 24 HOURS IN ADVANCE FOR INSPECTIONS WHERE REQUIRED.

5. VERIFY SIZE AND LOCATION OF ALL INSERTS, DRAINS, OPENINGS, RECESSES ETC.

6. DRAWINGS ARE SHOWN FOR COMPLETED STRUCTURES ONLY. THE CONTRACTOR IS RESPONSIBLE FOR THE DESIGN OF FORMWORK, SHORING AND OTHER TEMPORARY STRUCTURES DURING CONSTRUCTION. ALL SUCH STRUCTURES SHALL HAVE SUFFICIENT CAPACITY TO RESIST CONSTRUCTION LOADINGS.

7. CONSTRUCTION METHODS REQUIRING TEMPORARY SHORING OR BRACING SHALL BE SUBMITTED TO THE DESIGNER FOR REVIEW. THE CONTRACTOR SHALL RETAIN A PROFESSIONAL ENGINEER REGISTERED IN THE PROVINCE OF BRITISH COLUMBIA TO DESIGN AND TAKE RESPONSIBILITY FOR TEMPORARY SHORING AND BRACING AS REQUIRED TO COMPLETE THE CONSTRUCTION.

8. CONSTRUCTION OF THE WORKS SHALL COMPLY WITH THE FOLLOWING IN ORDER OF PRECEDENCE:
  a.a. DRAWINGS AND DRAWING NOTES
  a.b. GENERAL NOTES
  c.c. PROJECT CONSTRUCTION SPECIFICATIONS

9. ALL PLAN DIMENSIONS ARE MEASURED HORIZONTALLY UNO.

EARTHWORKS:

1. ALL SITE EARTHWORKS RECOMMENDATIONS SHOULD BE COMPLEMENTED BY REFERENCE TO CS XXXX. ANY DELETERIOUS OR CONTAMINATED FILLING SHOULD BE STRIPPED AND DISPOSED OF IN ACCORDANCE WITH THE RECOMMENDATION PROVIDED IN OUR ENVIRONMENTAL REPORT. THE EXPOSED SUBGRADE SHOULD BE PROOF ROLLED, ANY EXISTING UNCONTROLLED FILLING AND RUBBLE BE REMOVED AND REPLACED WITH ENGINEERED FILL AS SPECIFIED BELOW. ENGINEERED FILL IS TO BE USED TO BACKFILL BATTERS AND TO RAISE THE SITE LEVEL WHERE REQUIRED.

2. WHERE CLAYS ARE EXPOSED AT SUBGRADE LEVEL, THEY WILL UNDERGO SUBSTANTIAL LOSS IN STRENGTH WHEN WET AND MAY EVEN BECOME UNTRAFFICABLE. THEREFORE, IT IS IMPORTANT TO PROVIDE GOOD AND EFFECTIVE DRAINAGE DURING CONSTRUCTION. THE PRINCIPAL AIM OF THE DRAINAGE IS TO PROMOTE RUN OFF TOWARDS DESIGNATED SUMPS BY CROSS FALLS AND TO REDUCE PONDING.

3. FOLLOWING STRIPPING AND COMPLETION OF THE PROPOSED EXCAVATIONS, IT IS RECOMMENDED THAT THE SOIL SUBGRADE BE PROOF ROLLED AND INSPECTED BY AN EXPERIENCED GEOTECHNICAL ENGINEER. THE PROOF ROLLING SHOULD INVOLVE AT LEAST FOUR PASSES OF A VIBRATORY SMOOTH DRUM ROLLER (EG. MINIMUM 8 TONNE DEADWEIGHT) FOR THE DETECTION OF UNSTABLE OR "SOFT" AREAS.

4. SUBGRADE HEAVING MAY OCCUR DURING PROOF ROLLING IN AREAS WHERE THE CLAYS MAY HAVE BECOME "SATURATED". HEAVING AREAS SHOULD BE LOCALLY REMOVED TO A "STIFF" BASE AND REPLACED WITH ENGINEERED FILL AS DEFINED BELOW. DEPENDING ON THE EXTENT AND DEPTH OF THE HEAVING AREAS, IT MAY BE NECESSARY TO PROVIDE A BRIDGING LAYER. IF THE INSITU CLAYS EXHIBIT SHRINKAGE CRACKING, THEN THE SURFACE SHOULD BE WATERED AND ROLLED UNTIL THE SHRINKAGE CRACKS ARE NO LONGER EVIDENT. ENGINEERED FILL SHOULD ALSO BE USED WHERE IT IS PROPOSED TO RAISE THE LEVELS.

ENGINEERED FILL:

1. ENGINEERED FILL SHOULD COMPRISE WELL GRADED GRANULAR MATERIAL (SANDS, RIPPED OR CRUSHED SANDSTONE), FREE OF DELETERIOUS SUBSTANCES AND HAVING A MAXIMUM PARTICLE SIZE OF "XX MM". EXCAVATED SANDS FROM THE SITE MAY BE REUSED AS FILL PROVIDED THAT ANY UNSUITABLE MATERIAL (ORGANIC CLAYS) AND ANY BUILDING RUBBLE OR DELETERIOUS MATERIAL IS EXCLUDED. THE ENGINEERED FILL, AND ANY EXCAVATION BACKFILL WHERE SUBGRADE SUPPORT IS REQUIRED, SHOULD BE COMPACTED IN LAYERS OF NOT GREATER THAN "XXX MM" LOOSE THICKNESS, TO A DENSITY RATIO OF XX% OF STANDARD MAXIMUM DRY DENSITY (SMDD) OR TO A MINIMUM OF XX% DENSITY INDEX.
2. DENSITY TESTS SHOULD BE REGULARLY CARRIED OUT ON THE FILL IN ACCORDANCE OF CS XXXX STANDARD TO CONFIRM THE ABOVE SPECIFICATIONS ARE ACHIEVED. THE FREQUENCY OF DENSITY TESTING SHOULD BE AT LEAST ONE TEST PER LAYER PER "XXXX M2 ".

REINFORCED CAST-IN-PLACE CONCRETE:

THE WORK SHALL CONSIST OF:
1. SUPPLYING OF MATERIALS AND THE MIXING AND PLACING OF REINFORCED CAST-IN-PLACE CONCRETE AS SHOWN AND DESCRIBED ON THE DRAWINGS AND IN THIS SPECIFICATION, INCLUDING PLACING, VIBRATING, FINISHING AND CURING;
2. SUPPLYING, FABRICATING, CONSTRUCTING, MAINTAINING AND REMOVING TEMPORARY WORKS, INCLUDING FALSEWORK AND FORMWORK;
3. HEATING AND COOLING CONCRETE, IF NECESSARY;
4. DEVELOPING CONCRETE MIX DESIGN(S) THAT MEETS THE PERFORMANCE REQUIREMENTS, INCLUDING TRIAL BATCHES;
5. THE QUALITY CONTROL (QC) TESTING OF ALL MATERIALS; AND
6. SUPPLYING AND INSTALLING WATER SEALS AND JOINT FILLERS (WHEN APPLICABLE).

CONCRETE SUPPLIED UNDER THIS SPECIFICATION WILL BE SPECIFIED IN ACCORDANCE WITH CSA XXXX.

