University of British Columbia

Social Ecological Economic Development Studies (SEEDS) Sustainability Program

Student Research Report

Sustainability & Engineering – Wesbrook Mall Redesign, Phase 4

Prepared by: Cyrus Adams, Kris Atkinson, Jeff Chapman, Firas Mohammed Kamal, Sean Simao, Mateo Thompson

Prepared for:

Course Code: CIVL 446

University of British Columbia

Date: 6 April 2022

UBC Social Ecological Economic Development Studies (SEEDS) Sustainability Program
Student Research Report

Sustainability & Engineering – Wesbrook Mall Redesign, Phase 4

Authors:
Cyrus Adams
Kris Atkinson
Jeff Chapman
Firas Mohammed Kamal
Sean Simao
Mateo Thompson

University of British Columbia

CIVL 446 – Civil Engineering Design Project II

April 6, 2022

Executive Summary

The fourth phase of upgrades to Wesbrook Mall were designed to integrate both current user demands as well as the changing demands throughout the corridor's life cycle. Although corridor use is expected to grow substantially from 2021 to 2050, modelling indicates that single-occupancy vehicle use will continue to decline and be offset with an increase in pedestrian, cyclist, and transit use. The design will move forward with the construction of a pedestrian underpass, a dedicated bus lane, a protected bi-directional bike lane, minor storm-water improvements through the implementation of green infrastructure, and the reclamation of the existing roadway structure.

Detailed engineering drawings of the proposed upgrades are included in Appendix A. These drawings demonstrate our design rationale and are supported by technical analysis throughout the report. As the corridor is proposed to stay operational whenever possible, consideration of construction feasibility and sequence has been considered as a design objective and is detailed in the Construction Schedule section of the report. The project's tendering is proposed to be scheduled for the beginning of May 2022.

The Class A (+/- 5 to 10%) cost estimate for the work is $7,734,959.23 which includes a 10% contingency. The contingency has been applied for the variability in geotechnical conditions and utility relocation as described in the Risk Management section of the report.

With consideration to the detailed design outlined in the report, our team would like to make the following recommendations to the client: *A survey and mapping of underground utilities, a detailed geotechnical assessment at the location of the underpass, hiring a pilot communications representative, and adopting strict requirements regarding timelines of submittals and milestones.*

We would be happy to provide some or all these services to the client at an additional cost in accordance with our standard hourly rates and fees.

Contents

List of Tables

List of Figures

1.0. Introduction

Our team was retained by the University of British Columbia (UBC) to provide the design and project management for Phase 4 of the Wesbrook Mall Redesign. The following report has been prepared to demonstrate both detailed design rationale and feasibility.

The Wesbrook Mall improvement project is comprised of four phases, two of which have been completed. Project Phase 1 and Phase 2, completed in the Fall of 2019 and 2020 respectively, have seen Wesbrook Mall modified between Student Union Blvd. and Thunderbird Blvd. The first two phases provided the corridor users with improved pedestrian facilities, fully repaved roadways, new separated cyclist lane, and new dedicated bus lanes in the northbound and southbound directions.

The third phase of the project is projected to be completed in 2022 and spans from Student Union Blvd. to Chancellor Blvd. Our team has begun designing the project's fourth phase, which spans between Thunderbird Blvd. and West 16th Ave. The approximate locations of all four phases of the project can be seen in **Figure 1**.

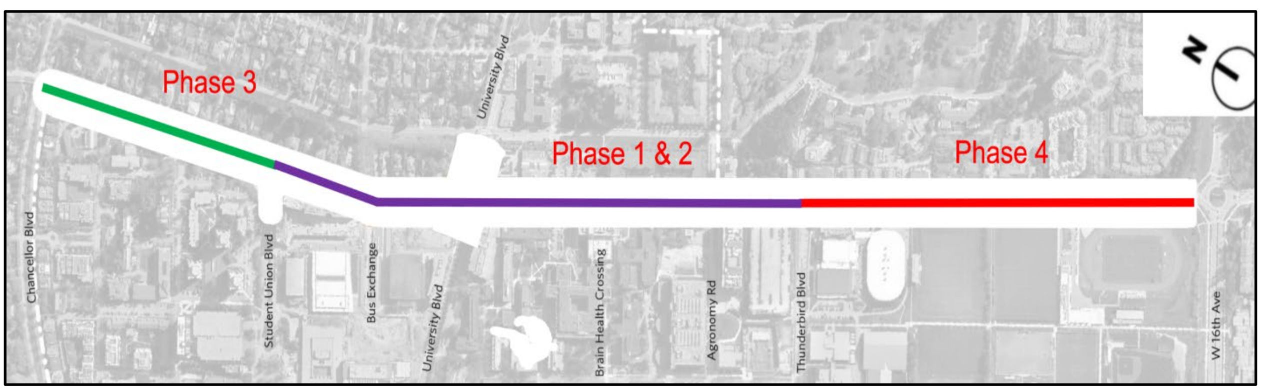


Figure 1 - Summary of Wesbrook Mall Project Phases

2.0. Design Criteria

Based on *UBC Vancouver Transportation Status Report*, the volume of single-occupant vehicles has decreased 11.0% over 22 years, while the trips by transit, pedestrian, and cyclist users have increased 34.9% [1]. As such, when considering the distribution of transportation modes and anticipated population growth, Phase 4 of the Wesbrook Mall will focus on redesigning the existing 750 meters roadway to accommodate the projected 2050 traffic volumes. Further, the corridor will be designed to maximize the safety, convenience, and enjoyability for transit, pedestrian, and cyclist users. A method of how safety and convenience will be achieved for pedestrians is through the installation of a pedestrian underpass, allowing them to traverse the high traffic roadway. Additionally, the Phase 4 redesign will tie into the existing Phase 2 of Wesbrook Mall to preserve the continuity of the redesigned road segments. Moreover, since the roadway is bounded by low-rise residential units and an RCMP precinct along the east side and the Thunderbird Stadium and subsequent sports fields along the west side, the retention of on-street parking will be maximized for the corridor users. Furthermore, to align with UBC's *Integrated Storm Water Management Plan*, the preservation of green space and incorporation of green infrastructure will aid in maximizing on-site rainwater retention to help limit flooding during torrential rainfalls and remove pollutants from the surrounding environment [2].

3.0. Design Approach

Our design of the fourth phase of the project is required to integrate with both geometry and function of Phase 1 and 2. The goal of the Wesbrook Mall Upgrades is to prioritize pedestrians, cyclists, and transit users to enhance safety and convenience for increased traffic through the project's lifecycle. To accommodate the goals and maximize safety for all users, both a pedestrian underpass and a separated cyclist lane are proposed to be constructed in the project's fourth phase. Additional considerations have been prioritized by stakeholders, including the integration of both indigenous artwork and green infrastructure as well as ensuring the construction results in minimal disruptions to current users. At this stage of the design, we have evaluated the possible design options based on a set of criteria, as shown in **Table 1**.

Table 1 - Evaluation of Design Options

Criteria	A-Exclusive Transit & Bike Lane, NB & SB	B-Bi-Directional Bike Lane with New Intersection Crossing	C-Shared Tunnel at Thunderbird Stadium
Feasibility	23	28	14.5
Usability	10	18	17
Sustainability & Cultural	9	14	15
Total (Score out of 70)	54	**60**	47

The evaluation criteria identified in **Table 1** can be broken into more detail as follows:

- Feasibility – Cost, Constructability, and Maintenance
- Usability – Public Transit and Street Usage
- Sustainability & Cultural – Environmental Impact, Indigenous Involvement, and Aesthetics

Taking into consideration the design options and each evaluation criteria, we moved forward with "Design Option-B". The final design has transitioned away from using a single diagonal crossing for the cyclist path at the Wesbrook and Thunderbird intersection. Our team determined that ensuring cyclist safety holds a higher priority than crossing efficiency, and as such, the design will move forward with directional cyclist crossings at the intersection. Further details regarding the intersection design are provided in *Section 4.2*.

4.0. Transportation Design

4.1. Traffic Analysis

The 2019 AM, MD, and PM traffic data for Wesbrook Mall and Thunderbird intersection was provided by UBC. A 1% growth rate was applied to each volume provided to estimate the 30-year traffic volumes and mode share distributions in 2050. **Figure 2** below illustrates the projected 2050 transit volumes and mode share distributions at the Wesbrook Mall and Thunderbird intersection during the AM, MD, and PM periods.

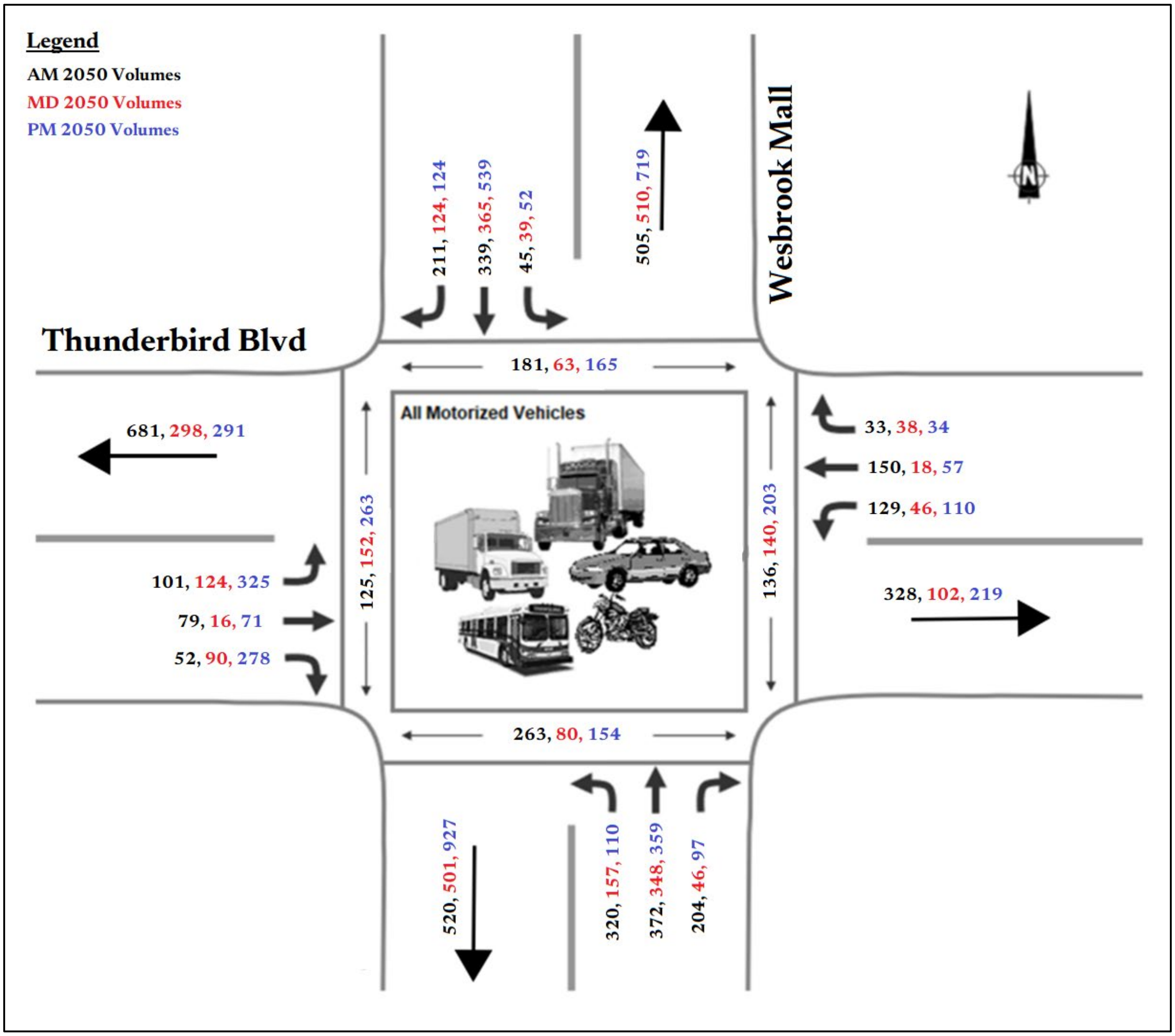


Figure 2 - Project 2050 Traffic Volumes and Mode Share Distribution

Using the traffic volumes and mode share distributions shown in **Figure 2**, the Wesbrook and Thunderbird intersection was initially modelled using SIDRA Intersections software to determine the LOS. After analyzing the current intersection using the projected traffic volumes and mode share distributions, there was reduction in LOS from B to C. The reduction in LOS for the intersection can be attributed to the increase in transit vehicles and cyclists. These two modes of transportation account for approximately 24% and 13% of the corridor's traffic volumes, respectively. Furthermore, modelling the highest projected traffic volumes (2050 PM) using the adjusted intersection geometry established in *Section 4.2* resulted in a reduction in LOS B to D. The further reduction of intersection LOS was determined to be caused by the conflicts created between the high volume of turning vehicles and the crossing cyclist at the intersection. As such, a separate cyclist phase was added to the intersection phasing to remove these conflictions and improve the overall safety for intersection users. Using the signal phases described and in established in *Section 4.3*, a model was created and analyzed using Synchro 6, which indicated that the new Wesbrook Mall and Thunderbird intersection was operating at an overall LOS of B during all periods of the day.

4.2. Wesbrook Mall & Thunderbird Boulevard Intersection.

The re-design of the corridor proceeded with the replacement of the existing northbound and southbound cyclist lane in the roadway with a bi-directional cyclist lane along the west side of the corridor between West 16th Ave and Thunderbird Blvd as described in *Section 4.4.2*. By proceeding with designing a bi-directional cyclist lane, one of the challenges encountered was how the northbound cyclists were going to transition back to the east side of the corridor at the Wesbrook and Thunderbird intersection. As such, directional cyclist crossings will be used at the intersection to transition the northbound cyclists from the west to the east side of the corridor, as illustrated in **Figure 3**.

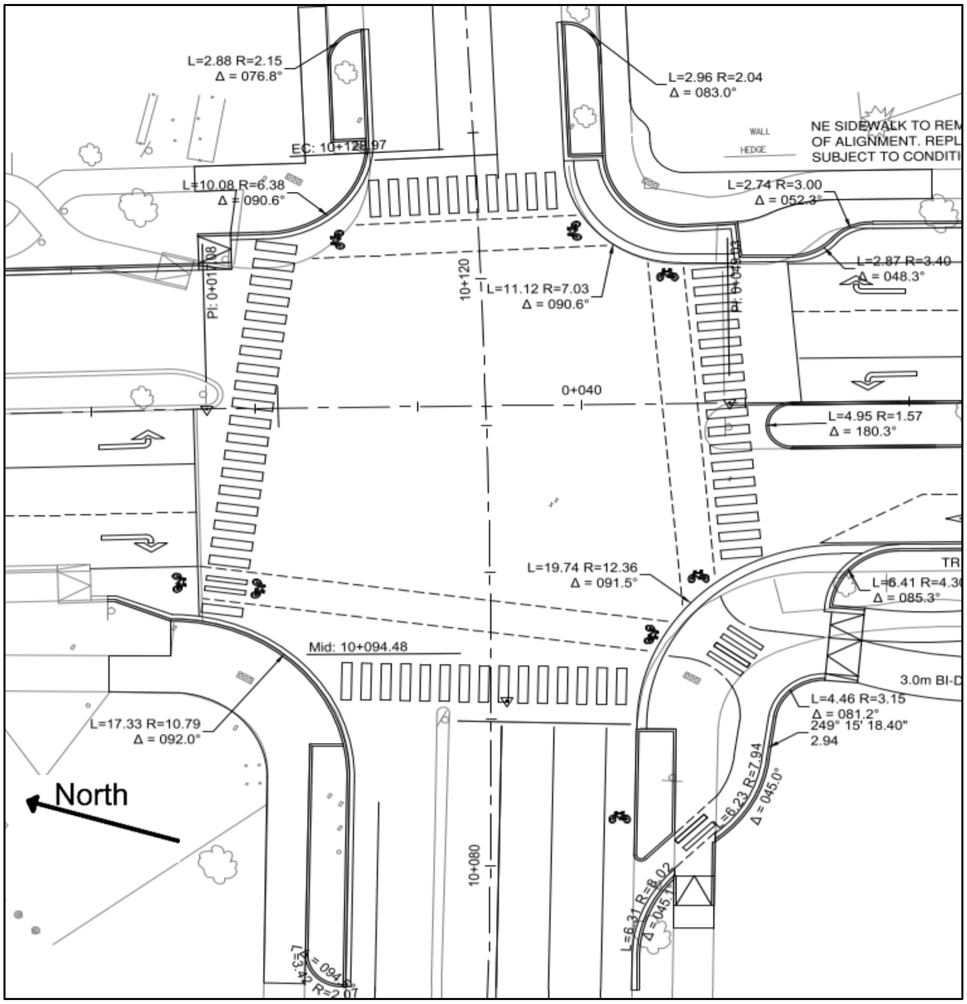


Figure 3 - Cyclist Crossing at Wesbrook & Thunderbird Intersection

The southbound cyclists will continue using the existing crossing at the west approach of the intersection, which will transition into the new bi-directional cyclist lane. Comparatively, the northbound and eastbound cyclists will traverse the intersection during the protected cyclist phase described in *Section 4.3*. The northbound cyclist will queue up on the mountable letdown at the southwest corner of the intersection and cross using the cyclist crossing adjacent to the pedestrian crossing. The northbound cyclist will then queue up on the mountable letdown at the southeast corner and cross in the same manner as previously described. Similarly, the eastbound cyclist will be able to remain in the roadway and use the existing cyclist lane to cross during the protected and through phase of the east and west bound movements.

To ensure cyclist safety during the movement phases described above, separate cyclist signal heads and call buttons will be provided at the appropriate crossing locations, further details are discussed in *Section 4.3*.

4.3. Signal Timing

As previously mentioned, a separate cyclist phase was added to the intersection phasing to remove the conflictions between the high volume of turning traffic and crossing cyclist at the intersection. As such, a concurrent protected cyclist phase was chosen for the phasing configuration. As shown in **Figure 4**, the cyclists are protected during their movement phase in the intersection and operate concurrently with the through vehicle phase. The conflicting vehicles will be prevented from turning right across the cyclist lanes until the cyclist phase is complete. An alternative signal head for the cyclist shown in the bottom right of **Figure 4** will be mounted to the adjacent traffic signals at the intersection to reduce the amount of traffic poles required.

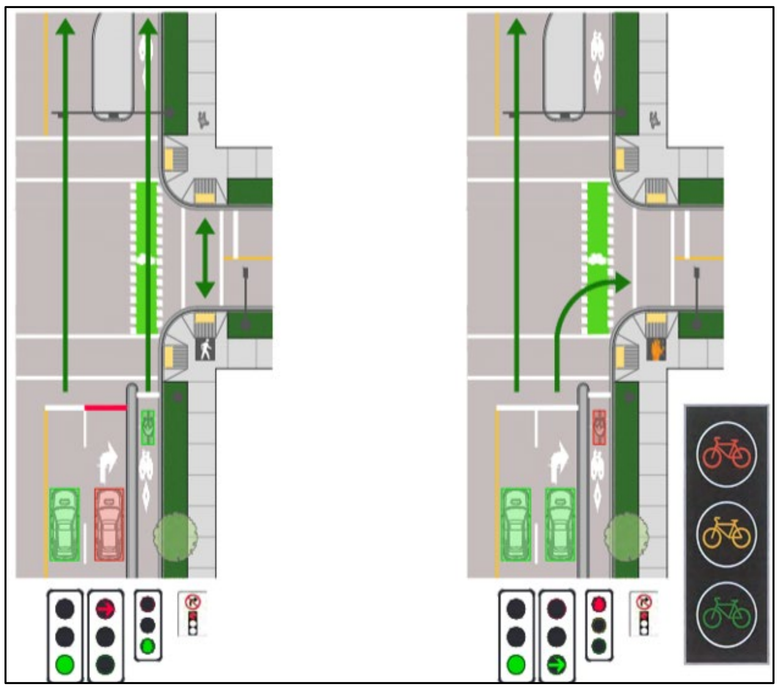


Figure 4 - Concurrent Protected Cyclist Phase & Cyclist Signal Head

Additionally, pedestrians will be able to cross the intersection simultaneously with the cyclist. To ensure the safety of the crossing cyclist and pedestrians, the existing cycle length was increased from 80 seconds to 90 seconds for the AM period. A detailed breakdown of the new intersection phases for the 2050 AM period are shown in **Figures 5 and 6.**

