University of British Columbia

Social Ecological Economic Development Studies (SEEDS) Sustainability Program

Student Research Report

UBC Wesbrook Mall Redesign

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Prepared for: [clients/community partners – organization name (NOT people)]

Course Code: CIVL 446

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SEEDS Sustainability Program

UBC sustainability

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EXECUTIVE SUMMARY

The following document contains our team's detailed design report for the UBC Wesbrook Mall Phase 4 Redesign from Thunderbird Boulevard to West 16th Avenue. The project's objectives are to: (1) Expand roadway capacities, (2) Minimize costs, (3) Incorporate a pedestrian tunnel or overpass, (4) Increase green space to improve stormwater retention, (5) Create a dedicated bike facility, (6) Maximize parking, (7) Minimize tree removals, and (8) overall, prioritize buses, cyclists and pedestrians by maximizing safety, convenience and enjoyability in using these transport modes.

This report will summarize the detailed design including a design overview, issue-for-construction drawings, cost estimate, schedule, construction management and service life maintenance plan.

The selected design includes a two-way, elevated bike lane along southbound Wesbrook Mall, the addition of a transit priority lane along northbound Wesbrook Mall, curb extensions, rain gardens and tree box filters for drainage, and a pedestrian overpass south of Doug Mitchell Thunderbird Sports Centre. The key considerations for this design have remained consistent throughout the duration of the project and address technical, economic, environmental, regulatory, construction planning and societal perspectives. To arrive at the detailed design, a structural analysis for the overpass and a traffic analysis to inform the geometric design were conducted.

The detailed design has a Class A cost estimate of CAD $8.4 million and the project is on track to begin construction in May, 2022 and is expected to be completed by October, 2022. The project's next steps include tendering the project and obtaining relevant permits and approvals.

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1.0 INTRODUCTION

1.1 Project Background

Our team was commissioned by UBC SEEDS to develop detailed design for the Phase 4 Wesbrook Mall Redesign Project. The Phase 4 scope of work extends along Wesbrook Mall from Thunderbird Boulevard to West 16th Avenue (**Figure 1.1**) and ties into the existing infrastructure from Phase 1 and 2. A preliminary design was developed by our team in December 2021 which included the addition of a bi-directional bike lane along southbound Wesbrook Mall, a northbound transit lane, rain gardens along the roadway median, and a reinforced concrete pedestrian overpass bridge south of Thunderbird Sports Centre. For the detailed design stage, we continued to develop the design addressing the client's objectives to: (1) Expand roadway capacities, (2) Minimize costs, (3) Incorporate a pedestrian tunnel or overpass, (4) Increase green space to improve stormwater retention, (5) Create a dedicated bike facility, (6) Maximize parking, (7) Minimize tree removals, and (8) overall, prioritize buses, cyclists and pedestrians by maximizing safety, convenience and enjoyability in using these transport modes.

Figure 1.1 Project Site

2.0 ROADWAY DESIGN

2.1 Standards and Software Used

Throughout the roadway design process, the guidelines that were referenced for both parametric and qualitative considerations are shown in **Table 2.1**. The software programs used to develop the preliminary design are summarized in **Table 2.2**.

Table 2.1: Standards and Guidelines References in Roadway Design

Guideline / Standard	Version / Year
Geometric Design Guidelines	
TAC Geometric Design Guide for Canadian Roads	June 2017
BC Active Transportation Design Guide ("ATDG")	2019
NACTO Urban Bikeway Design Guide	March 2014
Pavement Design Guidelines	
BC MoTI Pavement Structure Design Guidelines	2015
Other Guidelines for General Reference	
City of Vancouver Engineering Design Manual	V1 (2019)
City of Vancouver Standard Detail Drawing - Roadways	Sep 2018
City of Vancouver Construction Specifications	V1 (2019)

Table 2.2: Software in Roadway Design

Software	Project Application
AutoCAD 2022	The existing geometric section and widths were modified in accordance with our design to determine the new geometric widths to be used.
AutoTurn 11 Demo	A swept path analysis using AutoTurn was conducted on the roadway to verify turning movements for the proposed bike box location.
Synchro 6	The study area was modeled to determine link and node LOS, delay, and V/C. Modeling results informed our intersection bike crossing design.
SIDRA 2019	The roundabout at Wesbrook Mall and West 16th Avenue was modeled to determine viability and recommended modified design.

2.2 Design Criteria

Based on the guidelines and standards listed in **Section 2.1** and the client's objectives, the key design criteria below were identified for each design component in **Table 2.3**.

Table 2.3: Key Design Criteria in Roadway Design

Design Component	Key Design Criteria
Travel Lane	Design Vehicle = WB-17 Design Speed = 50 km/h Minimum K factor = 7 and Maximum grade = 6% (per TAC) Minimum width = 3.2 m (preferred) / 3.0 m (absolute) Synchro: Projected columns meets Level of Service > D and V/C Ratio <1
Parking Lane	Minimum width = 2.2 m (absolute) to 2.5 m (per CoV EDM) Maximize parking retention
Bicycle Through Lane	Design cyclist speed = 30 to 35 km/h Minimum width = 3.0 m Bi-Directional (per ATDG) Buffer width = 0.3 m (constrained) to 0.6 m (desirable) (per ATDG) Minimum horizontal radius = 24 m to 33 m (per TAC) for 30-35 km/h with 2% superelevation Bike Box = 10-16 feet deep
Transit Lane	Minimum width = 3.4 m (per UBC)
Pedestrian Through Lane	Minimum width = 2.0 m (per UBC) Desired width = 2.4 m for a collector road next to multi-family residential land use (per ATDG)
Safety Components	● For 50 km/h design speeds, stopping sight distance = 65 m (per TAC) ● Recommended setback distance from road edge = 4.4 m (per TAC) ● Curb Extension: Transition curve radius between the main and extended curve shall contain a 3 - 5 m radius for street cleaning vehicles to maneuver properly
Pavement Structure	<u>Vehicle and Transit Lanes (per CoV):</u> ● 50mm AC Surface Course ● 180mm AC Lower Course (2x90mm lifts) ● 150mm Granular Base ● 300mm Granular Subbase <u>Protected Bicycle Lanes (per CoV):</u> ● 50mm MMCD Upper Course #2/9.5mm ● 150mm Granular Base <u>Sidewalk:</u> ● Smooth Concrete Finishes 100mm

Landscape Zone	Furnishing Zones with Larger Trees Minimum width: 1.5 m (per ATDG)

2.3 Technical Considerations

2.3.1 Plan Drawing Components

Curb Extensions: All existing curbs were extended to accommodate for the bi-directional bike lane and to provide additional safety and comfort to the cyclists. Curb extensions will also mark the parking termination points and will maintain a minimum radius of 5 m. The design followed guidelines set out by the Transportation Association of Canada Geometric Design Guide. One of the three proposed curb extensions are shown in **Figure 2.1** below. For exact location of the curb extensions, refer to detailed plan drawings in Appendix A.

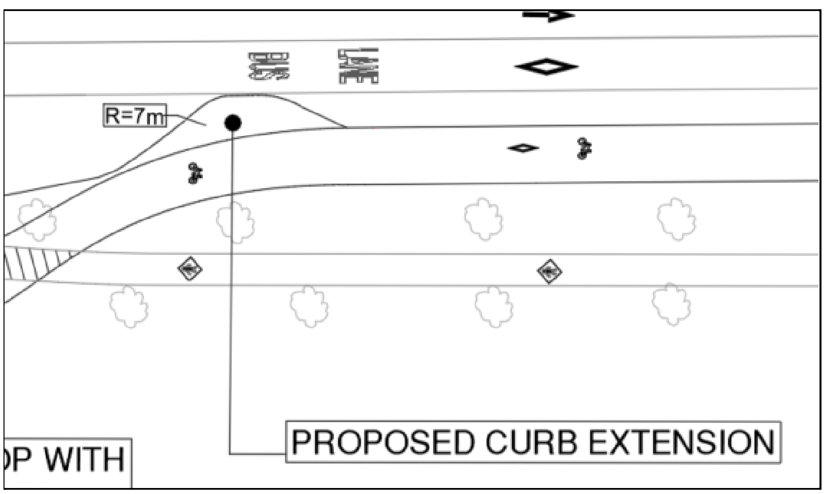

Figure 2.1: Curb Extension at South of SB Hampton Place Transit Stop

Bike Lane Transition and Bypass at Transit Stops: To fit the bi-directional bike lane and to maintain the existing infrastructure where possible, our proposed design shifts the two transit stops for the SB transit lane at Thunderbird Boulevard and Hampton Place towards the NE near the curb. This would allow for enough space to bypass the bike lane behind the bus stop. The bike lane at the SB Hampton Place transit stop features a horizontal radius curvature of 40 m to allow cyclists to perform safer turning maneuvers at lower speeds. The bike lane at SB

Thunderbird Boulevard transit stop will run parallel with the road. Configuration for the SB transit stop at Hampton Place is shown in **Figure 2.2**.

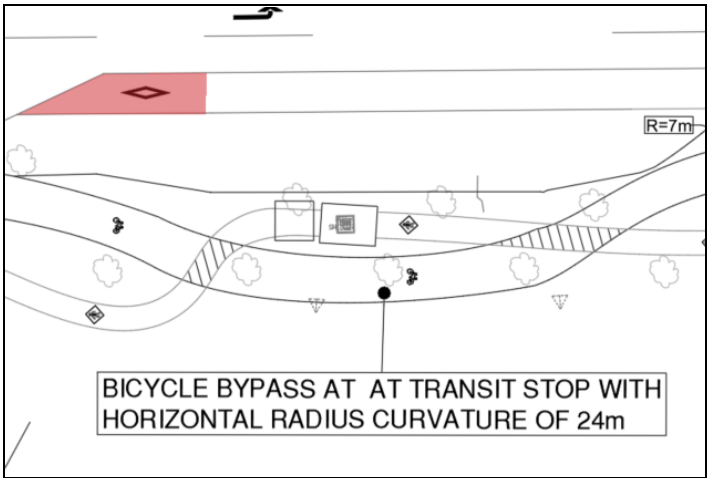

Figure 2.2: Bicycle Bypass at SB Transit Stop Hampton Place

Bike Lane Integration at Pedestrian Overpass: The bi-directional bike lane will travel underneath the pedestrian overpass, and is situated between the motor vehicle road and overpass stairs. The NB sidewalk will be shifted slightly away from the road to provide space for the proposed cycling and overpass infrastructure. **Figure 2.3** and **Figure 2.4** illustrate the bike lane integration at the pedestrian overpass from a section and plan view respectively.

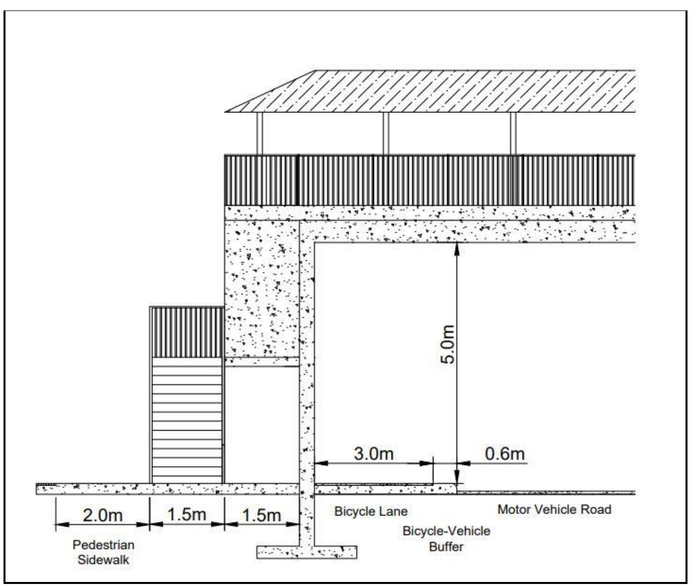

Figure 2.3: Section View of Bike Lane Integration at Pedestrian Overpass

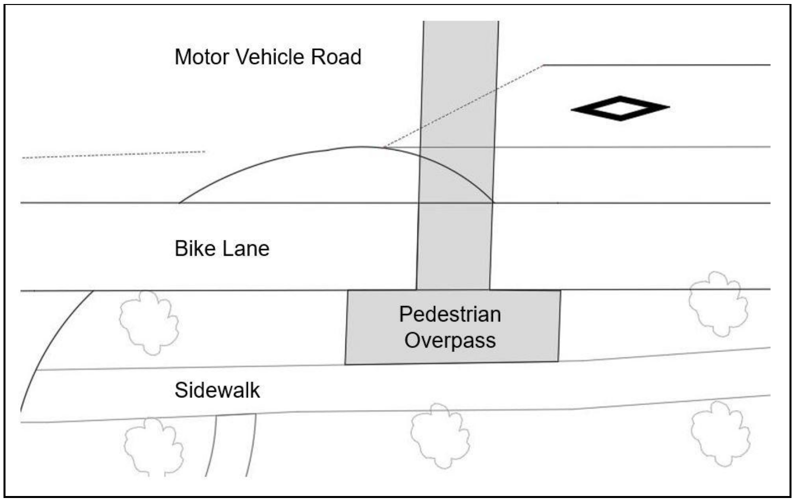

Figure 2.4: Plan View of Bike Lane Integration at Pedestrian Overpass

Bi-directional Bike Lane to One-directional Bike Lane: To tie the proposed bi-directional bike lane into earlier phases at Thunderbird Boulevard and Wesbrook Mall, NB cyclists must cross to the one-directional bike lane on the east side of Wesbrook Mall. To safely enable this movement, our team is proposing the addition of two bike box queueing zones at this intersection. The first bike box will be 5.5 m deep and placed in front of the EB vehicle travel lanes. NB cyclists will queue in this bike box for the cyclist-only signal to turn left into the second bike box. The 5 second cyclist-only signal will occur as part of the increased all-red time at this intersection. During the cyclist-only signal, NB cyclists will enter into the second bike box between the sidewalk letdowns on the NW side of the intersection. With the east-west traffic signal, cyclists can maneuver their bike onto the EB bike lane and travel across Wesbrook Mall onto the NB one-directional bike lane. **Figure 2.5** illustrates the described configurations, proposed pavement markings, and signage at this intersection. The bike box locations were selected because they allowed for effective vehicle turning movements, particularly right-turns-on-red for the SB and EB approach, without compromising cyclist safety.

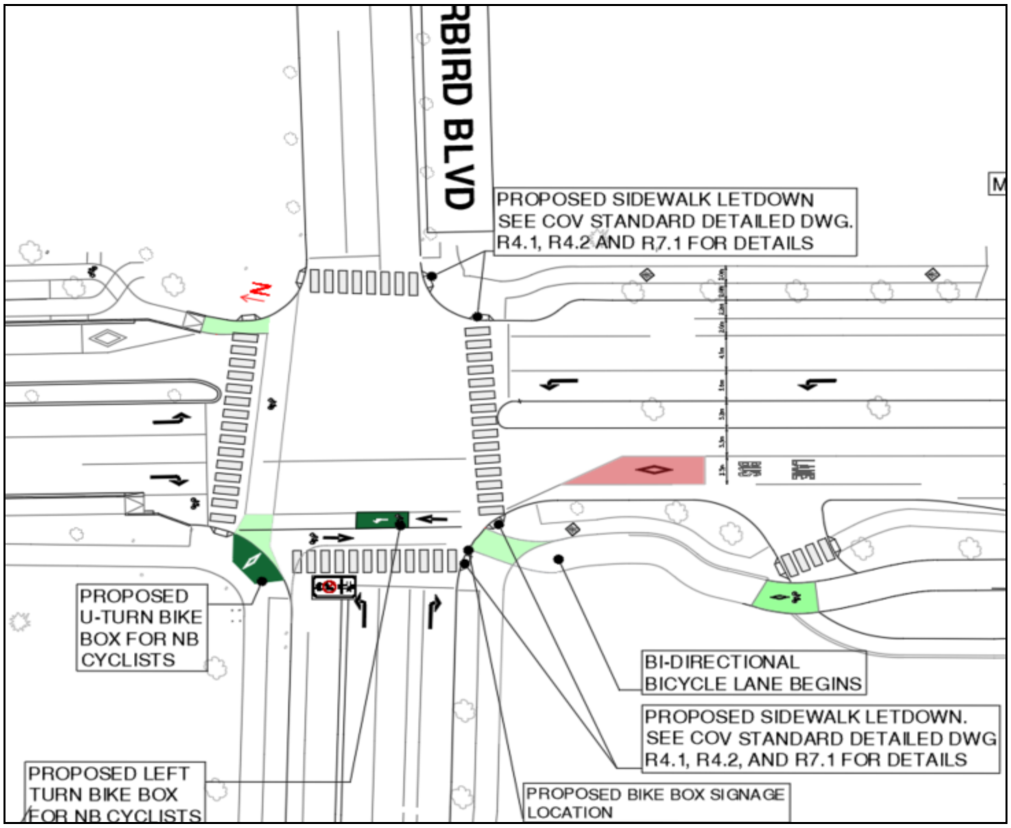

Figure 2.5 Thunderbird Boulevard Intersection Bike Lane Transition

2.3.2 Section Profile Components

The corridor will have a superelevation of 2% towards the median from Thunderbird Boulevard to West 16th Avenue. Based on rainfall capacity, this slope will help facilitate drainage of water into the three medians with rain gardens. For the two medians without rain gardens, the ponding depth will be sufficient enough to meet the campus community guidelines despite the absence of rain gardens.

The roadway pavement structure will follow the City of Vancouver's Engineering Design Manual. **Figure 2.6** illustrates the proposed pavement structure. The contractor will be responsible for the asphalt concrete mix design.

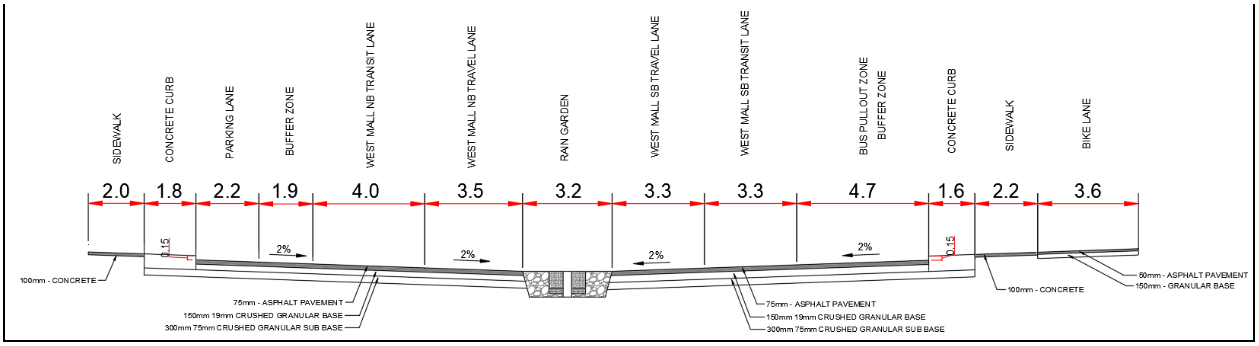

Figure 2.6: Proposed Roadway Cross Section

2.3.3 Sidewalk Replacement

The existing sidewalk that stretches from 2770 Wesbrook Mall to West 16th Avenue is severely damaged by overgrown roots and for this reason, we are proposing a full replacement of this section.

The proposed replacement material, quantities and dimensions are as listed:

- Width of sidewalk = 2 m
- Thickness of sidewalk = 0.15 m
- Length of sidewalk = 500 m
- Granular drain rock needed = 100 m^3
- Total amount of concrete needed = 150 m^3

Due to the cold temperatures that Vancouver experiences in winter months, the sidewalk concrete will be exposed to freeze-thaw cycles and de-icing salts. As a result, we recommend a concrete mix type with high air-content (air entrainment) to reduce water damage and cracking during freeze-thaw cycles. The proposed mix type is consistent with the latest edition (2019) CSA-A23.1 as listed:

- Minimum 28-day compressive strength of 32 MPa
- Air content based on maximum size aggregate of up to 20 mm (recommend 5.0 to 8.0 percent or 4.0 to 7.0 percent if aggregate size is up to 40 mm)
- Nominal maximum size of aggregate up to 40 mm
- Maximum water cementing ratio 0.45
- Exposure classification C–2

2.4 Traffic Analysis

To evaluate the proposed roadway design at key intersections, traffic analysis was conducted for the intersection at Thunderbird Boulevard and Wesbrook Mall using Synchro 6, and the existing roundabout as well as a potential redesign at Wesbrook Mall and West 16th Avenue using SIDRA. Traffic growth up to 2040 was analyzed. Traffic volumes used were from Bunt's *Stadium Neighbourhood Planning Traffic Analysis* (2020) report as well as data provided by the client from Creative Transportation Solutions. 2040 AM and PM peak vehicle Level of Service (LOS), delay, and volume-to-capacity ratios were found for the two intersections along Wesbrook Mall and are presented in **Table 2.6**. All intersections were found to operate at LOS C or better.