1. ALL CONCRETE PLANT, EQUIPMENT, AND TRUCK MIXERS COMPLY WITH THE REQUIREMENTS OF CSA XXX AND THIS SPECIFICATION;
2. ALL MATERIALS TO BE USED IN THE CONCRETE COMPLY WITH THE REQUIREMENTS OF CSA XXX AND THIS SPECIFICATION;
3. ALL THE CONCRETE MIX DESIGN(S) SATISFY THE REQUIREMENTS OF CSA XXXX AND THIS SPECIFICATION;
4. PRODUCTION AND DELIVERY OF CONCRETE WILL MEET THE REQUIREMENTS OF CSA XXXX AND THIS SPECIFICATION;

<u>CONTRACTOR'S PERFORMANCE CRITERIA</u>

THE SUBMISSION SHALL INCLUDE THE CONTRACTOR'S PERFORMANCE CRITERIA FOR EACH MIX DESIGN INCLUDING:
1. PLACEABILITY (I.E. PUMPING, BUGGIES, TRUCK CHUTE, ETC.) WORKABILITY
2. PROPOSED SLUMP AND SLUMP RETENTION TIME
3. SET TIME

REFERENCES AND RELATED SPECIFICATIONS
ALL REFERENCE STANDARDS AND RELATED SPECIFICATIONS SHALL BE CURRENT ISSUE OR THE LATEST REVISION AT THE DATE OF TENDER ADVERTISEMENT.
REFERENCES

- ASTM D 75, STANDARD PRACTICE FOR SAMPLING AGGREGATES
- ASTM D 516, STANDARD TEST METHOD FOR SULFATE ION IN WATER
- XXXXX
- XXXXX
- XXXXX

ASTM C 494, STANDARD SPECIFICATION FOR CHEMICAL ADMIXTURES FOR CONCRETE MATERIALS

1. COARSE AGGREGATE
THE MAXIMUM NOMINAL SIZE OF COARSE AGGREGATE SHALL BE 20 MM AND MEET THE GRADING REQUIREMENTS OF CSA XXX, TABLE XX, GROUP XX. COARSE AGGREGATE SHALL BE UNIFORMLY GRADED AND NOT MORE THAN 1% SHALL PASS A 75 UM SIEVE.

2. CEMENTITIOUS MATERIALS
CEMENTITIOUS MATERIALS SHALL CONFORM TO THE REQUIREMENTS OF CAN/CSA XXXX AND SHALL BE FREE FROM LUMPS. NORMAL PORTLAND CEMENT, TYPE GU OR GUB, OR SULPHATE RESISTANT, TYPE HS OR HSB, SHALL BE SUPPLIED UNLESS OTHERWISE SPECIFIED ON THE DRAWINGS.

3. WATER
WATER TO BE USED FOR MIXING AND CURING CONCRETE OR GROUT AND SATURATING THE SUBSTRATE SHALL BE POTABLE, SHALL CONFORM TO THE REQUIREMENTS OF CSA XXXX AND SHALL BE FREE OF OIL, ALKALI, ACIDIC, ORGANIC MATERIALS OR DELETERIOUS SUBSTANCES.

4. FORMWORK
FORMS FOR EXPOSED SURFACES SHALL BE MADE OF GOOD QUALITY PLYWOOD IN "LIKE-NEW" CONDITION AND UNIFORM IN THICKNESS, WITH OR WITHOUT A FORM LINER.

CONSTRUCTION METHOD:

1. MIXING CONCRETE
ALL CONCRETE SHALL BE MIXED THOROUGHLY UNTIL IT IS UNIFORM IN APPEARANCE, WITH ALL INGREDIENTS UNIFORMLY DISTRIBUTED. IN NO CASE SHALL THE MIXING TIME PER BATCH BE LESS THAN ONE MINUTE FOR MIXERS OF ONE CUBIC METRE CAPACITY OR LESS. THE "BATCH" IS CONSIDERED AS THE QUANTITY OF CONCRETE INSIDE THE MIXER. THIS FIGURE SHALL BE INCREASED BY 15 SECONDS FOR EACH ADDITIONAL HALF CUBIC METRE CAPACITY OR PART THEREOF. THE MIXING PERIOD SHALL BE MEASURED FROM THE TIME ALL MATERIALS ARE IN THE MIXER DRUM.

2. TIME OF HAULING
THE MAXIMUM TIME ALLOWED FOR ALL TYPES OF CONCRETE TO BE DELIVERED TO THE SITE OF THE WORK, INCLUDING THE TIME REQUIRED TO DISCHARGE, SHALL NOT EXCEED 90 MINUTES AFTER BATCHING. BATCHING OF ALL TYPES OF CONCRETE IS CONSIDERED TO OCCUR WHEN ANY OF THE MIX INGREDIENTS ARE INTRODUCED INTO THE MIXER, REGARDLESS OF WHETHER OR NOT THE MIXER IS REVOLVING. FOR CONCRETE THAT INCLUDES SILICA FUME, THIS REQUIREMENT IS REDUCED TO 60 MINUTES.

3. FALSEWORK AND FORMWORK
THE DESIGN, FABRICATION, ERECTION, AND USE OF CONCRETE FORMWORK SHALL CONFORM TO THE REQUIREMENTS OF CAN/CSA XXXXX AND CSA XXXX. ALL FORMS SHALL BE OILED OR OTHERWISE TREATED TO FACILITATE STRIPPING. FOR NARROW WALLS AND COLUMNS, WHERE THE BOTTOM OF THE FORM IS INACCESSIBLE, OR WHEREVER NECESSARY, REMOVABLE PANELS SHALL BE PROVIDED IN THE BOTTOM FORM PANEL TO ENABLE CLEANING OUT OF EXTRANEOUS MATERIAL IMMEDIATELY BEFORE PLACING THE CONCRETE.

FALSEWORK SHALL CONFORM TO CSA XXXX, FALSEWORK FOR CONSTRUCTION PURPOSES. ALL FALSEWORK SHALL BE DESIGNED AND

CONSTRUCTED TO PROVIDE THE NECESSARY RIGIDITY AND TO SUPPORT THE LOADS WITHOUT APPRECIABLE SETTLEMENT OR DEFORMATION.

4. PUMPING OF CONCRETE
WHEN THE CONTRACTOR CHOOSES TO PUMP THE CONCRETE, THE OPERATION OF THE PUMP SHALL PRODUCE A CONTINUOUS FLOW OF CONCRETE WITHOUT AIR POCKETS. THE EQUIPMENT SHALL BE ARRANGED SUCH THAT VIBRATION IS NOT TRANSMITTED TO THE FRESHLY

PLACED CONCRETE THAT MAY DAMAGE THE CONCRETE. WHEN PUMPING IS COMPLETED, THE CONCRETE REMAINING IN THE PIPELINE, IF IT IS TO BE USED, SHALL BE EJECTED IN SUCH A MANNER THAT THERE WILL BE NO CONTAMINATION OF THE CONCRETE OR SEPARATION OF THE INGREDIENTS.
COLD WEATHER PRECAUTIONS

1. GENERAL
WHEN THE AMBIENT TEMPERATURE FALLS BELOW 5°C OR WHEN THERE IS A PROBABILITY OF IT FALLING BELOW 5°C WITHIN 24 HOURS OF
PLACING THE CONCRETE, THE CONTRACTOR SHALL MAKE PROVISIONS FOR HEATING THE WATER, AGGREGATES AND FRESHLY DEPOSITED
CONCRETE.

2. AGGREGATES
AGGREGATES SHALL BE HEATED TO A TEMPERATURE OF NOT MORE THAN 65°C. FOR CONCRETE CONTAINING SILICA FUME, THE AGGREGATE SHALL NOT BE HEATED TO MORE THAN 40°C. THE HEATING APPARATUS AND THE HOUSING FOR THE AGGREGATES SHALL BE SUFFICIENT TO HEAT THE AGGREGATES UNIFORMLY WITHOUT THE POSSIBILITY OF THE OCCURRENCE OF HOT SPOTS WHICH MAY BURN THE MATERIALS.