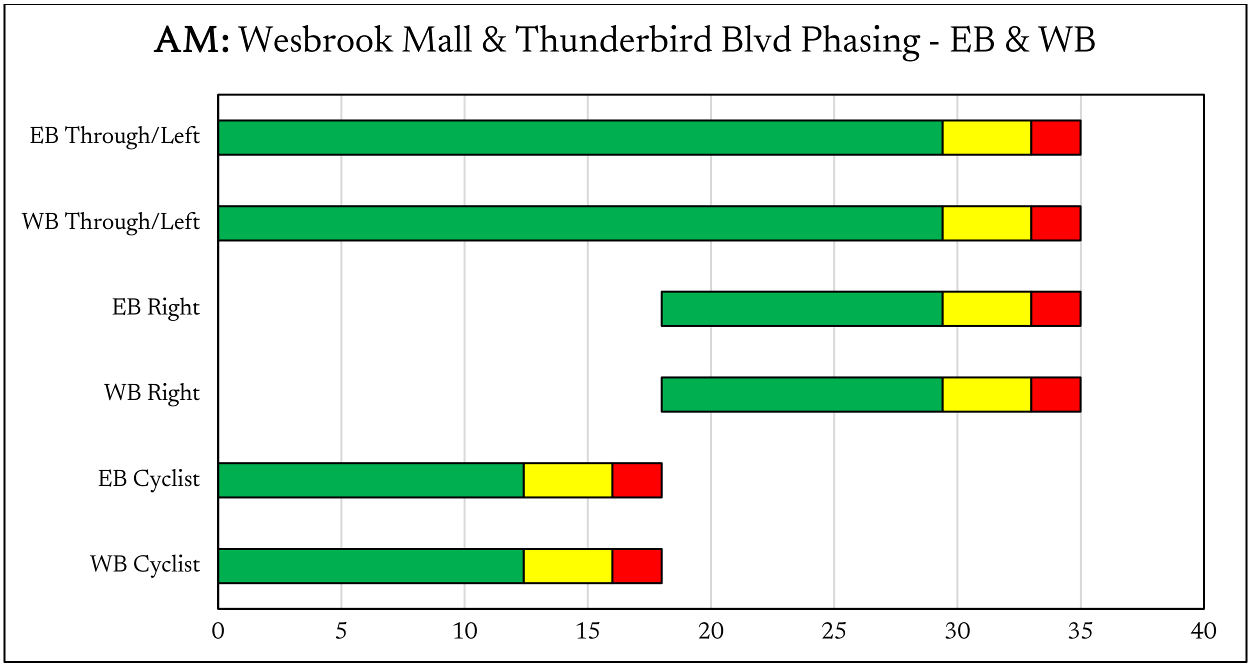


Figure 5 - Eastbound & Westbound Traffic Phasing

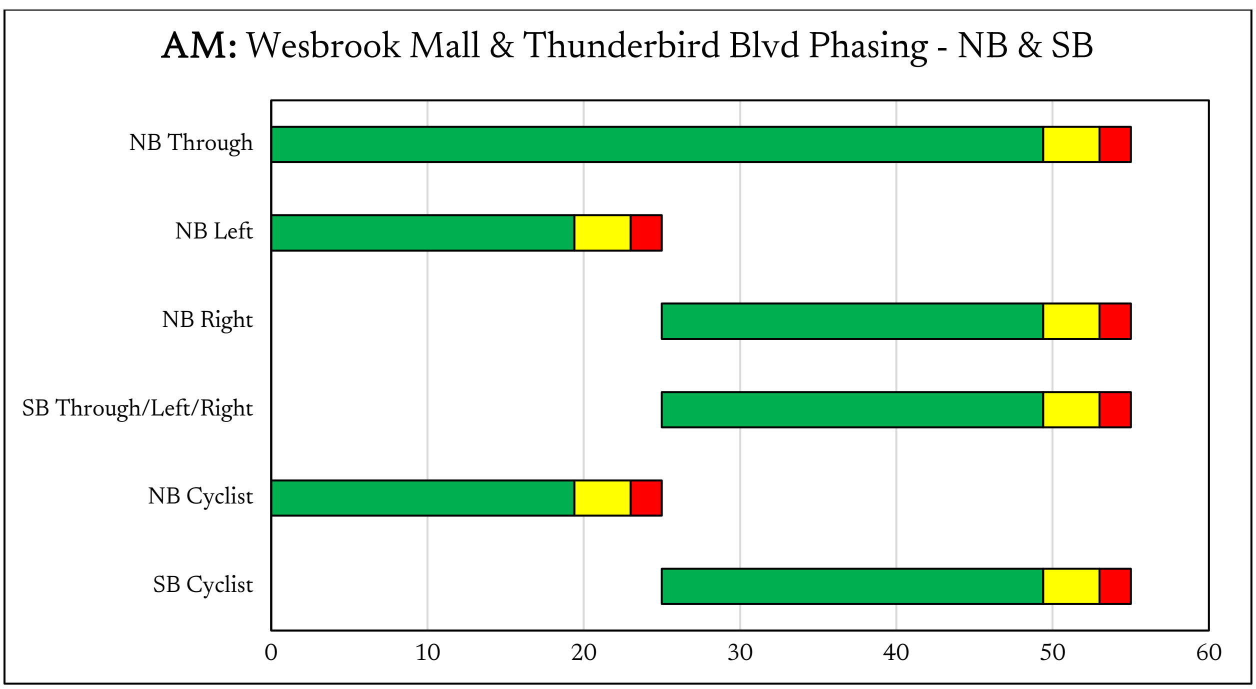


Figure 6 - Northbound & Southbound Traffic Phasing

As shown in the phasing diagrams for the 2050 AM period, more time was allotted to the northbound and southbound movement since there is a higher percentage of traffic travelling in that direction. Further details regarding the phasing diagrams for the MD and PM periods at the intersection can be found in **Appendix B**.

4.4. Corridor Design

4.4.1. Passenger & Transit Lane Details

While the existing corridor sufficiently accommodates the current traffic volumes of Wesbrook Mall, upgrades to the roadway cross-sections are required to accommodate the traffic projections of 2050. **Table 2** below summarizes the lane widths used for each mode of transportation within the corridor.

Table 2 - Lane Widths per Transportation Mode

Transportation Mode	Lane Width (m)
Passenger	3.2, 3.0
Transit	3.4
Cyclist	1.5
Parking Lane	2.2

A comfortable lane width of 3.2m is provided for the general traffic lanes, along with 3.0m exclusive left turn and merge lanes. Comparatively, the northbound and southbound transit exclusive lanes will be 3.4m along the corridor. The existing southbound infrastructure accommodates the transit lane requirements. The northbound transit lane will commence immediately after vehicles exit the roundabout at West 16th Ave. Additionally, the northbound transit lane will extend throughout the corridor and the existing intersection at Thunderbird Blvd. To maintain the continuity of the transit lane through the intersection, the crossing flares at the northwest corner will be moved outwards to create the space required for the transit through lane. A detailed view of the lane arrangements within the corridor and intersection can be seen in drawings 1 to 3 in **Appendix A**.

4.4.2. Bi-Directional Bike Lane Details

The re-design of the corridor replaces the existing northbound and southbound cyclist lanes in the roadway with a bi-directional cyclist lane along the west side between West 16th Ave and Thunderbird Blvd. We determined that the safety and convenience provided to cyclists by using an exclusive lane separated from traffic outweighs the possible cost saved by maintaining the bike lanes in their current location. The additional space acquired by removing the bike lanes from the roadway enables an exclusive transit lane to be added in the northbound direction. The following outlines key benefits of implementing the design:

- Improved cyclist safety via separated bike lanes
- Reduced traffic flow disruptions in the northbound direction
- Preservation of on-street parking for field users, residents, and visitors.
- Ties into the existing Phase 2 design at Thunderbird intersection.

The bi-directional bike lane will be 3 meter wide, starting at the Thunderbird Blvd. intersection and span the entire corridor until the roundabout at West 16th Ave. The bike lane will replace the existing sidewalk through the corridor until the transition zone along the track and field oval fence line. Details regarding the tie in between the bi-directional cyclist lanes and the West 16th Ave roundabout can be found in *Section 4.5*.

Another consideration for the bi-directional cyclist lane was the crossing near Thunderbird Stadium. The cyclist lane will cross the pick-up/drop-off zone at either end. Appropriate signage will be installed at the entrance and exit of the drop-off for vehicles to ensure the safety of cyclists. The bus stop shelter, and sidewalk will be relocated towards the road as shown in **Figure 7** below as per BC Transit Infrastructure Guidelines [3].

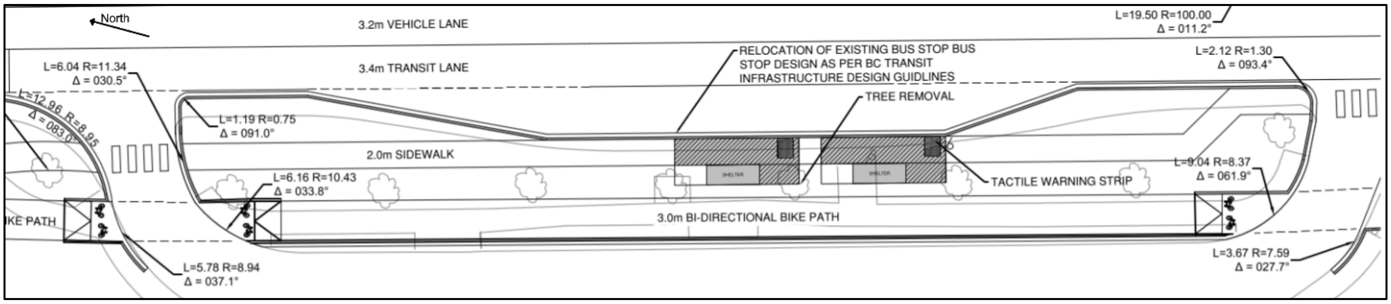


Figure 7 - Thunderbird Stadium Bus Stop

4.4.3. Sidewalks

The existing sidewalk along the east side will be maintained throughout the corridor, while the sidewalk along the west side will be relocated and sized to accommodate the bi-directional bike lane as per drawings 1 to 3 in **Appendix A**.

4.4.4. Roadway Structure

The roadway structure was designed in accordance to BC MoTI "Pavement Structure Design Guidelines" [4]. The provided "2019 UBC Fall Traffic Monitoring Program" data summary took the average northbound traffic between October 23, 2019 and October 30, 2019 to determine the Average Annual Daily Traffic (AADT) volume for the Wesbrook Mall corridor. Additionally, a Heavy Vehicle Percentage (HVP) of 8.3%, a Heavy Vehicle Design Lane Factor (HVDF) of 100%, a growth factor of 1%, and a Number of Equivalent Axle Loads per Vehicle (NALV) of 0.0004 for light vehicles and 4 for heavy vehicles was used. A 30-year design ESAL value of 30,000,000 was determine with a roadway designation of "High Volume", and a pavement structure of "Type A". An overview of the calculation procedure is provided in **Appendix C**.

According to the BC MoTI guidelines a roadway structure consisting of the following should be adequate:

- Superpave No.2 – PG 70-22 asphalt with up to 20% Recycled Asphalt Pavement (RAP) and a total thickness of 150 mm.
- Asphalt prime coat applied to the final grade of base coarse aggregate.
- Crushed Base Course (CBC) consisting of 25 mm Well Graded Base (WGB) crushed gravel with a layer thickness of 300 mm.
- Select Granular Sub-base (SGSB) consisting of 75mm-minus crushed gravel or approved MoTI alternative pit-run material with a layer thickness of 300 mm.

A schematic of the roadway structure is included within the attached drawing package with a sheet titled as "Roadway Structure" located on page 40 in **Appendix A.**

4.5. Wesbrook Mall & West 16th Avenue Roundabout

For the re-design of the roundabout, we determined that in order for the cyclists to safely cross the roundabout and utilize the bi-directional cyclist lane, changes to the upper quadrant of the roundabout were required. During the preliminary design, we assumed that the cyclist would remain within the roundabout and operate with the vehicle traffic. For the detailed design, the northeast corner of the roundabout will be cutback to add in a cyclist lane on the exterior of the roundabout as shown in in **Figure 8.**

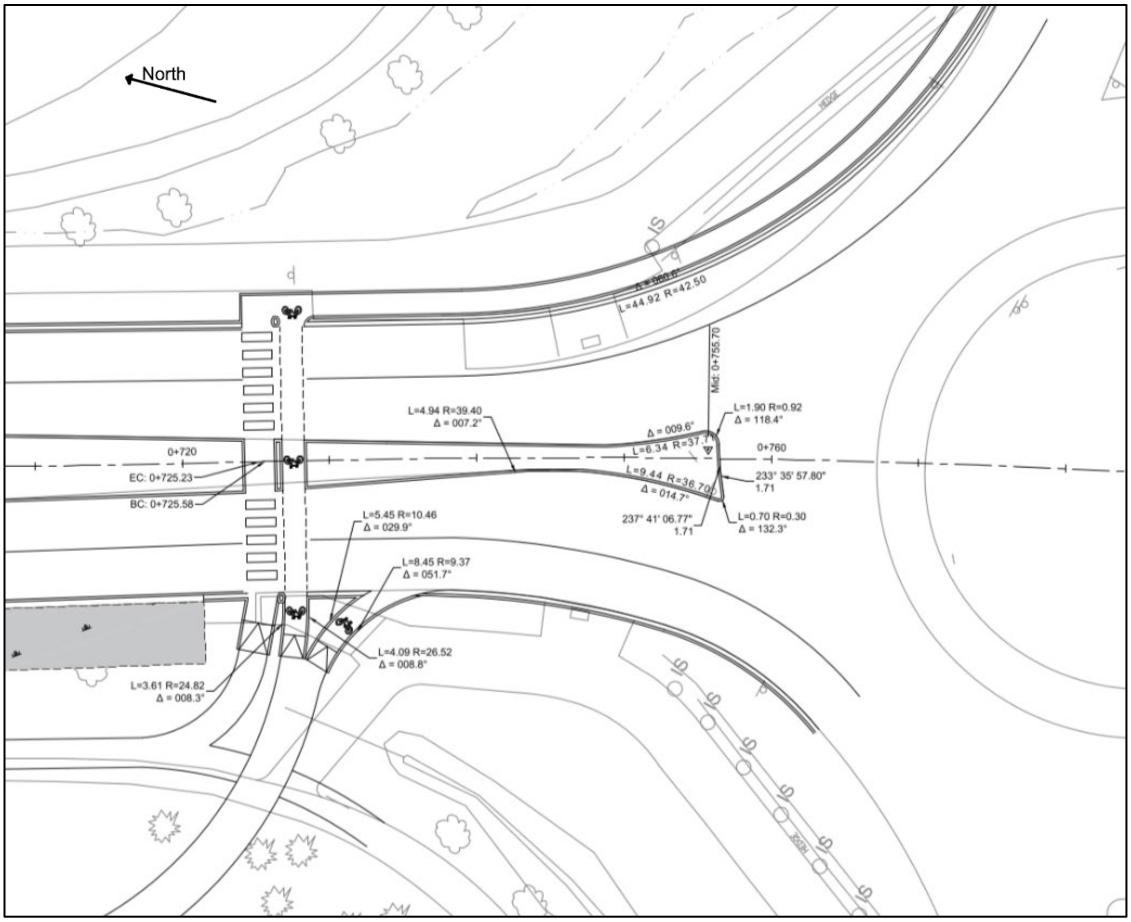


Figure 8 - Cyclist Lane & Crossing at West 16th & Wesbrook Mall

In addition to the new cyclist lane, the flare length for the North approach will be increased to compensate for the addition cyclist crossing. These new crossing enables the cyclist travelling northbound to easily transition to the bi-directional crossing along the westside of the corridor as shown in **Figure 8**. More detailed drawings for the roundabout can be found in drawing 3 of **Appendix A**.

5.0. Pedestrian Underpass

5.1. Orientation and Layout

The corridor design includes a pedestrian underpass located at the south end of Thunderbird Stadium, as seen in **Figure 9**.

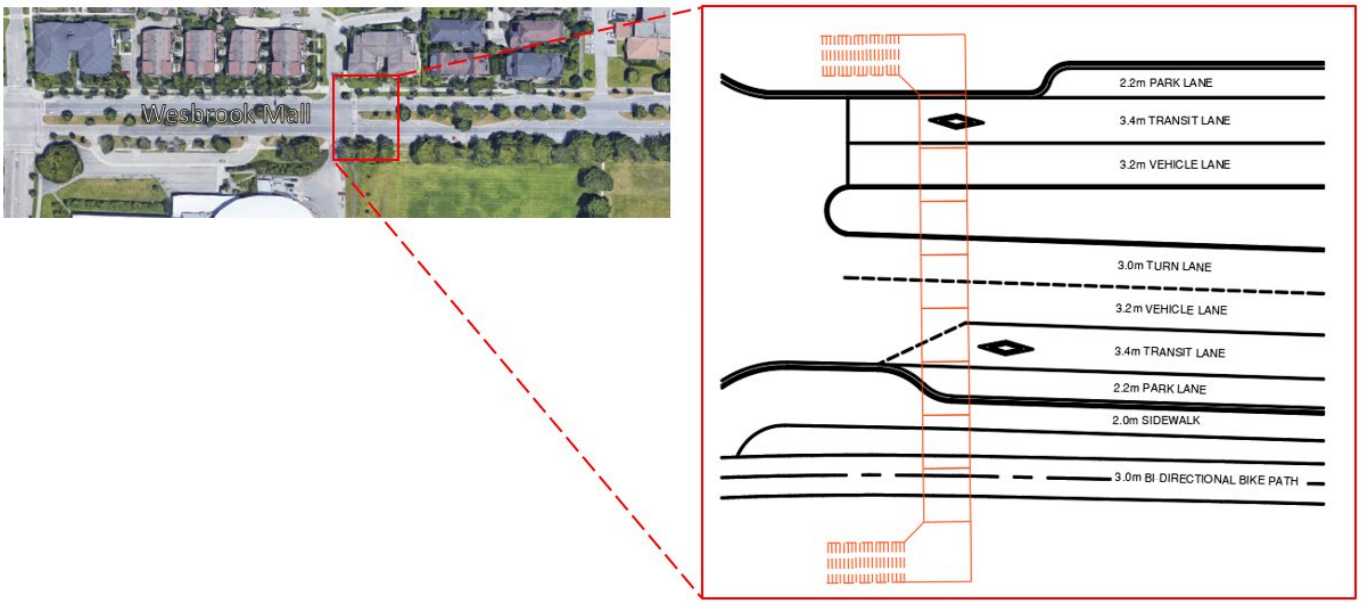


Figure 9 - Location of the Pedestrian Underpass

The location was chosen to help mitigate congestion at the intersection and accommodate safe pedestrian access to the recreation facilities located on the west side of the corridor. The use of approach ramps to increase the accessibility of the pedestrian underpass was considered during the preliminary design stage. However, based upon client feedback, space limitations, and the increased cost associated with accessibility ramps, stairways were chosen as the feasible option while proceeding with the design. Detailed design dimensions for the pedestrian underpass were chosen to conform with the guidelines from *CSA S6:19*, the *Canadian Highway Bridge Design Codes* [5] and are shown in drawings 4 to 6 in **Appendix A**.

5.2. Technical Considerations

5.2.1. Excavation

Due to the shallow nature of the excavations required for the installation of the pedestrian underpass and retaining walls, our team recommends that cut slopes be utilized to support the temporary excavations. The cut slopes should be dimension to the standards outlined in WorkSafe BC's Occupational Health and Safety Regulation. Moreover, utilizing prefabricated tunnel segments in conjunction with an expedited cut and cover construction methodology will help reduce costs associated with the underpass option.

5.2.2. Geotechnical

Based on the information provided from the UBC HydroGeo Study [6], soil information was determined using borehole TH01-04 located approximately 290 m Northeast of crossing. The soil is classified as Vashon drift deposit (glacial till) overlain with superficial fills. From the borehole data and appropriate correlations, the following design parameters were developed:

- Soil Unit Weight (γ) =20.4 kN/m^3
- Effective Friction Angle (θ') = 40°
- Serviceability Limit State = 400 kPa
- Ultimate Limit State = 600 kPa

Additionally, groundwater was not encountered until a significant depth below ground level and therefore was not considered for the design calculations.

5.3. Structural Loading and Design

The effects of dynamic vehicle loading were represented through two loading scenarios, one 9,100 kg axel bearing at the center of the segment, and 17,000 kg dual axel represented by two-point loads located at the third points. Soil pressure on the sides of the buried structure was modeled using Rankine's theory of active pressure. The pressure reaction on the bottom of the tunnel segments was modeled using a simplified stress distribution. The tunnel and retaining walls were then analyzed in Risa 2-D analysis software under the corresponding load cases to determine the combined axial, bending, and shear demands.

A detailed reinforced concrete design was then developed for both the precast tunnel segments and retaining walls. Detailed design drawings and calculations for the retaining wall and tunnel can be found in **Appendix A and D**, respectively.

5.4. Water Control

As discussed in *Section 5.2.2*, the ground water table is located significantly below the base of the tunnel and will not be a concern for the pedestrian underpass. The exterior of the tunnel will be coated in a mastic asphalt waterproofing membrane to divert infiltrated groundwater to a drain tile system running parallel to the base of the tunnel. Rainwater collected on exposed stairs and landings will be directed into grate drains located near the entrance to the tunnel. The tunnel segments will slope down from the sides of the road, allowing water to drain to a center catch basin located at the middle of the underpass. The water collected from these systems will be diverted into the existing stormwater pipe below the southbound lane.

5.5. Tunnel Lighting and Safety

In addition to regular street lighting, surface mounted overhead lighting will be installed throughout the length of the tunnel structure. Our team recommends that the client consult with UBC campus security regarding the installation of Code Blue emergency light phones as a part of the existing campus safety plan.

6.0. Environmental & Social Considerations

In accordance with *UBC's Climate Action Plan & Storm Water Management Plan* [2,7], bioswales and other forms of green infrastructure will be incorporated for on-site water retention. in addition, consultation meetings will be held to inform stakeholders and indigenous communities of the design plans. Furthermore, the excavations planned for installing the pedestrian underpass will follow *BC's Archaeological Artifact Regulation* [8] to ensure all land development Is with the governing policies.

6.1. Bioswale

To aid in rainwater retention and stormwater filtration, a bioswale will be installed within the corridor. Biofiltration swales are used as apart of low impact development strategies and are constructed using vegetative, trapezoid shaped channels to receive, filter and convey stormwater runoff. The contaminants in the stormwater runoff are removed through filtration, sedimentation, adsorption into the soil particles, and infiltration. The effectiveness of contaminant removal is dependant upon the geometry of the channel and the materials used to make-up the bioswale. **Figure 10** below illustrates the catchment area of Wesbrook Mall used to design the bioswale.