Table 2.4: 2040 Synchro and SIDRA Results Summary

Intersection	2040 AM			2040 PM		
	LOS	Total Delay (s)	Max V/C	LOS	Total Delay (s)	Max V/C
Thunderbird Blvd	C	32.0	0.90	C	23.4	0.82
W 16th Ave - Existing	C	34.6	1.079	B	13.0	0.827
W 16th Ave - Modified.	B	12.6	0.737	A	9.2	0.494

Intersection Analysis at Thunderbird Boulevard: The bike turn box will allow for the safe queueing of cyclists crossing to the NB bike lane and increases the all-red time of this signal to 5 seconds. This will enable the addition of a short cyclist only signal allowing them to turn left into the EB bike box on Thunderbird Boulevard without conflict. The existing signal timings with the proposed all-red time resulted in an LOS F for 2040 AM volumes. To remedy this, we recommend adding a protected-permissive left turn phase for the WB left with an extended cycle length of 90 seconds during peak AM hours. This adjustment shifts the LOS from F to D. As it is currently designed, there may still be potential capacity issues at Thunderbird Boulevard, with a 0.90 V/C in the NB through movement. The analysis assumes moderate vehicle growth into 2040. Given UBC's travel mode strategy, vehicle growth will likely be lower than modeled, and therefore active transportation oriented policies may be a viable strategy as opposed to roadway expansions.

Roundabout Analysis at West 16th Ave: At 2040 AM peak volumes, the existing roundabout design produced an overall LOS C but with a LOS F for the south single lane approach coming from Wesbrook Mall. By modifying the current design into a two lane south approach shown by **Figure 2.7**, the overall intersection LOS becomes B at peak AM volumes. As the roundabout redesign at West 16th Avenue is beyond the scope of this project, these changes were not factored into the project estimates. However, the client is encouraged to investigate the opportunities to improve upon the current design.

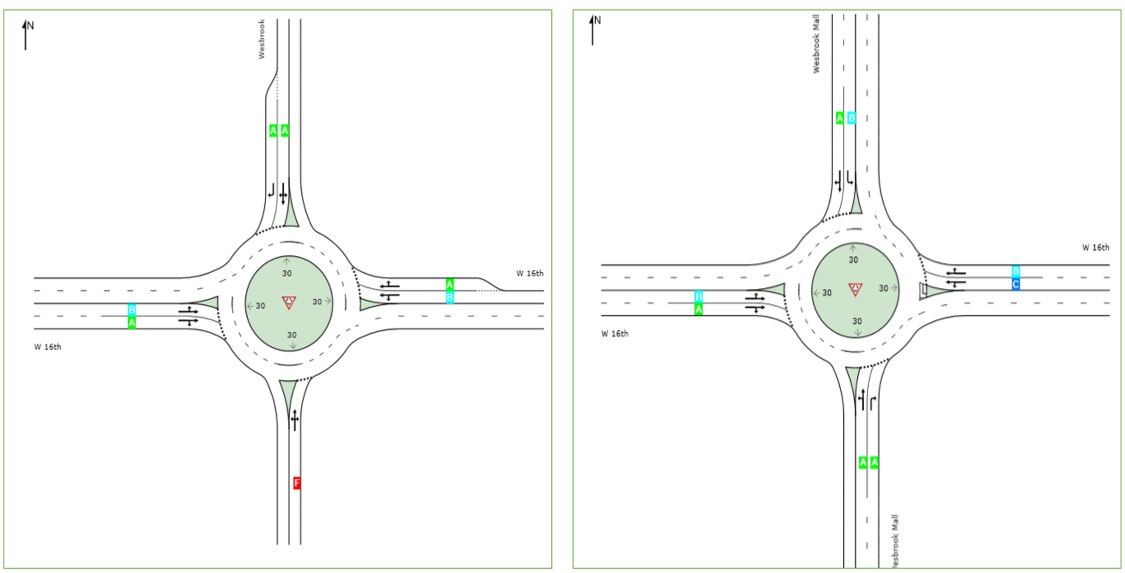

Figure 2.7: Existing Roundabout Layout (Left) and Modified Roundabout Design (Right)

2.5 Key Components Description

Key dimensions of lane widths, superelevation, and pavement layers are specified in **Table 2.5**. For detailing of other roadway components such as signages and lighting, please refer to municipal design standards. Detailed plan and section drawings are included in Appendix A.

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3.0 STORMWATER INFRASTRUCTURE

3.1 Rain Garden

3.1.1 Design Criteria

Stormwater management practices have evolved significantly over the past decade, with a greater emphasis being placed on providing more sustainable solutions and minimizing the environmental footprint of civil projects. Low Impact Development (LID) is a term that refers to systems or practices that mimic natural processes to manage stormwater runoff; LID and Green Infrastructure (GI) are two terms that are often used interchangeably. LID infrastructure is becoming more standardized, especially in urban environments. With pilot projects in Seattle and Vancouver, such as the North Shore Rain Garden, the benefits of implementing such systems is clear. LID practices generate numerous benefits, such as:

- Adding an extra layer of protection to aquatic habitats
- Minimizing loss of habitat for birds, bees and butterflies
- Reducing the urban heat island effect

Designing a stormwater management system that incorporates LID was a priority for our team, because LID also addresses specific stakeholder needs, such as retaining green space and limiting the impervious areas in our proposed design. Furthermore, LID practices can also have additional monetary benefits by increasing the use of natural processes such as infiltration and evapotranspiration to convey stormwater, reducing the reliance on engineered conveyance systems, treatment infrastructure, and saving capital costs up front.

We conducted a thorough investigation into LID practices in order to select the most appropriate solution for our project. Having looked at numerous options, such as rainwater harvesting systems, pervious pavements and green roofs, and considering the feasibility of each, the idea of implementing a rain garden along the corridor stood out as the most feasible and applicable LID system for this project.

Rain gardens, a type of source control, are a form of low impact development that utilizes traditional landscaping methods to increase the adsorbent landscape in an area. The landscape serves the dual purpose of increasing the aesthetic appeal of the corridor, as well as capturing and filtering rainwater runoff from smaller rain events.

Local governments and municipalities in Metro Vancouver regulate stormwater design criteria and set specific design targets that need to be addressed. Municipal criteria govern source control design criteria rather than provincial, but do not supersede watershed or site-specific criteria where defined. Source control design in Metro Vancouver is dictated by two main design criteria published by Fisheries and Oceans Canada (DFO) and the Ministry of Water, Air and Land Protection. **Table 3.1** outlines the design criteria set by the DFO in their published stormwater design guideline *"Urban Stormwater Guidelines and Best Management Practices for the Protection of Fish and Fish Habitats"* (2001), and **Table 3.2** shows the design criteria published by the Ministry of Water, Air and Land Protection published in *"Stormwater Planning: A Guidebook for British Columbia"* (2002).

Table 3.1: DFO Stormwater Guidelines

Objective	**Target**
Volume Reduction	Retain 6-month/24-hour post-development volume from on-site impervious areas and infiltrate to ground.
Water Quality	Collect and treat the volume of 24-hour precipitation event equalling 90% of the total rainfall from impervious areas
Detention	Reduce post-development flows to pre-development levels for the 6-month/24-hour or 2-year/24-hour precipitation events

Table 3.2: Design Criteria Published in Provincial Stormwater Guidebook

Objective	Target
Runoff Volume Reduction	Capture 50% of the Mean Annual Rainfall (MAR) and infiltrate, evaporate or reuse it.
Runoff Rate Reduction	Store 50 to 100% of MAR runoff and release at a rate that approximates the natural forested condition. Decrease downstream erosion impact of large storm events.
Peak Flow Conveyance	Ensure the drainage system is able to convey extreme storm events (up to 100-year return period).

When the design criteria outlined above is met, the estimated benefits produced by a rain garden system is provided by the Environmental Protection Agency (EPA) in their publication *"Effectiveness of Low Impact Development"* (2012). When designed adequately, a rain garden system will be able to:

- Reduce pollutant mass loading by 84% for total suspended solids in runoff
- Reduce the total nitrogen concentration in runoff by 63%
- Reduce total lead and motor oil concentration in runoff by over 90%
- Decrease discharge volumes by 48 to 74% into nearby creeks from minor precipitation events

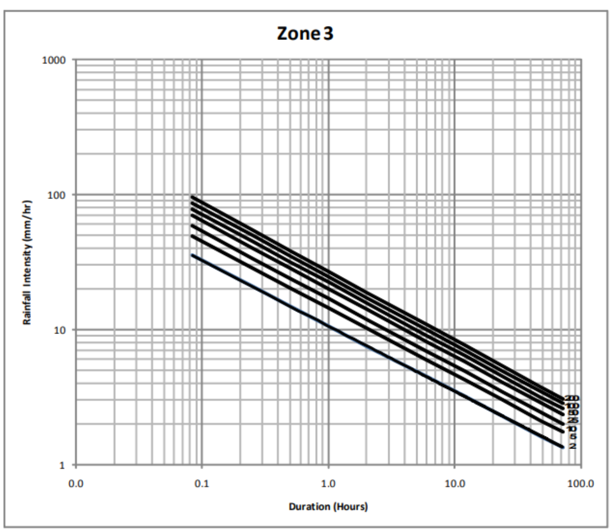
The implementation of a rain garden should decrease the total discharge conveyed to nearby creeks and outfalls significantly, particularly for minor storm events, and as a result decrease the pollutant load. Furthermore, the decrease in discharge volume also has a significant positive impact on downstream erosion.

3.1.2 Methodology

Rain garden sizing can be done in various ways. When site-specific data is ready and available, continuous simulation modeling techniques are utilized to provide more accurate sizing. Water Balance Model or SWMM are two commonly used software when continuous simulation modeling is required. In lieu of site-specific data, the simplified approach is used.

The rain garden area is based off the upstream impervious area it serves. To ensure that the capacity of the rain garden is not exceeded, maximum impervious to pervious (I/P) ratios have been developed. The maximum I/P ratio depends on the type of land use, as that dictates the amount of pollutants that will likely be captured along with the runoff. For the simplified design approach, the upstream impervious area for a rain garden is equal to the catchment area and the I/P ratio is then used to size the base area of the rain garden.

For the simplified approach, the key design inputs are the rainfall capture target and the inflow volume. In line with the methodology outlined in *"Stormwater Source Control Design Guidelines"* (2012) published by Metro Vancouver, rainfall intensity-duration-frequency (IDF) curves for Metro Vancouver were analyzed and the average annual rainfall was found. The location of proposed development falls under Zone 3, as defined by Metro Vancouver. The IDF curve for Zone 3 is shown below in **Figure 3.1**, and is taken from *"Regional IDF Curves"* (2009) published by Metro Vancouver.



Duration	2 year	5 year	10 year	25 year	50 year	100 year	200 year
5 min	35.3	49.2	58.3	69.7	78.2	86.6	95.0
15 min	20.7	28.6	33.7	40.2	44.9	49.7	54.4
30 min	14.8	20.3	23.9	28.4	31.7	35.0	38.3
1 h	10.6	14.4	16.9	20.0	22.3	24.6	26.9
2 h	7.6	10.2	12.0	14.1	15.7	17.3	18.9
6 h	4.5	5.9	6.9	8.1	9.0	9.9	10.8
12 h	3.2	4.2	4.9	5.7	6.4	7.0	7.6
24 h	2.3	3.0	3.5	4.1	4.5	4.9	5.4
48 h	1.6	2.1	2.5	2.9	3.2	3.5	3.8
72 h	1.3	1.7	2.0	2.3	2.6	2.8	3.1

Figure 3.1: Metro Vancouver Regional IDF Curve for Zone 3

The procedure to determine the capture rainfall volume is outlined below:

1. Identify intensity of 24-hour duration for 2-year storm
2. Multiply intensity by 24 to get the amount of rainfall in a 24-hour period (in mm)

3. Multiply the number obtained above by the fraction target given in design criteria (72% of 2-year, 24-hour storm)

From the regional IDF curve for Zone 3 shown in Figure 3.1, the following parameters were determined:

- 2-year, 24-hour rainfall intensity = 2.3 mm/hr
- Total rainfall over 24-hour period = 55.2 mm
- Capture rainfall amount = 39.7 mm in 24 hours

The inflow volume can then be calculated by multiplying the capture rainfall amount with the tributary area. The rain garden capture capacity should be equal to the inflow volume for the rain garden to function adequately. The rain garden capture capacity can be defined as the sum of:

- Depth of 24-hour evaporation
- Depth of growing medium multiplied by difference between field capacity and wilting point
- Depth of rock pit multiplied by rock porosity
- Depth of 24-hour infiltration

The maximum drain rock depth was calculated using the following equation:

$$D_R = \frac{K_s \times T \times 24}{n}$$

Where K_s is the saturated hydraulic conductivity for subsurface soil (mm/hr), T is the allowable drain time (days), and n is the drain rock porosity. For the simplified design approach, Kerr Wood Leidal provides standardized values for these parameters, based on historical data from Metro Vancouver. This provides a reasonably accurate estimate when compared to SWMM models (KWL, 2016). The saturated hydraulic conductivity was taken to be 13 mm/hr, typical for soils containing a higher percentage of loam The drain rock porosity was 40% and the allowable drain time was taken to be 1 day, which allows for a greater factor of safety since the maximum allowable drain time is 4 days.

The I/P ratio for the rain garden system was calculated using the following equation:

$$I/P = \frac{(24 \times K_S) + D_P + (D_R \times n) + (0.2 \times D_S)}{R} - 1$$

Once again, standardized values for Metro Vancouver were utilized. These values are outlined below:

- Dp = depth of ponding = 200 mm
- Ds = soil layer depth = 450 mm
- R = rainfall capture depth = 39.7 mm in 24 hours (as calculated above)

The calculated I/P ratio for our rain garden system was 22.2, which is much smaller than the maximum I/P ratio of 30:1.

3.1.3 Rain Garden System

The components of a rain garden system are as follows:

- Growing medium - Support plant growth, retain water and filter impervious surface runoff
- Vegetation - Promotes regeneration of infiltration surface
- Rock trench - Stores water and infiltrates it into the ground after a storm event
- Perforated pipe - Safely directs rock trench overflows to storm drainage system
- Above-ground storage - Provides temporary storage through ponding
- Overflow - Safely directs water away to a storm drainage system

Based on the input parameters listed above, the sizing of the rain garden system components was determined and is shown in **Table 3.3**. The cross-section of a typical rain garden for this project is shown in **Figure 3.2**. The total rain garden system area is 1950 square meters.

Table 3.3: Rain Garden System Design Summary

Component	Dimensions
Organic Mulch	50 mm
Growing Medium (Loam)	450 mm
Perforated Pipe	150 mm diameter
Drain Rock Reservoir	800 mm

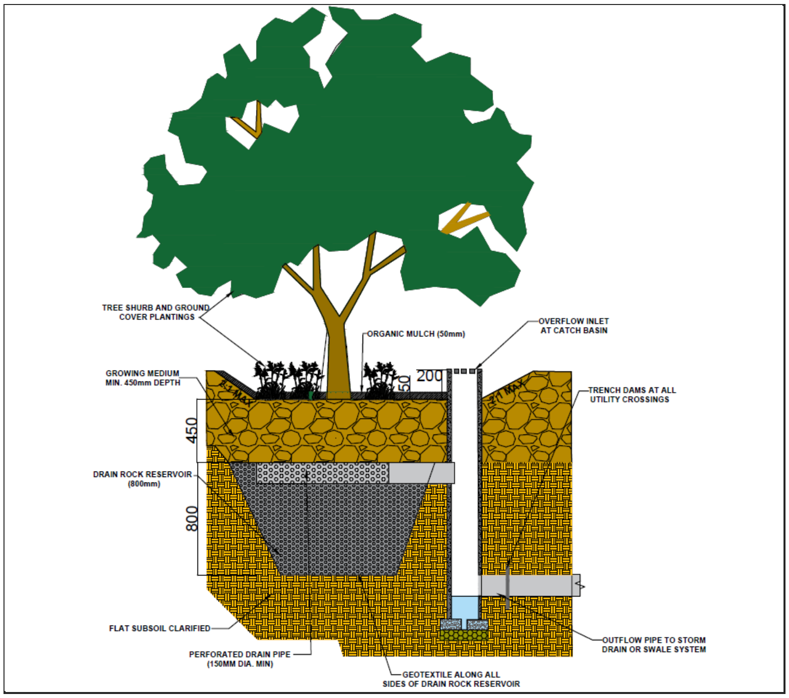


Figure 3.2: Cross-section of Rain Garden

3.1.4 Incorporation of Best Management Practices (BMPs)

Based on over a decade of designing and consulting on stormwater infrastructure management practices, Kerr Wood Leidal published *"Top Ten Design Considerations for Rain Gardens"* (2019). The lessons learned from previous projects in North America are incorporated into our design in order to maximize the design life of the proposed rain garden system. Specifically, the following considerations were included in our design:

- **The removal of grass buffers adjacent to the rain garden**
    - Grass filter strips are extremely efficient at trapping sediments
    - When placed adjacent to asphalt in a rain garden system, grass buffers will act as a 'new curb', building up sediment within the strip and preventing runoff from reaching the rain garden
    - Non-erodible material (in our case - plantings) should be used instead
- **Construction phasing**
    - Construct the rock trench, perforated drain and overflow at the same time as other subdivision utilities

    - Protect the newly installed rock trench layer with a sacrificial layer of soil and poly sheeting to prevent damage during construction
    - Growing medium and plantings to be added after the roads and driveways are completed to prevent materials from stockpiles from getting into the rain garden
- **Use of native plant species**
    - Incorporate plantings of Carex Rostrata, Carex Stipata, Cornus Stolonifera, Juncus Effusus, Salix Purpurea, and Sagittaria Latifolia, as outlined in *"Water Management through Rain Gardens SEEDS Report"* (2011)

The lessons learned from previous projects and recommendations from reputable sources will help maximize the service life of the proposed rain garden system.

3.2 Tree Box Filters

3.2.1 Design Targets

To provide a greater factor of safety for the proposed stormwater management system, tree box filters will be installed in conjunction with rain gardens. The reasoning for this is to increase the reliability of the proposed system by:

1. Reducing the demand on the rain gardens
2. Adding a cost-effective source control that can work independently, giving an extra layer of safety

One of the primary objectives of source controls is to achieve a volumetric reduction in runoff that is conveyed to the storm sewer system. This is achieved by storing and treating the runoff that falls on impervious areas within our development zone. Since rain gardens are designed for precipitation events with smaller return periods, it is important to ensure that the system is not overwhelmed during larger storm events. Without the added factor of safety provided by the addition of tree box filters, the treatment capacity of rain gardens could be overwhelmed and, as a result, the quality of the runoff that drains to the storm sewer system could be compromised. This can have devastating effects to aquatic habitats and would result in the inability of the proposed system to satisfy the design criteria outlined in Section 3.1.1.

3.2.2 System Components

Tree box filters are small, cost-effective biofiltration systems that can remove pollutants through natural processes such as infiltration and adsorption. A tree box filter has three main components:

- **Underground storage chamber**
  - Typically a precast concrete structure filled with a soil medium that is specifically designed for rapid infiltration
- **Soil media**
  - Soil mixture contains a higher percentage of sand, clay or loam to promote faster infiltration rates
  - Typical mixture is 80% sand and 20% compost
- **Plant**
  - Native plant species

In addition to the three main components listed above, an adequately designed tree box filter also needs to have a minimum ponding depth of 4 inches to allow time for infiltration during large storm events. Furthermore, the tree box filter needs to connect with the existing stormwater system in the area; this is done by adding a perforated subdrain and an overflow pipe.