3. WATER
THE WATER SHALL BE HEATED TO A TEMPERATURE OF NOT MORE THAN 65°C. FOR CONCRETE CONTAINING SILICA FUME, THE WATER SHALL NOT BE HEATED TO MORE THAN 40°C.

4. CONCRETE
THE TEMPERATURE OF THE MIXED CONCRETE SHALL NOT BE LESS THAN 15°C AND NOT MORE THAN 25°C AT THE TIME OF PLACING IN THE TEMPERATURE REQUIREMENTS FOR CONCRETE CONTAINING SILICA FUME SHALL BE BETWEEN 10°C AND 18°C AT THE TIME OF PLACING IN THE FORMS. SUFFICIENT STAND-BY HEATING EQUIPMENT MUST BE AVAILABLE TO ALLOW FOR ANY SUDDEN DROP IN OUTSIDE TEMPERATURES AND ANY BREAKDOWNS THAT MAY OCCUR IN THE EQUIPMENT.

5. CURING REQUIREMENTS
WATER CURING OF CONCRETE SHALL BE TERMINATED AT LEAST 12 HOURS BEFORE THE END OF THE PROTECTION PERIOD DURING PERIODS OF FREEZING WEATHER. THE CURING COMPOUND SHALL BE WATER BASED MEMBRANE FORMING AND OF A TYPE APPROVED BY THE ENGINEER. IT SHALL CONFORM TO THE REQUIREMENTS OF ASTM XXXX AND BE APPLIED AS DIRECTED BY THE MANUFACTURER. THE RATE OF EACH APPLICATION SHALL NOT BE LESS THAN THE RATE SPECIFIED BY THE MANUFACTURER OF THE COMPOUND. IF RAIN FALLS ON THE NEWLY COATED CONCRETE BEFORE THE FILM HAS DRIED SUFFICIENTLY TO RESIST DAMAGE, OR IF THE FILM IS DAMAGED IN ANY OTHER MANNER DURING THE CURING PERIOD, A NEW COAT OF SOLUTION SHALL BE APPLIED TO THE AFFECTED PORTIONS EQUAL IN CURING VALUE TO THAT SPECIFIED ABOVE.
ALL SUPERSTRUCTURE CONCRETE WITH A SPECIFIED EXPOSURE CLASS OF C-XL OR C-1 SHALL BE WET CURED FOR A MINIMUM PERIOD OF 7 DAYS AT A MINIMUM TEMPERATURE OF 15°C AND FOR THE TIME NECESSARY TO ATTAIN 50% OF THE SPECIFIED COMPRESSIVE STRENGTH.

6. QUALITY CONTROL
SAMPLING OF CONCRETE SHALL BE CARRIED OUT IN ACCORDANCE WITH CSA XXXXX. WHEN A CONCRETE PUMP IS USED TO PLACE CONCRETE, SAMPLING SHALL BE AT THE END OF THE DISCHARGE HOSE. MAKING AND CURING CONCRETE TEST CYLINDERS SHALL BE CARRIED OUT IN ACCORDANCE WITH CSA XXXXX, EXCEPT THAT THE TIME FOR CYLINDERS TO REACH THE TESTING LABORATORY SHALL BE BETWEEN 20 AND 48 HOURS. THE TEST CYLINDERS SHALL BE CAST BY THE CONTRACTOR IN STANDARD CSA APPROVED MOULDS.

7. OPEN TO TRAFFIC
THE STRUCTURE SHALL NOT BE OPENED TO TRAFFIC UNTIL THE CONCRETE HAS ATTAINED A MINIMUM COMPRESSION STRENGTH OF 100% OF THE DESIGN STRENGTH. THE CONTRACTOR SHALL BE RESPONSIBLE FOR ALL COSTS ASSOCIATED WITH ANY ADDITIONAL TESTING THAT MAY BE REQUIRED TO SATISFY THE STRENGTH REQUIREMENT.

NO.	DATE	BY	CK	REVISIONS DESCRIPTION
	2024-04-10	XH	RS	ISSUE FOR 100% REVIEW
	2023-12-05	XH	RS	ISSUE FOR 50% REVIEW

SEAL

DATE:

GREMH11
Engineering Ltd.

DESIGNED BY:	
DRAWN BY:	
CHECKED BY:	
APPROVED BY:	
SCALE	HORIZ: AS SHOWN VERTI: AS SHOWN

DIMENSIONS IN METERS

PROJ NO.

PROJECT: Redesign of 16th Avenue / SW Marine Drive Intersection

LOCATION: 49°15'07.2"N 123°14'47.5"W

DRAWING NO.

SHEET

REV

LOCATION

GENERAL
LAYOUT

NO.	DATE	BY	CK	REVISIONS DESCRIPTION
	2024-04-1	XH	RS	ISSUE FOR 100% REVIEW
	2023-12-0	XH	RS	ISSUE FOR 50% REVIEW

SEAL

DATE:

GREMH11
Engineering Ltd.

DESIGNED BY:
DRAWN BY:
CHECKED BY:
APPROVED BY:
SCALE HORIZ: AS SHOWN VERT: AS SHOWN

DIMENSIONS IN METERS

PROJ NO.