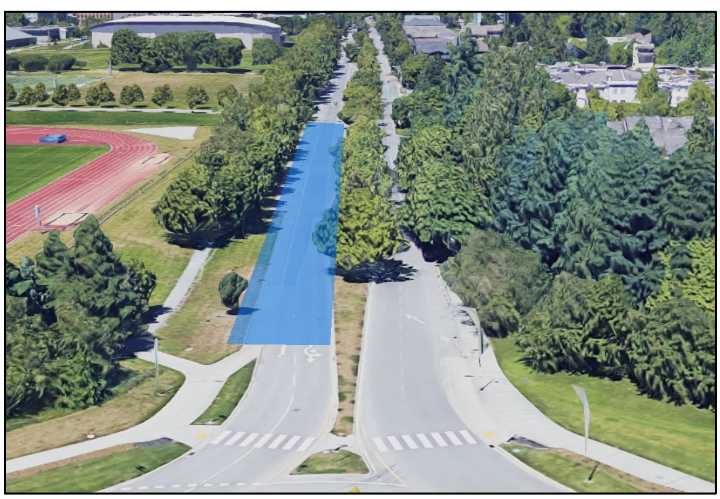


Figure 10 - Bioswale Catchment Area

The bioswale will consist of two main layers, a growing medium and drain rock layer. The growing medium is engineered to aid in removing contaminants from the stormwater by suspending plastics and particulate metals, retaining the contaminants within the growing medium [9]. Additionally, the vegetation planted within the growing medium move the soil particles and prevents the contaminants from solidifying and congesting the bioswale. The filtered water from the growing medium then passes through the drain rock layer which allows the water to infiltrate back into the surrounding area. Furthermore, a perforated pipe will be installed within the drain rock layer to convey any excess water in the event of a high intensity storm. **Figure 11** below illustrates a cross section of the bioswale, and all the design details discussed.

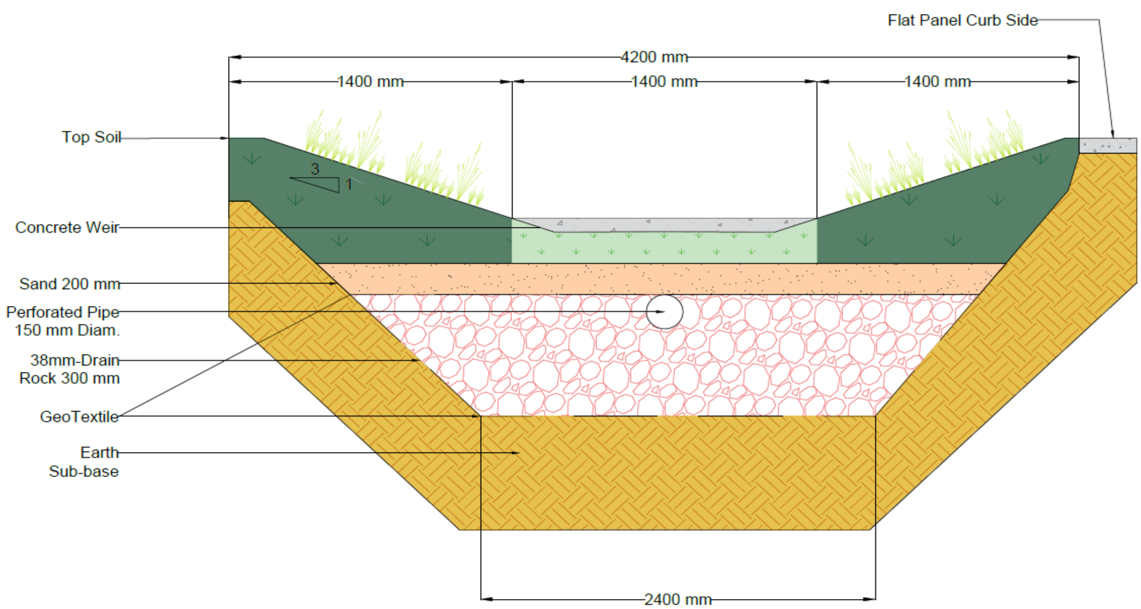


Figure 11 - Bioswale Cross-Section

According to the City of Vancouver's design guidelines, a sand layer is required between the growing medium and drain rock layers to ensure the contaminants are filtered out of the stormwater [10]. Additionally, as shown in **Figure 11**, a geotextile is required between the layers to prevent erosion of material. Furthermore, 150mm concrete weirs will be placed at 10m intervals to aid in channeling water within the bioswale as per the City of Vancouver's design guidelines [10]. Further details regarding the location of the bioswale and design calculations can be found in **Appendix A and E**, respectively.

6.2. Social Impacts

Phase 4 of the project will involve cut and cover construction in addition to typical roadway construction disturbances. Key construction events will be scheduled to minimize disruptions to stakeholders, commuters, and residents. On-street parking will be restricted during the construction period, and it is recommended that UBC offers campus parking accommodations to local residents. Additionally, traffic congestion and transit re-routing is addressed as per the traffic management plan in *Section 7.2*. Furthermore, the project will be scheduled during summer where a majority of the students and faculty will not be on campus.

6.3. Indigenous Art

The underpass structure offers a suitable opportunity to incorporate permanent artwork installations, particularly around the perimeter of the landings at the east and west entrance of the tunnel. During the detailed design, local indigenous artists were consulted and commissioned to design and create the artwork, the cost associated with the indigenous artwork is located in **Appendix F**.

6.4. Indigenous Artifacts

In BC, new archaeological discoveries are recorded every year, and it is not uncommon to find indigenous artifacts during an excavation. As such, if there is any evidence of artifacts findings such as petroglyph, antler or bone artifacts, we will contact the BC Association of Professional Archaeologists [11]. Upon further verification and assessment of indigenous artifacts, permitting may be required for any further excavation. Moreover, under these circumstances, it is assumed that UBC will employ their own archaeologist during construction, and if not, our team will supply one as necessary.

7.0. Stakeholders and Indigenous Consultation

7.1. Identification

A stakeholder is a generalized term given to groups or individuals who have a specific interest in a project. The Wesbrook Mall Phase 4 project centers on redesigning an important transportation link to one of Canada's most prominent universities. Thus, stakeholder identification is an important consideration to assess their potential impacts and investigate how directly they could be involved. Throughout the project's construction, a continuous process will be used to identify a list of stakeholder groups. Each specific group has a different level of interest and perceived impacts and needs a catered approach to best mitigate and manage. A list of stakeholders in the detailed design stage are identified below:

- Residents
- TransLink
- Emergency Services (VFRS, RCMP, Hospital)
- UBC Users (Students, Faculty, Staff)
- UBC Transport Planning
- Indigenous Communities
- UBC Sustainability

7.2. Engagement

Consult, collaborate, and inform are the cornerstones in managing and understanding stakeholders' expectations. We anticipate that a significant contributor to the impacts of stakeholders will be the delays and detours associated with the construction process. As an example: notifications via email and or social media platforms could prove to be effective methods to inform UBC students, faculty, and staff of delays imposed by construction activities. Some of the construction activities may create unavoidable and temporary vibration or sound pollution for nearby residents for which mitigation strategies and adequate notice will be distributed prior to the work. Moreover, TransLink will be provided with any route disruptions and temporary closures of bus stops along the corridor with sufficient notice.

7.3. Traffic Management Plan

A detailed traffic management plan was created to maintain traffic flow along Wesbrook Mall during the construction process. When construction is being performed along the corridor, traffic can be diverted to the side opposite to the construction. Once existing curbs and sidewalks are removed, sufficient space is created for two-way traffic on both sides of the road. A temporary construction speed limit zone will be implemented while crews are performing any work along the corridor. For a more detailed view of the traffic routing during the construction phase, see drawings 11 to 18 in **Appendix A**.

7.3.1. Pedestrian Underpass

The construction of the pedestrian underpass will be performed in two phases split along the existing center median. Firstly, the two lanes on the west side of Wesbrook Mall will be reserved for two-way traffic to allow construction crews to install the tunnel segments on the east side of the corridor. Delineators and sufficient signage will be provided to ensure the northbound vehicles safely traverse to the west side of the corridor and to combine with the southbound traffic into the existing bus lane. Once the east side tunnel segments have been installed and temporary gravel is placed, vehicles can be diverted to the east side to continue with the two-way temporary routing while construction crews compete the remainder of the underpass installation.

7.3.2. Intersection Line Painting

The line painting for the intersection will be completed at night while traffic is at a minimum to prevent disruptions to traffic flow. The intersection will be divided into east and west portions with the traffic being diverted accordingly as the lines are being painted.

7.3.3. Roadway

The east and west sides of the corridor will be completed separately to allow for two-way traffic flow on the side opposite to construction. Additionally, parking will be temporarily unavailable along the corridor during construction.

8.0. Technical Details

8.1. Standards and Software Packages

Tables 3 and 4 below outline the software's and standards used throughout the detailed design.

Table 3 - Standards & Software used for the Detailed Design

Software	Application
Synchro 6	Intersection Signal Timing
SIDRA INTERSECTION 9	Geometric Design and Traffic Analysis
AutoCAD 2022	Detailed Drawings
MS Project	Project Sequencing and Scheduling
EPASWIMM	Storm Water Analysis
RISA-2D	Structural Analysis

Table 4 - Standards used for the Detailed Design

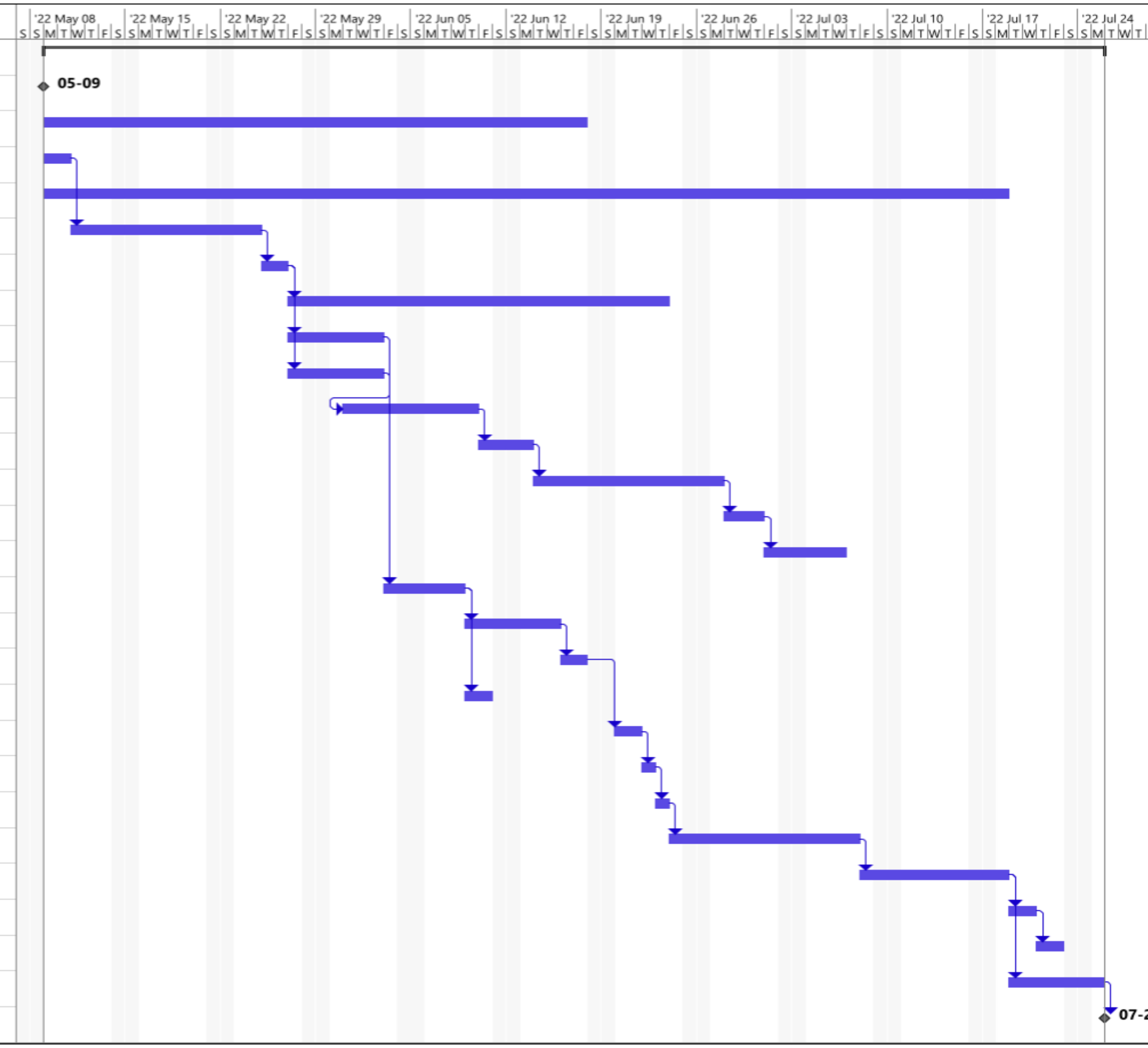
Standard	Application
National Building Code of Canada (2015)	User Requirements and Loading
AASHTO Highway Design Manual	Roadway and Corridor Design
BC Transit Infrastructure Design Summary	Roadway and Corridor Design
TAC Geometric Design Guide for Canadian Roads	Geometric Design and Corridor Design
CSA S6:19 The Canadian Highway Bridge Design Codes	Pedestrian Underpass Design
CAN/CSA-A23.3-04 Design of Concrete Structures	Structural Design

8.2. Construction Schedule

To ensure that the project is delivered in a timely and effective manner, a construction schedule was created using Microsoft Project. The schedule provides the stakeholders and general contractors with an estimated timeline for the project's delivery. The construction phase will span 56 days starting on May 9th, 2022 and terminating on August 25th, 2022. The provided construction schedule is susceptible to change as the project proceeds through the construction phase due to any changes in scope, contractors, or unanticipated conditions. A detailed view of the construction schedule is shown in **Figure 12** on the following page.

~This section is intentionally left blank~

ID		Task Mode	Task Name	Duration	Start	Finish
1			**Wesbrook Mall Phase 4 Upgrades and Redesign**	**56 days**	**Mon 22-05-0**	**Mon 22-07-25**
2			Start	0 days	Mon 22-05-0	Mon 22-05-09
3			Submitals and Shop Drawings	30 days	Mon 22-05-0	Fri 22-06-17
4			Utility Locates	2 days	Mon 22-05-0	Tue 22-05-10
5			Traffic Control	51 days	Mon 22-05-0	Mon 22-07-18
6			Removal of Existing Infrastructure, Curb, Sidewalk Ect.	10 days	Wed 22-05-1	Tue 22-05-24
7			Full Depth Reclamation	2 days	Wed 22-05-2	Thu 22-05-26
8			Temporary Patching	20 days	Fri 22-05-27	Thu 22-06-23
9			Storm Service Connection Piping	5 days	Fri 22-05-27	Thu 22-06-02
10			Tunnel Excavation & Shoring	5 days	Fri 22-05-27	Thu 22-06-02
11			Tunnel Utillity Relocation	8 days	Tue 22-05-31	Thu 22-06-09
12			Tunnel Install and Backfill Precast	2 days	Fri 22-06-10	Mon 22-06-13
13			Tunnel Stair Concrete Form & Pour	10 days	Tue 22-06-14	Mon 22-06-27
14			Tunnel Lightning	3 days	Tue 22-06-28	Thu 22-06-30
15			Artwork and Tunnel Finishes	4 days	Fri 22-07-01	Wed 22-07-06
16			Sidewalk Prep	4 days	Fri 22-06-03	Wed 22-06-08
17			Curb Prep	5 days	Thu 22-06-09	Wed 22-06-15
18			Concrete Curb and Gutter	2 days	Thu 22-06-16	Fri 22-06-17
19			Concrete Sidewalk	2 days	Thu 22-06-09	Fri 22-06-10
20			Asphalt Paving - Road	2 days	Mon 22-06-2	Tue 22-06-21
21			Asphalt Paving - Sidewalk	1 day	Wed 22-06-2	Wed 22-06-22
22			Asphalt Paving - Driveways	1 day	Thu 22-06-23	Thu 22-06-23
23			Bioswale Installation	10 days	Fri 22-06-24	Thu 22-07-07
24			Restoration and Landscaping	7 days	Fri 22-07-08	Mon 22-07-18
25			Commisioning	2 days	Tue 22-07-19	Wed 22-07-20
26			Demobilization	2 days	Thu 22-07-21	Fri 22-07-22
27			Close Out Documentation	5 days	Tue 22-07-19	Mon 22-07-25
28			Project Finish	0 days	Mon 22-07-2	Mon 22-07-25



Project: Schedule_for_Final
Date: Tue 22-03-08

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

Page 1

Figure 12 - Wesbrook Mall Phase 4 Construction Schedule

8.3. Cost Estimate

Class A (+/- 5-10%) cost estimate for the work is $7,734,959.23 which includes a 10% contingency and GST. The contingency has been applied for the variability in geotechnical conditions and utility relocation as described in the Risk Management section of the report. A summary of the key sections of the cost estimate is shown in **Table 5** below. A detailed breakdown of the cost estimate can be found in **Appendix F**.

Table 5 - Wesbrook Mall Phase 4 Cost Summary

Section	Title	Amount
1	General Requirements	$ 818,000.00
2	Trench Excavation, Bedding and Backfill	$ 197,692.00
3	Storm Sewer System	$ 30,600.00
4	Curbs and Sidewalks	$ 711,745.00
5	Streets & Asphalt	$ 1,588,730.50
6	Landscaping and Irrigation	$ 622,040.00
7	Pedestrian Underpass	$ 1,895,000.00
8	Operation & Maintenance	$ 417,144.00
9	Project Management and Design	$ 445,100.00
	Tender Price	$ 6,726,051.50
	G.S.T.	$ 336,302.58
	Total Price + G.S.T. + Contingency	$ 7,734,959.23

8.3.1. Project Management

The total cost of the consulting services to deliver the design reports and drawings for tender is $160,100.00 + GST. For project management services throughout the assumed 5-month duration of construction, a total cost of $285,000.00 + GST is estimated. We have assumed that one project manager and two technicians will be employed to perform layout, testing, and monitoring of the project. Additionally, a fixed daily rate of $80.00 per day for equipment and vehicle allowance has been applied for the project's duration. The total cost of both services is expected to be $445,100.00 + GST.

8.3.2. Maintenance Cost

As a preventative measure, the condition of the asphalt on the roadway should be checked at least once a year by UBC Facilities Group to maintain good road conditions and elongate the service life of the roadway. Similarly, the line-markings should be checked for clarity and repainted approximately every 10 years or as appropriate. Additionally, the vegetation and sediment traps in the bioswale should be checked and maintained every three years by UBC Facilities Group to maintain acceptable water quality. Furthermore, an operational cost will be incurred mainly from the traffic signals at Thunderbird Blvd. and the lighting for the pedestrian underpass.

8.4. Risk Management

A detailed risk analysis was performed to identify potential issues throughout the design and construction process. **Table 6** shows the identification and classification of potential risks. These values are then categorized for importance in our risk analysis matrix shown in **Table 7**. **Table 8** outlines the consequences of different risk levels. Items classified as "extreme" are found to be intolerable risks and therefore will require alternative solutions. In the assessment process, construction delays resulting in the project continuing into the winter school semesters was identified as an extreme risk. The risk will be mitigated through careful selection of a proponent with appropriate experience for cut and cover culvert installation, setting strict contractual obligations around milestones and submittals, and performing additional geotechnical analysis before construction.

Table 6 – Identification of Potential Risks

Risk	Likelihood	Consequence
(1) Variability in geotechnical conditions	Moderate	Major
(2) Uncertainty of underground services locations	Likely	Moderate
(3) Uncertainty of groundwater table	Unlikely	Moderate
(4) Objection from residents	Moderate	Negligible
(5) Discovery of culturally significant artifacts	Unlikely	Moderate
(6) Damage to existing underground utilities	Moderate	Minor
(7) Delays do to construction sequencing	Likely	Moderate
(8) Permitting delays	Unlikely	Minor

(9) Unexpected increase in traffic demands	Moderate	Major
(10) Design unsafe for pedestrians/cyclists	Unlikely	Major
(11) Temporary traffic disruptions	Likely	Negligible
(12) Damage to neighboring properties	Improbable	Minor
(13) Change in available financing	Improbable	Major
(14) Issues with right away and land acquisition	Improbable	Major
(15) Errors or omissions in design	Unlikely	Moderate
(16) Cost overruns and budget issues	Moderate	Moderate
(17) Skilled Labour shortages causing delay	Moderate	Major
(18) Unexpected ground issues for tunnel design	Unlikely	Moderate
(19) Corruption or mismanagement of project	Unlikely	Major
(20) Global supply chain disruptions	Improbable	Moderate
(21) Oppositions from local indigenous groups	Unlikely	Major
(22) Construction delays into winter semester	Likely	Major

Table 7 - Risk Analysis Matrix

Risk Level	Tolerance Criteria
Extreme	Intolerable - Find Alternative Methods
High	Tolerable - Provide Continues Review
Medium	Tolerable - Provie Periodic Review
Low	Low - Provide Periodic Review

Table 8 - Consequences of Potential Risks

Likelihood of Occurrence	Consequence of Occurrence				
	Negligible	Minor	Moderate	Major	Extreme
Frequent					
Likely	11		7,2	22	
Moderate	4	6	16	9,17,1	
Unlikely		8	3,5,18	10,19,21	
Improbable		12	15,20	13,14	

9.0. Recommendations

With consideration to the detailed design outlined in the report, our team would like to make the following recommendations to the client:

1) The client should retain a qualified consultant to perform survey and mapping of all underground utilities and infrastructure along the corridor prior to construction.
2) A detailed geotechnical assessment should be performed at the underpass location with ground conditions and bearing capacities to be confirmed.
3) To pre-emptively mitigate conflict throughout the construction phase, the client should retain a public communications representative to facilitate continuous dialogue between the contractor, the client, indigenous communities, and local residences.
4) To mitigate the risk of construction being prolonged into the UBC winter semester, the client should require the adoption of strict requirements regarding timelines of submittals and milestones.

Our team would be happy to provide some or all these services to the client at an additional cost in accordance with our standard hourly rates and fees.

10.0. References

[1] "UBC Vancouver Transportation Status Report Fall 2019", *UBC Campus and Community Planning*, 2020. [Online]. Availablehttps://planning.ubc.ca/sites/default/files/2019-11/PLAN_UBC_ISMP_Final2017.pdf [Accessed: November 5, 2021].