Similar to rain gardens, tree box filters need to be designed to remove at least 80% of the total suspended solids in the runoff that it treats. To achieve this, the system components were sized as shown in **Table 3.4**. A typical cross-section of the proposed tree box filter is shown in **Figure 3.3.**

Table 3.4: Tree Box Filter Design Summary

Component	Dimensions
Underground Storage Chamber	6 ft. diameter 4 ft. depth
Soil Media Depth	1 ft. depth Bioretention soil mix (80% sand, 20% compost)
Drain Rock Depth	24 in. depth

Overflow Pipe	12 in. diameter overflow pipe
Perforated Subdrain	12 in. diameter perforated subdrain

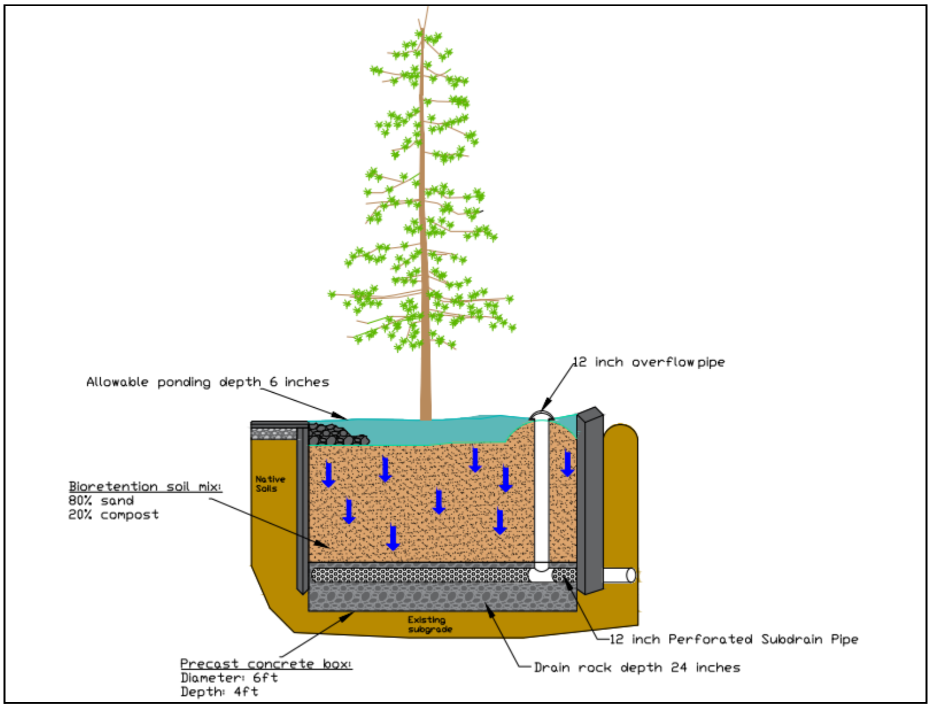


Figure 3.3: Cross-section of Tree Box Filter

3.2.3 Incorporation of Best Management Practices (BMPs)

Tree box filters are a very popular form of source control that is used extensively around the world. Historical implementation results have demonstrated the effectiveness of tree box filters as a form of source control, but projects in North America, due to its cold climate, have seen the effectiveness of these systems being reduced in the winter times.

Many tree box filters around the world use deciduous trees to provide added aesthetic appeal; however, this decreases the performance of tree box filters in North America because in the winter time, the deciduous trees will lose their leaves. The tree leaves have a tendency to smother vegetation, reduce soil infiltration rates and plug overflow drains.

This has caused a significant increase in Operation & Maintenance (O&M) costs; O&M costs have been shown to rise by over 50% when deciduous trees or shrubs are incorporated into the design (KWL, 2019).

Consequently, the plants used for this design will include only native species and non-deciduous plants. This will maximize the service life of the proposed design and reduce the frequency of maintenance operations.

3.3 Pipeline Infrastructure

Design requirements and specifications were adopted from the UBC Technical Guidelines section 33 49 00. A storm water control panel was not required for our project scope as the rain garden size was less than the minimum requirement. Overflow structures were connected from the rain garden to the main storm drainage system which will convey any overflow to the rain garden to the main stormwater drainage system. The use of the tree box filter would also reduce any overflow to the roadway. The original stormwater system was kept and only portions near the rain gardens were modified. This will be sufficient for the identified rainfall event at an acceptable ponding depth of 6 inches. Locations of the rain garden components can be found in the detailed drawing package in Appendix A. The system component specifications for the pipeline infrastructure is summarized in **Table 3.5**.

Table 3.5: Pipeline Infrastructure System Components Summary

Pipeline	• Length = 790m • 150mm perforated pipe • 450mm below ground level • Minimum slope of 0.2% • 750mm horizontal clearance within a common trench with sanitary sewer • Flows only by gravity at a 3m/s velocity when flowing from full to half full • 75m maximum length between building face to closest storm sewer
Manhole	• Manhole spacing every 80m • Located at every bend in the pipeline
Catch Basin	• Placed every 19m (42L/s flow each catchbasin) • Minimum slope of 1% catch basin leads • Services an area of 1950m2 of rain garden

4.0 PEDESTRIAN OVERPASS

4.1 Design Standards and Criteria

Our team utilized CSA 23.3-2014 and BCBC-2018 for design standards and guidelines in the development of the pedestrian overpass. Further analysis was conducted with S-FRAME to ensure structural integrity and safety.

Reinforced Concrete Members Sizing: Wind, snow, and pedestrian loads were identified using the Load and Resistance Factor Design (LRFD) Guide and Specifications for Design of Pedestrian Bridges. The dead load was calculated using the member's self weight. Calculated load demands were then inputted into S-FRAME structural analysis software to determine the internal load demand taken by each member. The capacity of the structure is calculated following CSA 23.3-2014 criteria and can be found in Appendix C. Column, beam, and slab members were sized to ensure that capacity exceeded demand and an appropriate factor of safety was met. Tie spacing, reinforcement quantity, and concrete cover depth were developed in accordance with CSA 23.3-2014 and BCBC-2018 design standards.

Footing Stability: CSA 23.3-2014 standards were utilized to develop footing reinforcements, anchors, and lateral ties. Footing depth was calculated to prevent shear failure and longitudinal reinforcements were determined to resist bending. Footings were sized to ensure that capacity exceeded demand and an appropriate factor of safety was met.

4.2 Site Location

The overpass is located just south of the existing at grade pedestrian crossing on the east side of the Thunderbird Sports Centre. The existing crosswalk will be maintained, and the new overpass will provide a conflict free crossing alternative for vulnerable users such as children walking to/from school. It will span approximately 26.5 m across Wesbrook Mall and will extend over the motor vehicle lanes, median, and the new bi-direction bike lane. The stairs are positioned perpendicular to the overpass and will occupy the space between the sidewalk and bike lane in the SB direction, and between the sidewalk and motor vehicle lane in the NB direction. A plan view of the overpass is illustrated in **Figure 4.1**.

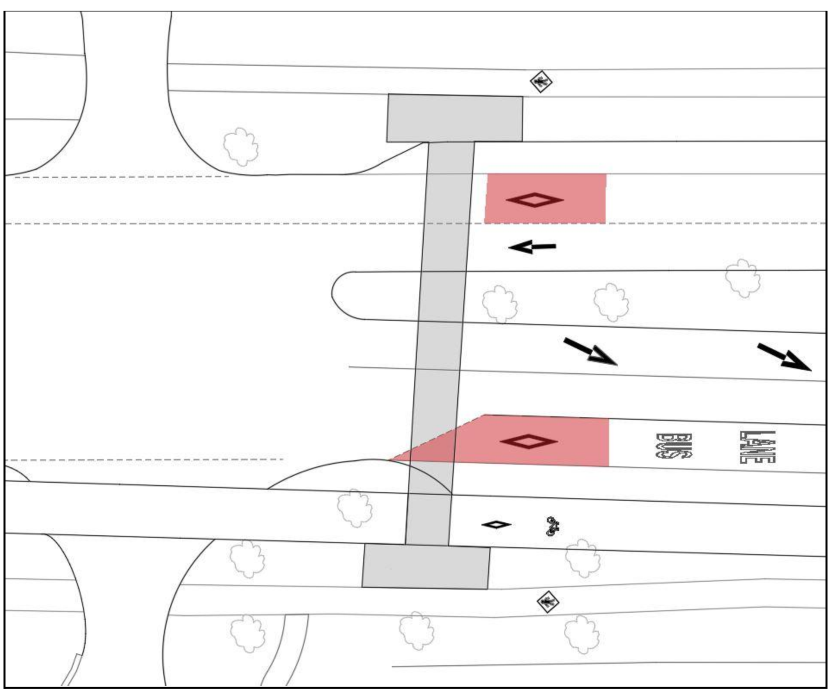


Figure 4.1: Plan View of Proposed Overpass Location

4.3 Key Components Description

A description of key overpass components is summarized in **Table 4.1**. The complete drawing set for the detailed design of the overpass is attached in Appendix A. The front view of the overpass structure is shown in **Figure 4.2**.

Table 4.1: Summary of Key Overpass Components

Design Component	Description
Superstructure	● 5m tall 40MPa square concrete columns 300mm x 300mm with 6-15M steel reinforcements ● 26.5m long 25MPa rectangular concrete beam 300mm x 500mm with 10-30M steel reinforcements and 10M ties spaced at 200mm ● 1.5m wide 25MPa concrete slab walkway with 10M at 200mm transverse reinforcements and 25M at 400mm longitudinal reinforcements ● 1.5m wide 25MPa concrete stair treads, rise = 175mm, run = 280mm
Foundation	● 500mm deep 1.5m x 1.5m concrete footing with 6-20M steel reinforcements along the top and bottom ● 75mm concrete cover
Roof and Railings	● 14mm thick transparent carbonate roof, sloped at 26 degrees with gap at the end to avoid water accumulation ● Galvanized steel pedestrian railings decorated with indigenous and UBC art

4.4 Structural Analysis and Design Checks

Capacity of structural elements of the overpass were calculated using BCBC-2018 design standards and formulas. The capacity values were then compared to demand values obtained from S-FRAME to ensure an adequate factor of safety. **Table 4.2** illustrates the design checks for the major structural members of the overpass. More details of the capacity calculations and S-FRAME demand analysis can be found in Appendix C.

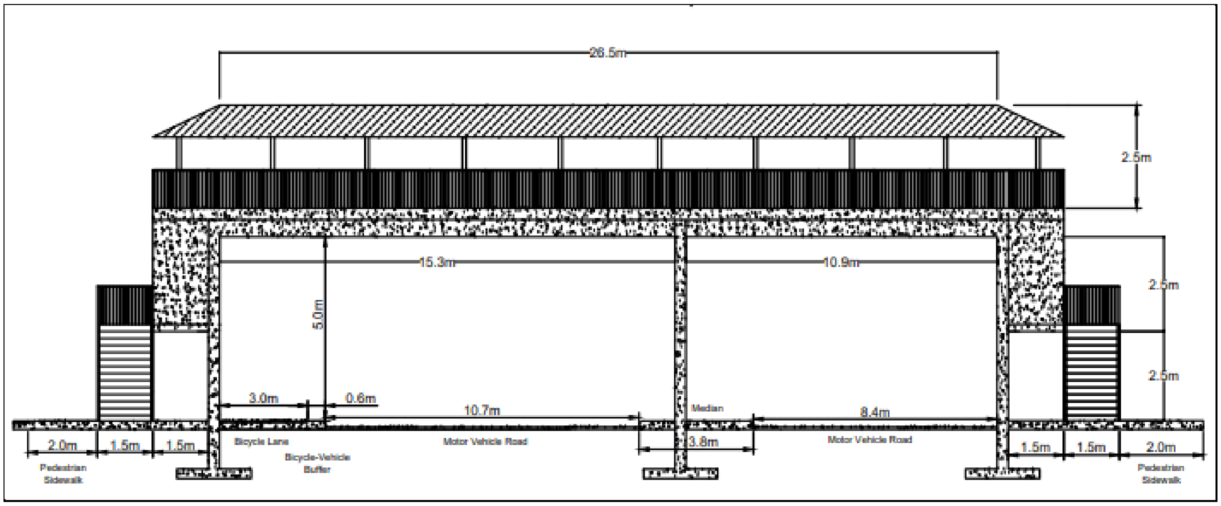


Figure 4.2: Front View of Pedestrian Overpass

Table 4.2. Demand and Capacity Summary for Major Structural Components

Components	Max Demand	Max Capacity	D/C	Type of Force
Reinforced Concrete Column	379 kN	650 kN	58%	Axial
Reinforced Concrete Beam	190 kN	469 kN	41%	Shear
	548 kNm	717 kNm	76%	Bending
Reinforced Concrete Footing	130 kN	282 kN	46%	Shear
	39 kNm	606 kNm	7%	Bending

5.0 PROJECT MANAGEMENT

5.1 Site Plan and Anticipated Issues

5.1.1 Wesbrook Mall Construction

Utilities Management: The infrastructure under the corridor consists of gas, storm, sewer and water lines. Based on UBC Technical Guidelines, these are approximately 1 meter underground. Light post Design Guidelines from Campus and Community Planning will be followed for fixture design of standing light poles adjacent to the pedestrian overpass with an illuminance between 50-100 Lux. As there are minimal changes to the pedestrian walkway in the NB direction which is beside private housing, these utilities will remain unchanged. A BC One Call must be made to identify any underground utilities before construction begins in that region.

Landscaping Planning: Paving design guidelines provided in the Vancouver Campus Plan from Campus and Community Planning will be followed. Campus Core (type 1) pavement instructions will be used for pedestrians and bike paths north of Doug Mitchell Thunderbird Sports Stadium and campus core (type 6) for all major paths south of the stadium. Tree protection fencing will be installed around subject trees which will consist of wood posts and frames with a radius of 1 meter per 8 centimeter of trunk diameter and 1.8 meter high.

Waste Management: Our team recommends leaving as much of the current infrastructure in place as possible. Waste material storage and disposal will follow the guidelines set by UBC Risk Management Services (RMS). Proper procedures will be followed when handling and disposing of any encountered toxic material. Construction staff must be prepared for a toxic spill to ensure contaminants do not enter the storm sewer network. Erosion and sediment control plans must be completed to ensure that the project site meets all environmental requirements outlined by Environmental Management Systems from UBC's RMS. Water can be sprayed on loose soil to reduce air pollution from dust. The air quality and discharge of contaminants will be regulated in accordance with the Federal Environment Canada National Pollutant and Metro Vancouver guidelines. Construction will only happen during working hours. The aforementioned stakeholders should ensure an automated waste management system during non-working hours so that users are not affected.

Sidewalk Replacement Considerations: Our team recommends that poured sidewalks be blocked off for at least 7 days before use to avoid compromising its strength. Furthermore, poor maintenance of concrete can lead to significant shortening of surface lifespan. Our team's maintenance and repair recommendations will be elaborated in Section 5.5.

5.1.2 Pedestrian Overpass Construction

The pedestrian overpass will be constructed just south of Doug Mitchell Thunderbird Stadium. Key construction considerations are discussed in **Table 5.1** and proposed walkway staging is shown in **Figure 5.1**. Erection of the overpass structure will cause a full closure of Wesbrook Mall for 5 days. To minimize impacts, the phase of construction that leads to full road closures will be scheduled in the gap between the two UBC summer terms, beginning on June 30 and ending by July 4. The only full road closure is during the assembly of the overpass. This is because a crane will have to be on site to lift the precast structure in place. **Figure 5.2** shows a site plan with detour routes while this 5 day shutdown takes place. The project site plan during construction is shown in .

Table 5.1: Anticipated Construction Issues for Pedestrian Overpass Construction

Issues	Mitigation Measures
Construction interference with pedestrian and traffic flow	● Majority of construction is advised to take place from May to August 2022 during UBC summer term with less student traffic ● Public information and traffic management plan (See **Section 5.1.3**)
Sidewalk Closures and Pedestrian Safety	● Construction will be completed in phases with active construction zone along Wesbrook Mall closed and fenced off from pedestrians
Lane Closures	● Single lane alternating traffic along Wesbrook Mall when needed ● Using traffic control persons ● Full lane closures to occur during gap between summer terms (June 30, 2022 and July 4, 2022)
Material deliver, staging, and storage	● Proposed staging yard in parking lot outside of Gerald McGavin Rugby Center (See **Figure 5.1**)
Foundation and substructure stability	● Geotechnical analysis performed by geotechnical firm to assess characteristics of rocks, soil, and other subsurface conditions

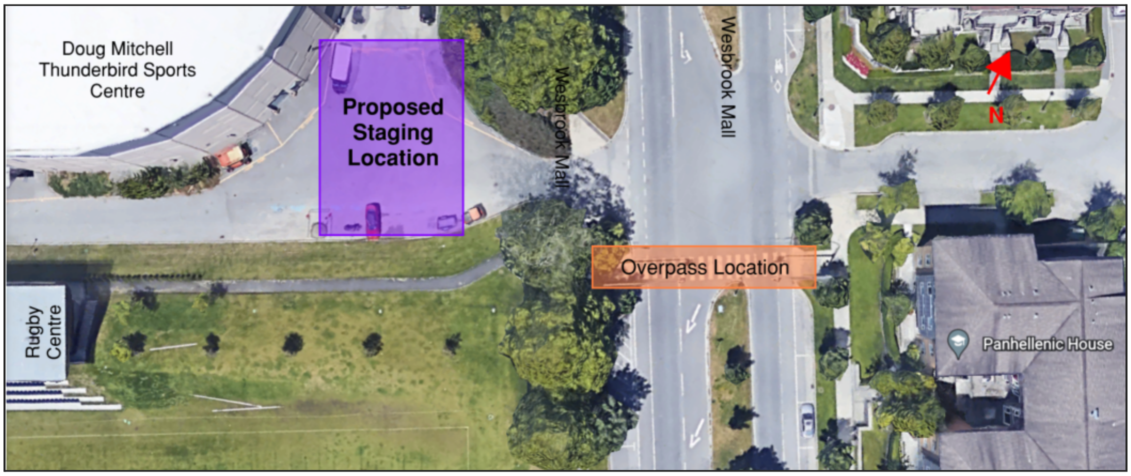


Figure 5.1: Staging Yard Location

Figure 5.2: Pedestrian Overpass Construction Site Plan and Proposed Detour Route

5.1.3 Traffic Management Plan

Table 5.2 summarizes the full traffic management plan proposed for phase 4. The plan accounts for site personnel, site considerations, pedestrian detours, procedural considerations, site parking and transportation, and results from a preliminary work zone impact assessment.

Table 5.2: Proposed Traffic Management Plan

Traffic Management	Implementation Plan
Site Name	• Site Name: Westbrook Mall Redesign – Overpass construction
Exact Site Location	• 2770 Wesbrook Mall, Vancouver, BC V6T
Site Personnel	• Project Supervisor: Peter Ehrlich • Traffic Control Supervisor: TBD • Traffic Control Person(s)
Site Factors	• Outside of road shutdown, there will be traffic going back and forth • Major shut down will be 5 days from October 3rd to October 7th • Residents are adjacent to construction site, therefore work can only happen between the hours of 8-5pm • For hard shutdown there are barricades on Wesbrook Mall just north of Hampton Place and at the other end, barricades on Wesbrook Mall and Thunderbird Blvd. • Construction signs to be implemented around site and on Thunderbird Blvd • Inbound and outbound traffic will take-on different routes to and from site (Figure 5.2)
Pedestrian Detours	Our construction site is located around main roads. Most of our traffic control will be done through pedestrian rerouting as the roads will be closed during overpass construction. We are keeping all sidewalks open for pedestrians by only fencing around the construction site. The map below indicates vehicle detour routes in orange arrows. The blue boundary indicates site fencing around where the overpass construction will happen.
Procedural Factors	• Work will be conducted inside fencing of the construction site • Machinery such as a crane and excavator will be maneuvering throughout the day within the site fencing boundaries.

	● Temporary construction equipment and tools will be maintained within ● Fencing boundaries to ensure pathways stay clear for pedestrian access
Site Parking and Transportation	● Our site will have one entrance during the construction. The muster point will be located further from gate 1 on the Frank Buck Field. Its location was analyzed to be the safest in case of an emergency as the gathering of people will not interrupt emergency vehicles from coming. ● Site workers will park in the closest parking available, which is the Thunderbird Parkade.
Preliminary Work Zone Impact Assessment	We aim to mitigate the impact of circulation and access on the UBC campus for pedestrians, cyclists, public transit, and motor vehicles. Our main objectives are: ● Always maintain public safety and impacts to pedestrians ● Detail truck loading and unloading procedures that will be utilized to ensure the safety of site workers and pedestrians. ● Provide the traveling public with advanced warning of impacts and direct them to alternative routes.

5.2 Cost Estimate

A Class A cost estimate was developed for the detailed design of this corridor. A Bill of Quantities (BOQ) was generated to estimate the material costs for each component of the detailed design. The quantities used in take-off were estimated based on the detailed design drawings presented in Appendix A.

In addition to the material costs, the Class A cost estimate also takes into account elements such as General Requirements, Construction, Equipment, Labour and Landscaping to provide a more reasonable estimate of the overall costs for this project. A standard 15% contingency fee is applied to the calculated costs to account for unexpected delays during construction or permitting. Furthermore, the provided costs take GST applied into consideration.

The cost breakdown for the project is provided in Table 5.3 below; the detailed Class A cost estimate can be found in Appendix D alongside the BOQ generated for this project. The total project cost is anticipated to be CAD $8.4 million.