PROJECT: Redesign of 16th Avenue / SW Marine Drive Intersection

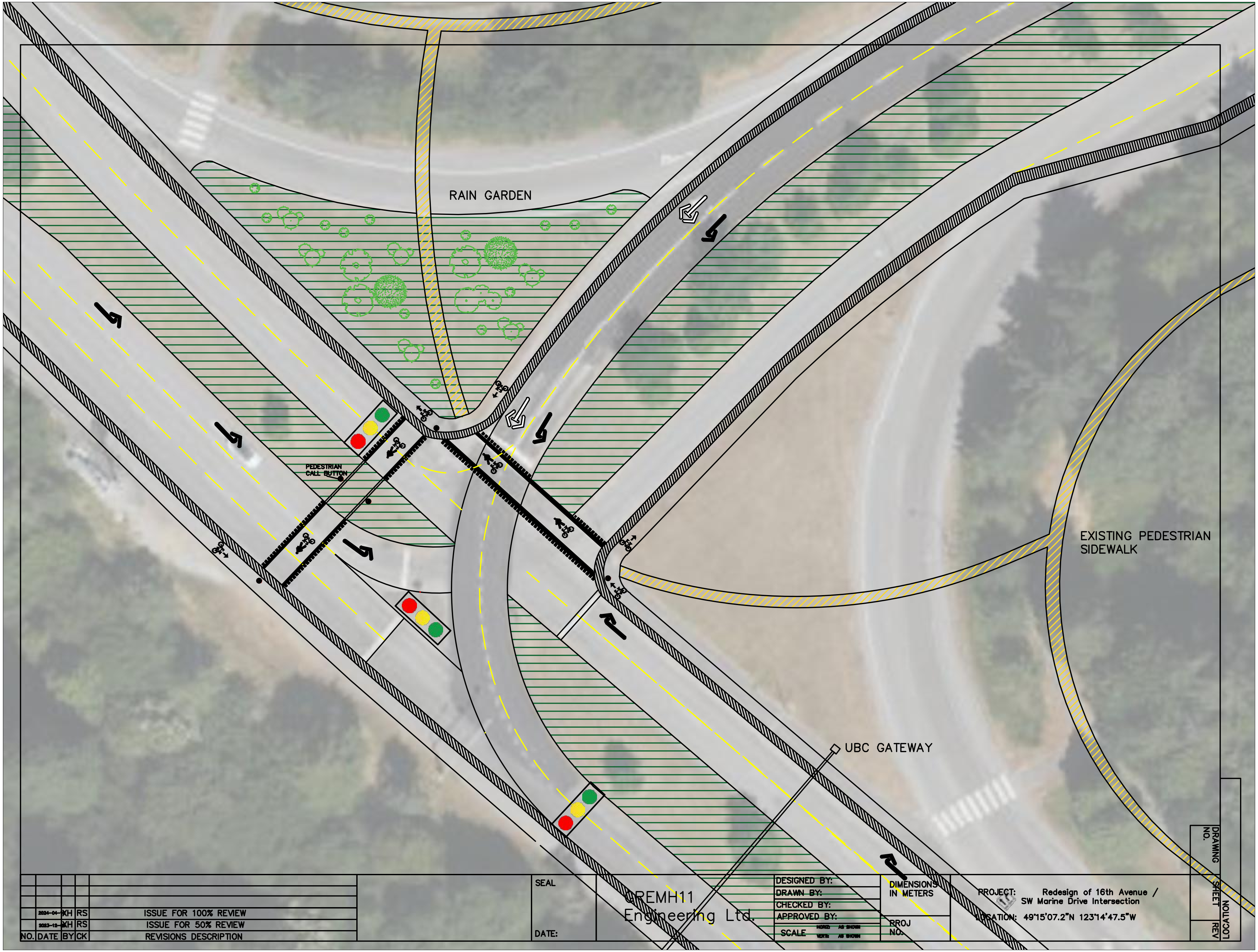
LOCATION: 49°15'07.2"N 123°14'47.5"W

DRAWING NO.

SHEET

REV

LOCATION


RAIN GARDEN
PEDESTRIAN CALL BUTTON
EXISTING PEDESTRIAN SIDEWALK
UBC GATEWAY
SEAL
DATE:
GREMH11 Engineering Ltd.
2024-04-1 XH RS ISSUE FOR 100% REVIEW
2023-12- XH RS ISSUE FOR 50% REVIEW
NO. DATE BY CK REVISIONS DESCRIPTION
DESIGNED BY:
DRAWN BY:
CHECKED BY:
APPROVED BY:
SCALE HORIZ: AS SHOWN VERT: AS SHOWN
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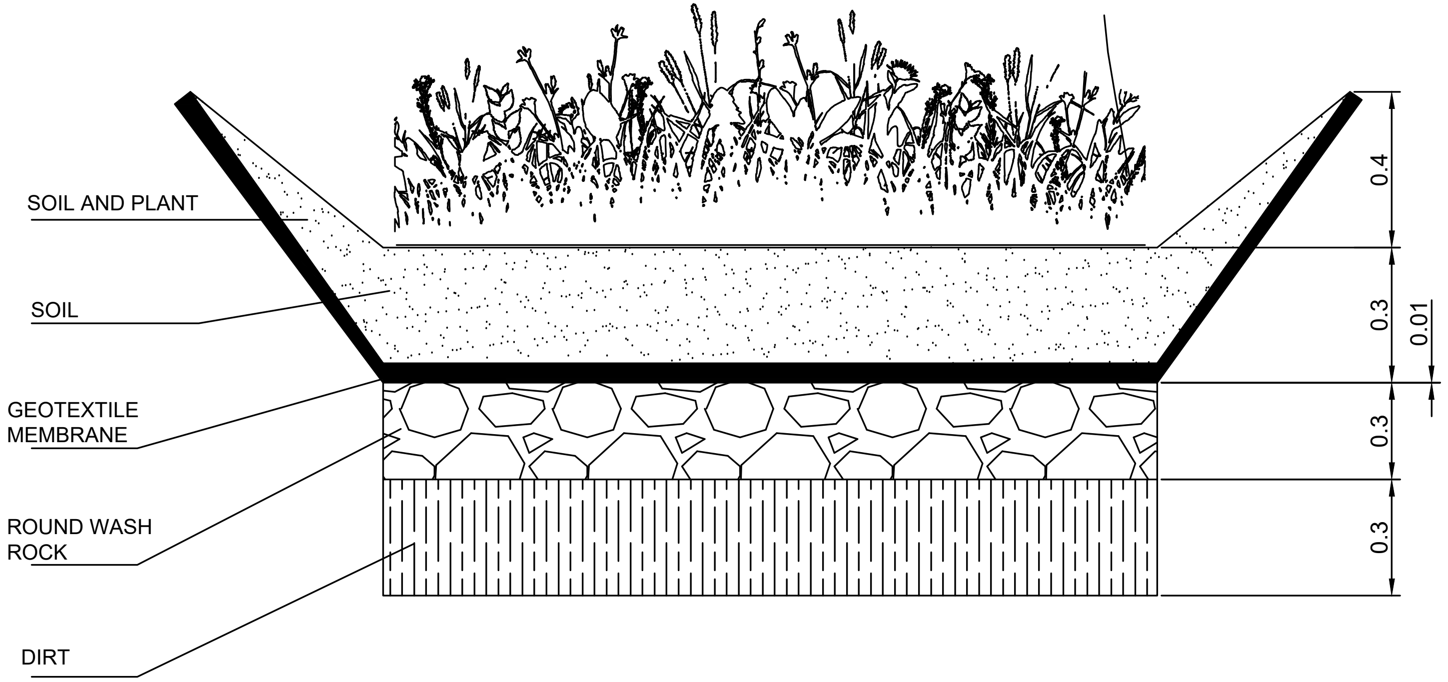

RAIN GARDEN CROSS-SECTIONAL AREA VIEW

NO.	DATE	BY	CK	REVISIONS DESCRIPTION
	2024-04-10	XH	RS	ISSUE FOR 100% REVIEW
	2023-12-05	XH	RS	ISSUE FOR 50% REVIEW

SEAL

DATE:

GREMH11
Engineering Ltd.