[2] "UBC Vancouver Campus Integrated Storm Water Management Plan", *UBC Campus and Community Planning,* 2017. [Online]. Available: https://planning.ubc.ca/sites/default/files/2019-11/PLAN_UBC_ISMP_Final2017.pdf [Accessed: October 7, 2021].

[3] "British Columbia Active Transportation Guidelines", *British Columbia Ministry of Transportation and Infrastructure*, 2012. [Online]. Available: https://www2.gov.bc.ca/assets/gov/driving-and-transportation/funding-engagement-permits/grants-funding/cycling-infrastructure-funding/active-transportation-guide/2019-06-14_bcatdg_compiled_digital.pdf [Accessed: October 27, 2021].

[4] "Pavement Structure Design Guidelines", *British Columbia Ministry of Transportation and Infrastructure,* 2015. [Online]. Available: https://www2.gov.bc.ca/assets/gov/driving-and-transportation/transportation-infrastructure/engineering-standards-and-guidelines/technical-circulars/2015/t01-15.pdf [Accessed: March 6, 2022]

[5] "Bridge Standards and procedures Manuel Vol. 1", *British Columbia Ministry of Transportation and Infrastructure*, 2016. [Online]. Available: https://www2.gov.bc.ca/assets/gov/driving-and-transportation/transportation-infrastructure/engineering-standards-and-guidelines/bridge/volume-1/2016/volume-1.pdf [Accessed: October 5, 2021].

[6] "UBC Properties Trust: Hydrogelogical and Geotechnical Assessment of Northwest Area UBC Campus, Vancouver", *Piteau Associates*, 2002. [Online]. Available: https://canvas.ubc.ca/courses/82967/pages/project-iii-wesbrook-mall-redesign-phase-4?module_item_id=4060016 [Accessed: March 1, 2022]

[7] "University of British Columbia Climate Action Plan", *The University of British Columbia,* 2020. [Online]. Available: https://planning.ubc.ca/sites/default/files/2019-11/PLAN_UBC_ClimateActionPlan.pdf [Accessed: November 1, 2021].

[8] "Report Finding an Archeological Artifact or Human Remains", *The British Columbia Provincial Government,* 2021. [Online]. Available: https://www2.gov.bc.ca/gov/content/industry/natural-resource-use/archaeology/report-a-find#Protecting%20archaeological%20sites [Accessed: October 29, 2021]

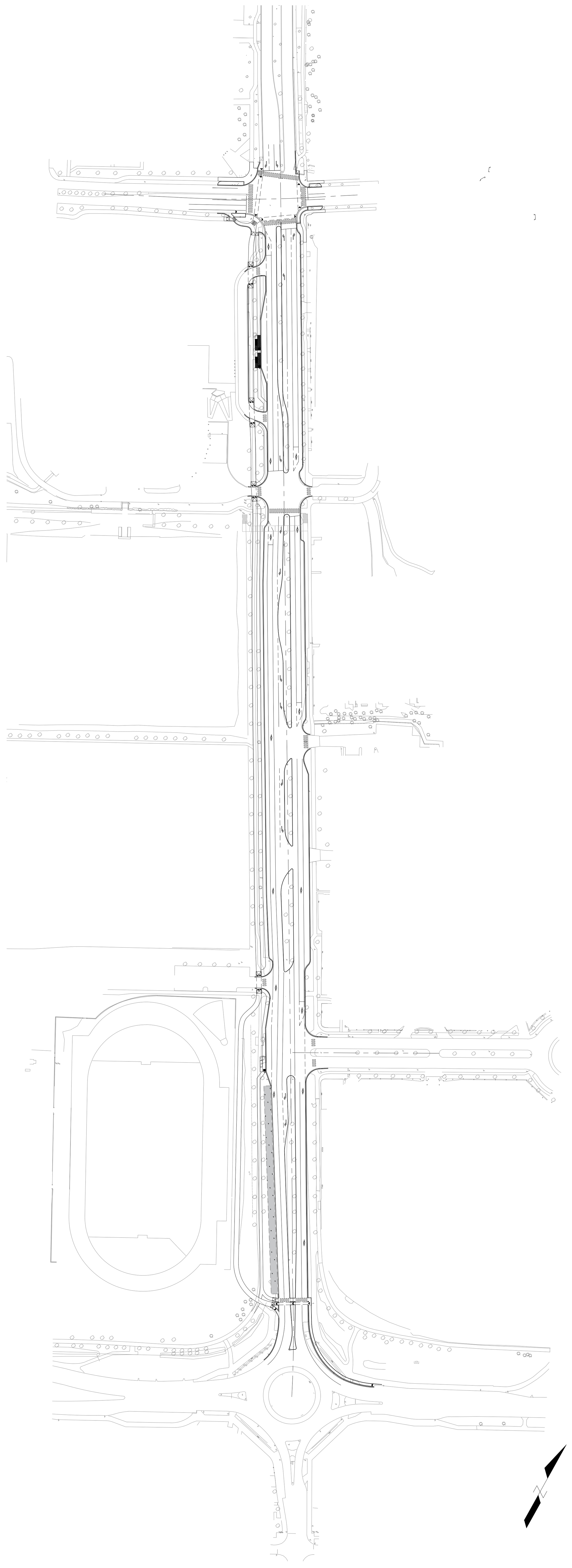
[9] "Biofiltration Swale Design Guidance", *California Department of Transportation Division of Environmental Analysis Storm Water Program*, 2012. [Online]. https://dot.ca.gov/-/media/dot-media/programs/design/documents/dg-biofiltration-swale-092712-a11y.pdf [Accessed: February 20, 2022]

[10] "Infiltration Swale System", *Greater Vancouver Sewerage & Drainage District*, 2012. [Online]. http://www.metrovancouver.org/services/liquid-waste/LiquidWastePublications/04StormwaterSourceControlDesignGuidelinesInfiltrationSwales.pdf [Accessed: February 20, 2022]

[11] "Bylaws Codes and Standards", *British Columbia Association for Professional Archeologists*, 2020. [Online]. Available: https://www.bcapa.ca/archaeology/bylaws/ [Accessed: November 5, 2021]

Appendix A – Detailed Design Drawings

1. SITE PLAN:



2. GENERAL NOTES:

NOTES, PLANS, DETAILS, AND SPECIFICATIONS (IF ANY) SHALL BE READ AS ONE DOCUMENT

CONSTRUCT THE ROADWAY TO THE EXTENT OF THE DRAWINGS

FIELD MEASURE AND ,ALE ADJUSTMENTS TO SUIT EXISTING CONDITIONS

THE CONTRACTOR SHALL KEEP WORK SITES CLEAN AND FREE OF CONSTRUCTION DEBREE DURING THE PROCESS OF CONSTRUCTION AND LEAVE THE SITE CLEAN UPON COMPLETION OF WORK OR PORTIONS OF WORK

IF DESCREPANCIES EXIST BETWEEN THESE DRAWINGS AND SPECIFICATIONS, CONTACT ENGINEER FOR REVIEW AND APPROVAL PRIOR TO PROCEEDING

ALL RELEVANT PERMITS FROM GOVERNIN AUTHORITIES ARE THE RESPONSIBILITY OF OTHERS AND MUST BE IN PLACE PRIOR TO START OF CONSTRUCTION

SITE INSPECTIONS TO DETERMINE LOCATION OF UTILITIES EITHER SHOWN OR NOT SHOWN ON THE DRAWINGS IS THE RESPONSIBILITY OF THE CONTRACTOR.

REPORT ALL DISCREPTENCIES BETWEEN ACTUAL CONDITIONS AND EXCAVATION DRAWINGS IMMEDIATELY. UTILITY DATA IS PROVIDED FROM THE UBC WESBROOK BASE PLAN.

INFORMATION ON DRAWINGS IS TO BE USED AS PRELIMINARY ONLY.

DRAWINGS ARE SCALED BASED ON A1 PAGE SIZE, PRINTING TO OTHER SIZES MAY CHANGE THE INDICATED SCALE.

3.0 GENERAL MATERIALS:

DELIVER MATERIALS TO JOB SITE IN DRY CONDITION. KEEP MATERIALS DRY UNTIL USE.

SITE IS TO BE ENCLOSED BY FENCING OR HOARDING PRIOR TO START OF TUNNEL EXCAVATION. FENCING/HOARDING IS THE RESPONSIBILITY OF OTHERS AND IS TO BE ACCEPTABLE BY MUNICIPAL BYLAWS.

4.0 DRAWING LIST:

1. WESBROOK MALL 0+000 - 0+360
2. WESBROOK MALL 0+360 - 0+770
3. INTERSECTION IMPROVEMENTS
4. PEDESTRIAN UNDERPASS PLAN & PROFILE
5. PEDESTRIAN UNDERPASS
6. SHOP-DRAWINGS PRECAST TUNNEL SECTION
7. ROADWAY CROSS-SECTION - 0+190
8. ROADWAY STRUCTURE
9. BIOSWALE PROFILE - 0+710 - 0+720
10. BIOSWALE CROSS-SECTIONS AND DETAILS
11. TRAFFIC MANAGEMENT TUNNEL PHASE 1 0+000 - 0+360
12. TRAFFIC MANAGEMENT TUNNEL PHASE 1 0+360 - 0+770
13. TRAFFIC MANAGEMENT TUNNEL PHASE 2 0+000 - 0+770
14. TRAFFIC MANAGEMENT TUNNEL PHASE 2 0+000 - 0+770
15. TRAFFIC MANAGEMENT ROADWAY PHASE 1 0+000 - 0+360
16. TRAFFIC MANAGEMENT ROADWAY PHASE 1 0+360 - 0+770
17. TRAFFIC MANAGEMENT ROADWAY PHASE 2 0+000 - 0+770
18. TRAFFIC MANAGEMENT ROADWAY PHASE 2 0+000 - 0+770

4.0 CONCRETE

ALL CONCRETE WORK AND FORMWORK TO BE PERFORMED IN ACCORDANCE WITH CSA-A23.1-04.

CONCRETE USED IN THE RETAINING AND TUNNEL STRUCTURES IS TO BE OF NORMAL WEIGHT (23.5KG.M3) AND HAVE MAXIMUM AGGREGATE SIZE OF 19 MM. DO NOT USE ADMIXTURES OR ADD ADDITIONAL WATER TO THE BATCH WITHOUT APPROVAL OF THE ENGINEER. IF THE TIME ELAPSED BETWEEN BATCHING AND PLACING EXCEEDS 1HR 20 MIN THE BATCH IS TO BE REJECTED.

TOLERENCES FOR CONCRETE RETAINING WALLS AND TUNNEL SEGMENTS ARE AS FOLLOWS:
- CUMULATIVE DEVIATION FROM VERTICAL LINE < 1/4" IN 10'0"
- FLAT SURFACES AND SLABS < 1/4" IN 10'0"
- CUMULATIVE DECIATION FROM HORIZONTAL LINE < 1.4" IN 10'-0"
- BUILDING LINE < 1/4"

PERFORM MECHANICAL VIBRATION TO CONSOLIDATE ALL CONCRETE. NON STRUCTURAL CONCRETE INCLUDING ART INSTALLATIONS AT THE TUNNEL LANDINGS ARE THE RESPONSIBILITY OF OTHERS.

CONCRETE STRENGHTS AS SPECIFIED ON SEALED IFC DRAWINGS. TWO (2) CYLANDERS SHALL BE CAST, AND CORRESPONDING TO SLUMP TESTS PERFORMED FOR EVERY 20M3 OF CONCRETE CAST. THE RESULTS OF THESE TESTS WILL BE PROVIDED TO CAMBRIDGE CONSULTING.

MIN 28 DAY COMPRESSIVE STRENGTH OF CONCRETE SHALL BE 90% OF THE SPECIFIED CONCRETE STRENGTH

5.0 REINFORCING STEEL

CONCRETE REINFORCING STEEL FOR TUNNEL SEGMENTS AND RETAINING WALLS SHALL BE NON WELDABLE CSA G30.18 GRADE 400 BILLETED STEEL BARS.

HOOKS, BENDS, AND SPLICES TO BE IN ACCORDANCE WITH CSA-A23.1-04. DO NOT WET DOWEL REINFORCING UNLESS WITH APPROVAL IN WRITING BY THE ENGINEER.

6.0 GEOTECHNICAL

SITE IS TO BE ENCLOSED BY FENCING OR HOARDING PRIOR TO START OF TUNNEL EXCAVATION. FENCING/HOARDING IS THE RESPONSIBILITY OF OTHERS AND IS TO BE ACCEPTABLE BY MUNICIPAL BYLAWS.

ENGINEERED FILL TO BE PLACED UPON APPROVED SUBRADE AND CONSIST OF WELL GRADED, SELECT GRANULAR MATERIAL. ENGINEERED FILL SHOULD BE PLACED IN MAXIMUM 150mm LISTS AND COMPACTED TO AT LEAST 100% STANDARD PROCTOR MAXIMUM DRY DENSITY OR JUDGED EQUIVALENT. PLACEMENT AND COMPACTION IS TO BE MINITORED BY A GEOTECHINCAL PROFESSIONAL.

NUCLEAR DENSOMETER COMPACTION TESTING OF ALL PLACED CBC AND SGSB LIFTS WITH ONE TEST EVERY 20m PER LANE.

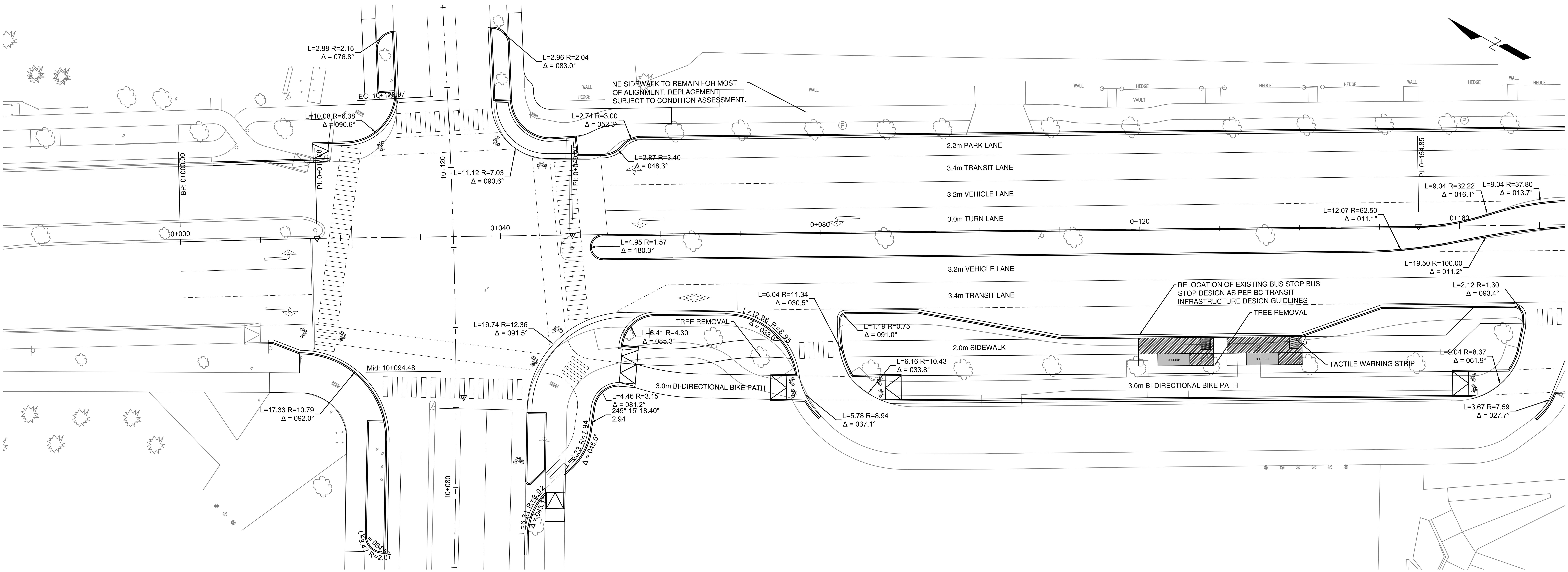
SUPERPAVE MIX COMPLIANCE ASPHALT TESTING EVERY 1200 TONS OR MINIMUM ONE PER DAY DURING PAVING.

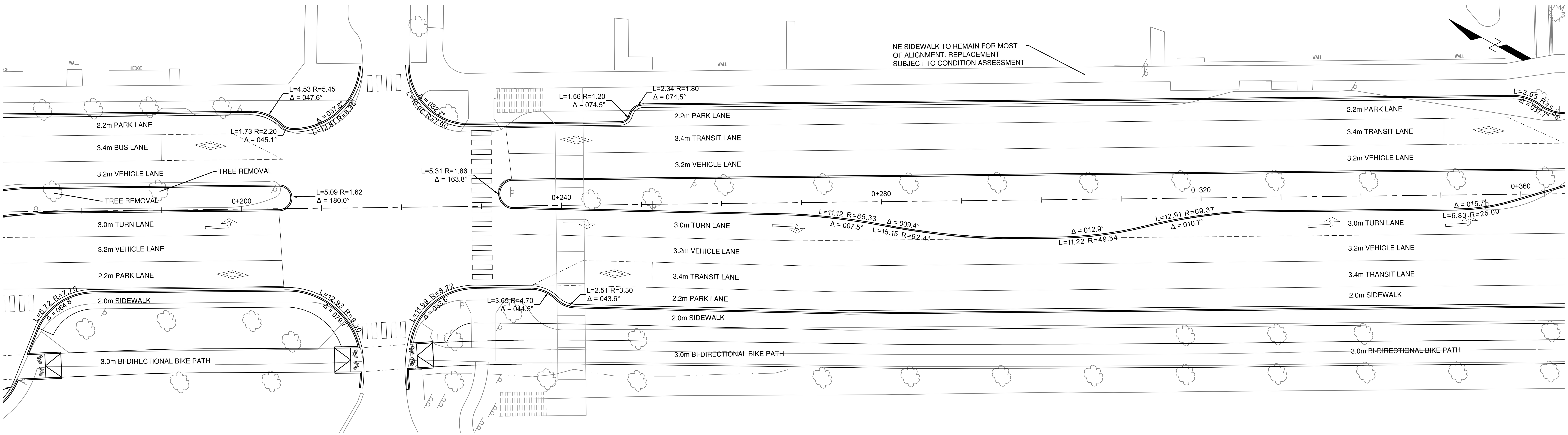
REV NO	REVISIONS	DATE	DRAWN	APPR'D
1	FINAL DETAILED DESIGN REPORT, FOR CONSTRUCTION	2022-03-30	KA	CA

WESBROOK MALL
GENERAL NOTES AND SITE PLAN

SCALE		DATE	2022-03-30
DRAWN BY		DESIGN BY	
CHECKED BY		APPROVED BY	

DWG. NO.