Table 5.3: Class A Cost Estimate

Category	Cost
General Requirements	$48,391.00
Construction	$3,511,226.00
Equipment	$145,920.00
Materials	$2,496,127.07
Landscaping	$48,391.00
Labor	$1,037,000.00
Contingency (15%)	$1,093,058.26
TOTAL PROJECT COST	**$8,400,000.00**

The methodology for calculating the cost estimate was in line with the Government of British Columbia's *Transportation Project Cost Estimating Guidelines* (2020) and AASHTO's *Practical Guide to Cost Estimating* (2013). Material costs were retrieved from RS Means Cost Data 2020, adjusted for inflation in 2021 using the Covington Index.

In addition to the cost of constructing the proposed design, there will be annual maintenance and operation fees. Routine inspection and maintenance will be required to ensure that the facility is fit for use for the entirety of its intended lifespan. Inspection and maintenance activities are critical to ensure safe operation, and thorough documentation of each conducted inspection activity should be included in the implemented maintenance policy. **Table 5.4** below summarizes the annual maintenance activities, their frequencies, and the cost estimate, as it applies to the roadway. Specific activities, including maintenance of other corridor components (e.g., stormwater infrastructure, pedestrian overpass) are detailed in Section 5.5.

Table 5.4: Annual Operation and Maintenance Costs

Activity	Frequency	Unit Cost	Total Cost
Drainage maintenance	Once a year	$1.3 / m	$923.00
Asphalt repair	Every 5 years	$1.3 / m	$923.00
Line painting	Every 5 years	$1.3 / m	$923.00
Signage removal/repair	Every 5 years	$1.3 / m	$923.00
Sweeping	Every 9 weeks	$1.3 / m	$5,538.00
Vegetation maintenance	Every 2 weeks	$1.3 / m	$23,998.00
		Subtotal	$33,228.00
		Contingency (15%)	$4,984.20
		Total Annual Operation and Maintenance Cost	**$38,212.20**

The annual operation and maintenance cost estimated above was made with the following assumptions:

1. Equipment capital costs are not included
2. Cost of amenities such as lighting, garbage cans, benches, bike parking, etc. is not included
3. The frequency of maintenance activities is subject to change depending on weather elements; with Vancouver being subject to more extreme weather in recent years, it is likely that the frequency of maintenance activities will have to be increased in the near future

The unit cost of each listed activity was obtained from *Maintenance Practices and Costs of Rail-Trails* (Rails-to-Trails Conservancy, 2015).

5.3 Schedule

Figure 5.3 shows major milestones of the project. A full construction schedule breakdown including milestones and activities can be found in Appendix F. Starting August 27, 2021, the planning and permitting process has been taking place. Roadworks are set to begin May 2, 2022, followed by pedestrian overpass construction, stormwater infrastructure construction, and replacement of sidewalks at the proposed location. Heavy construction is scheduled to take place during the slower summer months to minimize impacts on students, staff, and faculty. The total expected duration of the project is 153 work days excluding weekends and holidays.

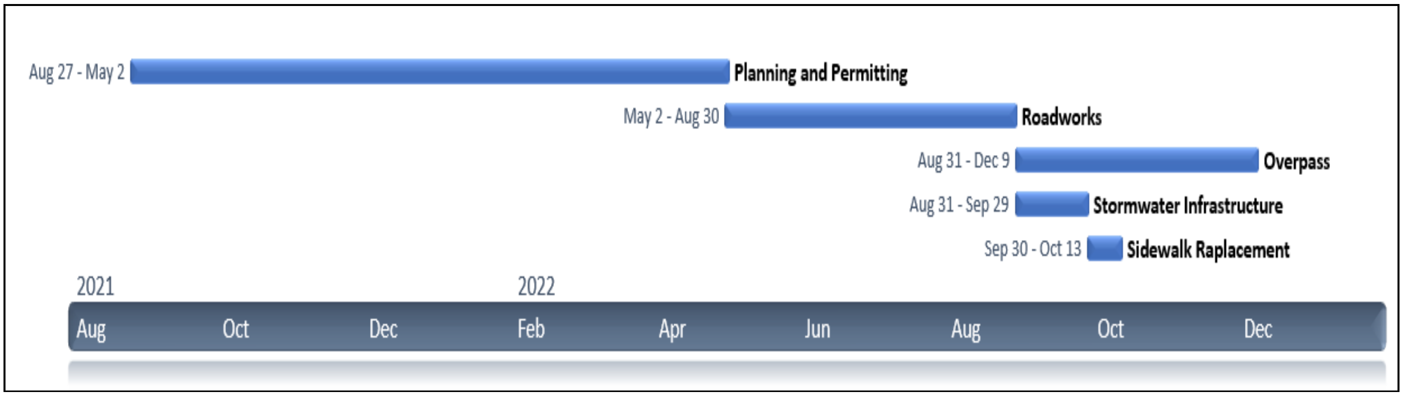


Figure 5.3: High Level Project Schedule

For construction, the project was split into 6 main phases that included:

- SB1 = Southbound Thunderbird to beginning of Gerald McGavin Rugby field
- SB2 = Southbound start Gerald McGavin Rugby field to RCMP Station
- SB3 = Southbound RCMP Station to W 16th Ave
- NB1 = Northbound W 16th Ave to RCMP Station
- NB2 = Northbound RCMP Station to end Gerald McGavin Rugby field
- NB3 = Northbound Gerald McGavin Rugby field to Thunderbird Blvd

The phases were planned to ensure maximum efficiency of existing traffic flows while also minimizing any full road closures. All of these phases are referenced in the detailed construction schedule located in Appendix F.

5.4 Stakeholder Engagement Plan

Stakeholder engagement is a critical part of detailed design development, and our team utilized the feedback gained from Phases 1 and 2 of the Wesbrook Mall Redesign Project to satisfy stakeholder needs. The public consultation summary reports from Phase 1 and Phase 2 provided valuable insight into the aspects of design that stakeholders actively wanted, which were incorporated into the proposed design as much as possible. **Table 5.5** below outlines the key takeaways from these public consultation summary reports.

Table 5.5: Key Takeaways from Stakeholder Consultation Process

Vibrant Spaces	● Provide adequate rain shelter ○ Permanent umbrellas ○ Umbrella sharing services ○ Covered walkways ● Interactive public realm features ○ Infobooth ○ UBC history panels ● Digital signage ○ Real time bus schedules ○ Displays of UBC events ● Artwork ○ Alumni commissioned artwork ○ Featured work by UBC students ○ Indigenous
Pedestrian & Bike Connections	● Bike parking ● Separated bike lanes connected throughout UBC ● Wider sidewalks ○ No-texting lanes for faster walkers
Academic Identity	● More green spaces and trees ● Sculptures

Through the consultation process done in Phases 1 and 2, it was clear that stakeholders enjoyed the green aesthetic of the corridor in its current design and would like to have as much green space as possible. This played a key role in determining which stormwater management practices would be best suited for this project, and consequently a design consisting of rain gardens and tree box filters were chosen, as these will retain the vibrant, green aesthetic of this corridor while serving a critical functional purpose for stormwater management.

Moreover, the use of vibrant spaces and providing shelter from weather elements were also key takeaways that were incorporated in the design of the pedestrian overpass.

5.5 Service Life and Maintenance Plan

This section details the proposed service life and maintenance plan for the overall project. As a supplement to the annual maintenance cost table presented in Section 5.2, Table 5.4. A year-by-year cost breakdown of all maintenance activities is shown in Appendix F. For a 50 year life cycle, a total present worth cost for maintenance is expected to be $2,955,314.00. An estimated 2% inflation rate was used for items that will require recurring maintenance over the service life of each project component.

5.5.1 Roadway Pavement

The service life and maintenance plan for the roadway will be considered for a 50 year maintenance life. The BC Ministry of Transportation and Infrastructure suggests conducting maintenance every 7 years to maintain, at minimum, LOS D. The construction manager (CM) is responsible for the preparation of such a maintenance plan as well as the oversight of the maintenance works themselves. The depth of the asphalt thickness and lowest global warming potentials would be the two most significant factors to consider before initiating a pavement rehabilitation. Our team recommends adopting the asphalt overlay method for rehabilitation throughout the entire strip of the roadway and consider Maltene Replacement Technology for restoration in location with small cracks.

Asphalt Overlay

An overlay is the placing of one or more lifts of asphalt pavement on top of an existing asphalt pavement. The asphalt overlay method can add strength to the existing roadway, prove to be a cost effective method, and treat any width of roadway. The asphalt overlay procedure is as follows:

- Prepare surface to be rehabilitated by removing any loose sediments or debris
- Apply a tack coat of emulsified asphalt evenly onto the road surface using a distributor truck
- Pave the road with a thin overlay (40mm to 75mm)

- Compact the asphalt mix with an appropriately sized roller at the right speed. Too small or fast and improper compaction results; too large or slow and aggregate is crushed.
- Apply a second overlay if needed

A combination of steel and rubber rollers is recommended to ensure proper sealing throughout the roadway.

Maltene Replacement Technology

Applying the right treatment at the beginning of the pavements life is the remedy. The Maltene replacement technology ensures the roadway will stay smooth and in good condition, adding four to five years of pavement life. Using MRT with asphalt overlay simultaneously every 7 years can be done. Pavement restoration treatments are a fraction of the cost of repaving, so every year of added service life extends the paving budget while reducing carbon footprint.

Genuine asphalt rejuvenation using MRT technology can also prove to be cost effective, costing only a dollar per square yard of treatment. When combined with crack sealing in a program of proactive preventive maintenance, including two cycles of MRT treatments, the cost of life-extending restoration is less than 30 percent of the cost of resurfacing.

Repainting of the roadway can be conducted simultaneously. All relevant costs for repainting of lines are represented in the cost estimate in Appendix G.

5.5.2 Sidewalk Pavement

The sidewalk upkeep and maintenance recommended include maintaining good drainage across the sidewalk and boulevard (e.g., through tree-box filters), pruning tree roots and repairing localized defects. Removing snow and ice is important for safety, and salting the pedestrian facility in the winter is recommended. However, excess salt on the concrete can erode the material over time, so it is recommended that salt is applied on the surface in no excess. Dirt covering the sidewalk can also trap moisture which can slowly wear away the concrete. We recommend that sidewalks within the scope be routinely cleared for cleanliness and aesthetics. Other ways to avoid root damage in the future include utilizing root barriers and structural soils. With proper upkeep and maintenance, the expected service life of the concrete sidewalk is 80 years.

5.5.3 Green Stormwater Infrastructure

The stormwater management components (e.g., rain garden, tree-box filter, outlet controls) will be periodically inspected to ensure function is maintained. Regular maintenance will also be conducted to remediate issues in the system. For rain garden beds, the client is recommended to follow manufacturer guidelines. **Table 5.6** provides the recommended maintenance activities and schedule according to guidelines published by Blue Water Baltimore (n.d).

Table 5.6: Rain Garden Typical Maintenance Activities

Activity	Frequency
• Watering rain garden plants • Add or replace vegetation in eroded area	As Needed
• Maintain appearance of swale by pruning and weeding • Remove trash and debris in rain garden	Monthly
• Remove accumulated sediment as needed • Remove dying vegetation and mulch which • may have moved around the garden	Yearly
• Test planting bed for PH. If PH is below 5.2, limestone should be applied. If above 8, iron-sulfate and sulfur should be applied. • Replace dying mulch	2-3 Years

5.5.4 Pedestrian Overpass

The pedestrian overpass will undergo periodic preventative maintenance and inspections. Inspections will be conducted at least once every 2 years to ensure that all items of user safety are accounted for and performing properly. **Table 5.7** provides a summary of maintenance tasks recommended by Bridge Masters Inc. (2017) that will help preserve overpass condition, delay future deterioration, and extend the useful life of the structure.

Table 5.7: Recommended Overpass Maintenance Activities

Activity	Frequency
• Washing and cleaning • Removing trash and other debris • Sealing cracks • Clearing drainage areas	As Needed
• Painting	As Needed or 5-10 Years
• Sealing deck joints	3-5 Years

6.0 CONCLUSION AND RECOMMENDATIONS

6.1 Summary

The Wesbrook Mall Phase 4 Redesign Project is ready with Issue-For-Construction (IFC) drawings complete for the roadway, stormwater, and pedestrian overpass aspects of the project including:

- Roadway construction consists of new elevated and bi-directional bike lanes along the SB corridor, pavement markings, curb extensions, and road resurfacing. Median narrowing is proposed on three out of five medians along the scope to create space for a NB transit lane
- Proposed stormwater retention system includes a total rain garden area of 1950 m2 in three of the medians, 32 total tree box filters along the sidewalk, and proposed green curb extensions
- 5 m tall covered pedestrian overpass just south of the Doug Mitchell Thunderbird Sports Arena

The project is expected to cost $8,380,000 CAD in 2022 capital costs. Construction is expected to begin on May 2, 2022 and last until October 13, 2022 with an expected duration of 199 work days.

6.2 Recommendations and Next Steps

The following recommendations have been made for project implementation:

- UBC SEEDS to tender project and award bid to suitable contractor
- Contractor to obtain relevant permits and approvals
- Contractor should conduct / obtain further evaluation of site conditions (e.g., borehole drilling)

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APPENDIX A - Detailed Design Drawings

THE UNIVERSITY OF BRITISH COLUMBIA

CAPSTONE Engineering Inc

PROJECT NO. 000-001

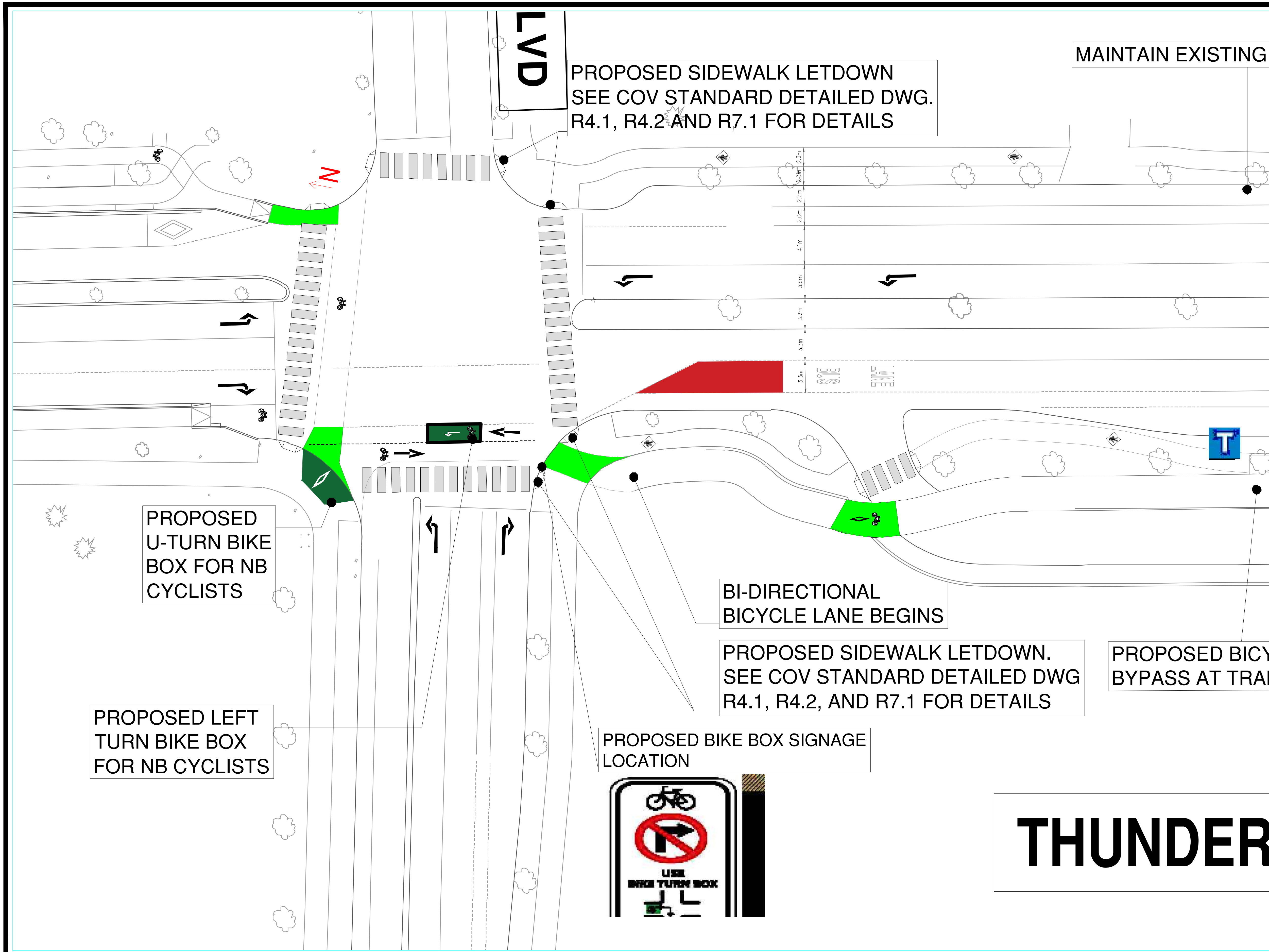
WESBROOK MALL REDESIGN PHASE 4 (W16TH AVE TO THUNDERBIRD BLVD)

UBC VANCOUVER CAMPUS

ISSUED FOR CONSTRUCTION APRIL 6, 2022

(FOR CIVL 446 COURSE PURPOSES ONLY)

REV	DATE
A	APRIL 6, 2021



UBC

CAPSTONE Engineering Inc

KEYED NOTES:

1. FOR ROADWAY CROSS SECTION, SEE DWG. A6 TO A7 FOR DETAILS.
2. FOR PEDESTRIAN OVERPASS, SEE DWG. C1 TO DWG. C5 FOR DETAILS.
3. FOR STANDARD DETAIL DRAWINGS:
   - 3.1. STREET LIGHTS - SEE SURREY MMCD DWG. SSD-R.E.1 TO R.E.4 (PROPOSED STREET LIGHTS TO BE PLACED ON THE EAST SIDE OF EAST MALL
   - 3.2. CURBS - SEE CITY OF VANCOUVER STANDARD DETAIL DWG. C4.1 AND C19.1.
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   - 3.5. PARKING METER LAYOUT - SEE CITY OF VANCOUVER STANDARD DETAIL DWG. R9.1.