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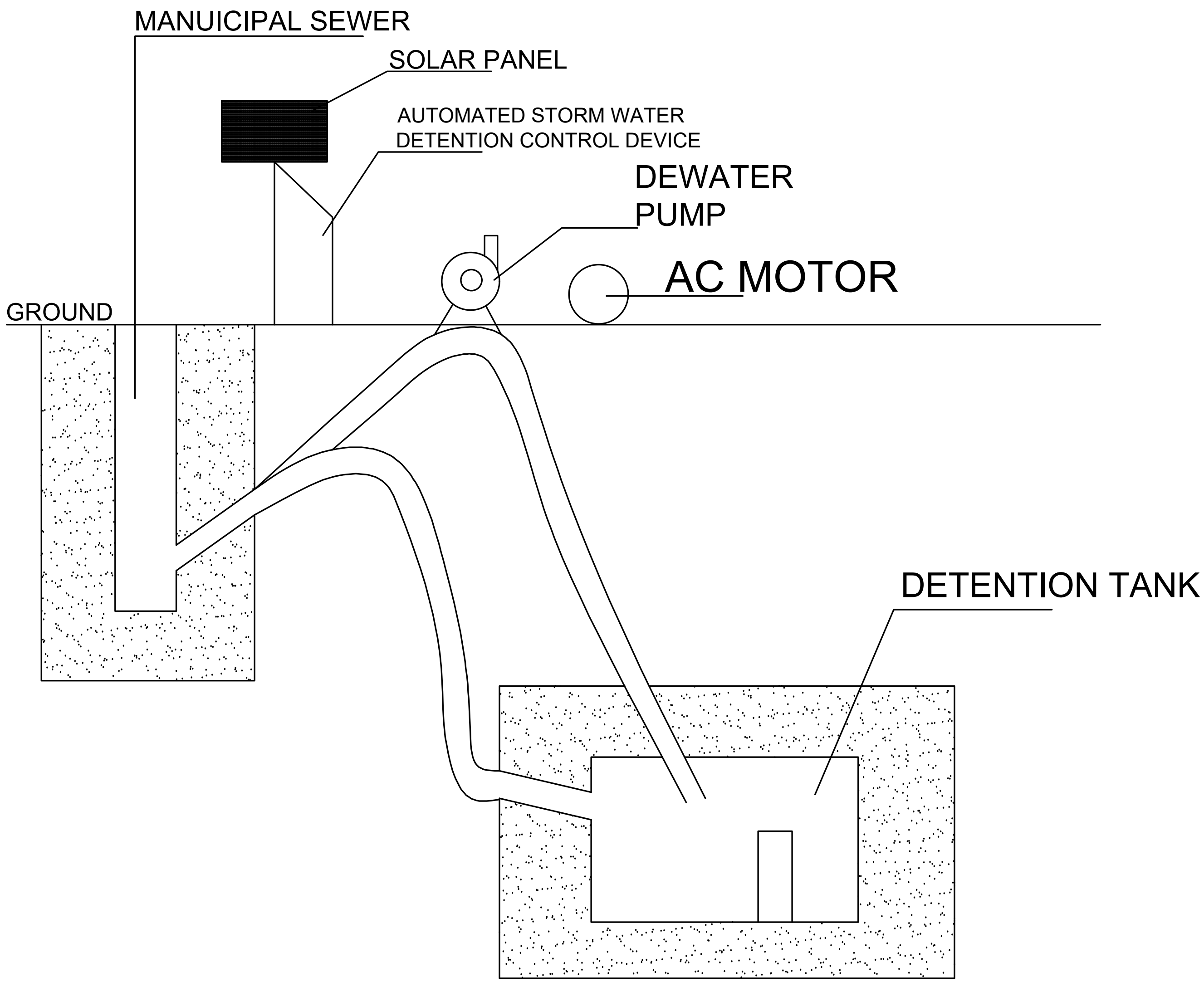

DETENTION TANK DETAILS

NO.	DATE	BY	CK	REVISIONS DESCRIPTION
	2024-04-10	XH	RS	ISSUE FOR 100% REVIEW
	2023-12-05	XH	RS	ISSUE FOR 50% REVIEW

SEAL

DATE:

GREMH11
Engineering Ltd.

DESIGNED BY:
DRAWN BY:
CHECKED BY:
APPROVED BY:
SCALE HORIZ: AS SHOWN VERTI: AS SHOWN

DIMENSIONS IN METERS

PROJ NO.

PROJECT: Redesign of 16th Avenue / SW Marine Drive Intersection

LOCATION: 49°15'07.2"N 123°14'47.5"W

DRAWING NO.
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REV
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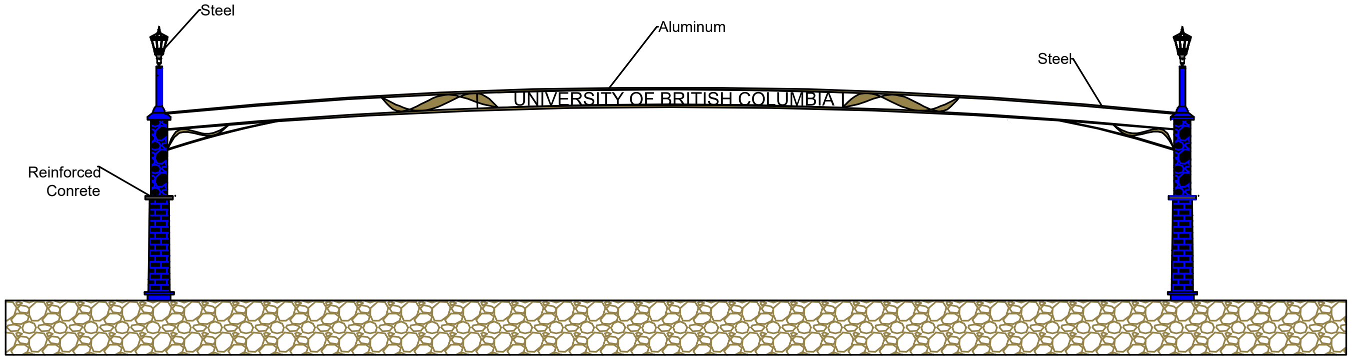
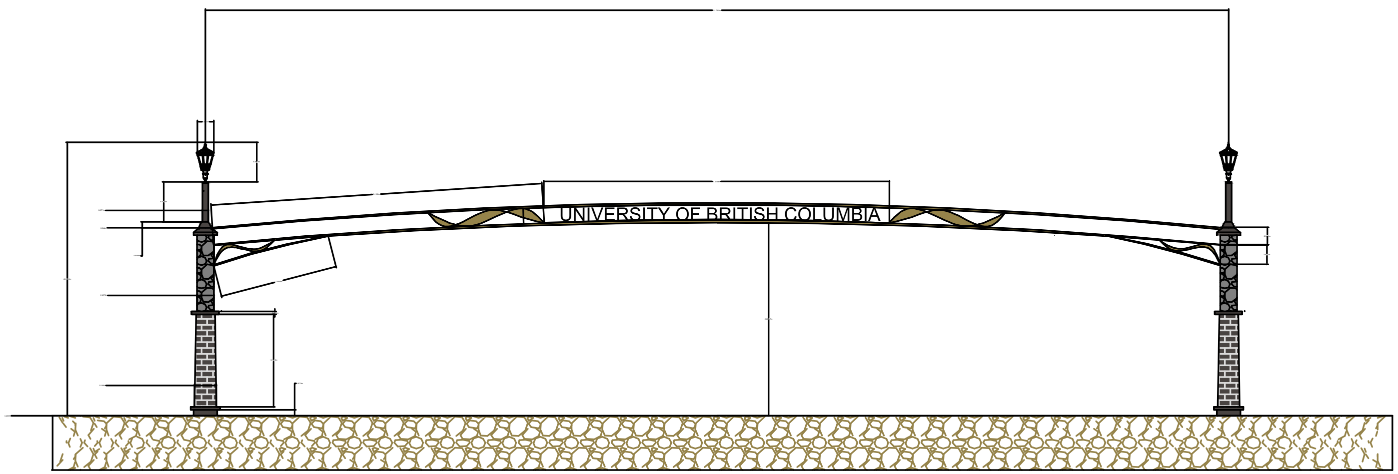
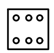


GATEWAY MATERIAL PLAN



GATEWAY DIMENSION PLAN

Cross-section of the Column



700mmX700mm
6-35M

Cross-section of the Beam

170mmX170mm
2-15M
30mmClear
Cover

NO.	DATE	BY	CK	REVISIONS DESCRIPTION
	2024-04-10	XH	RS	ISSUE FOR 100% REVIEW
	2023-12-05	XH	RS	ISSUE FOR 50% REVIEW

SEAL

DATE:

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Engineering Ltd.