REV NO	REVISIONS	DATE	DRAWN	APPR'D
1	PRELIMINARY DESIGN REPORT. FOR REVIEW ONLY	2021-11-30	CA	CA
2	ISSUE FOR TENDER	3/30/2022	CA	CA

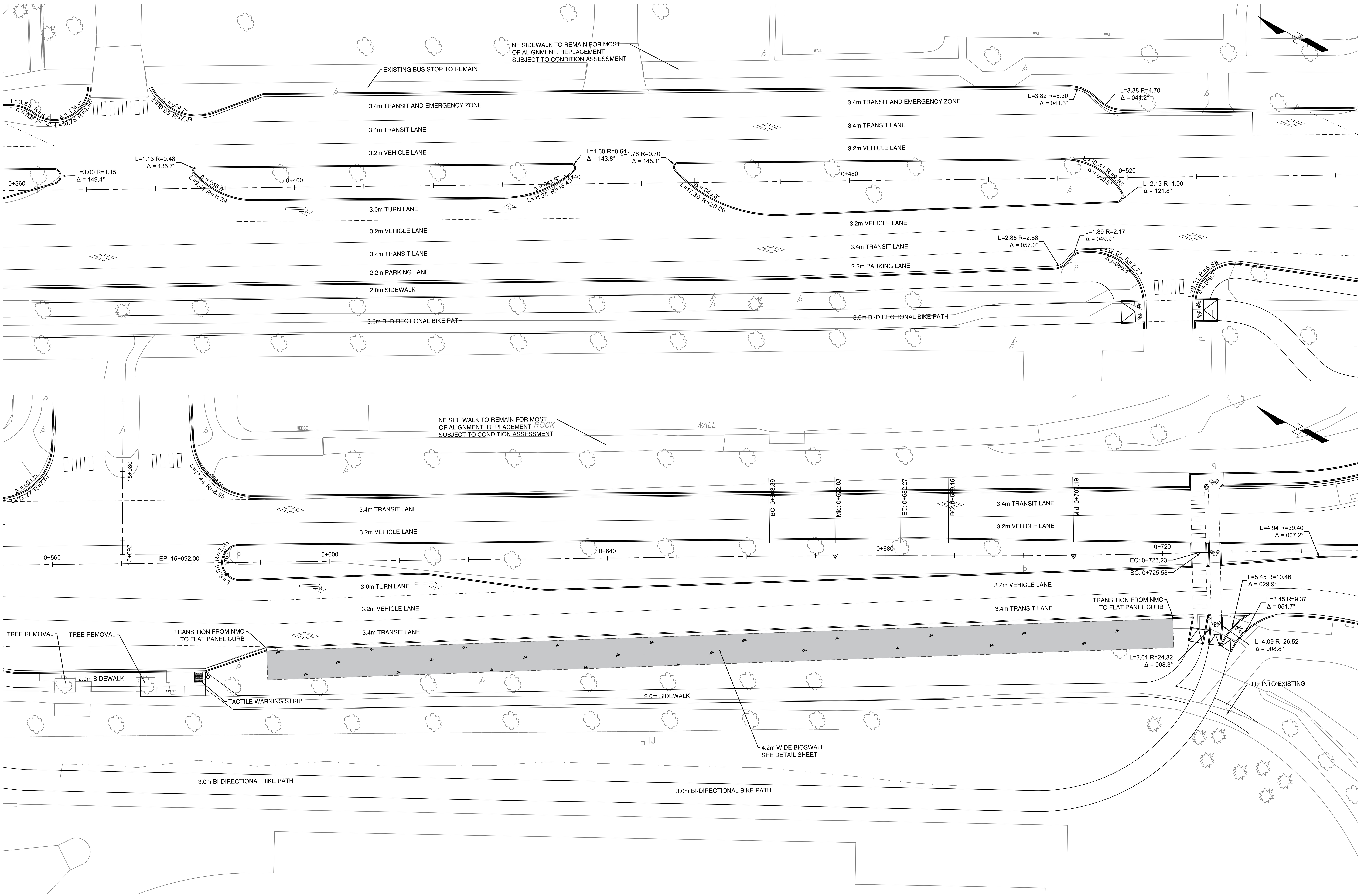
WESBROOK MALL

0+000 - 0+360

SCALE	1:250H 1:250V	DATE	2022-03-30
DRAWN BY	CA	DESIGN BY	CA
CHECKED BY	CA	APPROVED BY	CA

DWG. NO. R02

1 OF 18

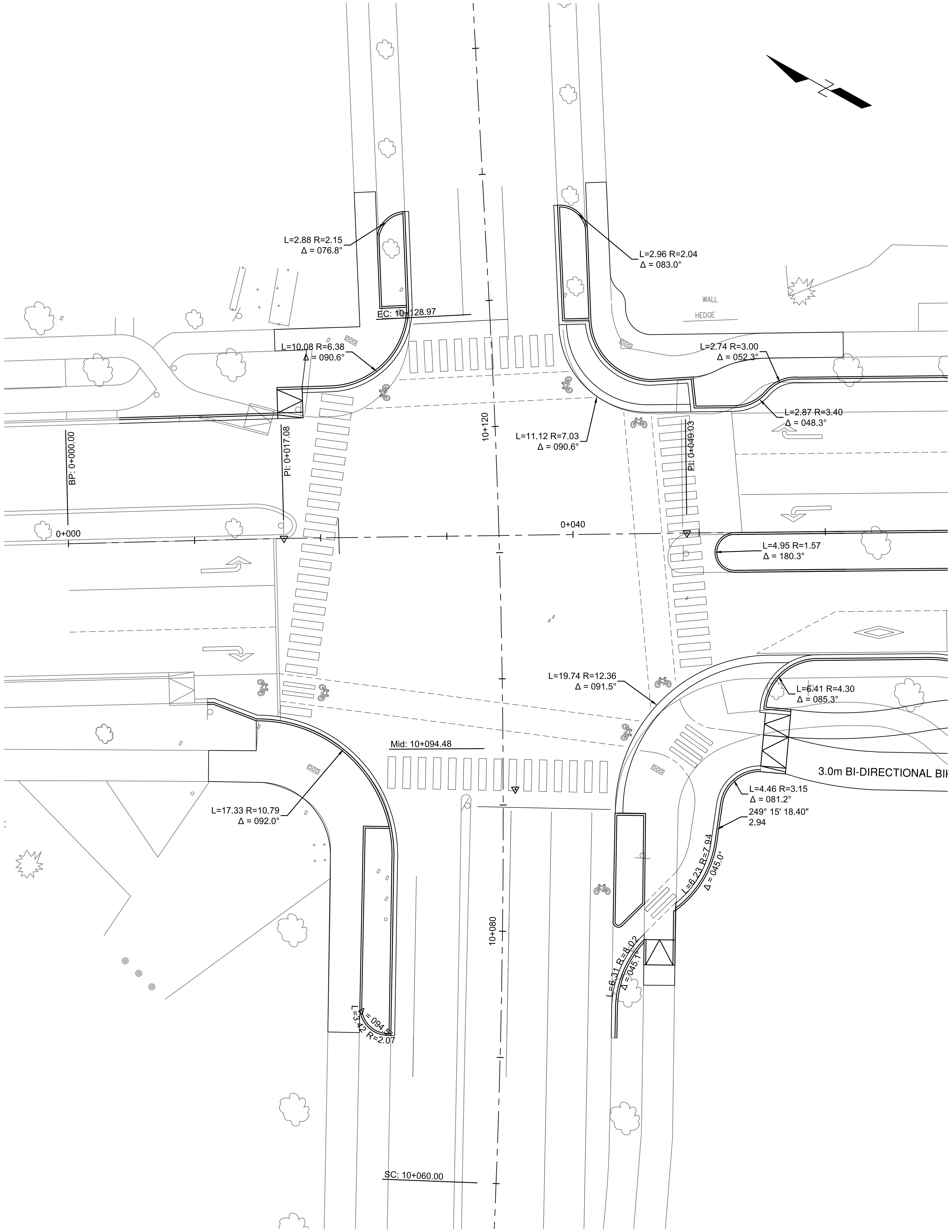


REV NO	REVISIONS	DATE	DRAWN	APPR'D
1	PRELIMINARY DESIGN REPORT. FOR REVIEW ONLY	2021-11-30	CA	CA
2	ISSUE FOR TENDER	3/30/2022	CA	CA

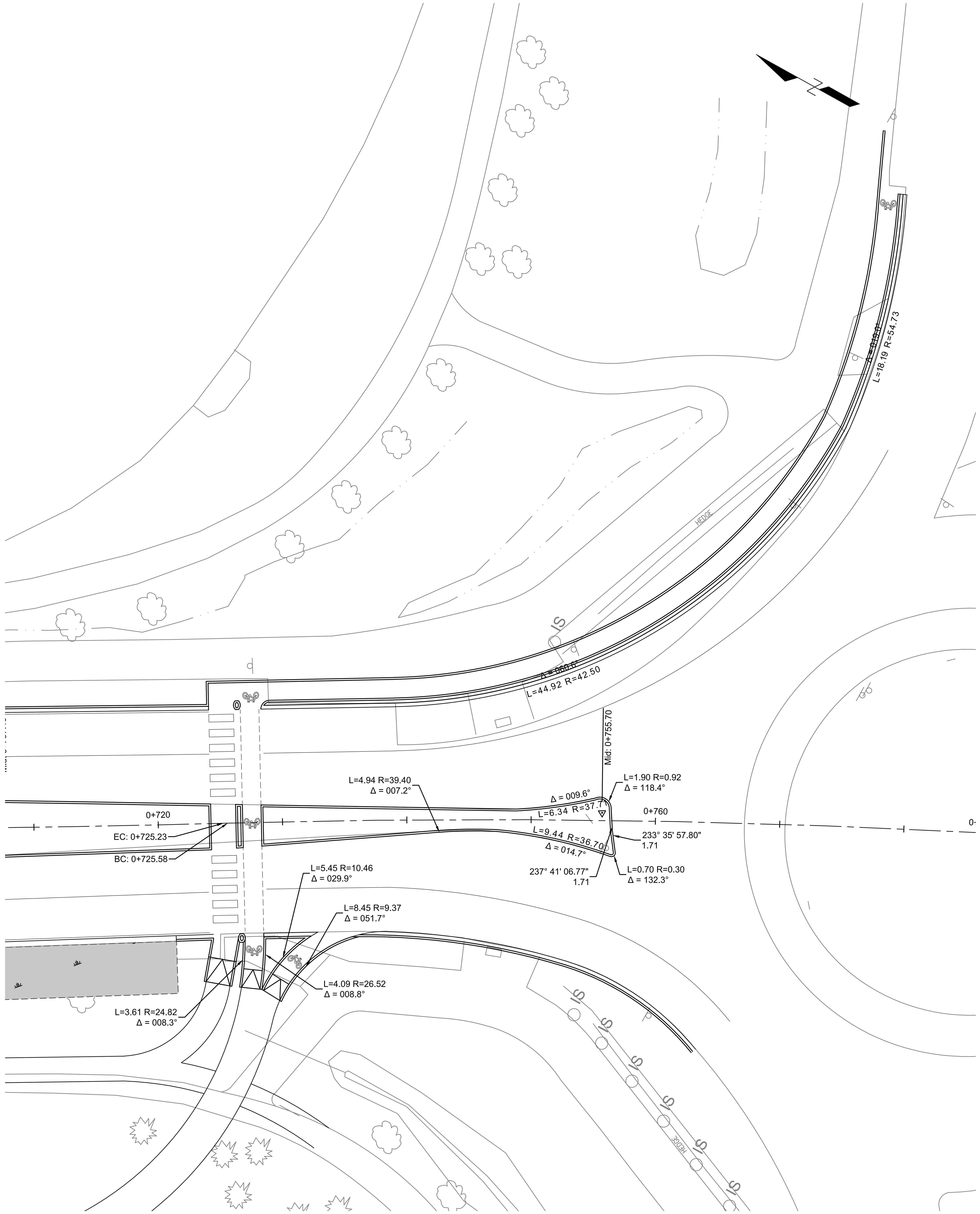
WESBROOK MALL
0+360 - 0+770

SCALE	1:250H 1:250V	DATE	2022-03-30
DRAWN BY	CA	DESIGN BY	CA
CHECKED BY	CA	APPROVED BY	CA

DWG. NO.
R02
2 OF 18



WESBROOK MALL & THUNDERBIRD INTERSECTION



WESBROOK MALL AND 16th AVE W ROUNDABOUT IMPROVEMENTS

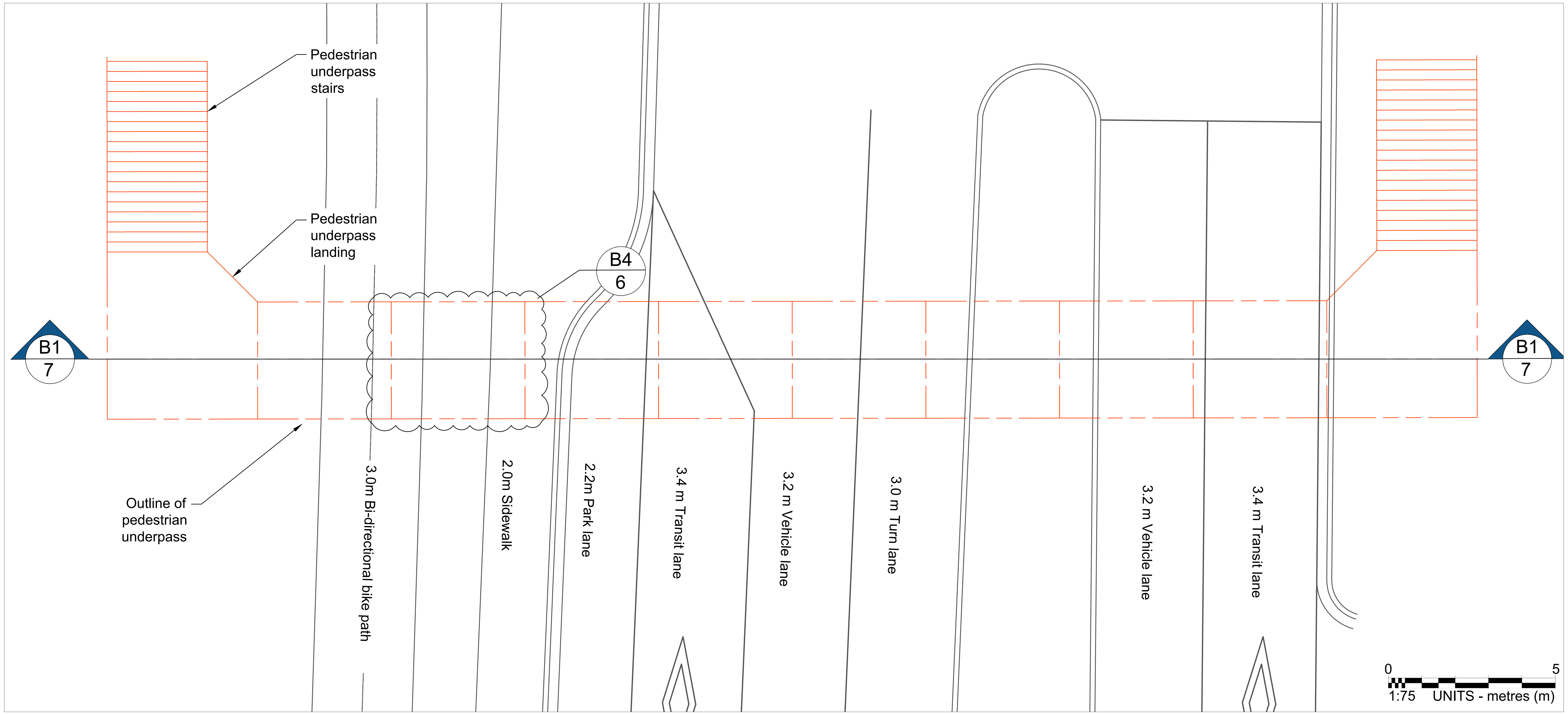
REV NO	REVISIONS	DATE	DRAWN	APPR'D
1	PRELIMINARY DESIGN REPORT. FOR REVIEW ONLY	2021-11-30	CA	CA
2	ISSUE FOR TENDER	3/30/2022	CA	CA

WESBROOK MALL
INTERSECTION IMPROVEMENTS

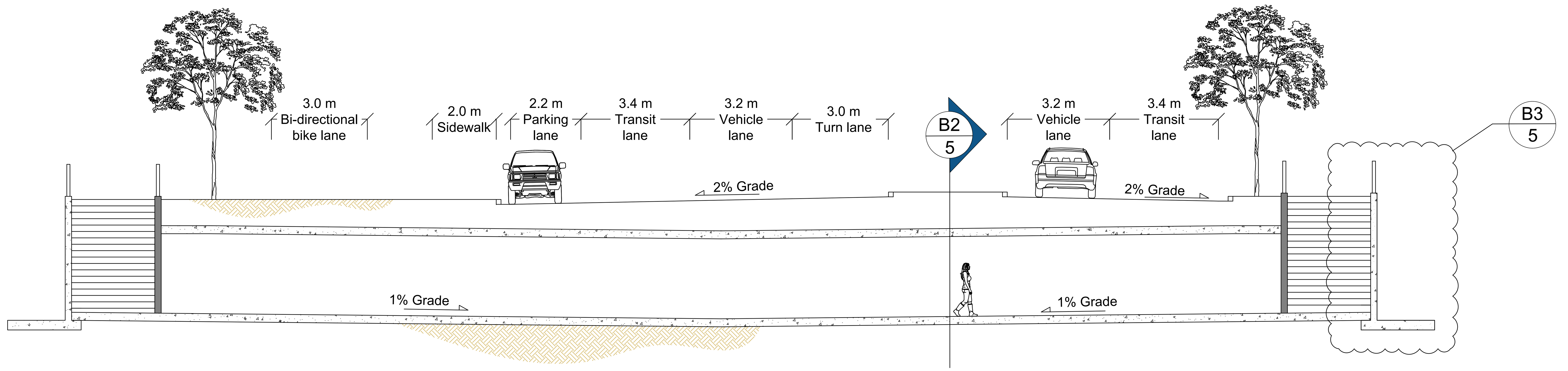
SCALE	1:200H 1:200V	DATE	2022-03-30
DRAWN BY	CA	DESIGN BY	CA
CHECKED BY	CA	APPROVED BY	CA

DWG. NO. R02
3 OF 18

A1 - Wesbrook Mall Corridor Overview - Not to Scale



A2 - Pedestrian Underpass Plan View



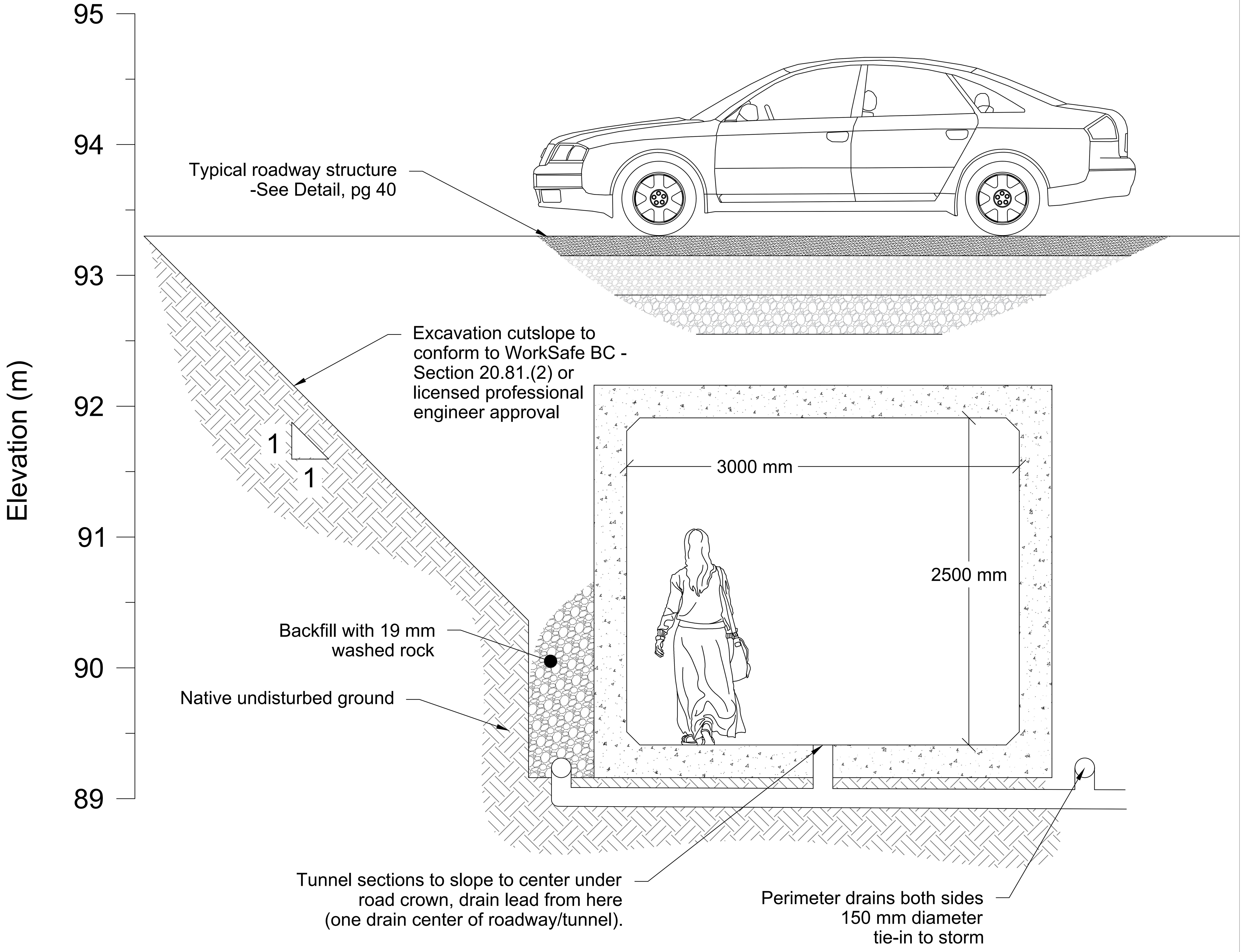
A3 - Pedestrian Underpass Profile at 0+237

▶ DESIGN

REV NO	REVISIONS	DATE	DRAWN	APPR'D
1	DESIGN SUMMARY REPORT, FOR REVIEW ONLY	2022-03-01	KA	CA
2	FINAL DETAILED DESIGN REPORT, FOR CONSTRUCTION	2022-03-30	KA	CA

WESBROOK MALL
PEDESTRIAN UNDERPASS PLAN & PROFILE - 0+237

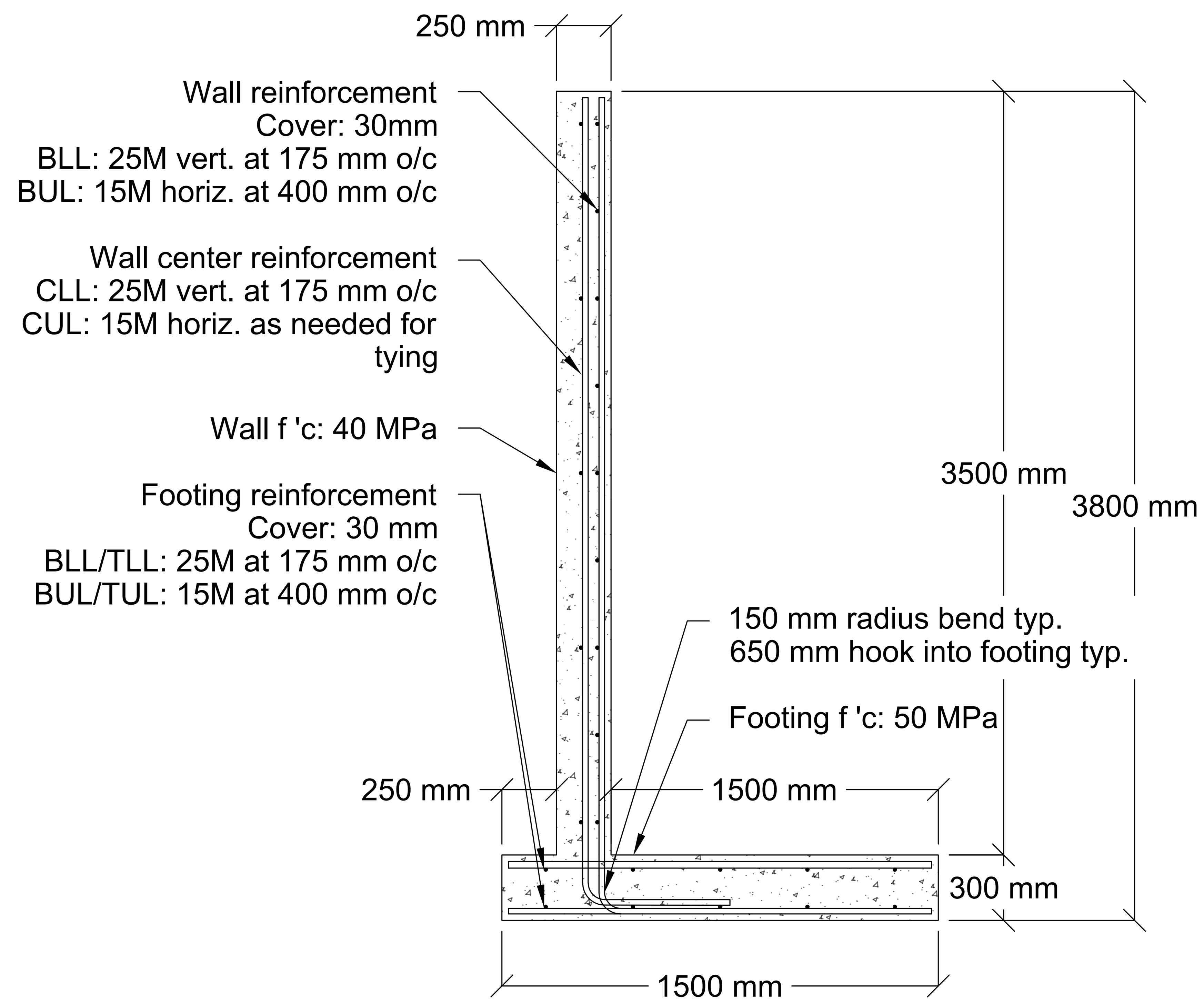
SCALE	1:75H 1:75V	DATE	2022-03-30	DWG. NO. R02
DRAWN BY	KA	DESIGN BY	JC	4 OF 18
CHECKED BY	CA	APPROVED BY	CA	