PLAN
WESBROOK MALL
THUNDERBIRD BLVD
INTERSECTION

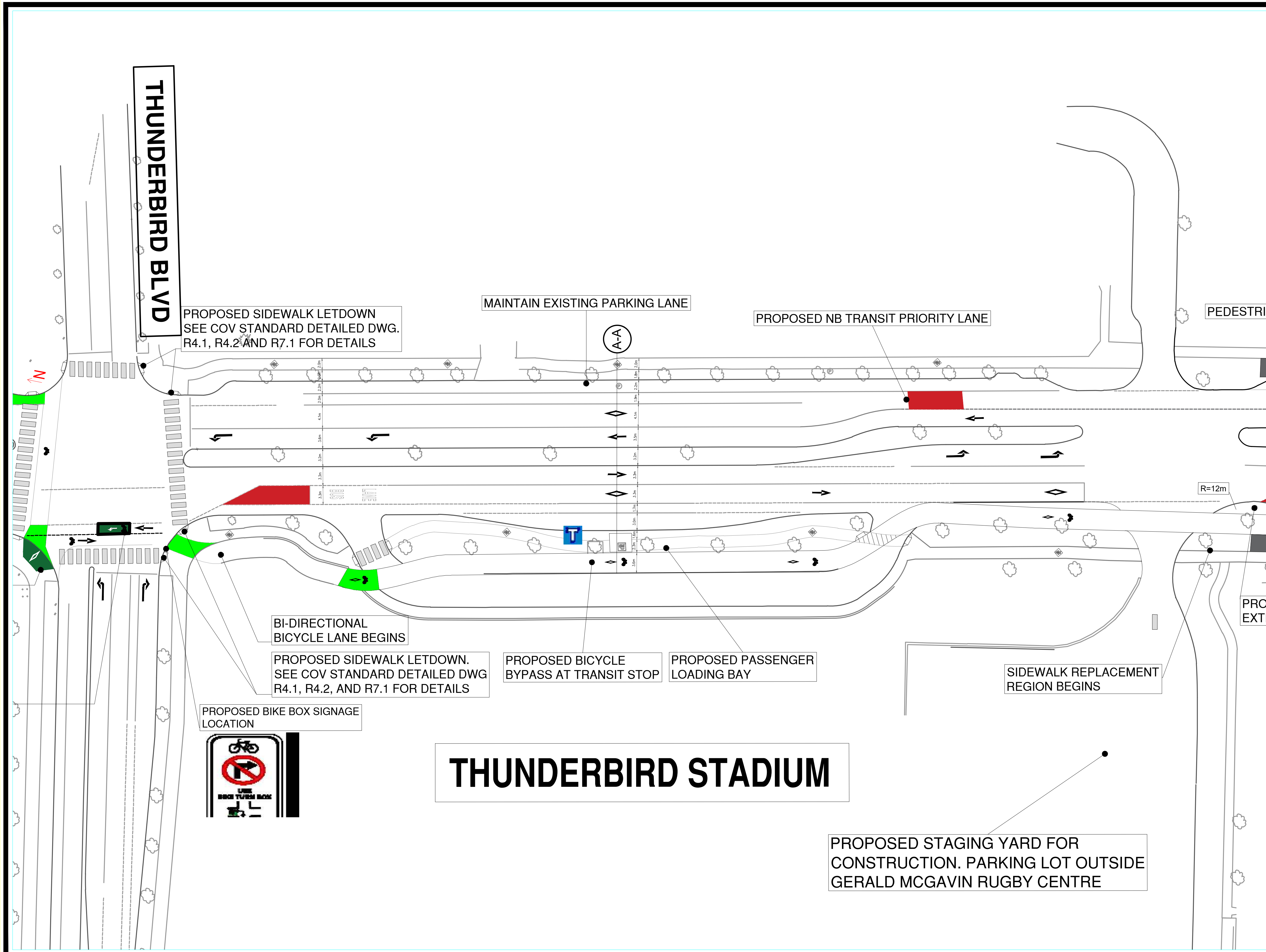
DRAWINGS FOR:
CIVL 446 DETAILED DESIGN

PROJECT: WESBROOK MALL REDESIGN PHASE 4

DATE: 2022-04-06

SCALE: 5mm : 2m

A1



UBC

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PLAN
WESBROOK MALL
THUNDERBIRD BLVD TO FRANK BUCK FIELD

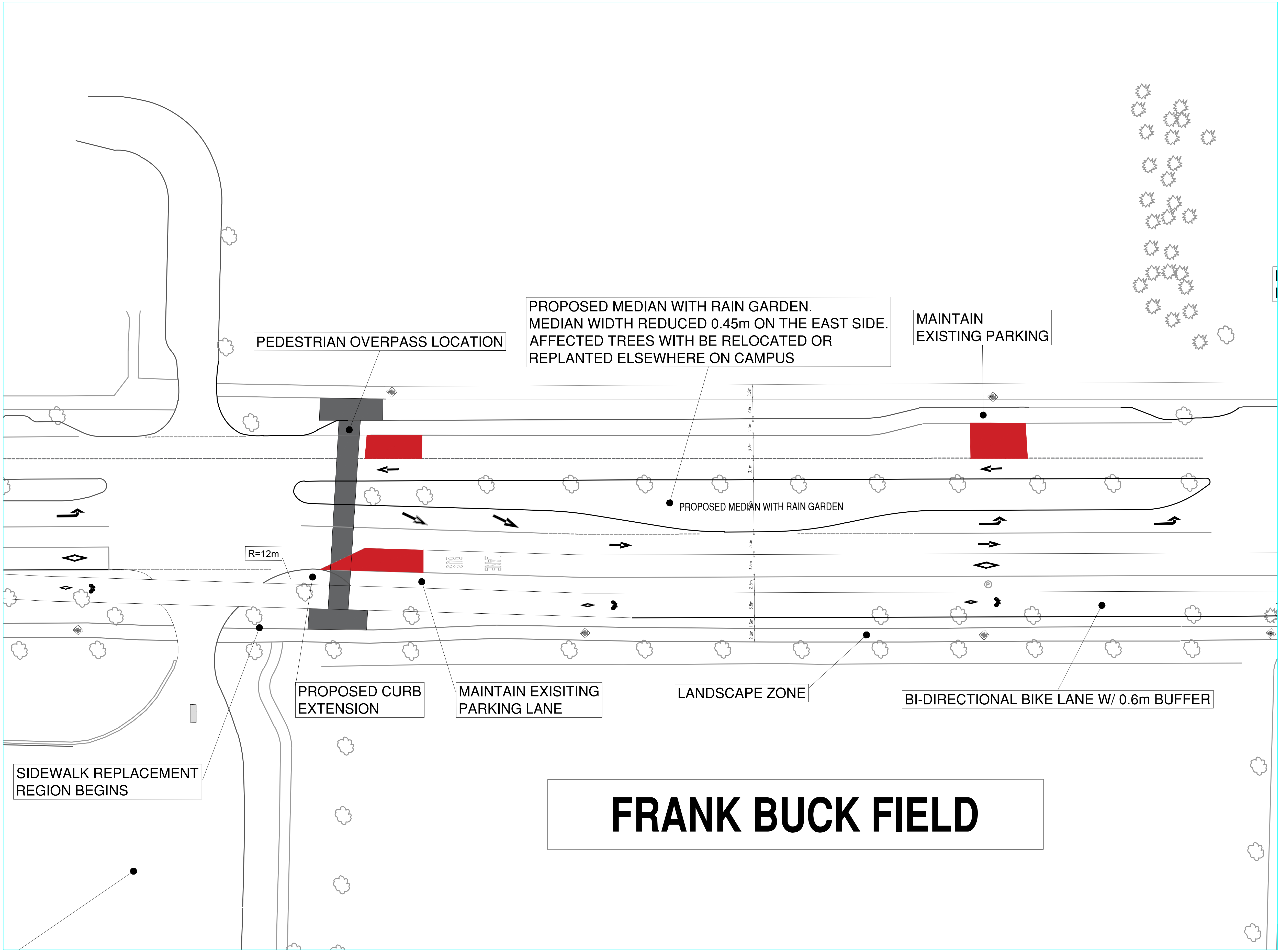
DRAWINGS FOR:
CIVL 446 DETAILED DESIGN

PROJECT: WESBROOK MALL REDESIGN PHASE 4

DATE: 2022-04-06

SCALE: 3mm : 2m

A2



KEYED NOTES:

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PLAN
WESBROOK MALL
FRANK BUCK FIELD

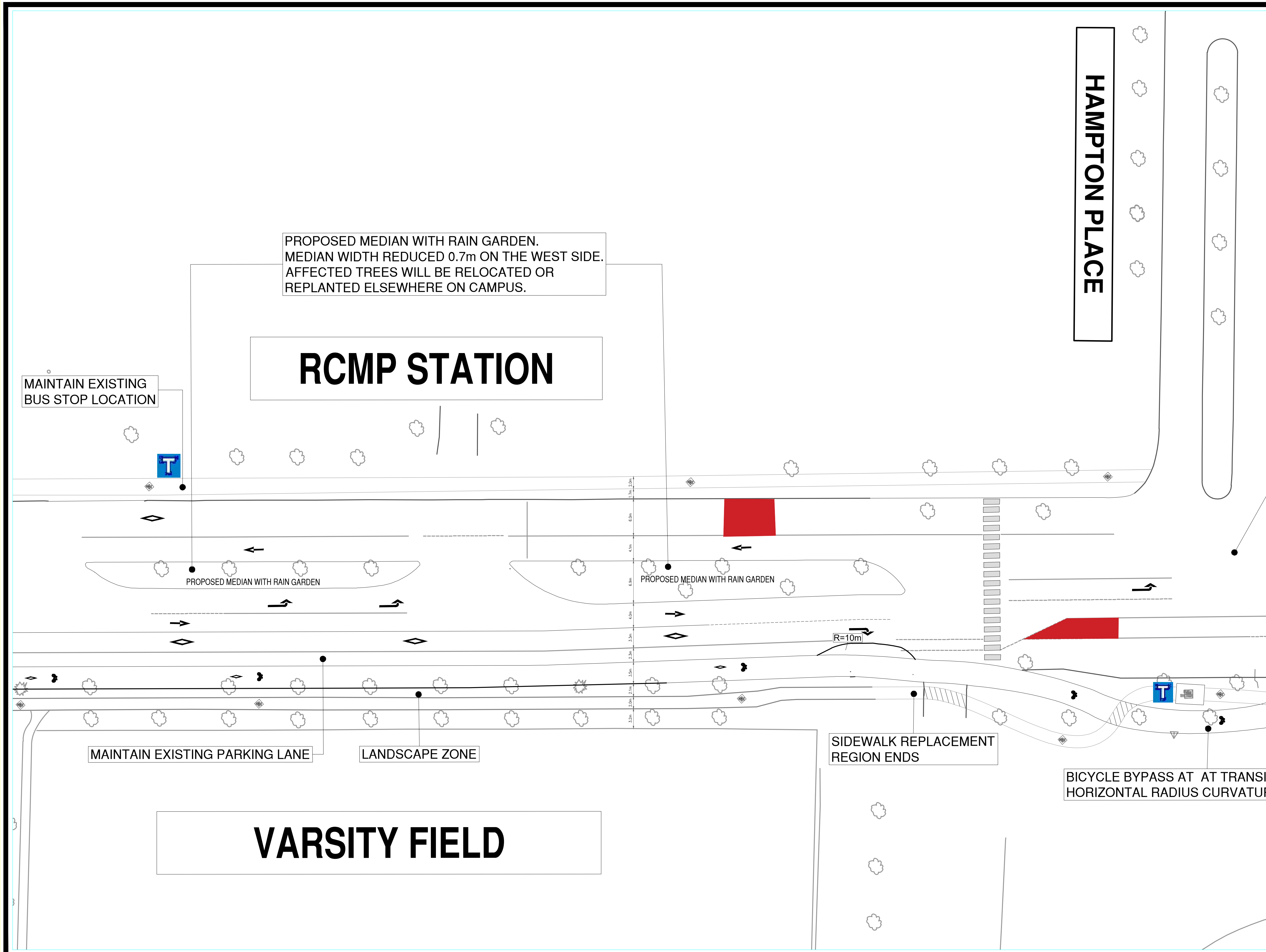
DRAWINGS FOR:
CIVL 446 DETAILED DESIGN

PROJECT: WESBROOK MALL REDESIGN PHASE 4

DATE: 2022-04-06

SCALE: 3mm : 2m

A3



UBC

CAPSTONE Engineering Inc

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PLAN
WESBROOK MALL
VARSITY FIELD

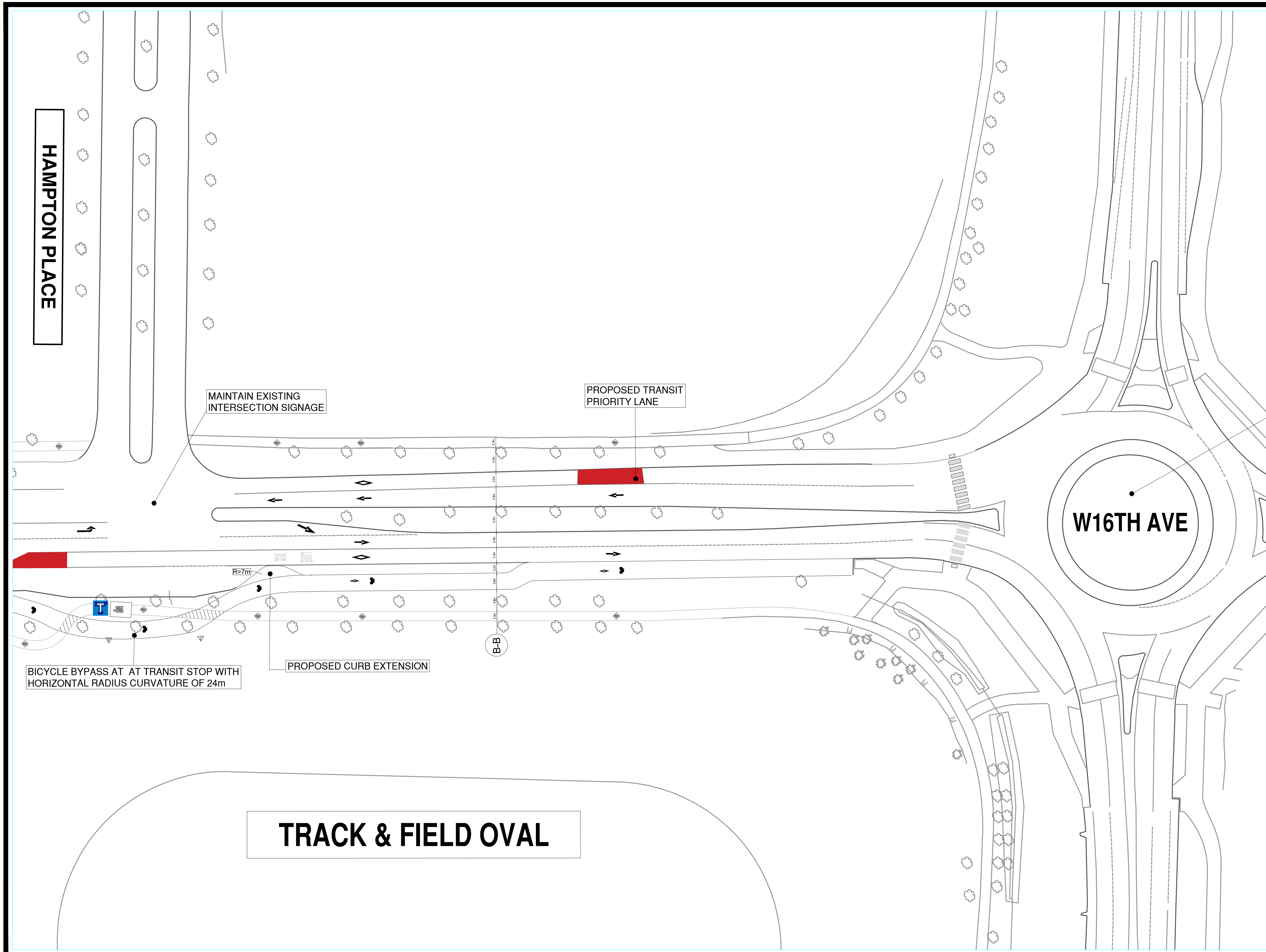
DRAWINGS FOR:
CIVL 446 DETAILED DESIGN

PROJECT: WESBROOK MALL REDESIGN PHASE 4

DATE: 2022-04-06

SCALE: 3mm : 2m

A4



UBC

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PLAN
WESBROOK MALL
HAMPTON PLACE TO W16TH AVE

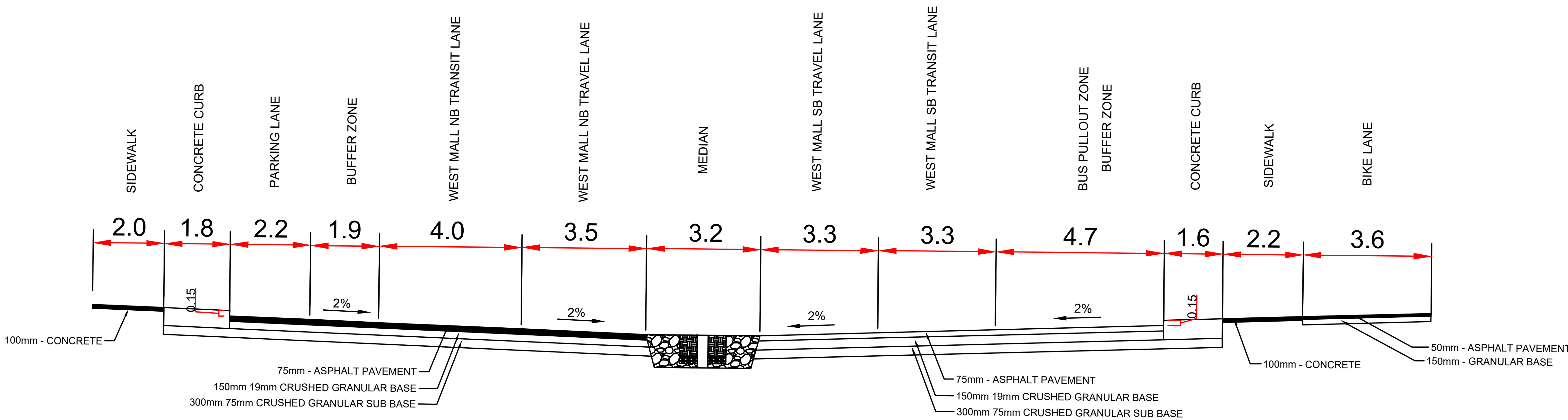
DRAWINGS FOR:
CIVL 446 DETAILED DESIGN

PROJECT: WESBROOK MALL REDESIGN PHASE 4

DATE: 2022-04-06

SCALE: 10mm : 9m

A5



UBC

CAPSTONE Engineering Inc

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CROSS SECTION
WESBROOK MALL
THUNDERBIRD BLVD TO FRANK BUCK FIELD

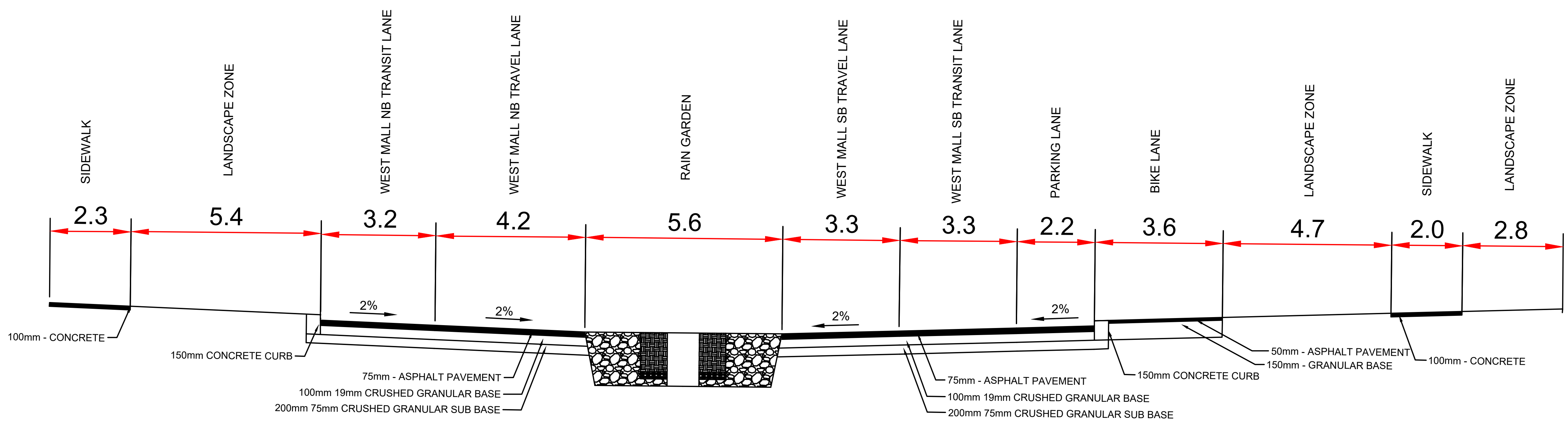
DRAWINGS FOR:
CIVL 446 DETAILED DESIGN

PROJECT: WESBROOK MALL REDESIGN PHASE 4

DATE: 2022-04-06

SCALE: N/A

A6



CAPSTONE Engineering Inc

KEYED NOTES:

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CROSS SECTION
WESBROOK MALL
HAMPTON PLACE TO W16TH AVE

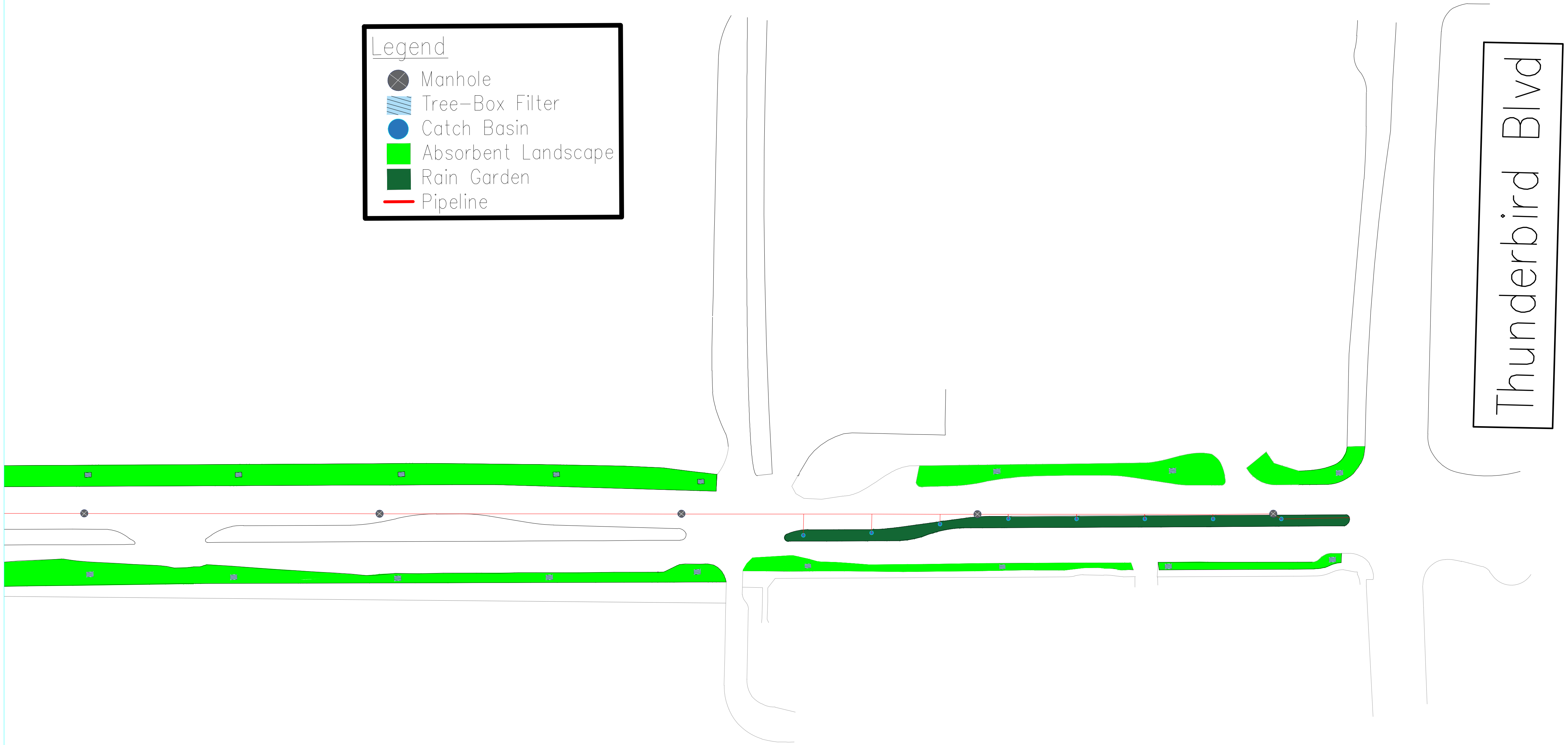
DRAWINGS FOR:
CIVL 446 DETAILED DESIGN

PROJECT: WESBROOK MALL REDESIGN PHASE 4

DATE: 2022-04-06

SCALE: N/A

A7



CAPSTONE Engineering Inc

KEYED NOTES:

1. REFER TO PLAN DRAWINGS FOR DIMENSIONS OF ROAD COMPONENTS (A1 TO A5)
2. PROVIDE ADEQUATE SAFETY MEASURES FROM VEHICLE TRAFFIC AND PEDESTRIANS DURING, AND AFTER CONSTRUCTION
3. MAXIMUM SIDE SLOPE OF 20%
4. PIPELINE
   4.1 FOLLOW UBC TECHNICAL GUIDELINES SECTION 33 49 00
   4.2 CONNECTS TO PRE-EXISTING STORM SEEING - SEE PLAN LAYOUT (A__)
   4.3 FOLLOW COV STANDARD DETAIL DRAWINGS OF STORM & SANITARY SEWERS (DWG S1.1 TO S20.2)

.

PLAN
WESBROOK MALL
THUNDERBIRD BLVD TO FRANK BUCK FIELD

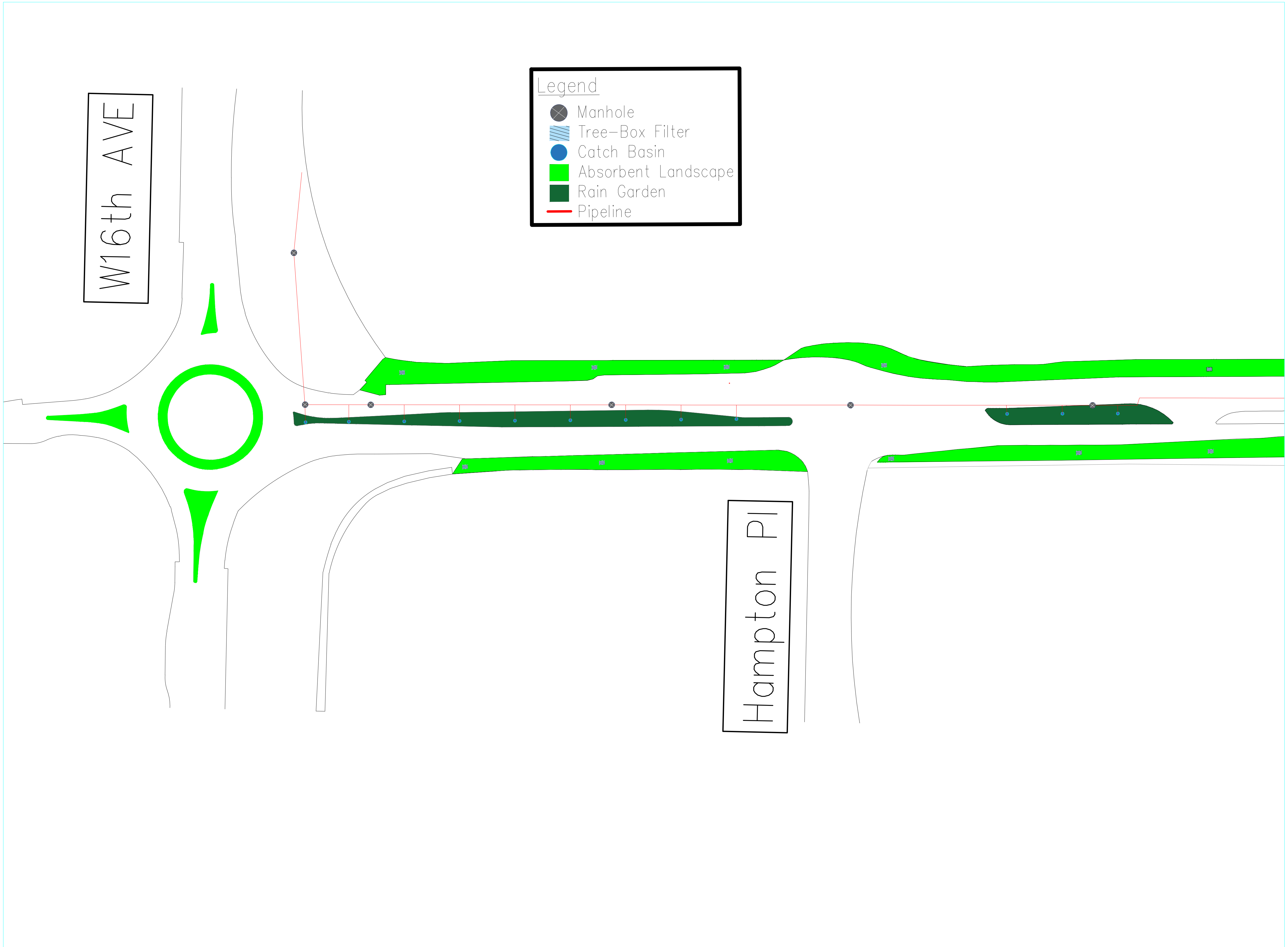
DRAWINGS FOR:
CIVL 446 DETAILED DESIGN

PROJECT: WESBROOK MALL REDESIGN PHASE 4

DATE: 2022-04-06

SCALE: 3mm : 4m

B1



UBC

CAPSTONE Engineering Inc

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PLAN
WESBROOK MALL
FRANK BUCK FIELD TO W16TH AVENUE

DRAWINGS FOR:
CIVL 446 DETAILED DESIGN

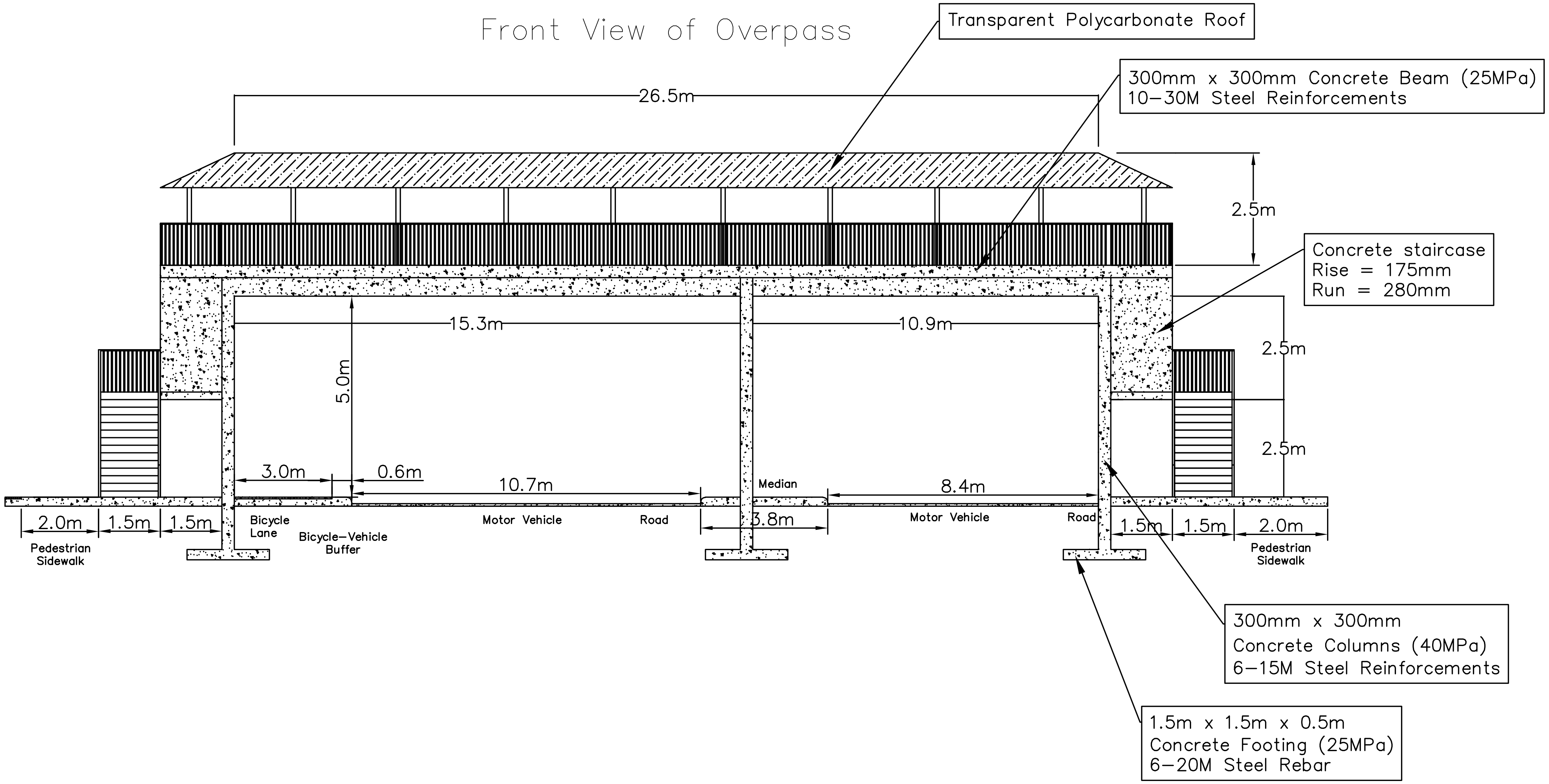
PROJECT: WESBROOK MALL REDESIGN PHASE 4

DATE: 2022-04-06

SCALE: 3mm : 4m

B2

Front View of Overpass



UBC

CAPSTONE Engineering Inc

KEYED NOTES:

COMPLETE OVERPASS FRONTVIEW

DRAWINGS FOR: CIVL 446 DETAILED DESIGN

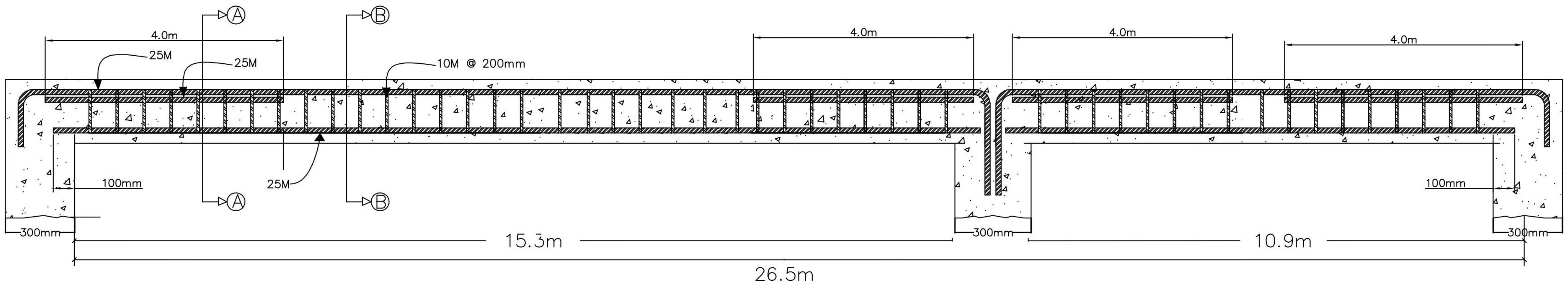
PROJECT: WESBROOK MALL REDESIGN PHASE 4

DATE: 2022-04-06

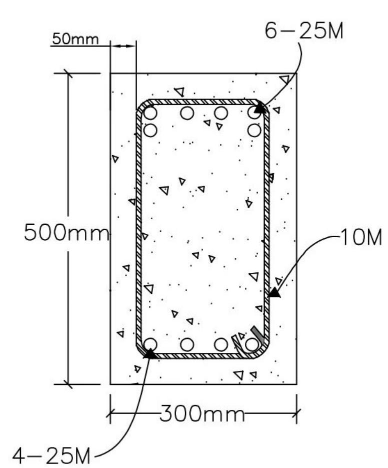
SCALE: 120:1

C1

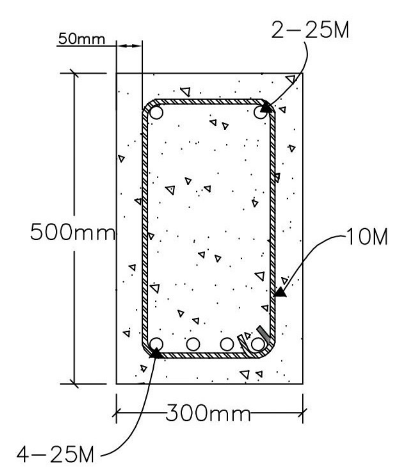
Beam Side View



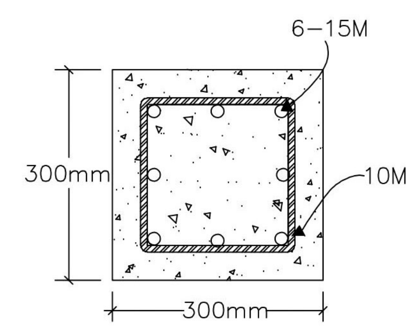
Section A–A



Section B–B



Column Section



CAPSTONE Engineering Inc

KEYED NOTES:

OVERPASS BEAM AND COLUMNS

DRAWINGS FOR:
CIVL 446 DETAILED DESIGN

PROJECT: WESBROOK MALL REDESIGN PHASE 4

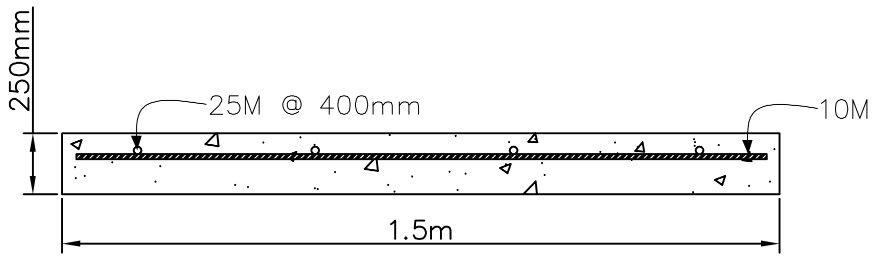
DATE: 2022-04-06

SCALE: N/A

C2

Slab Side View

Slab Cross-Section View



KEYED NOTES:

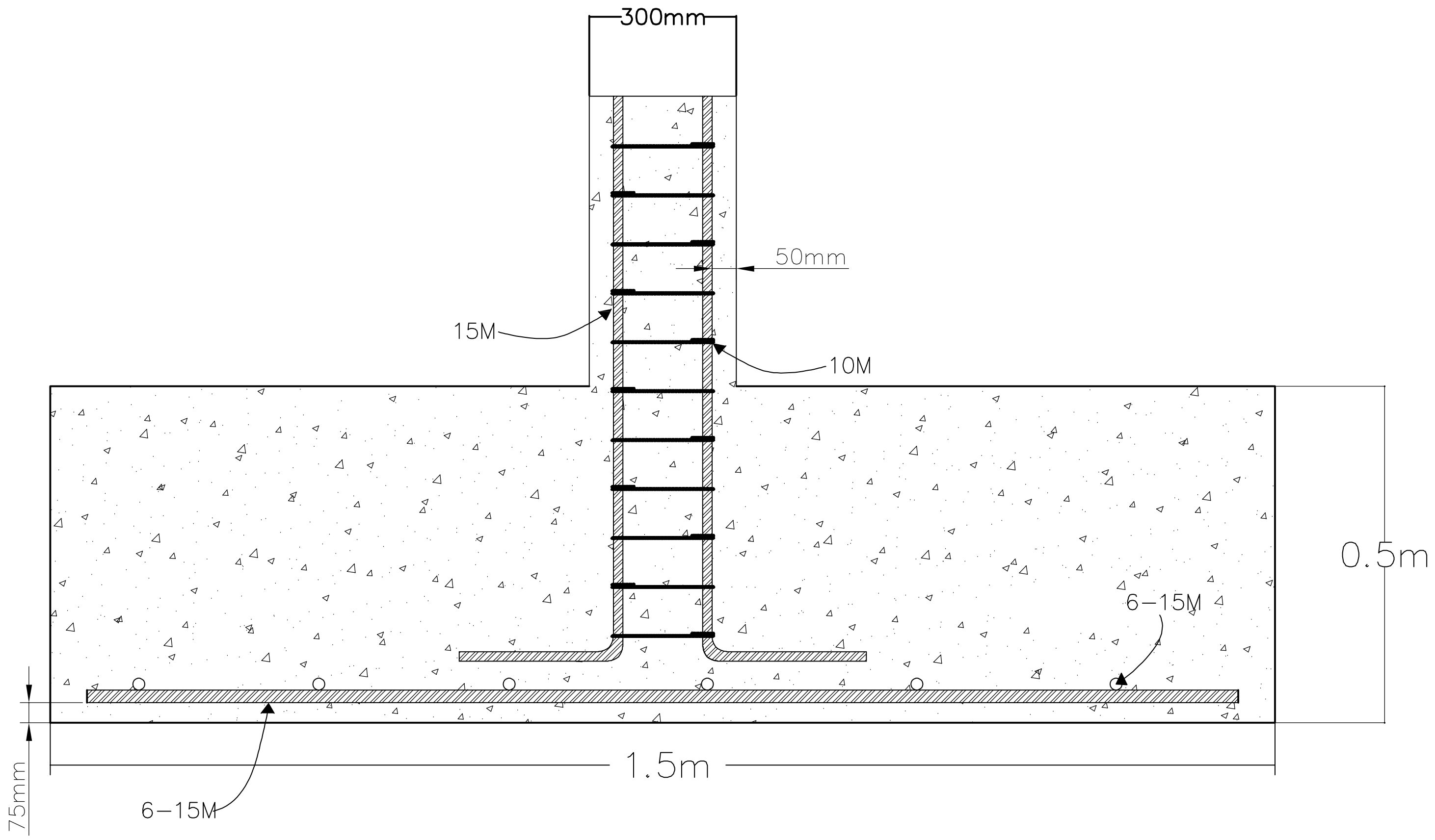
OVERPASS
SLAB

DRAWINGS FOR:
CIVL 446 DETAILED DESIGN

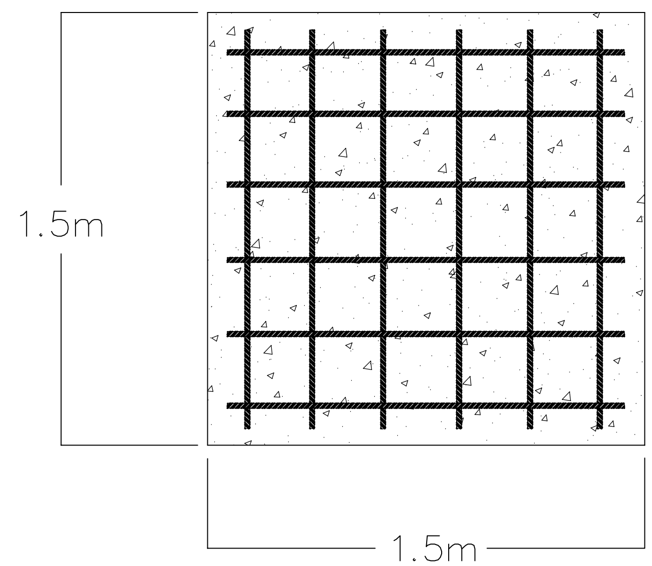
PROJECT: WESBROOK MALL REDESIGN PHASE 4

DATE:	2022-04-06	C3
SCALE:	N/A	

CAPSTONE Engineering Inc



Side View



Section View

UBC

CAPSTONE Engineering Inc

KEYED NOTES:

OVERPASS FOOTING

DRAWINGS FOR:
CIVL 446 DETAILED DESIGN

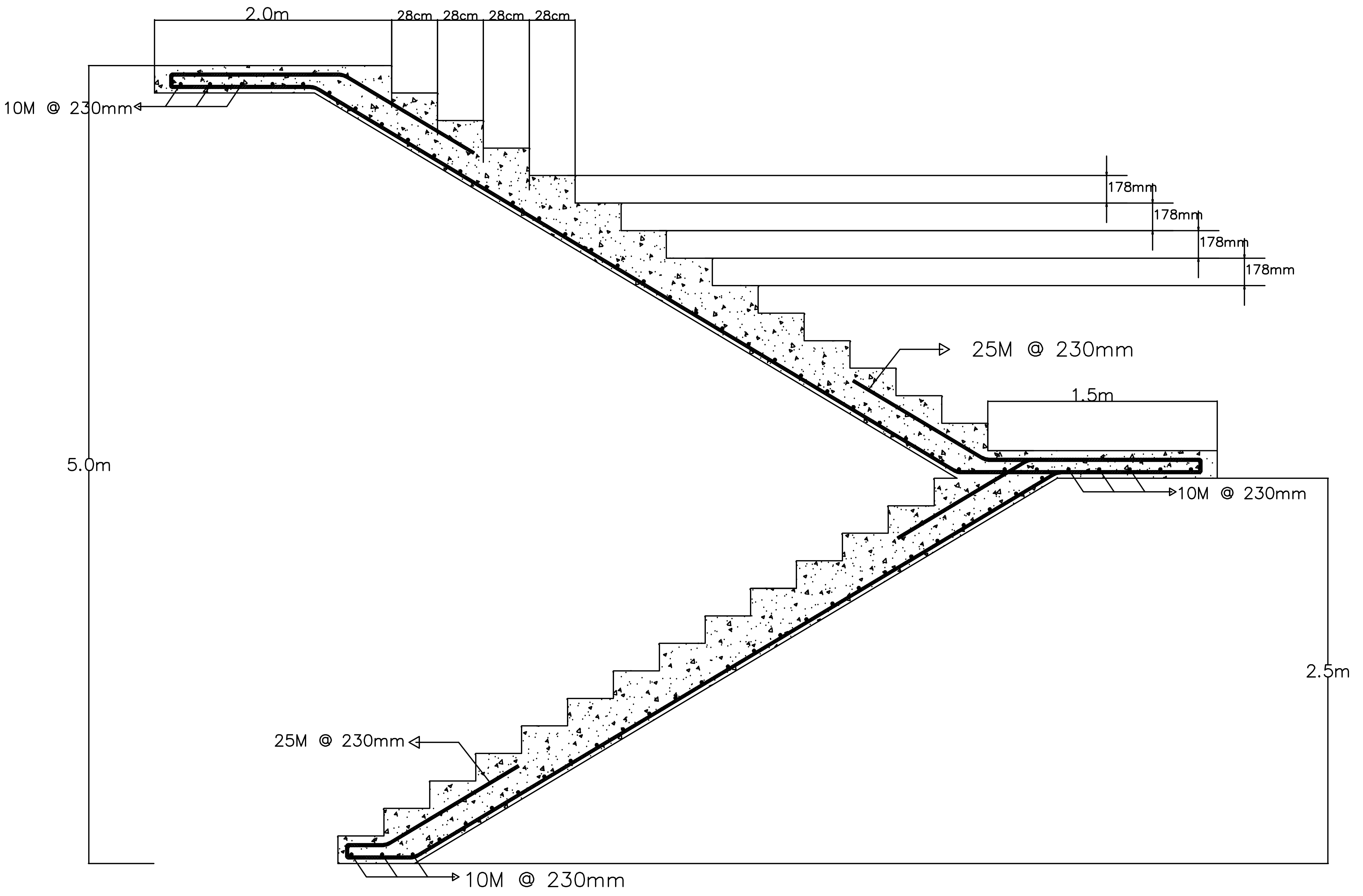
PROJECT: WESBROOK MALL REDESIGN PHASE 4

DATE: 2022-04-06

SCALE: N/A

C4

Stairs Side View



CAPSTONE Engineering Inc

KEYED NOTES:

COLUMNS AND RAILINGS ARE NOT SHOWN

OVERPASS STAIRS

DRAWINGS FOR:
CIVL 446 DETAILED DESIGN

PROJECT: WESBROOK MALL REDESIGN PHASE 4

DATE: 2022-04-06

SCALE: 30:1

C5

APPENDIX B - Traffic Analysis Results Table

Synchro Analysis Tables for Wesbrook Mall and Thunderbird Boulevard

2040 AM

Intersection	Measure	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBL
Thunderbird	V/C	0.58	0.80	0.14	0.84	0.44		0.61	0.90		0.22	0.56	0.32
	LOS	D	D	B	D	C		C	D		C	C	A
	95th Percentile Queue	21.5	45.6	5.8	33.9	35.4		32.2	190.1		9.9	84.8	0.1

2040 PM

Intersection	Measure	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBL
Thunderbird	V/C	0.58	0.80	0.14	0.84	0.44		0.61	0.90		0.22	0.56	0.32
	LOS	D	D	B	D	C		C	D		C	C	A
	95th Percentile Queue	21.5	45.6	5.8	33.9	35.4		32.2	190.1		9.9	84.8	0.1

SIDRA Analysis Tables for Wesbrook Mall and West 16th Ave

Existing 2040 AM	South: Wesbrook			East: W 16th Ave			North: Wesbrook			West: W 16th Ave		
Movement ID	1	2	3	4	5	6	7	8	9	10	11	12
v/c	1.079	1.079	1.079	0.611	0.611	0.611	0.377	0.377	0.285	0.412	0.412	0.412
LOS	F	F	F	B	A	A	B	A	A	B	A	A
95th Percentile Queues		425.1			38.5			15.2			19.7	

Exisiting 2040 PM	South: Wesbrook			East: W 16th Ave			North: Wesbrook			West: W 16th Ave		
Movement ID	1	2	3	4	5	6	7	8	9	10	11	12
v/c	0.827	0.827	0.827	0.540	0.540	0.540	0.517	0.517	0.314	0.613	0.613	0.613
LOS	B	B	B	B	A	A	B	A	A	C	B	B
95th Percentile Queues		64.6			27.9			25.4			46.1	

Modified 2040 AM	South: Wesbrook			East: W 16th Ave			North: Wesbrook			West: W 16th Ave		
Movement ID	3	2	1	12	11	10	9	8	7	6	5	4
v/c	0.540	0.540	0.604	0.737	0.737	0.737	0.317	0.551	0.551	0.469	0.469	0.469
LOS	B	A	A	C	B	B	B	A	A	B	A	A
95th Percentile Queues		29.9			76.4			28.9			21.1	

Modified 2040 PM	South: Wesbrook			East: W 16th Ave			North: Wesbrook			West: W 16th Ave		
Movement ID	3	2	1	12	11	10	9	8	7	6	5	4
v/c	0.353	0.353	0.348	0.484	0.484	0.484	0.345	0.491	0.491	0.494	0.494	0.494
LOS	B	A	A	B	A	A	B	A	A	B	A	A
95th Percentile Queues		13.3			24.7			23.5			23.1	

APPENDIX C - Rain Garden Sample Calculations

Stormwater Management: Source Control Design

Volumetric Reduction Criteria*:* 72% of 2-year, 24-hour rainfaill

Set volumetric reduction criteria = rainfall capture target

Rainfall intensity = 2.3 mm/hr

Total rainfall over one return period = 55.2 mm

Capture rainfall target = 0.72 * 55.2 = 39.7 mm in 24 hours

Mean Annual Rainfall data (obtained from Metro Vancouver Regional IDF Curves 2009)

ZONE	OWNER	NAME	UTM X	UTM Y	MEAN ANNUAL PRECIPITATION (mm)
03	Metro Van	Abbotsford	550445	5432441	1002
03	Metro Van	Kitsilano High School	488103	5456596	1330
03	Env Can	Abbotsford A	546792	5429876	1573
03	Env Can	Point Atkinson	481105	5463062	1356
03	Env Can	Surrey Newton	511672	5441920	1409
03	Env Can	Surrey Municipal Hall	513139	5438588	1370
03	Env Can	Langley Lochiel	530689	5433099	1487
03	Metro Van	Heilings Reservoir	507165	5445096	1391
03	Metro Van	Newton Reservoir	509618	5440376	1123
03	Metro Van	Cloverdale Pump Station	516966	5439069	1197
03	Metro Van	Langley Central	531605	5438203	1261
03	Metro Van	31790 Walmsley Rd., Aldergrove	546000	5430400	1181
03	Metro Van	Kersland Reservoir	491704	5453913	1343
03	Metro Van	Gleneagles Pump Station No. 5	480621	5466118	1417
03	Env Can	VANCOUVER UBC	481806	5455278	1277
03	Metro Van	Gleneagles Pump Station No. 2	479880	5468789	1401

Equations Used:

Assume soil is dry for capture target calculation, standard practice (KWL, 2019)

Evaporation Volume = pervious lot area * evaporation rate = 297.5 m2 * (1 mm/day * 10^-3) = 0.30 m3

Infiltration Volume = pervious lot area * infiltration rate = 297.5 m2 * 1.5 mm/hr * 24 hours * 10^-3 m = 10.7 m3

Dr = (Ks * T * 24 hours) / n = (13 mm/hr * 1 * 24) / 0.4 = 780 -> Choose 800 mm

APPENDIX D - Pedestrian Walkway Calculations

Loading Calculations

Dead Load		
Slab		
Length	26.5	m
Width	1.7	m
Height	0.25	m
Density	23.5	kN/m^3
Weight	264.6688	kN
Beam		
Length	26.5	m
Width	0.3	m
Height	0.5	m
Density	23.5	kg/m^3
Weight	93.4125	kN
Column		
Length	0.41	m
Width	0.41	m
Height	5	m
Density	23.5	kN/m^3
Weight	14.39375	kN

Live Load	
Pedestrian	4.31 kPa
Snow	1.2 kPa
Wind	0.95 kPa

Load Conditions					
Case	Dead	Live	Snow	Wind	Total
I	1.4	1	1	1	643.8191 kN
II	1.25	1.5	1	1	650.2877 kN
III	1.25	1	1.5	1	609.0802 kN
IV	1.25	1	1	1.4	603.2502 kN

Column Design

$$Factored\ Load\ for\ Structural\ Design, P_f = 650.3\ kN$$

$$(\alpha_1 \varphi_1 f'_c A_c + \varphi_s f_y A_s) * 0.8 \geq P_f$$

$$\left((0.78)(0.65)(40MPa)(0.99)A_g + (340)(0.01)A_g\right)0.8 = 650.3kN$$

$$A_g = 34{,}624mm^2 \rightarrow Column\ Dimensions = 300mm\ x\ 300m$$

$$A_s = 0.01(300mm)^2 = 900mm^2 \rightarrow 6 - 15\ M\ bars$$

Column Design Summary

- Dimension = 300 mm x 300 mm
- Concrete Strength = 40 MPa
- Steel = 6 – 15M
- See design drawings for column details and layout

Footing Design

$$Bearing\ pressure = 500\ kPa$$

$$Max\ footing\ depth = \frac{50\ kPa}{23.5\frac{kN}{m^3}} = 2.13m$$

$$\frac{P_s}{500kPa} = \frac{508.8kN}{\frac{500kN}{m}} = 1.02m^2 \rightarrow Footing\ Dimension = 1.5\ m\ x\ 1.5\ m$$

$$f_{bf} = \frac{650.3kN}{(1.5m)^2} = \frac{289kN}{m^2}$$

$$v_r = (0.38)(0.65)\sqrt{25} = 1.235 \rightarrow Assume\ no\ size\ effect\ because\ 2.15 < 2(1.235)$$

$$v_f = \frac{(289.2)\left((1.5m)^2 - \left(0.300 + \frac{d}{1000}\right)^2\right) * 1000}{4(300 + d)d}\ where\ v_r \geq v_f \rightarrow use\ d = 275mm$$

$$d_v = 0.9d = 250mm$$

$$v_f = 289.2\big(1.5(0.600 - 0.300)\big) = 130.4\ kN$$

$$v_r = 0.65(0.21)\sqrt{25MPa}(275)(1500) = 281.5kN > v_f \therefore ok!$$

$$h = d + 1.5d_b + 75mm = 275 + 45 + 75 = 395mm \rightarrow choose\ 500\ mm < 2.13m\ \therefore ok!$$

$$M_f = 289.2 * 1.5\left(\frac{0.600}{2}\right)^2 = 39kNm$$

$$A_s = 0.002 * 1500 * 500 = 1500mm^2 \rightarrow 6 - 20M$$

$$M_r = \varphi_s f_y A_s(d - (\varphi_s f_y A_s)/(\ 2\alpha_1\varphi_1 f'_c b))$$

$$M_r = (0.85)(400)(1800)\left(1000 - \frac{340 * 1800}{2 * 0.81 * 0.65 * 40 * 1500}\right) = 606.1kNm$$

$$M_r > M_f \therefore ok!$$

$$F_b = (0.85)(0.65)(25)(0.300m)^2 * 3 = 3729.3kN > P_f\ \therefore no\ dowels\ needed$$

Footing Design Summary

- Dimensions (l x w x h) = 1.5 m x 1.5 m x 0.5 m
- Concrete Strength = 25 MPa
- Steel = 6-20 M, cover = 75 mm
- See design drawings for footing details and layout

Beam Structural Checks

Shear Resistance

$$v_r = v_c + v_s$$

$$v_c = \varphi_c \beta \sqrt{f'_c} b_w d_v$$

$$d = h - cover - d_s - \frac{d_b}{2} = 500 - 50 - 10 - \frac{25}{2} = 428mm$$

$$d_v = 0.9d = 385mm$$

$$\beta = 0.18 \rightarrow v_c = (0.65)(0.18)\big(\sqrt{25}\big)(300)(385) = 67.6\ kN$$

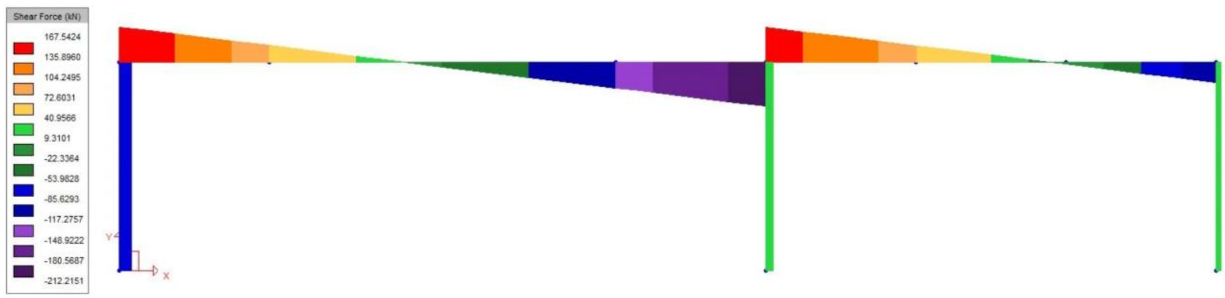
$$v_s = \frac{\varphi_s f_y A_v d_v cot\theta}{s} \; where\ s = 400mm\ and\ A_v = 200mm^2$$

$$Check\ that\ A_v > A_{v,min}: A_{v,min} = \frac{0.06\sqrt{25}}{400} * (300)(200) = 45\ mm^2 < 200mm^2 \therefore ok!$$

$$v_s = \frac{(0.85)(400)(200)(385)\cot(35°)}{200} = 186.9kN$$

$$v_r = v_c + v_s = 254.5kN$$

$$(0.25)(0.65)(25)(300)(385) = 469kN > v_r \therefore ok!$$

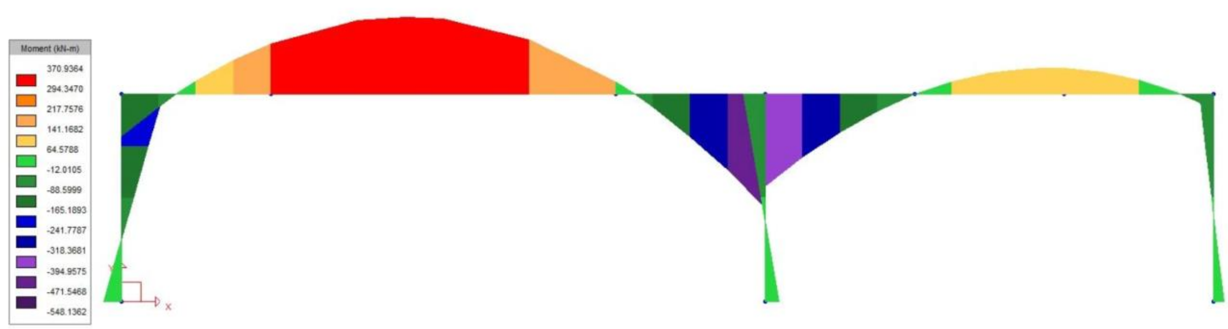


Moment Resistance

$$M_r = \varphi_s f_y A_s \left(d - \frac{\beta_1 c}{2}\right)$$

$$\beta_1 c = \frac{(0.85)(400)(7000)}{\left(0.81(0.65)(25)(300)\right)} = 602.7$$