DESIGNED BY:
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DIMENSIONS
IN METERS

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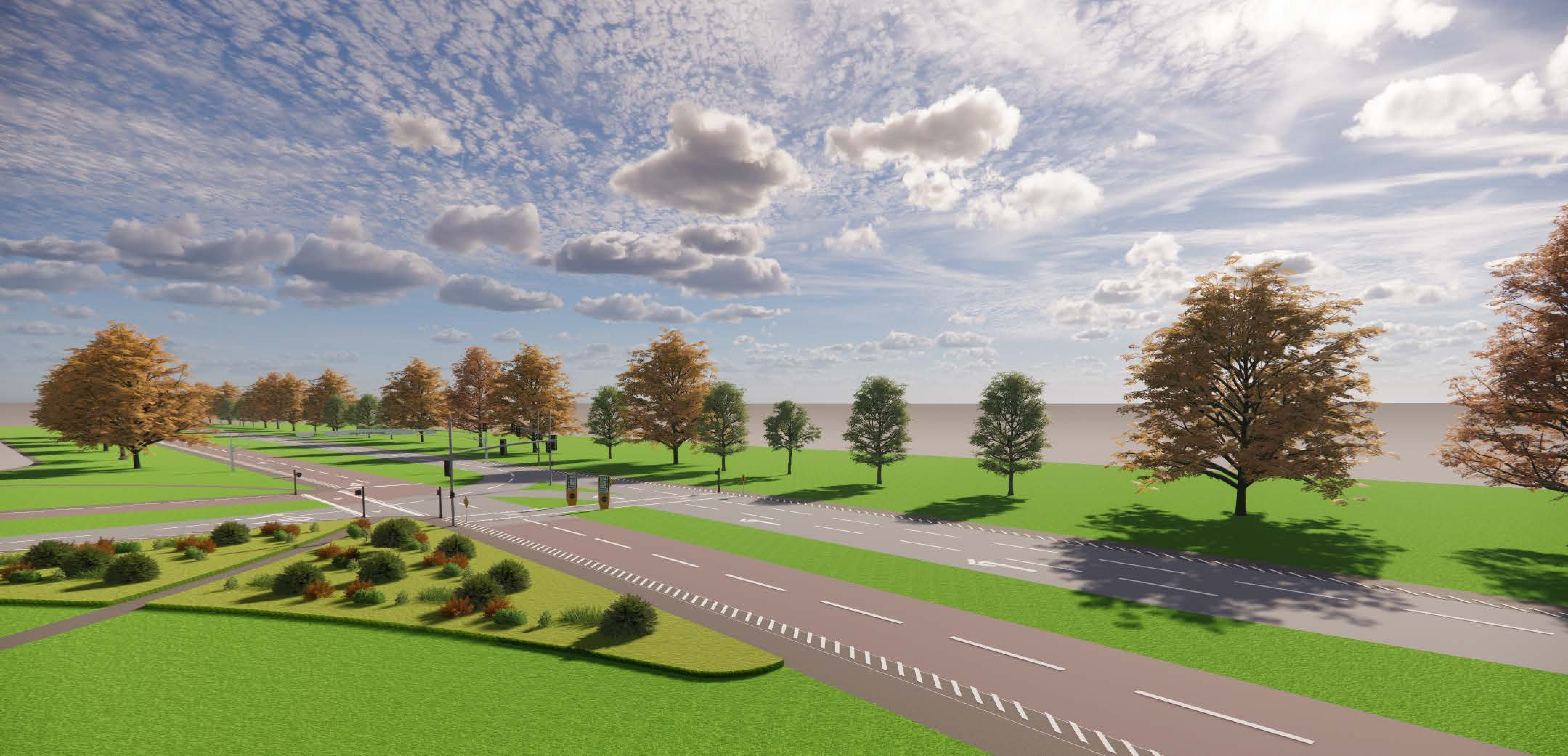


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Appendix B: Stormwater Calculations

Total Study Area = 24000m^2; Area of non-permeable pavement: 4 * 3000m^2 = 12000m^2

For a 50-year 24-hour storm, the precipitation amounts besides evaporation that needs to be captured is 109.64mm/day-1mm/day = 108.64mm/day.

For a 10-year 24-hour storm, the precipitation amounts besides evaporation that needs to be captured is 80.44mm/day-1mm/day = 79.44mm/day.

Stormwater can not be drained in a 10-year 24-hour storm: 79.44mm/day*(1-95%)=3.972mm/day.

Stormwater can not be drained in a 50-year 24-hour storm: 108.64-79.44+3.972= 33.2mm/day.

The stormwater volume created by the pavement is 0.0332m * 12000m^2 = 398.4m^3

The capture volume for rain gardens in a 24-hour period is calculated below:

Growing Medium = Volume of growing medium * Soil available for water retention
= 1000m^2 * 0.117
= 117m^3

Infiltration = 24-hour infiltration * Surface area
= 0.0015m * 24hr * 1000m^2
= 36m^3

Rockpit = Volume of Rockpit * Available water content
= 1000m^2 * 0.4m * 0.35
= 140m^3

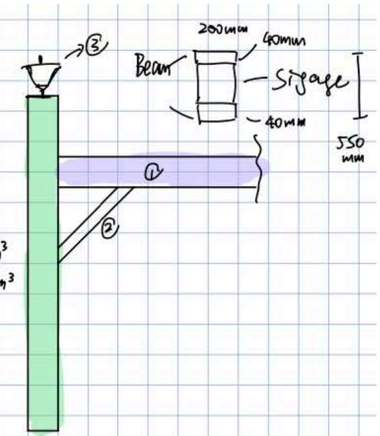
Capture Volume = Growing Medium + Infiltration + Rockpit
= 117m^3 + 36m^3 + 140m^3
= 293m^3

The left stormwater volume is 398.4-293 = 105.4m^3 (Detention tank min requirement)

Acceptable flow rate: 1200 m^3 / 20h / 3600s = 0.016m^3/s

Appendix C: Gateway Structural Analysis

Since the gateway design have 2 column on each side symmetric,
we can only conside one part as the other side is the same



Column Design

Dead Load:

Approximate:

"University of British Columbia" sign $= 11.14 \times (0.55 - 0.04 \times 2)(0.2) = 1.05\ m^3$ → Aluminum $24\ kN/m^3$

Decoration besides the sign $= 3.69 \times 2 \times 0.47 \times 0.02 \times 50\% = 0.035\ m^3$ → Steel $77\ kN/m^3$

$\Rightarrow$ $1.05\ m^3 \times 24\ kN/m^3 = 25.2\ kN$
$0.035\ m^3 \times 77\ kN/m^3 = 2.695\ kN$ ①

Weight of light and beam ②:

$77\ kN/m^3 \cdot (0.53m)^2 (1.28m) = 27.69\ kN$ ③

$23.5\ kN/m^3 \cdot 3.82m \cdot 0.2m \cdot 0.04m \cdot 2 = 1.44\ kN$ ②

Total weight: $1.05 + 0.035 + 27.69 + 1.44 = 30.22\ kN$

From BCBC Table 4.1.3.2.-A case 1 & 2 is suitable.