B2 Pedestrian Underpass

\- Cross-Section

0 2
1:20 UNITS - metres (m)



B3 Pedestrian Underpass Retaining Wall

\- Cross-Section

0 2
1:20 UNITS - metres (m)

▸DESIGN

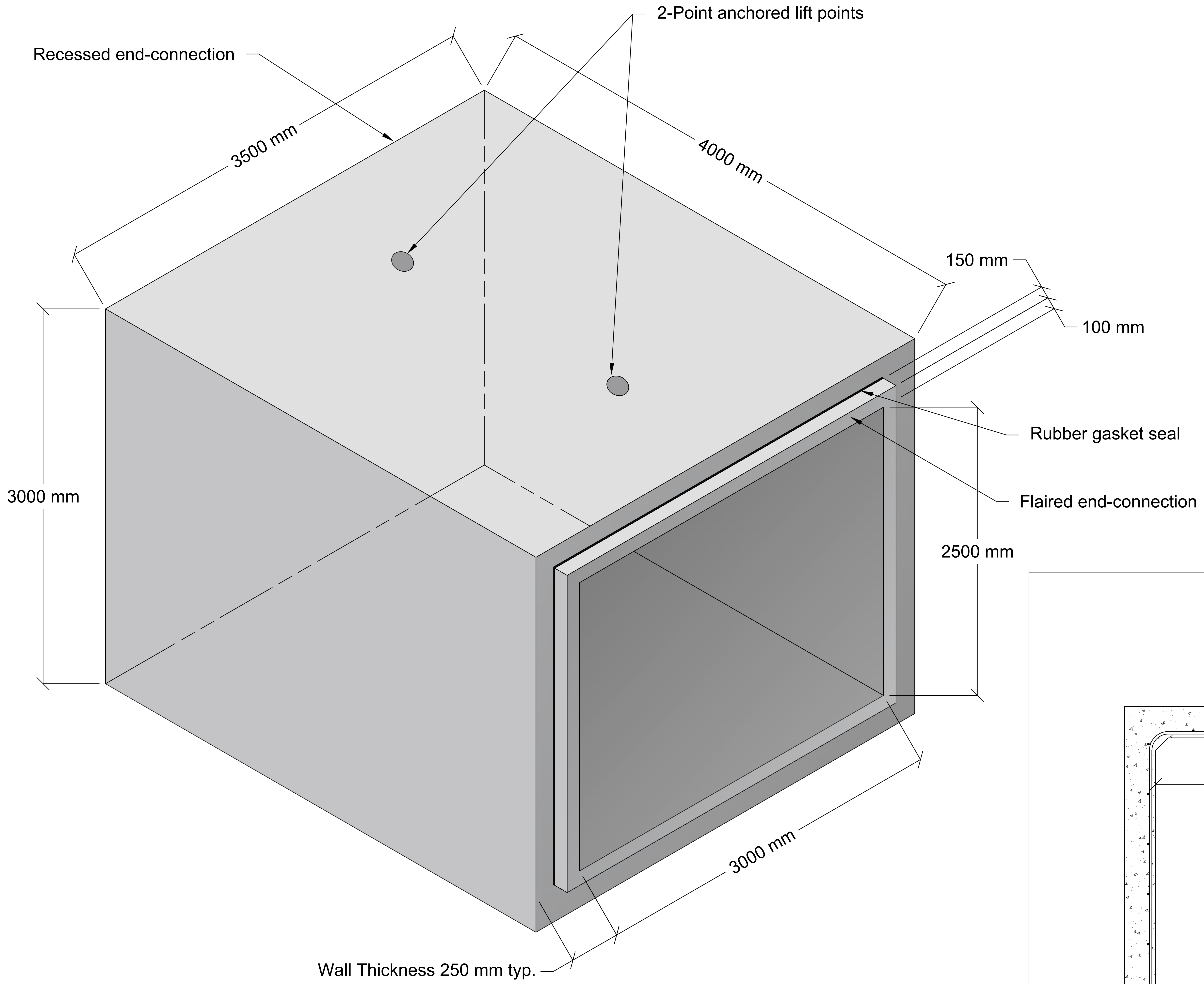
REV NO	REVISIONS	DATE	DRAWN	APPR'D
1	DESIGN SUMMARY REPORT, FOR REVIEW ONLY	2022-03-01	KA	CA
2	FINAL DETAILED DESIGN REPORT, FOR CONSTRUCTION	2022-03-30	KA	CA

WESBROOK MALL
PEDESTRIAN UNDERPASS

SCALE	1:20H 1:20V	DATE	2022-03-30
DRAWN BY	KA	DESIGN BY	JC
CHECKED BY	CA	APPROVED BY	CA

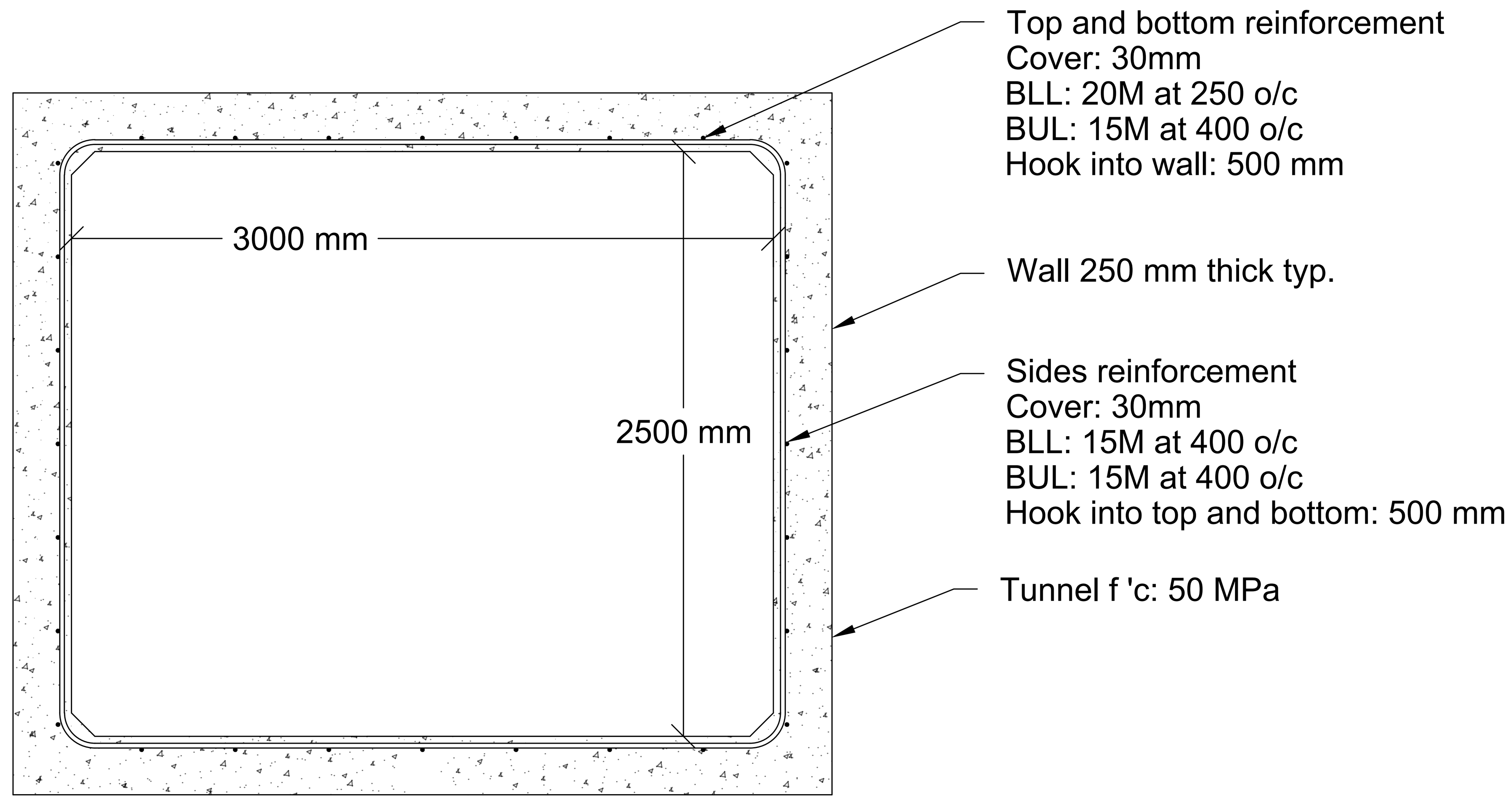
DWG. NO. R02

5 OF 18



B4 - Precast Tunnel Section
Shop-Drawing Isometric

0 2
1:20 UNITS - metres (m)



B4 - Precast Tunnel Section
Shop-Drawing Cross-Section

0 2
1:20 UNITS - metres (m)

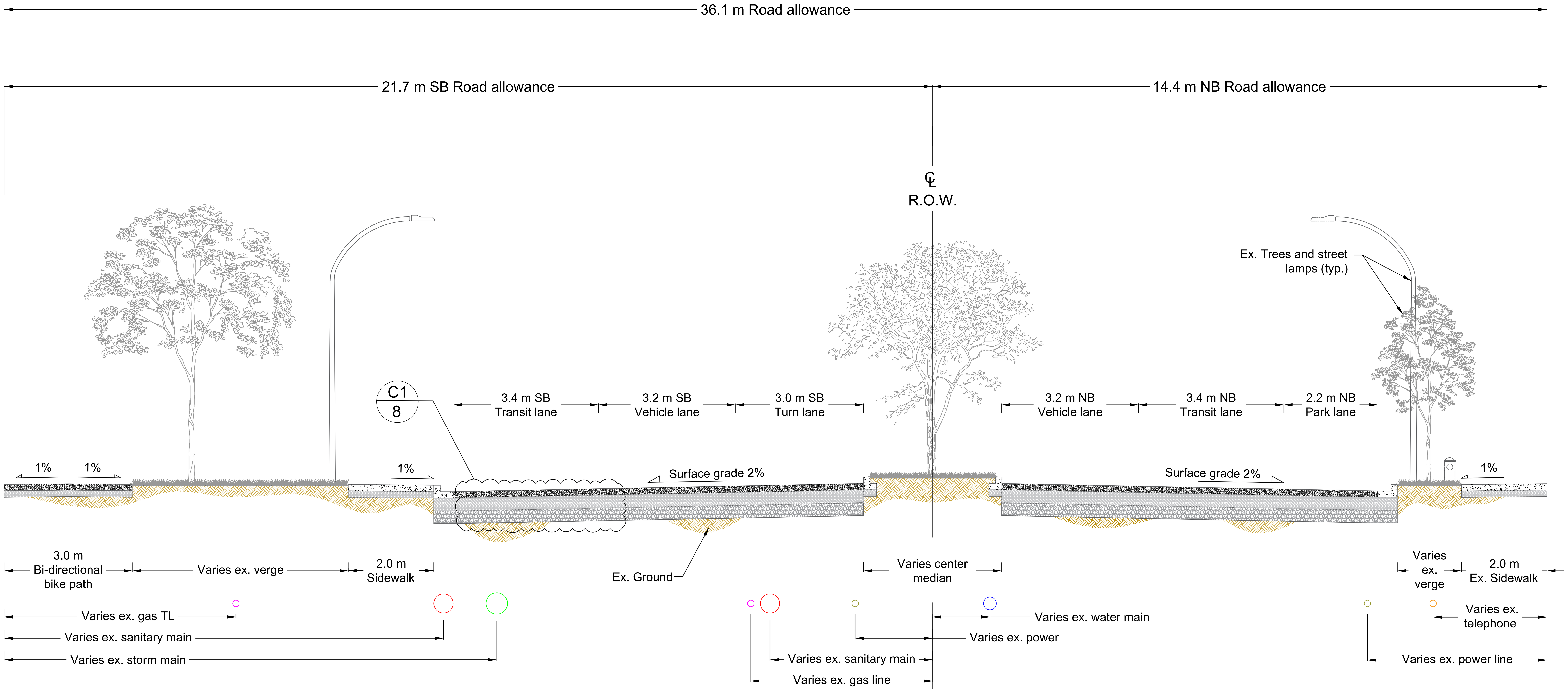
▸ DESIGN

REV NO	REVISIONS	DATE	DRAWN	APPR'D
1	DESIGN SUMMARY REPORT, FOR REVIEW ONLY	2022-03-01	KA	CA
2	FINAL DETAILED DESIGN REPORT, FOR CONSTRUCTION	2022-03-30	KA	CA

WESBROOK MALL
Shop-Drawings Precast Tunnel Section

SCALE	1:20H 1:20V	DATE	2021-11-30
DRAWN BY	KA	DESIGN BY	JC
CHECKED BY	CA	APPROVED BY	CA

DWG. NO. R02
6 OF 18



B1 - Roadway Cross-Section

Section 0+190

0 5
1:50 UNITS - metres (m)

REV NO	REVISIONS	DATE	DRAWN	APPR'D
1	FINAL DETAILED DESIGN REPORT, FOR CONSTRUCTION	2022-03-30	KA	CA

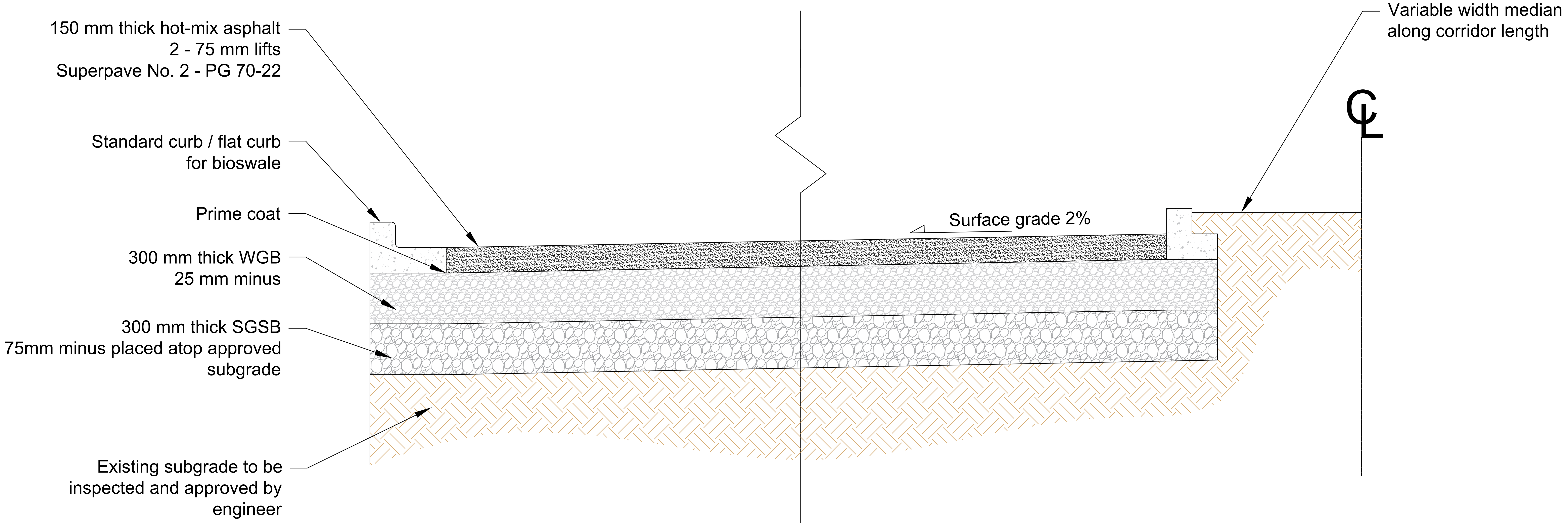
WESBROOK MALL

ROADWAY CROSS-SECTION - 0+190

▸DESIGN

SCALE	1:50H 1:50V	DATE	2022-03-30
DRAWN BY	KA	DESIGN BY	CA
CHECKED BY	CA	APPROVED BY	CA

DWG. NO.
R02
7 OF 18



Notes:

Material selection, placement and testing is to conform to BC MoTI specifications including:

1. Subgrade to be inspected by engineer to determine suability, which may include compaction testing, visual inspection, or proof rolls. Subgrade to be completely free of organic materials.
2. Granular materials to conform to aggregate gradation and fracture counts as applicable.
3. WGB and SGSB to be compacted to standard proctor maximum dry density (SPMDD) value of 100% or modified proctor equivalent of 95%, with maximum compacted lift thickness of 150 mm.
4. Crushed base course to be proof-rolled and not rut when rolled with a fully loaded dump truck with dual tires.
5. Hot mix asphalt to be placed compacted to ≥ 95.6% of MMTD, and smoothened so no roller marks are present.

C1 Roadway Structure

\- Typical Structure

0 — 2
1:15 UNITS - metres (m)

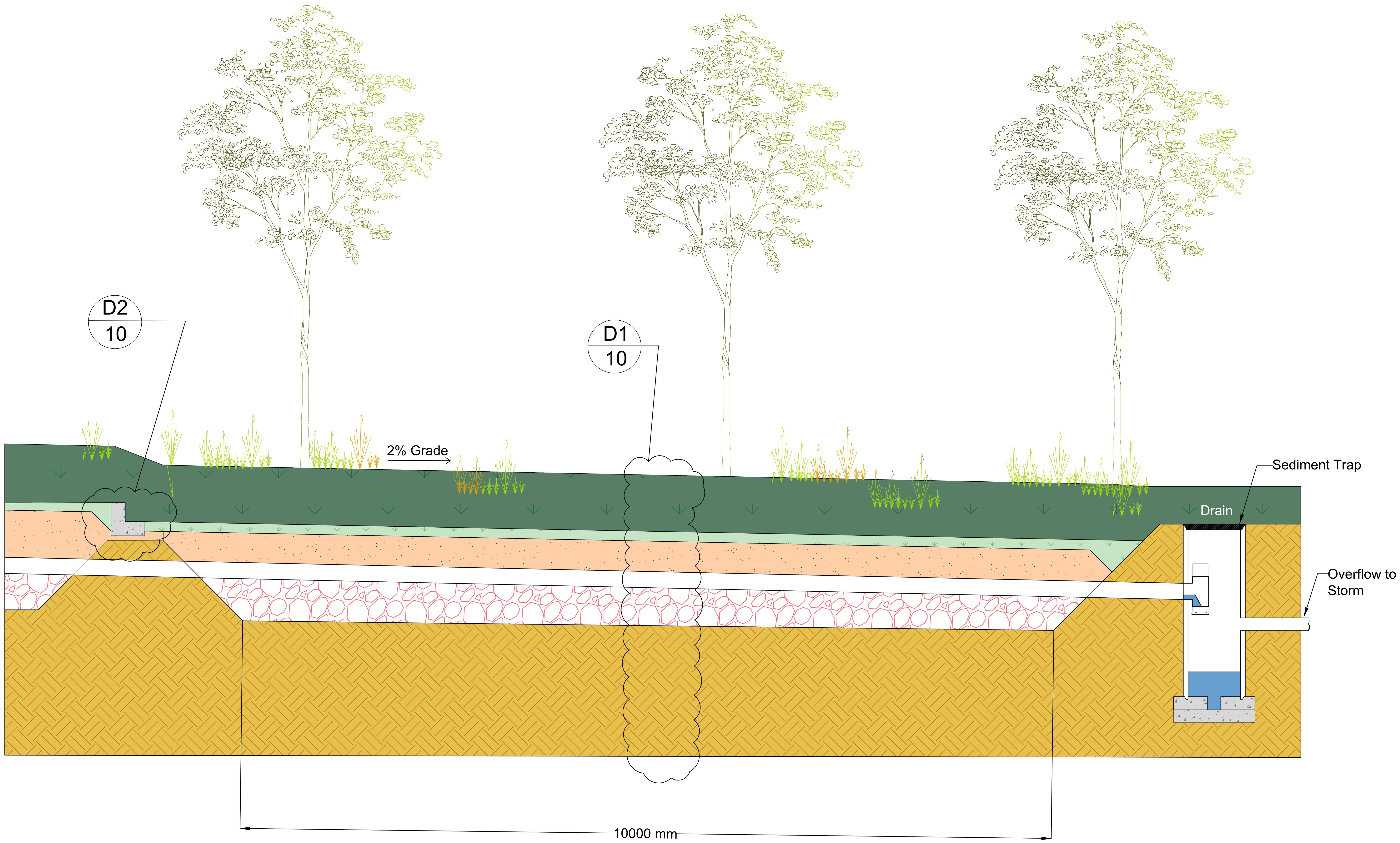
▸ *DESIGN*

REV NO	REVISIONS	DATE	DRAWN	APPR'D
1	FINAL DETAILED DESIGN REPORT, FOR CONSTRUCTION	2022-03-30	KA	CA

WESBROOK MALL
ROADWAY STRUCTURE

				DWG. NO.
SCALE	1:15H 1:15V	DATE	2022-03-30	R02
DRAWN BY	KA	DESIGN BY	KA	8 OF 18
CHECKED BY	CA	APPROVED BY	CA	

Typical 10m Sections



0 2000
1:30 UNITS - millimetres (mm)