$$M_r = (0.85)(400)(7000)\left(428 - \frac{602.7}{2}\right) = 717.2kNm$$



APPENDIX E - Quantity Takeoff and Cost Estimate

Bill of Quantities

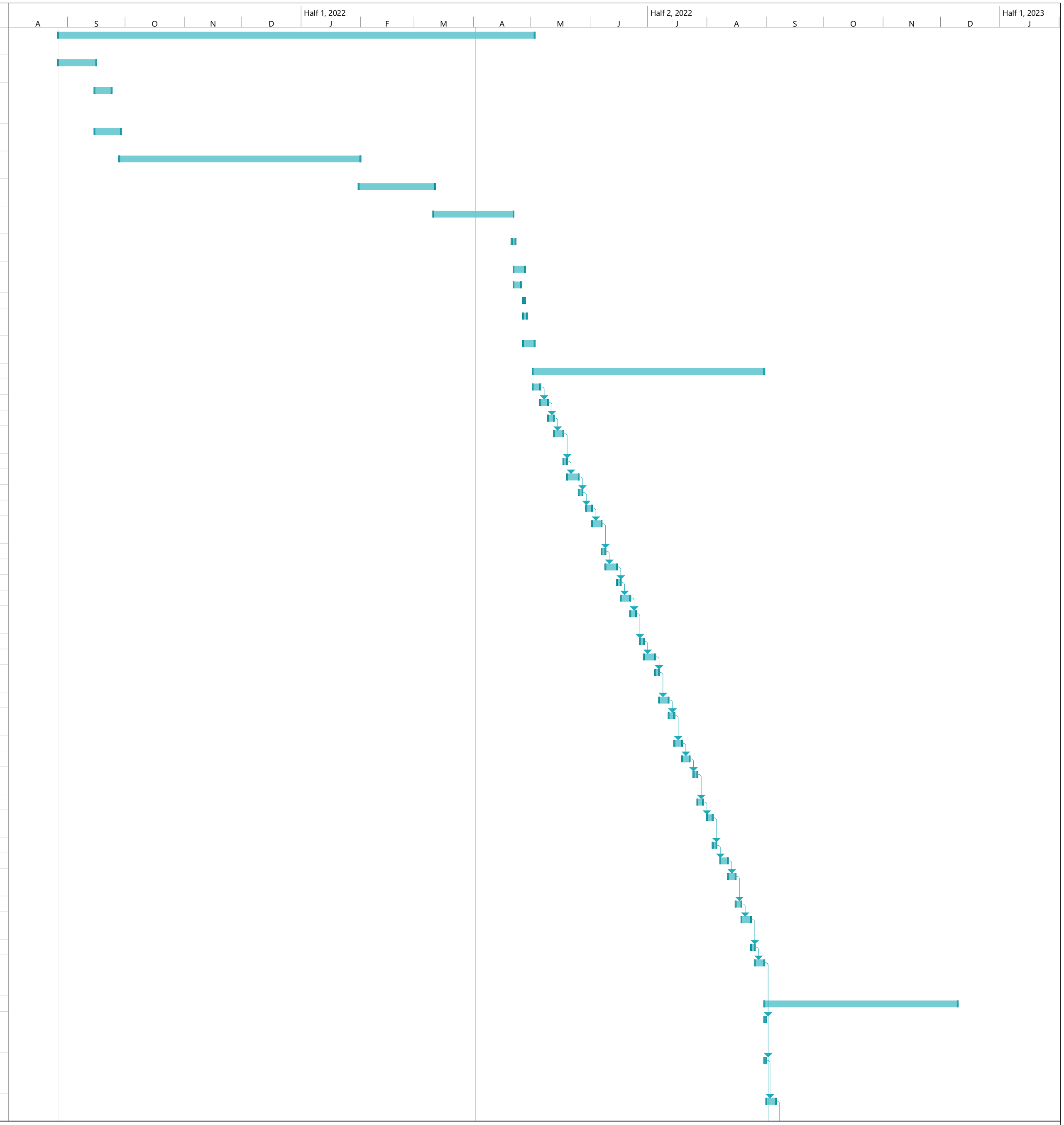
SR. No.	Description	UOM	Quantity	Unit Cost	Amount
ROADWAY					
1	Concrete	m3	518.00	$685.00	$354,830.00
2	Asphalt	ton	371.70	$202.50	$75,268.65
3	Cold milling	m3	41.34	$40.00	$1,653.60
4	Curb Extension	m2	12.70	$170.00	$2,158.58
5	Sidewalk Removal	m2	1150.00	$20.00	$23,000.00
				SUBTOTAL	$456,910.82
STORMWATER & ROADWAY DRAINAGE					
1	PVC Perforated pipe, 150mm	LF	2000.00	$43.17	$86,340.00
2	Growing medium, loam	CY	1154.61	$42.11	$48,620.43
3	Organic mulch with tackifiers	A	97.50	$1,371.86	$133,756.35
4	Drain Rock (1 inch gravel)	CY	1560.00	$23.40	$36,504.00
5	Overflow pipe, 12 in.	LF	192.00	$50.00	$9,600.00
6	Riprap	CY	27.00	$87.50	$2,362.50
				SUBTOTAL	$317,183.28
PEDESTRIAN OVERPASS					
1	Formwork	m2	59.09	$952.00	$56,253.68
2	Foundation	CY	1.13	$685.00	$770.63
3	CIP Concrete, 25 MPa	CY	35.30	$170.94	$6,034.18
4	Grade 400 Steel reinforcement, 25M	LB	1664.20	$50.00	$83,210.00
5	Grade 400 Steel reinforcement, 15M	LB	433.32	$18.25	$7,908.09
6	Grade 400 Steel reinforcement, 10M	LB	398.00	$15.00	$5,969.93
7	Galvanized steel	LF	491.80	$20.76	$10,209.68
8	Polycarbonate panel	# panels	18.00	$180.00	$3,240.00
9	Structural steel, roof	LB	111.47	$2.23	$248.58
				SUBTOTAL	$1,722,032.97
				TOTAL	**$2,496,127.07**

Class A Cost Estimate

Line Item	Description of Work	Units	Unit Cost	Quantity	Duration	Contingency	Total Cost
	GENERAL REQUIREMENTS						
	Permitting	Lump Sum	$14,395.00	1	1		$14,395.00
	Surveying	$ / lbr-hrs	$30.00	3	3		$270.00
	Project Cleanup	$ / lbr-hrs	$1,990.90	4	32		$254,835.20
	Mobilization, Demobilization	Lump Sum	$60,000.00	1	1		$60,000.00
1						SUBTOTAL	$48,391.00
	CONSTRUCTION						
	Site Grading	km	$542,000.00	0.71			$384,820.00
	Roadway Design	km	$3,800,000.0C	0.71			$2,698,000.00
	Pedestrian Overpass	m2	$2,750.00	120			$330,000.00
	Sidewalk	m2	$77.00	1278			$98,406.00
2						SUBTOTAL	$3,511,226.00
	EQUIPMENT						
	Asphalt Compactor	hrs	$140.00	1	128		$17,920.00
	Asphalt Paver	hrs	$800.00	1	128		$102,400.00
	Excavator	hrs	$250.00	1	80		$20,000.00
	Dump Truck	days	$800.00	1	7		$5,600.00
3						SUBTOTAL	$145,920.00
	MATERIALS						
	refer to Bill of Quantities						
4						SUBTOTAL	$2,496,127.07
	LANDSCAPING						
	Clearing, grubbing & stripping	LS	$10,000.00				$10,000.00
	Common Excavation	CY	$11.46	1100			$12,606.00
	Waste storage & disposal	$	$15.00	300			$4,500.00
	Granular Backfill	CY	$28.38	750			$21,285.00
5						SUBTOTAL	$48,391.00
	LABOUR						
	Specialist Design Engineers	$ / lbr-hrs	$120.00	6	1000		$720,000.00
	Independent Design Reviewer	$ / lbr-hrs	$150.00	1	500		$75,000.00
	Superintendent	$ / lbr-hrs	$100.00	1	800		$80,000.00
	Traffic Controllers	$ / lbr-hrs	$50.00	4	800		$160,000.00
	Excavation Workers	$ / lbr-hrs	$50.00	2	20		$2,000.00
6						SUBTOTAL	$1,037,000.00
						TOTAL WITHOUT CONTINGENCY	$7,287,055.07
7						CONTINGENCY (15%)	$1,093,058.26
						TOTAL COST	$8,380,113.33

APPENDIX F - Detailed Construction Schedule

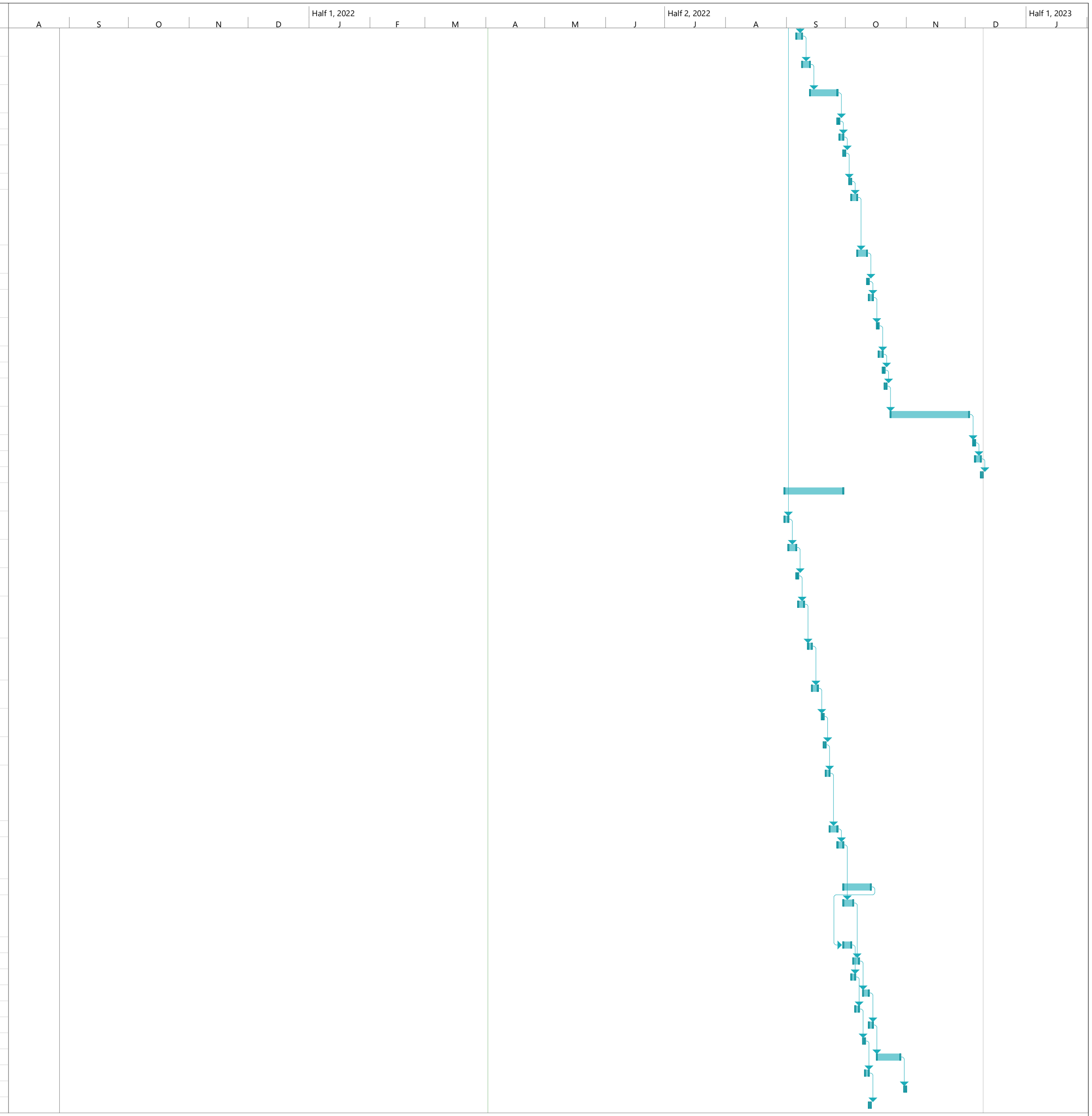
ID	Task Mode	Task Name	Duration	Start	Finish	Predecessors	Resource Names
1		**Planning and Permitting**	177 days	Fri 8/27/21	Mon 5/2/22		
2		Apply for Streets and Landscape Permit	14 days	Fri 8/27/21	Wed 9/15/21		
3		Arborist to assess mitigation damage to nearby trees	7 days	Wed 9/15/21	Thu 9/23/21		
4		Develop Traffic Management Plan	10 days	Wed 9/15/21	Tue 9/28/21		
5		Apply for Development Permit	90 days	Tue 9/28/21	Mon 1/31/22		
6		Apply for Building Permit	30 days	Mon 1/31/22	Fri 3/11/22		
7		Tender out work to contractors	30 days	Fri 3/11/22	Thu 4/21/22		
8		Tendering proccess complete	2 days	Thu 4/21/22	Fri 4/22/22		
9		Fence off work area	4 days	Fri 4/22/22	Wed 4/27/22		
10		Install Site Offices	2 days	Fri 4/22/22	Mon 4/25/22		
11		Porta Pottie Delivery	1 day	Wed 4/27/22	Wed 4/27/22		
12		Install Water Treatment Tank	2 days	Wed 4/27/22	Thu 4/28/22		
13		Fence around nearby trees	4 days	Wed 4/27/22	Mon 5/2/22		
14		**Roadworks**	87 days	Mon 5/2/22	Tue 8/30/22		
15		Demo and removal S	4 days	Mon 5/2/22	Thu 5/5/22		
16		Grading and sloping S	2 days	Fri 5/6/22	Mon 5/9/22	15	
17		Preparing Sub Base S	3 days	Tue 5/10/22	Thu 5/12/22	16	
18		Install New Asphalt Surface SB1	3 days	Fri 5/13/22	Tue 5/17/22	17	
19		New Curb Install SB1	2 days	Wed 5/18/22	Thu 5/19/22	18	
20		Demo and removal S	4 days	Fri 5/20/22	Wed 5/25/22	19	
21		Grading and sloping S	2 days	Thu 5/26/22	Fri 5/27/22	20	
22		Preparing Sub Base S	3 days	Mon 5/30/22	Wed 6/1/22	21	
23		Install New Asphalt Surface SB2	3 days	Thu 6/2/22	Mon 6/6/22	22	
24		New Curb Install SB2	2 days	Tue 6/7/22	Wed 6/8/22	23	
25		Demo and removal S	4 days	Thu 6/9/22	Tue 6/14/22	24	
26		Grading and sloping S	2 days	Wed 6/15/22	Thu 6/16/22	25	
27		Preparing Sub Base S	3 days	Fri 6/17/22	Tue 6/21/22	26	
28		Install New Asphalt Surface SB3	3 days	Wed 6/22/22	Fri 6/24/22	27	
29		New Curb Install SB3	2 days	Mon 6/27/22	Tue 6/28/22	28	
30		Demo and removal N	4 days	Wed 6/29/22	Mon 7/4/22	29	
31		Grading and sloping NB1	2 days	Tue 7/5/22	Wed 7/6/22	30	
32		Preparing Sub Base N	3 days	Thu 7/7/22	Mon 7/11/22	31	
33		Install New Asphalt Surface NB1	3 days	Tue 7/12/22	Thu 7/14/22	32	
34		New Curb Install NB1	2 days	Fri 7/15/22	Mon 7/18/22	33	
35		Demo and removal N	4 days	Tue 7/19/22	Fri 7/22/22	34	
36		Grading and sloping NB2	2 days	Mon 7/25/22	Tue 7/26/22	35	
37		Preparing Sub Base N	3 days	Wed 7/27/22	Fri 7/29/22	36	
38		Install New Asphalt Surface NB2	3 days	Mon 8/1/22	Wed 8/3/22	37	
39		New Curb Install NB2	2 days	Thu 8/4/22	Fri 8/5/22	38	
40		Demo and removal N	4 days	Mon 8/8/22	Thu 8/11/22	39	
41		Grading and sloping NB3	2 days	Fri 8/12/22	Mon 8/15/22	40	
42		Preparing Sub Base N	3 days	Tue 8/16/22	Thu 8/18/22	41	
43		Install New Asphalt Surface NB3	3 days	Fri 8/19/22	Tue 8/23/22	42	
44		New Curb Install NB3	2 days	Wed 8/24/22	Thu 8/25/22	43	
45		Re-paint road markings and install new road signage	3 days	Fri 8/26/22	Tue 8/30/22	44	
46		**Overpass Constructio**	73 days	Wed 8/31/22	Fri 12/9/22		
47		Install road Closures at Thunderbird Blvd and W 16th Ave	1 day	Wed 8/31/22	Wed 8/31/22	45	
48		Install fencing around overpass construction	1 day	Wed 8/31/22	Wed 8/31/22	45	
49		Set foundation formwork	3 days	Thu 9/1/22	Mon 9/5/22	48	



Project: Project1
Date: Sat 4/2/22

Task | Split | Milestone | Summary | Project Summary | Inactive Task | Inactive Milestone | Inactive Summary | Manual Task | Duration-only | Manual Summary Rollup | Manual Summary | Start-only | Finish-only | External Tasks | External Milestone | Deadline | Progress | Manual Progress

ID		Task Mode	Task Name	Duration	Start	Finish	Predecessors	Resource Names
50			Install foundation footing rebar	3 days	Tue 9/6/22	Thu 9/8/22	49	
51			Pour foundation footings	2 days	Fri 9/9/22	Mon 9/12/22	50	
52			Let Footings cure for 7-10 days	10 days	Tue 9/13/22	Mon 9/26/22	51	
53			Set column formwork	1 day	Tue 9/27/22	Tue 9/27/22	52	
54			Install column rebar	2 days	Wed 9/28/22	Thu 9/29/22	53	
55			Pour concrete for columns	1 day	Fri 9/30/22	Fri 9/30/22	54	
56			Mobilize in RT Crane	1 day	Mon 10/3/22	Mon 10/3/22	55	
57			Have precast concrete bridge deck delivered and flown in with w crane	3 days	Tue 10/4/22	Thu 10/6/22	56	
58			Install steel stairs on both ends	3 days	Fri 10/7/22	Tue 10/11/22	57	
59			Install railings	1 day	Wed 10/12/2	Wed 10/12/2	58	
60			Install membranes and treading to	2 days	Thu 10/13/22	Fri 10/14/22	59	
61			Install polycarbonate glass to walls and	1 day	Mon 10/17/22	Mon 10/17/22	60	
62			Apply paint and finish	2 days	Tue 10/18/22	Wed 10/19/2	61	
63			Hang musqueam art	1 day	Thu 10/20/22	Thu 10/20/2	62	
64			Conduct inspection with UBC	1 day	Fri 10/21/22	Fri 10/21/22	63	
65			Apply for occupancy permit	30 days	Mon 10/24/22	Fri 12/2/22	64	
66			Remove fencing	1 day	Mon 12/5/22	Mon 12/5/22	65	
67			Landscaping at grade	3 days	Tue 12/6/22	Thu 12/8/22	66	
68			Open for public use	1 day	Fri 12/9/22	Fri 12/9/22	67	
69			**Storm Water Infrastucture**	22 days	Wed 8/31/22	Thu 9/29/22		
70			Prelocation test for each raingarden	2 days	Wed 8/31/22	Thu 9/1/22	45	
71			Excavate based on specifications	2 days	Fri 9/2/22	Mon 9/5/22	70	
72			Compact and flatten bottom layer	1 day	Tue 9/6/22	Tue 9/6/22	71	
73			Install required pipes/swales for inflow/outflow	3 days	Wed 9/7/22	Fri 9/9/22	72	
74			Bacfkill with appropriate raingarden mix	2 days	Mon 9/12/22	Tue 9/13/22	73	
75			Connect inflow and outflow pipes	3 days	Wed 9/14/22	Fri 9/16/22	74	
76			Plant and irrgigate as soon as possible	1 day	Mon 9/19/22	Mon 9/19/22	75	
77			Install mulch based on design	1 day	Tue 9/20/22	Tue 9/20/22	76	
78			Remove all sediment and erision-control layers (after construction)	2 days	Wed 9/21/22	Thu 9/22/22	77	
79			Backfill to ground lev	2 days	Fri 9/23/22	Mon 9/26/22	78	
80			Install operation and maintenance plan as regulated	3 days	Tue 9/27/22	Thu 9/29/22	79	
81			**Sidewalk Replaceme**	10 days	Fri 9/30/22	Thu 10/13/2		
82			First rip out and demolish existing asphalt sidewalk	3 days	Fri 9/30/22	Tue 10/4/22	80	
83			Remove ripped up co	2 days	Fri 9/30/22	Mon 10/3/22	81	
84			Compact base layer o	3 days	Wed 10/5/22	Fri 10/7/22	82	
85			Compaction of the so	2 days	Tue 10/4/22	Wed 10/5/22	83	
86			Set concrete formwo	3 days	Mon 10/10/2	Wed 10/12/2	84	
87			Install rebar	2 days	Thu 10/6/22	Fri 10/7/22	85	
88			Pour cast in place con	2 days	Thu 10/13/22	Fri 10/14/22	86	
89			Ensure adequate con	1 day	Mon 10/10/2	Mon 10/10/2	87	
90			Let concrete cure for	10 days	Mon 10/17/2	Fri 10/28/22	88	
91			Apply finish paint and	2 days	Tue 10/11/22	Wed 10/12/2	89	
92			Remove fencing	1 day	Mon 10/31/2	Mon 10/31/2	90	
93			Open for public use	1 day	Thu 10/13/22	Thu 10/13/2	91	



Project: Project1
Date: Sat 4/2/22

Task | Split | Milestone | Summary | Project Summary | Inactive Task | Inactive Milestone | Inactive Summary | Manual Task | Duration-only | Manual Summary Rollup | Manual Summary | Start-only | Finish-only | External Tasks | External Milestone | Deadline | Progress | Manual Progress

APPENDIX G - Operation and Maintenance Cost Table

Section	Component	Existing	Description	Cost ($)	Recurrence (every x years)
Structural	Overpass	No	Inspections	600	2
Structural	Overpass	No	Surfacing	30	1
Structural	Overpass	No	Resealing	500	1
Transportation	Sidewalk	Yes	Repairs/resealing	5,200	1
Transportation	Roadway	Yes	Resealing	12,100	1
Transportation	Bike lane	No	Repairs	4,800	1
Transportation	Boulevard and Median	Yes	Maintenance	5,600	1
Utilities	Lighting	Yes	Painting	3,230	5
Utilities	Drainage	No	Main's inspections and cleaning	2,000	5
Utilities	Drainage	Yes	Drains repairs/maintenance	1,500	3
Stormwater	Rain Garden/Tree Box	No	Fixture repairs	800	1
			Total FW	7,954,487	
			Total PW	2,955,314	
			Total Annuity	94,050	