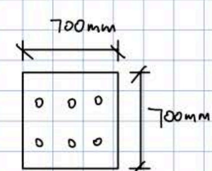
$Load_{ULS} = 1.4D = 1.4 \times (30.22) = 42.31\ kN$ ✓

$Load_{ULS} = 1.25D + 1.5L = 1.25(30.22) = 37.78\ kN$

Total Axial Load (P_f) is $42.31\ kN$

BAR Design ~ BIG BARS 6x 35M BAR

	Bar Size	Nominal Diameter (mm)	Nominal Area (mm^2)
Small Bars	10M	10	100
	15M	15	200
	20M	20	300
Big Bars	25M	25	500
	30M	30	700
	35M	35	1000



cross-section of Tied Rectangular column

$A_b = 1000\ mm^2 \quad A_s = 6 \cdot A_b = 6000\ mm^2$

$A_c = A_g - A_s = 700^2 - 6000 = 484000\ mm^2$

$\rho = \frac{A_s}{A_g} = \frac{6000}{484000} = 1.23\%$ ✓ within the range of 1% and 4%

Axial Load Resistance of Column (Design Column Req: $P_r \le P_{r,max}$)

Assumed $f'_c = 30MPa$, 400W steel $\alpha_1 = 0.85 - 0.015 f'_c = 0.805$

$A_c = (700mm)^2 = 490000\ mm^2$

For tied columns with least dim = 700 mm:

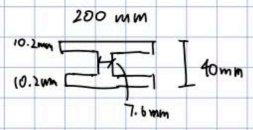
$P_{ro} = \alpha_1 \phi_c f'_c A_c + \phi_s f_y A_s = (0.805)(0.65)(30)(484000) + (0.85)(400)(6000) = 9837.59\ kN$

$P_{r,max} = 0.80 P_{ro} = 7710.07\ kN$

$P_{r,max} > P_f$ ✓

STEEL Design - Flexural Member (Beams)

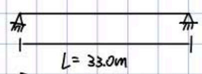
LATERALLY SUPPORTED BEAM → NO CTB



W310x52

Assume: W400 steel → $F_y = 400$ MPa

simply supported



① Flange $\frac{b_{el}}{t} = \frac{216}{2} \times \frac{1}{13.2} = 8.19 \le \frac{170}{\sqrt{F_y}} = 8.5$

Web $\frac{h}{w} = \frac{40-2\cdot 10.2}{7.6} = 2.5 \le \frac{1700}{\sqrt{F_y}} = 85$ } Class

② $M_r = \phi \cdot Z \cdot F_y = 0.9 \cdot 837\times10^3 mm^3 \cdot 400MPa = 301.32 kN\cdot m$

2 beam

③-④ $M_u = M_{max} = \frac{PL}{4} = \frac{36.26 \cdot 33}{4} = 299.15 \ kN\cdot m$ $\left(\frac{P}{2} = \frac{6684+5.68}{2} = 36.26\right)$

$M_r > M_{max}$ ✓

Shear Capacity

$V_r = \phi A_w F_s$ $\phi = 0.9$ A_w = shear Area F_s = critical shear stress

$V_r = 0.9 \cdot 7.6 \cdot (40-2\cdot10.2) \cdot 0.66 \cdot 400 = 35.39 kN$

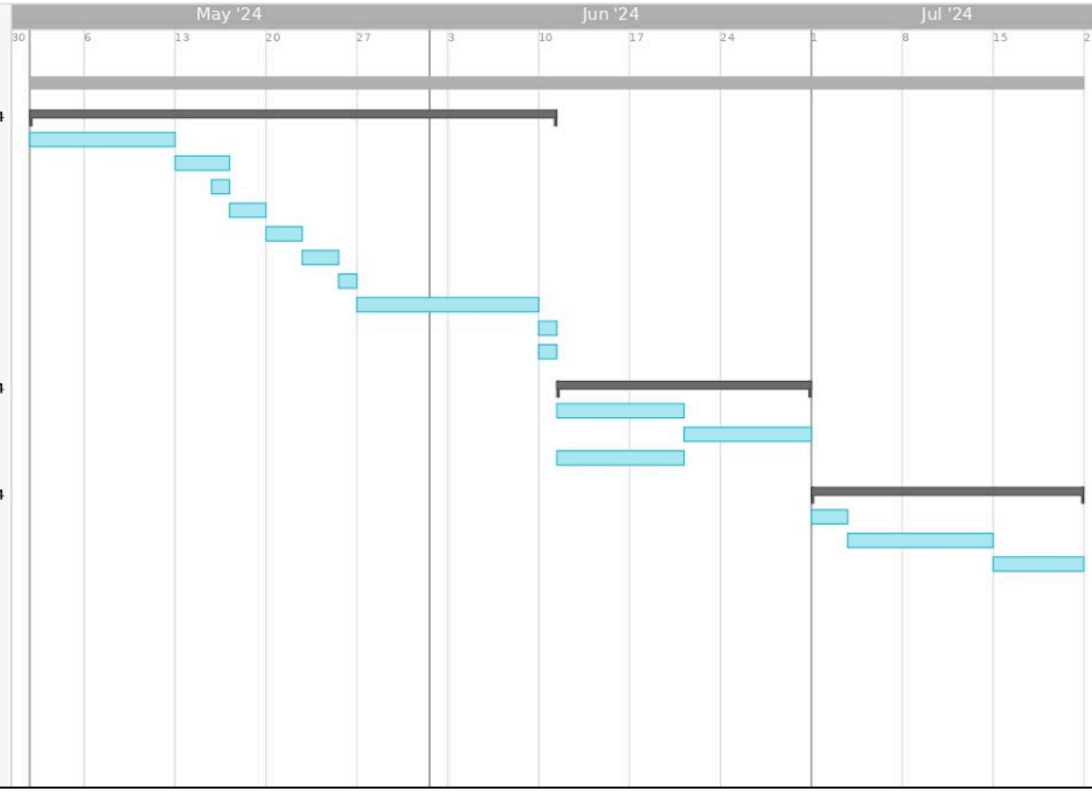
$\frac{h}{w} \le 439\sqrt{\frac{k_v}{F_y}}$ $\frac{19.6}{7.6} \le 439 \cdot \sqrt{\frac{5.34}{400}} \Rightarrow 2.58 \le 50.72 \Rightarrow F_s = 0.66F_y$

$V_{max} = \frac{P}{2} = \frac{36.26}{2} = 18.13 kN$

$V_r > V_{max}$ ✓

Appendix D: Construction Schedule

Redesign of 16th Avenue / SW Mar...	start	end
Phase 1	**05/01/24**	**06/10/24**
Mobilization	05/01	05/10
Existing Utility Removal	05/13	05/15
Temporary Stop Installation	05/15	05/15
Excavation	05/16	05/17
Pavement Removal	05/20	05/21
Grading/Leveling/Compaction	05/22	05/23
Asphaltic Concrete Paving	05/24	05/24
Lighting Installation	05/27	06/07
Lane Separation Markings	06/10	06/10
Signage Installation	06/10	06/10
Phase 2	**06/11/24**	**06/28/24**
Detention Tank Installation	06/11	06/19
Rain Garden Installation	06/20	06/28
Gateway Installation	06/11	06/19
Phase 3	**07/01/24**	**07/19/24**
Final Road Markings and Signage Installation	07/01	07/02
Site Clean-up/Demobilization	07/03	07/12
Regulatory Standard Inspection/Testing	07/15	07/19