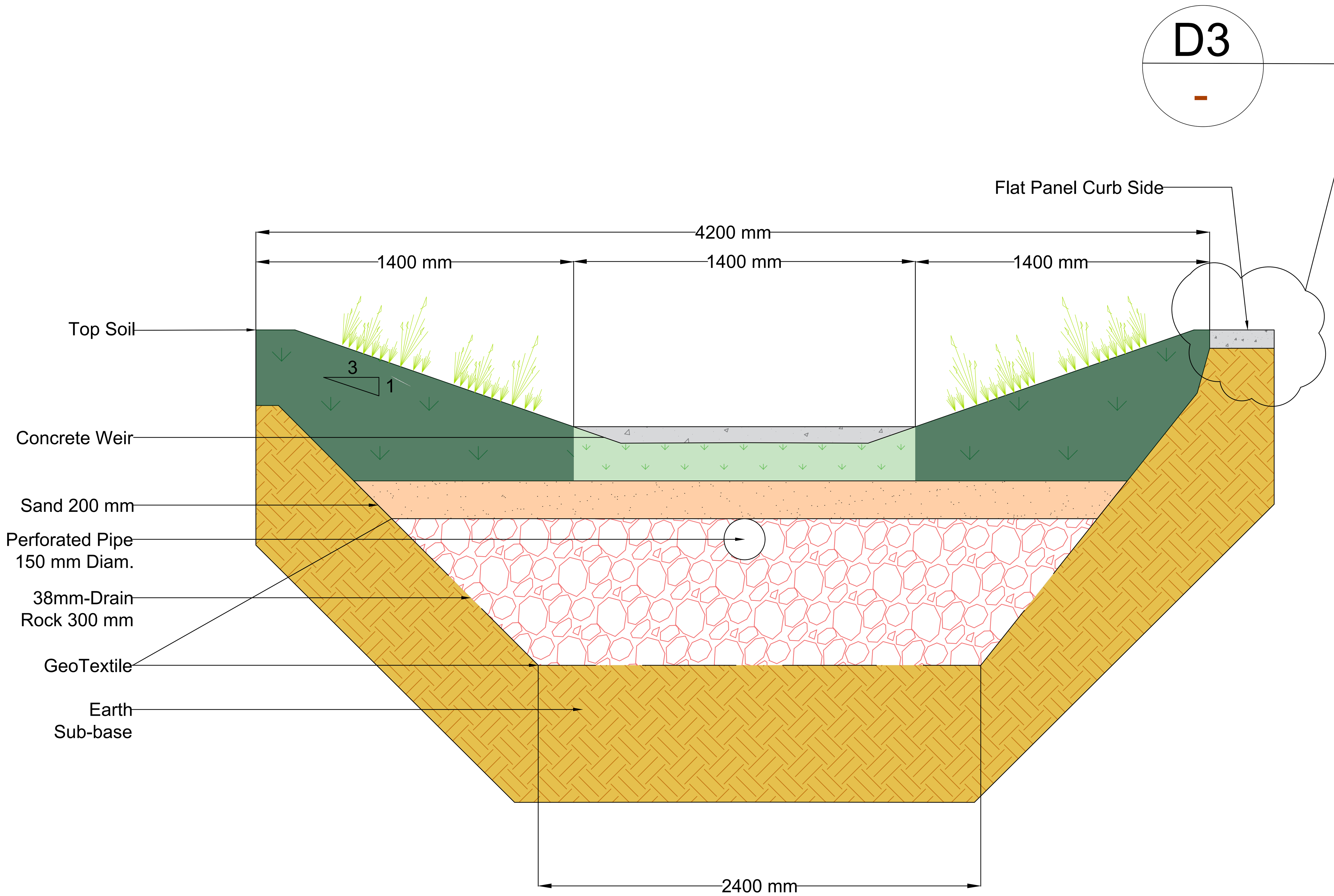
▸*DESIGN*

REV NO	REVISIONS	DATE	DRAWN	APPR'D
1	DESIGN SUMMARY REPORT, FOR REVIEW ONLY	2022-03-01	FM	CA
2	FINAL DETAILED DESIGN REPORT, FOR CONSTRUCTION	2022-03-30	FM	CA

WESBROOK MALL

BIOSWALE PROFILE - 0+710 to 0+720

SCALE	1:30H 1:30V	DATE	2022-03-30	DWG. NO. R02
DRAWN BY	FM	DESIGN BY	FM	9 OF 18
CHECKED BY	CA	APPROVED BY	CA	

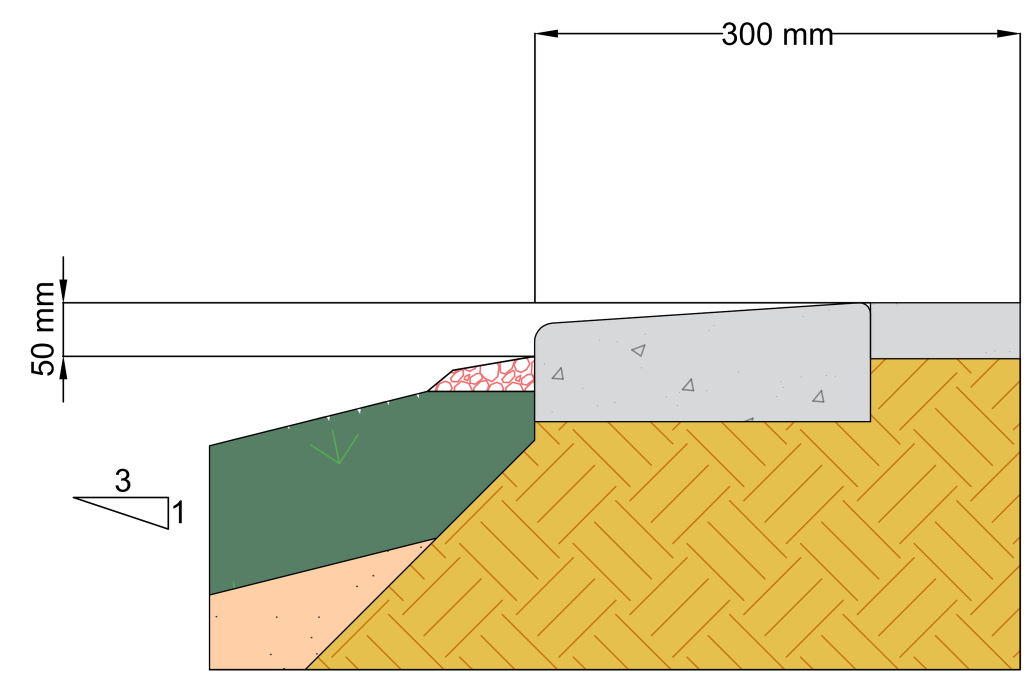


D1 -

Bioswale Segment Cross-Section

SCALE: 1:16 UNITS - millmetres (mm)

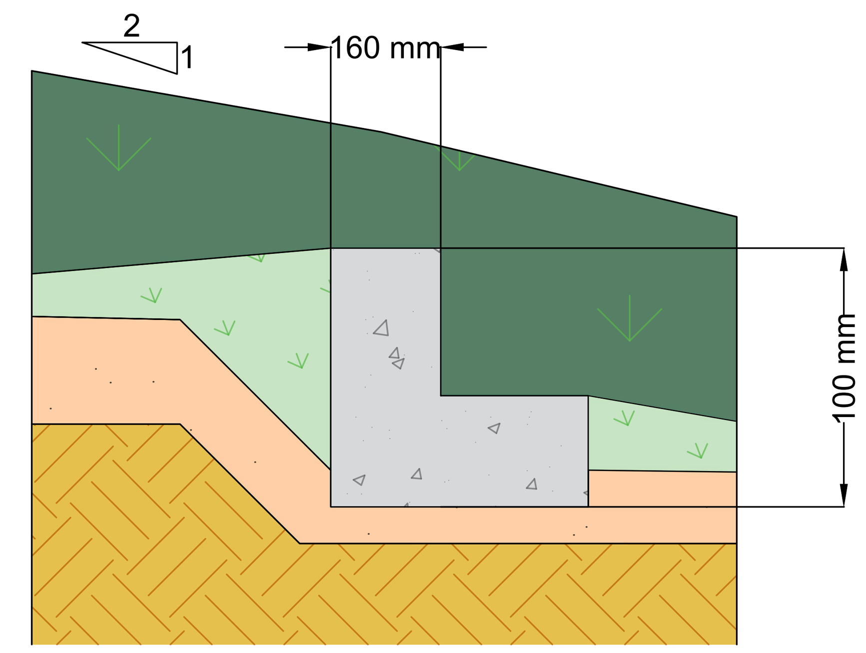
Flat Curb Detail



D2 -

Flat Curb Detail

Keyed Weir Design



D3 -

Weir Cross-Section

SCALE: 1:20 UNITS - millmetres (mm)

▸ *DESIGN*

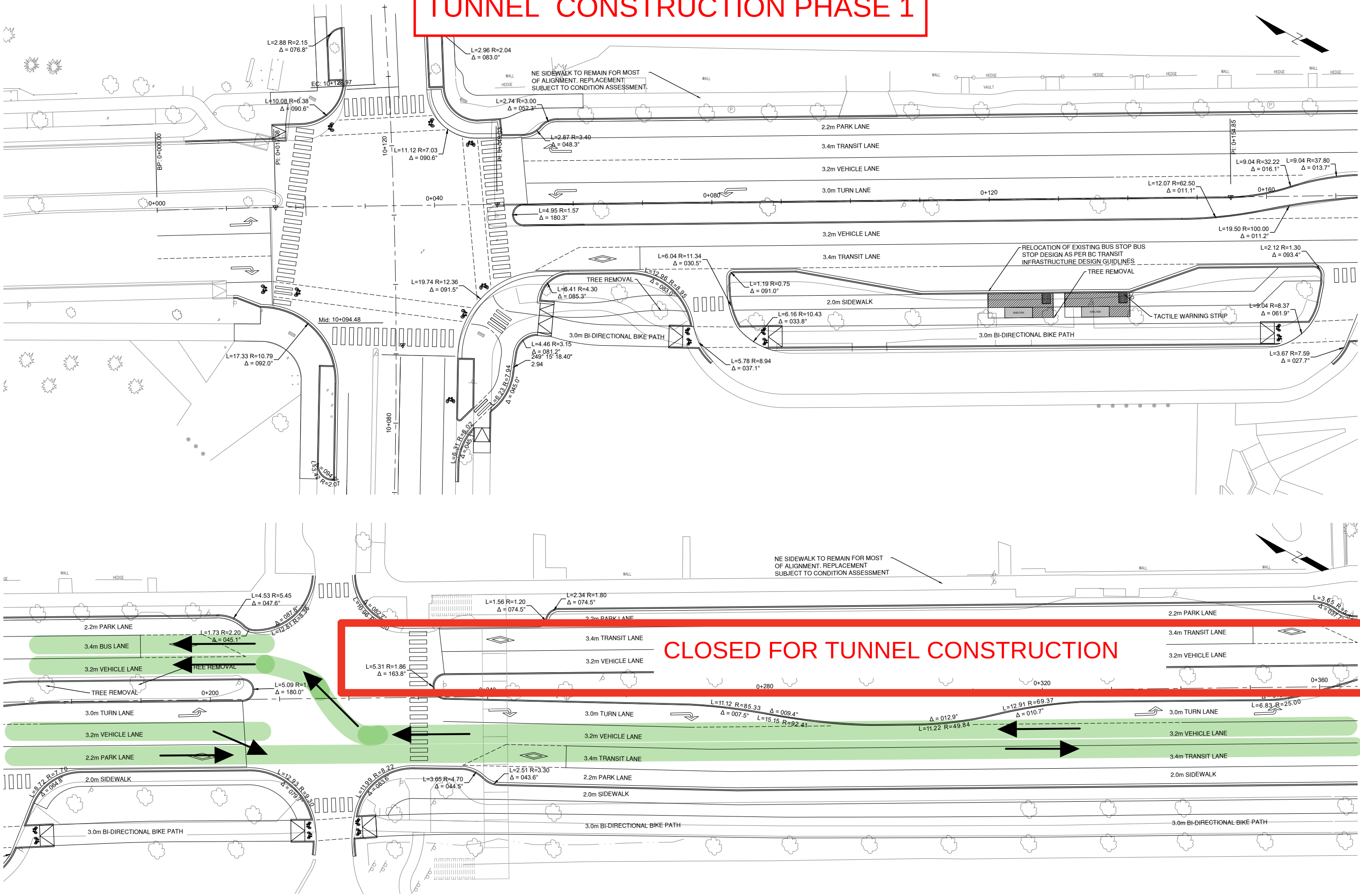
REV NO	REVISIONS	DATE	DRAWN	APPR'D
1	DESIGN SUMMARY REPORT, FOR REVIEW ONLY	2022-03-01	FM	CA
2	FINAL DETAILED DESIGN REPORT, FOR CONSTRUCTION	2022-03-30	FM	CA

WESBROOK MALL

BIOSWALE CROSS-SECTIONS and DETAILS

SCALE	AS SHOWN	DATE	2022-03-30	DWG. NO. R02
DRAWN BY	FM	DESIGN BY	FM	10 OF 18
CHECKED BY	CA	APPROVED BY	CA	

TUNNEL CONSTRUCTION PHASE 1

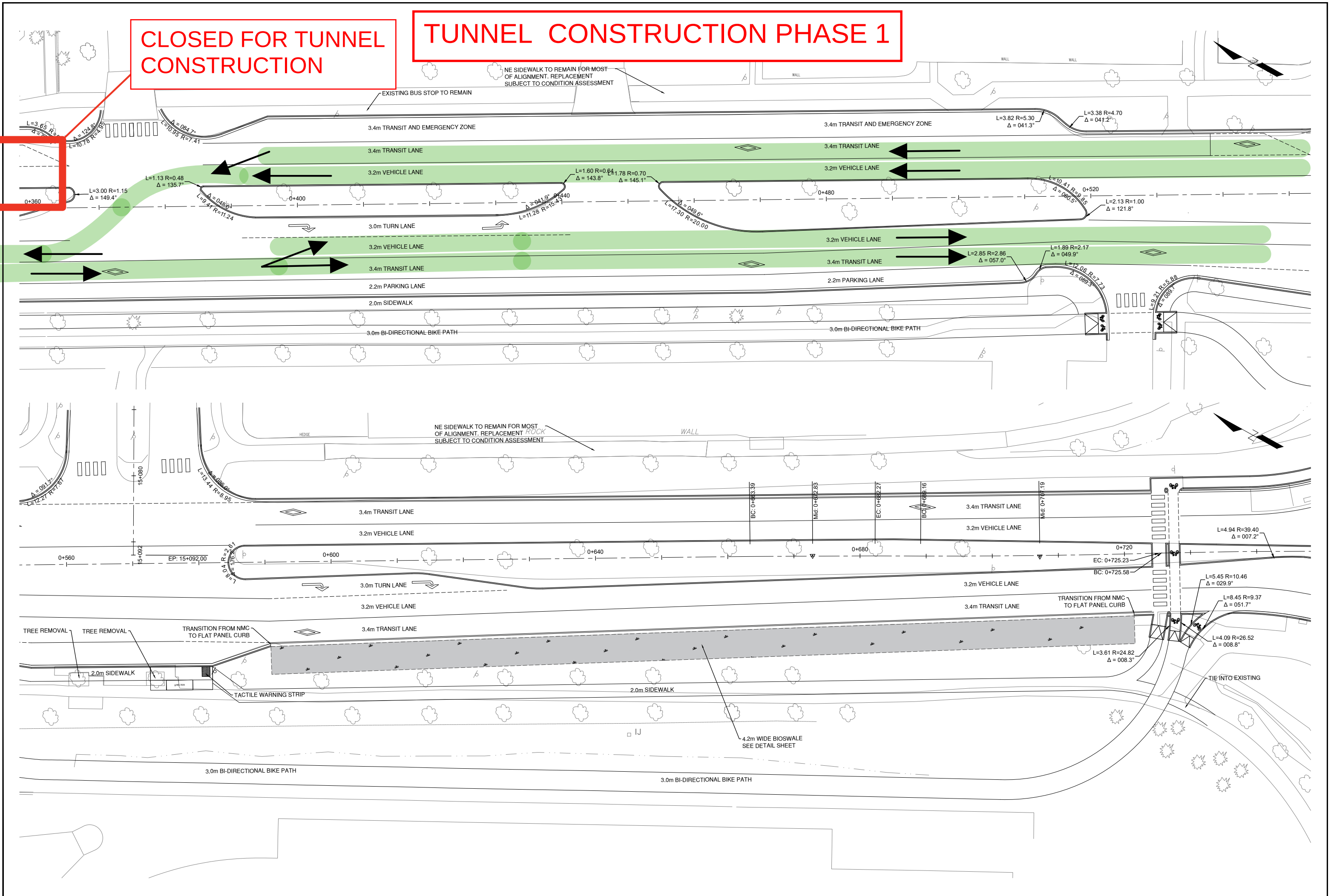


REV NO	REVISIONS	DATE	DRAWN	APPR'D
1	PRELIMINARY DESIGN REPORT. FOR REVIEW ONLY	2021-11-30	CA	CA
2	ISSUE FOR TENDER	3/30/2022	CA	CA

WESBROOK MALL
0+000 - 0+360

SCALE	1:250H 1:250V	DATE	2022-03-30
DRAWN BY	CA	DESIGN BY	CA
CHECKED BY	CA	APPROVED BY	CA

DWG. NO. R02 11of18



REV NO	REVISIONS	DATE	DRAWN	APPR'D
1	PRELIMINARY DESIGN REPORT. FOR REVIEW ONLY	2021-11-30	CA	CA
2	ISSUE FOR TENDER	3/30/2022	CA	CA

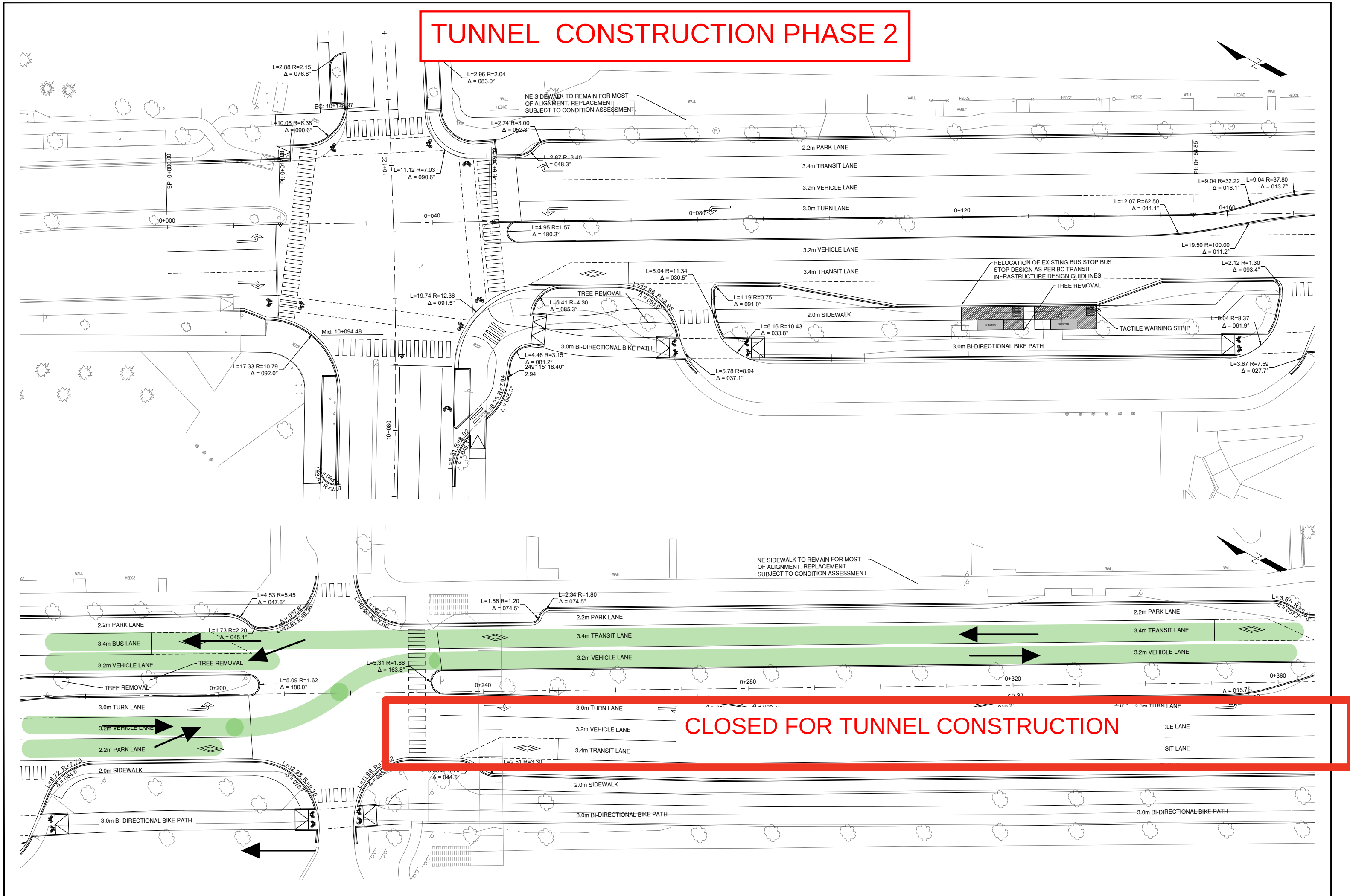
WESBROOK MALL

0+360 - 0+770

SCALE	1:250H 1:250V	DATE	2022-03-30
DRAWN BY	CA	DESIGN BY	CA
CHECKED BY	CA	APPROVED BY	CA

DWG. NO. R02

12of18



REV NO	REVISIONS	DATE	DRAWN	APPR'D
1	PRELIMINARY DESIGN REPORT. FOR REVIEW ONLY	2021-11-30	CA	CA
2	ISSUE FOR TENDER	3/30/2022	CA	CA