Appendix E: Cost Estimate Tables

Sec.	Description	MATERIAL			LABOUR			Subtotal
		Unit	Unit Rate	Qty.	Unit	Unit Rate	Qty.	
PHASE 1								
1.1	***Mobilization***	trailer	$1,370.00	2	trailer	$1,687.20	2	$6,114.40
1.2	***Excavation***	m^3	$3.78	130.25	m^3	$3.74	130.25	$979.48
1.3	***Pavement Removal***	m^2	$4.53	1570	m^2	$3.52	1570	$12,638.50
1.4	***Grading/Levelling/Compaction***	m^2	$4.12	1830.5	-	-	-	$7,541.66
1.5	***Asphaltic Concrete Paving***	m^2	$2,502.79	260.5	m^2	$38.09	260.5	$661,898.53
1.6	***Lighting Installation***							
1.6.1	Vertical Mast/Foundation	signal	$15,177.00	4	signal	$11,578.5	4	$107,022.00
1.6.2	Pedestrian Signals/Callers	signal	$4,441.85	3	signal	$2,303.25	3	$20,235.30
1.6.3	Miscellaneous	signal	$35,630.20	1	signal	$23,157.00	1	$58,787.20
1.7	***Lane Separation Markings***	m	$3.04	2078	m	$0.80	2078	$7,979.52
1.8	***Signage Installation***	each	$50.00	3	each	$70.00	3	$360.00
							PHASE 1 TOTAL	**$883,556.59**
PHASE 2								
2.1	***Detention Tank Installation***							
2.1.1	Detention Tank Excavation	-	-	-	m^3	$10.00	400	$4,000.00

2.1.2	Detention Tank	piece	$62,000.00	1	piece	$1,222.45	1	$63,222.45
2.1.3	8in Pipe	m	$1,000.00	10	m	$12.53	10	$10,125.30
2.1.4	8in Pump	LS	$5,000.00	1	LS	$1,407.00	1	$6,407.00
2.1.5	Motor	LS	$7,500.00	1	LS	$1,369.00	1	$8,869.00
2.1.6	Control Device	LS	$3,000	1	LS	$1,376.00	1	$4,376.00
2.2	***Rain Garden Installation***							
2.2.1	Foundational Work	m^3	$90.00	300	m^3	$9.48	300	$29,844.00
2.2.2	Geotextile Membrane	m^2	$5.00	1000	m^2	$0.65	1000	$5,650.00
2.2.3	Top Soil	m^3	$85.00	400	m^3	$7.41	400	$36,964.00
2.2.4	Planting	-	-	-	LS	$30,000.00	1	$30,000.00
2.3	***Gateway Installation***							
2.3.1	Reinforced Concrete Beam	m^2	$17.65	18.15	m^2	$116.33	18.15	$2,431.74
2.3.2	Reinforced Concrete Column	m^2	$22.19	7.4152	m^2	$114.55	7.4152	$1,013.95
2.3.3	Steel/Aluminum Lettering/Bars	m^2	$9.89	7.423	m^2	$1.92	7.423	$87.67
							PHASE 2 TOTAL	**$202,991.11**
PHASE 3								
3.1	***Final Road Markings/Signage***	m^2	$9.30	67.5	m^2	$85.94	67.5	$6,428.70
3.2	***Site Clean-up/Demobilization***	trailer	$1,370.00	2	trailer	$1,687.2	2	$6,114.40
3.3	***Standard Inspection/Testing***							
3.3.1	Engineer, Average	-	-	-	week	$2,300.00	1	$2,300.00

3.3.2	Senior Engineer	-	-	-	week	$2,600.00	1	$2,600.00
							PHASE 3 TOTAL	**$17,443.10**
							CONSTRUCTION SUBTOTAL	**$1,103,990.80**
							CPI ADJUSTED SUBTOTAL	**$1,310,058.05**

		Cost ($)	Description	
A	**ADDITIONAL FEES**			
A.1	Consultation	$249,867.08	All engineering consulting fees up to the end of Detailed Design Phase	
A.2	Permitting/Approvals	$83,188.69	5% of total construction costs	
			SECTION C TOTAL	**$333,055.77**

Project Subtotal	**$1,643,113.82**
Total with Taxes (5% GST, 7% PST) and 15% Contingencies	**$2,116,330.59**
Future Operation/Maintenance Cost (Section B below)	**$83,897.70**

		Qty.	Unit	Yearly Unit Rate	Total Yearly Cost ($)	Description
B	**OPERATION AND MAINTENANCE**					
B.1	Traffic Signal Maintenance	3	each	$5,319.46	$15,958.37	
B.2	Crossing Signal Maintenance	4	each	$2,727.93	$10,911.70	
B.3	Stormwater Tank Maintenance	-	-	-	$9,699.98	10% of detention tank costs

B.4	Rain Garden Maintenance	-	-	-	$7,245.80	10% of rain garden costs
B.4	Lane Markings (Repainting)	2078	m	$0.64	$268.80	Requires repainting every 6 years
B.5	Arrow/Symbol Markings (Repainting)	67.5	m^3	$95.24	$6,095.36	Requires repainting every 6 years
D.6	Site, Road, and Shrub Maintenance	1000	m^2	$1.83	$1,830.00	De-icing and greenery maintenance
				SECTION D TOTAL	**$55,670.01**	Yearly operation and maintenance costs may increase over the project life span due to inflation.
				CPI ADJUSTED TOTAL	**$66,061.18**	
				Total with Taxes (5% GST, 7% PST) + 15% Contingencies	**$83,897.70**	

References

BC MoTI. (2023, April). Capital Program Board - Memorandum

BC MoTI. CONSTRUCTION AND REHABILITATION COST GUIDE (2013).

BC MoTI. Traffic Management Manual for Work on Roadways (2020)

BCRB Asphalt index (BCRBAI). (2023). Retrieved from: *https://www.roadbuilders.bc.ca/bc-asphalt-index/*

BC Supplement to TAC Geometric Design Guide for Canadian Roads. (2019). Retrieved from: https://www2.gov.bc.ca/gov/content/transportation/transportation-infrastructure/engineering-standards-guidelines/highway-design-survey/tac-bc

Computerized IDF_CC Tool. Retrieved from: *Computerized IDF CC Tool for the Development of Intensity-Duration-Frequency Curves under a Changing Climate: (idf-cc-uwo.ca)*

Dhillon, N. (2022, February 2). Civil Engineering Services Rates. Retrieved from cadcrowd: *https://www.cadcrowd.com/blog/civil-engineering-services-rates-budget-breakdown-and-project-costs/*

First Nations & Indigenous Studies at The University of British Columbia. (n.d.). Retrieved from: (Home | First Nations and Indigenous Studies (ubc.ca)

HomeGuide. (2020, December 17). How much does asphalt cost. Retrieved from Home Guide: *https://homeguide.com/costs/asphalt-prices*

Home Guide. (2022). How much does landscaping cost. Retrieved from HomeGuide: *https://homeguide.com/costs/landscaping-costs*

HomeStars. (2022). Guide to Landscaping Costs. Retrieved from HomeStars: *https://homestars.com/cost-guides/landscaping-cost/*

O'Neill, A. (2023). Retrieved from: *https://www.statista.com/statistics/271247/inflation-rate-in-canada/*

RS Means Data. (n.d.). Retrieved from: *https://www.rsmeans.com/*

smartPOND™ - Ferguson Waterworks Geo & Stormwater. (n.d.). Retrieved from: *(https://www.fergusongss.com/product/smartpond/)*

Teply, S., & Gough, J. W. (2007). Canadian Capacity Guide for Signalized Intersections. Retrieved from: Institute of Transportation Engineers.

Tractor Suppoly Co. (2022). Retrieved from TRACTOR SUPPLY CO: https://www.tractorsupply.com/tsc/catalog/culverts

UBC Brand: Visual Identity Best Practice Guidelines. (n.d.). Retrieved from: (Visual Identity | UBC Brand)

Vancouver, C. of. (n.d.). Retrieved from: https://vancouver.ca/home-property-development/green-infrastructure.aspx