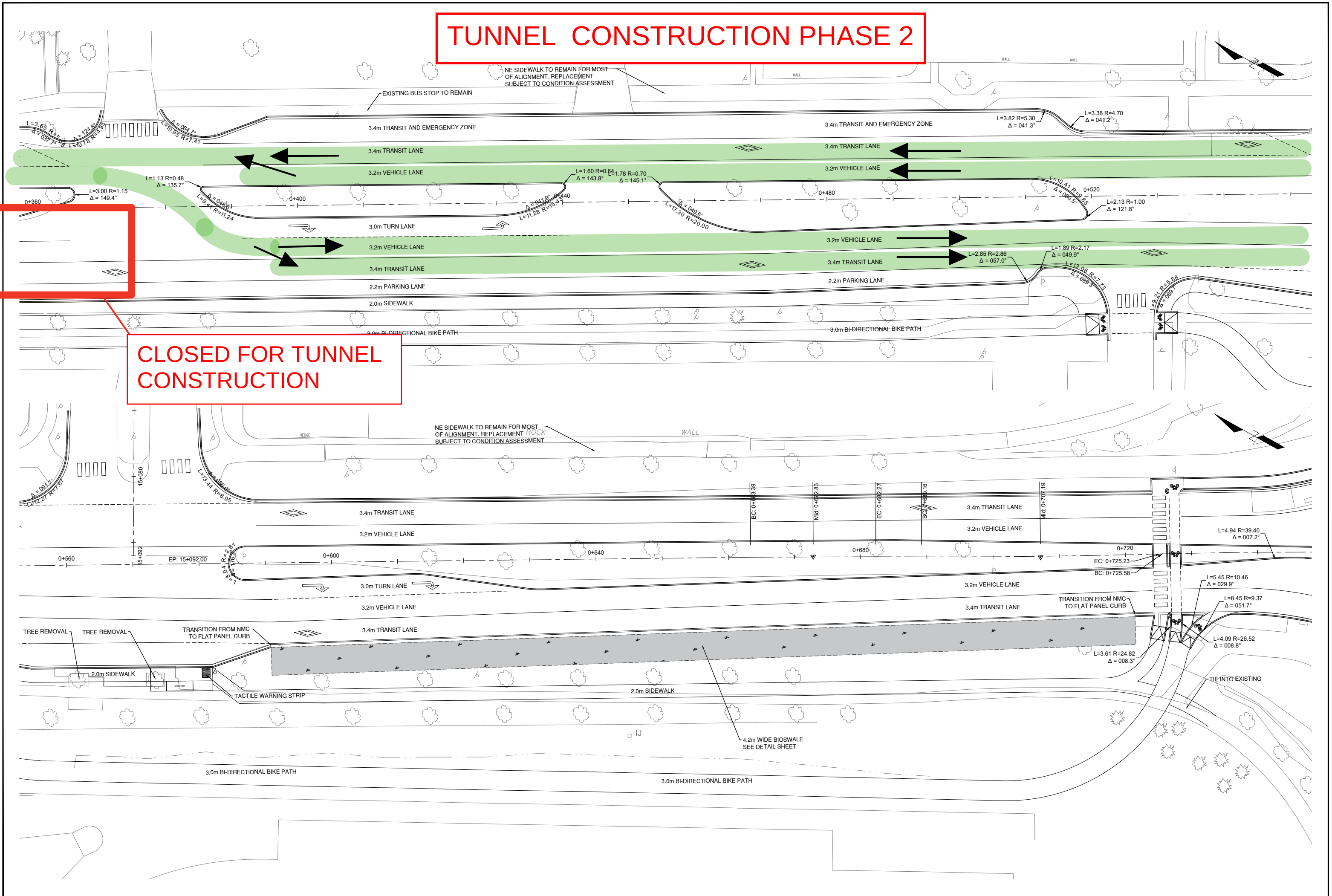
WESBROOK MALL

0+000 - 0+360

SCALE	1:250H 1:250V	DATE	2022-03-30
DRAWN BY	CA	DESIGN BY	CA
CHECKED BY	CA	APPROVED BY	CA

DWG. NO. R02

13of18



REV NO	REVISIONS	DATE	DRAWN	APPR'D
1	PRELIMINARY DESIGN REPORT. FOR REVIEW ONLY	2021-11-30	CA	CA
2	ISSUE FOR TENDER	3/30/2022	CA	CA

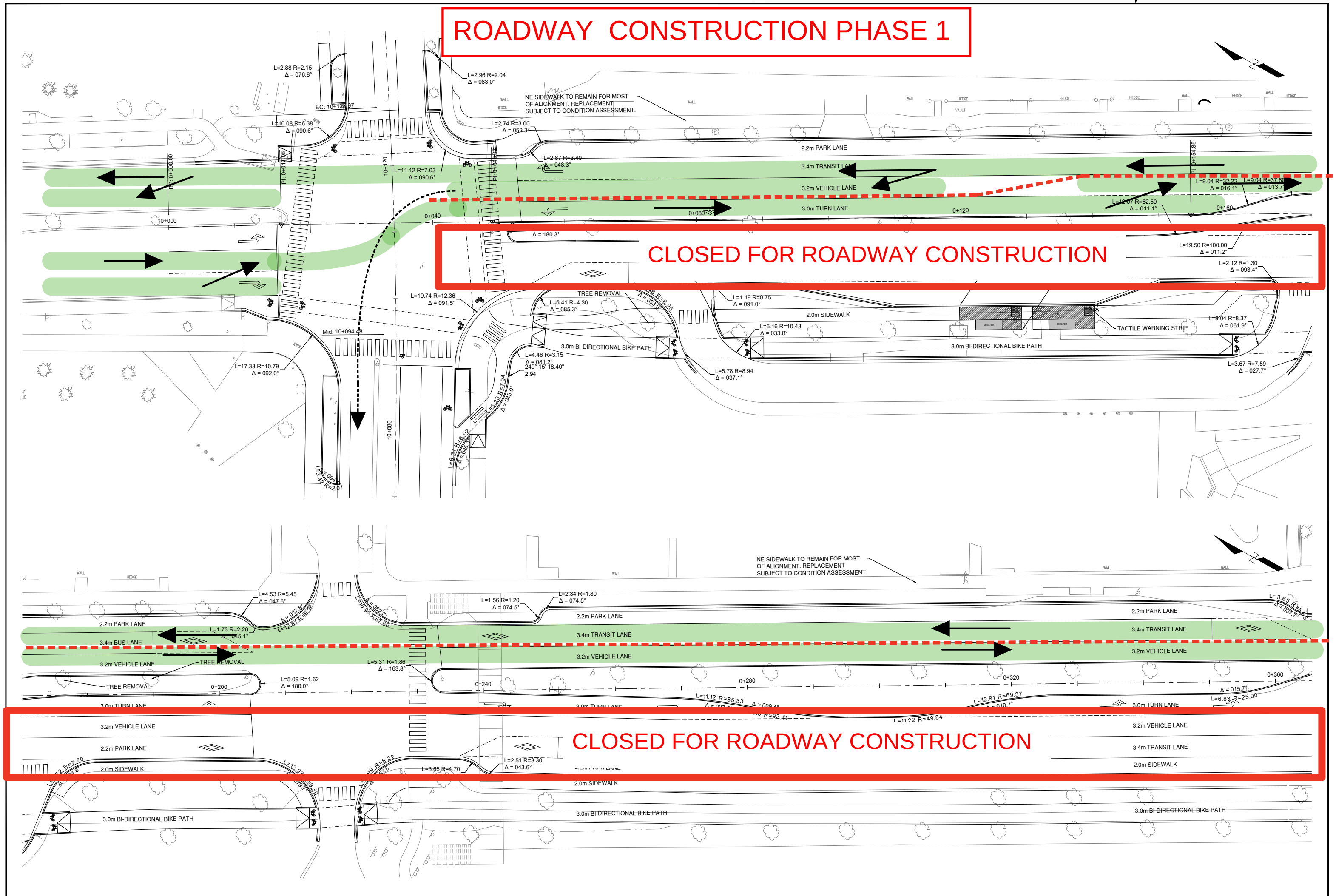
WESBROOK MALL

0+360 - 0+770

SCALE	1:250H 1:250V	DATE	2022-03-30
DRAWN BY	CA	DESIGN BY	CA
CHECKED BY	CA	APPROVED BY	CA

DWG. NO. R02

14of18



REV NO	REVISIONS	DATE	DRAWN	APPR'D
1	PRELIMINARY DESIGN REPORT. FOR REVIEW ONLY	2021-11-30	CA	CA
2	ISSUE FOR TENDER	3/30/2022	CA	CA

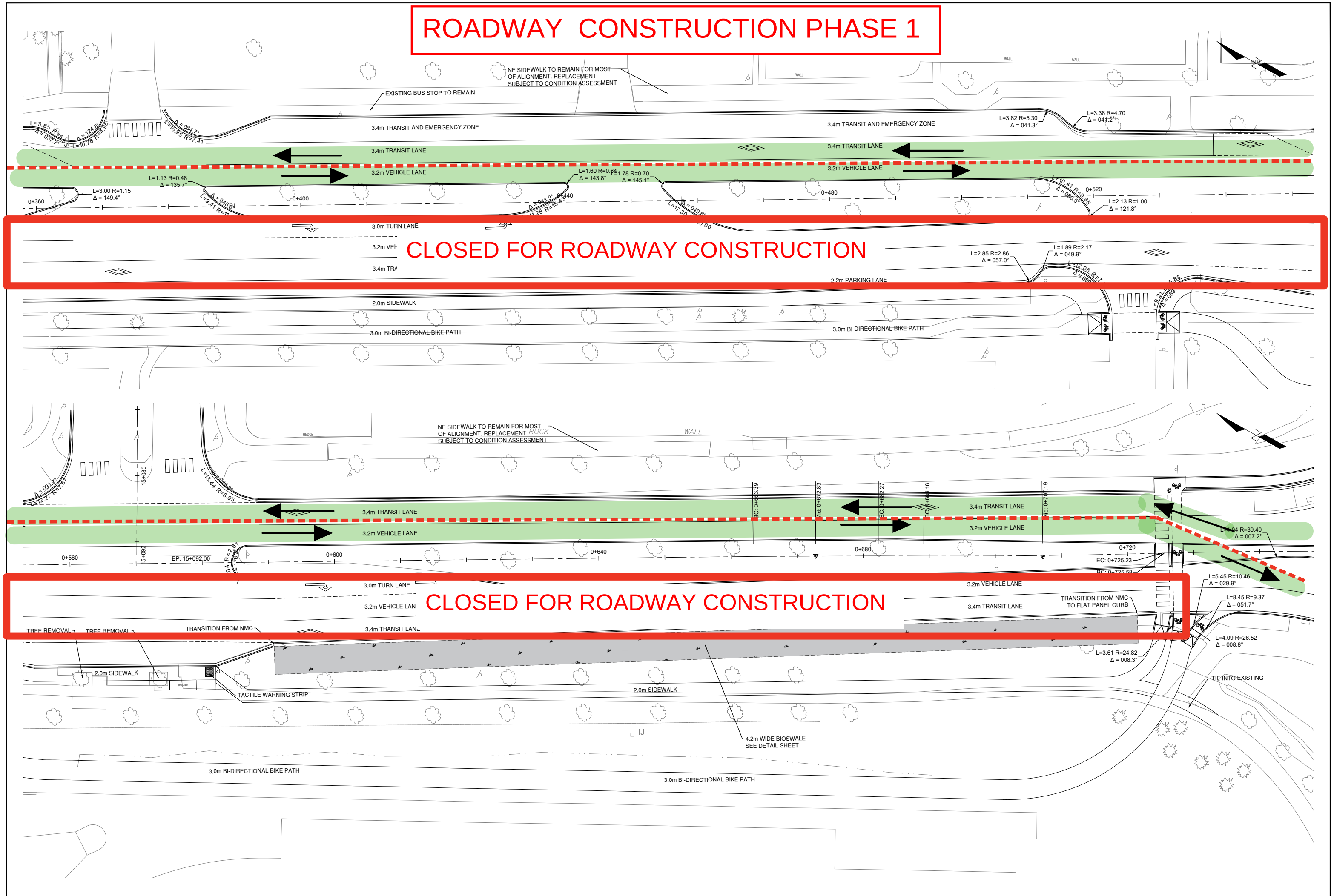
WESBROOK MALL

0+000 - 0+360

SCALE	1:250H 1:250V	DATE	2022-03-30
DRAWN BY	CA	DESIGN BY	CA
CHECKED BY	CA	APPROVED BY	CA

DWG. NO. R02

15of18



REV NO	REVISIONS	DATE	DRAWN	APPR'D
1	PRELIMINARY DESIGN REPORT. FOR REVIEW ONLY	2021-11-30	CA	CA
2	ISSUE FOR TENDER	3/30/2022	CA	CA

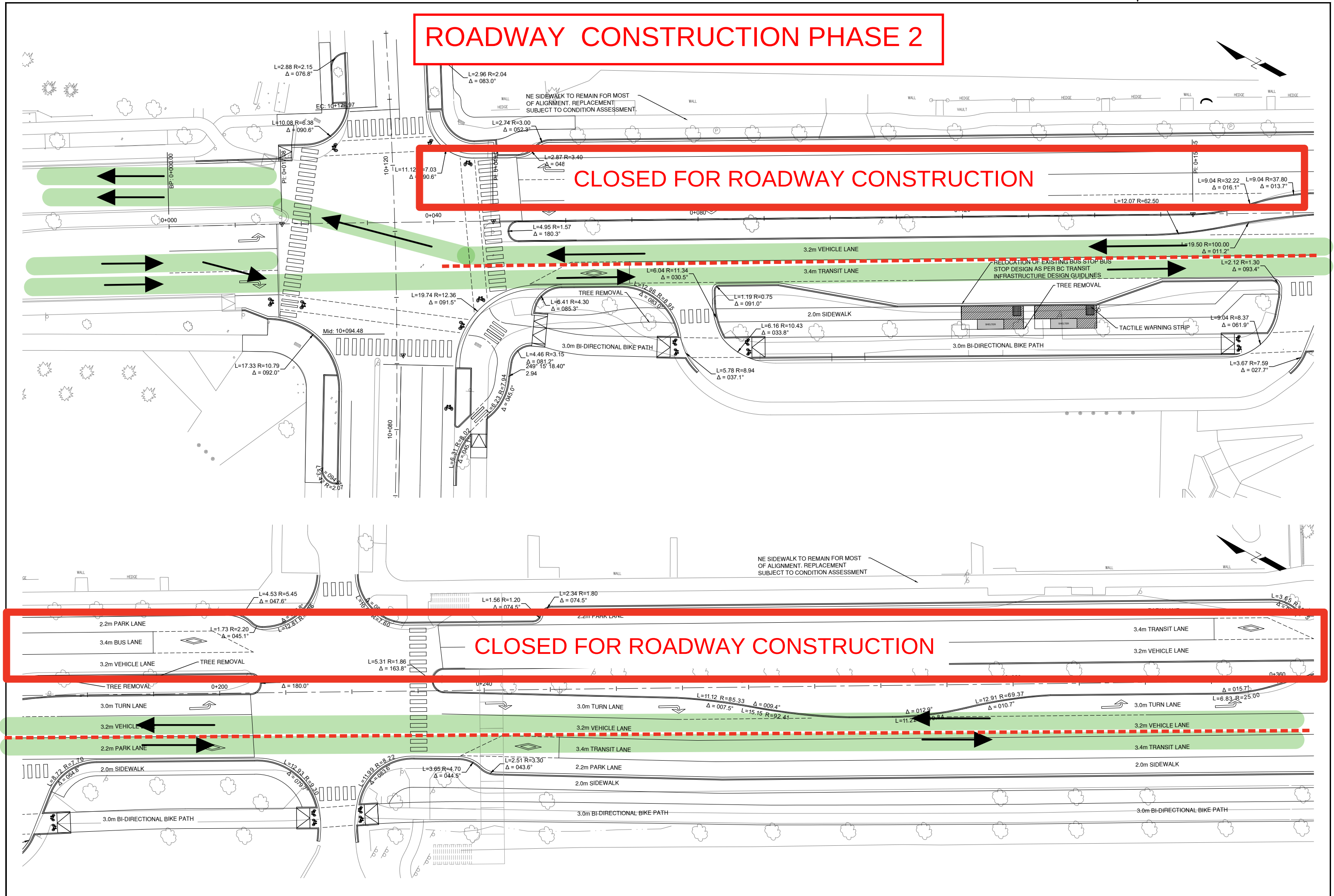
WESBROOK MALL

0+360 - 0+770

SCALE	1:250H 1:250V	DATE	2022-03-30
DRAWN BY	CA	DESIGN BY	CA
CHECKED BY	CA	APPROVED BY	CA

DWG. NO. R02

16of18

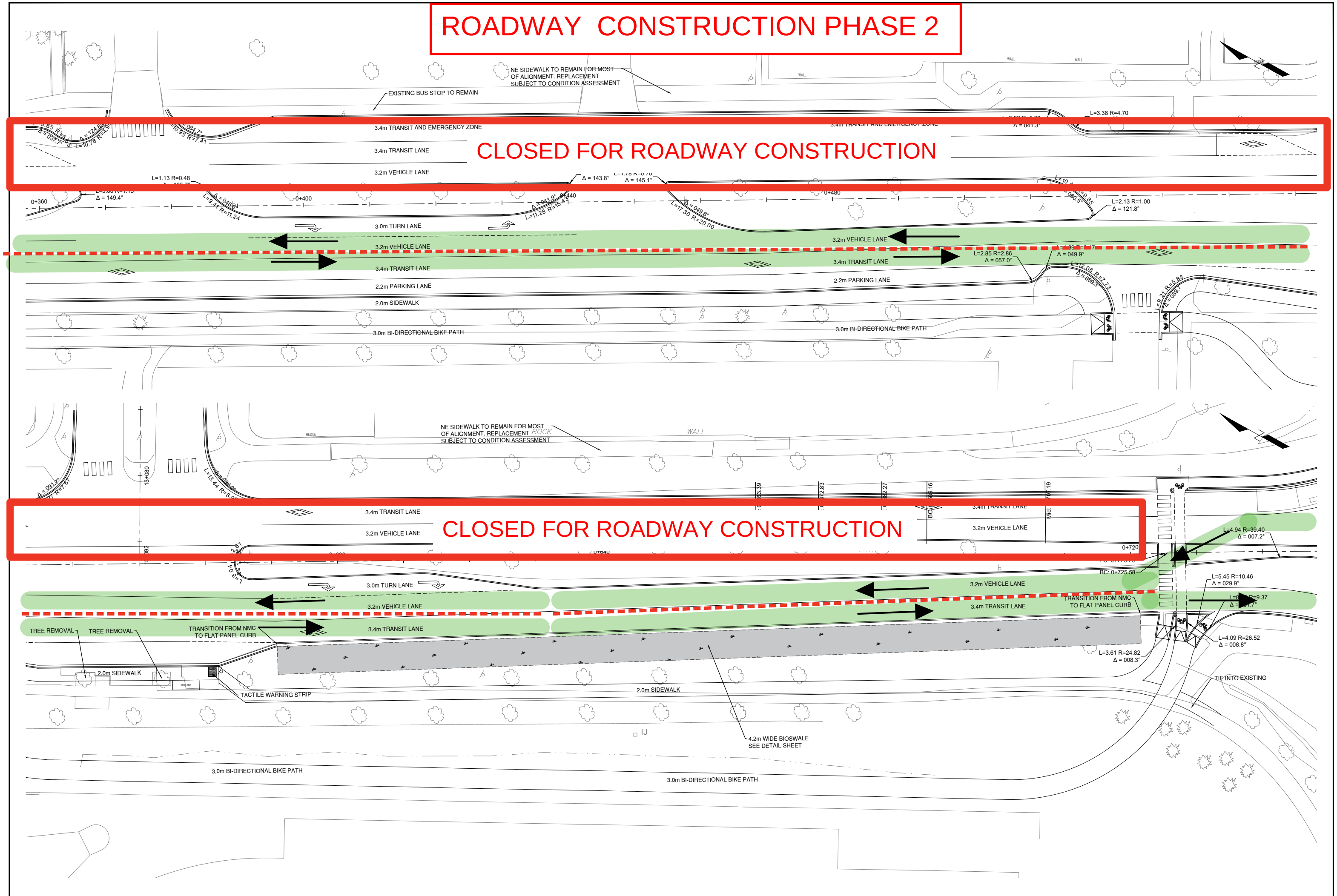


REV NO	REVISIONS	DATE	DRAWN	APPR'D
1	PRELIMINARY DESIGN REPORT. FOR REVIEW ONLY	2021-11-30	CA	CA
2	ISSUE FOR TENDER	3/30/2022	CA	CA

WESBROOK MALL
0+000 - 0+360

SCALE	1:250H 1:250V	DATE	2022-03-30
DRAWN BY	CA	DESIGN BY	CA
CHECKED BY	CA	APPROVED BY	CA

DWG. NO. R02
17of18



REV NO	REVISIONS	DATE	DRAWN	APPR'D
1	PRELIMINARY DESIGN REPORT. FOR REVIEW ONLY	2021-11-30	CA	CA
2	ISSUE FOR TENDER	3/30/2022	CA	CA

WESBROOK MALL

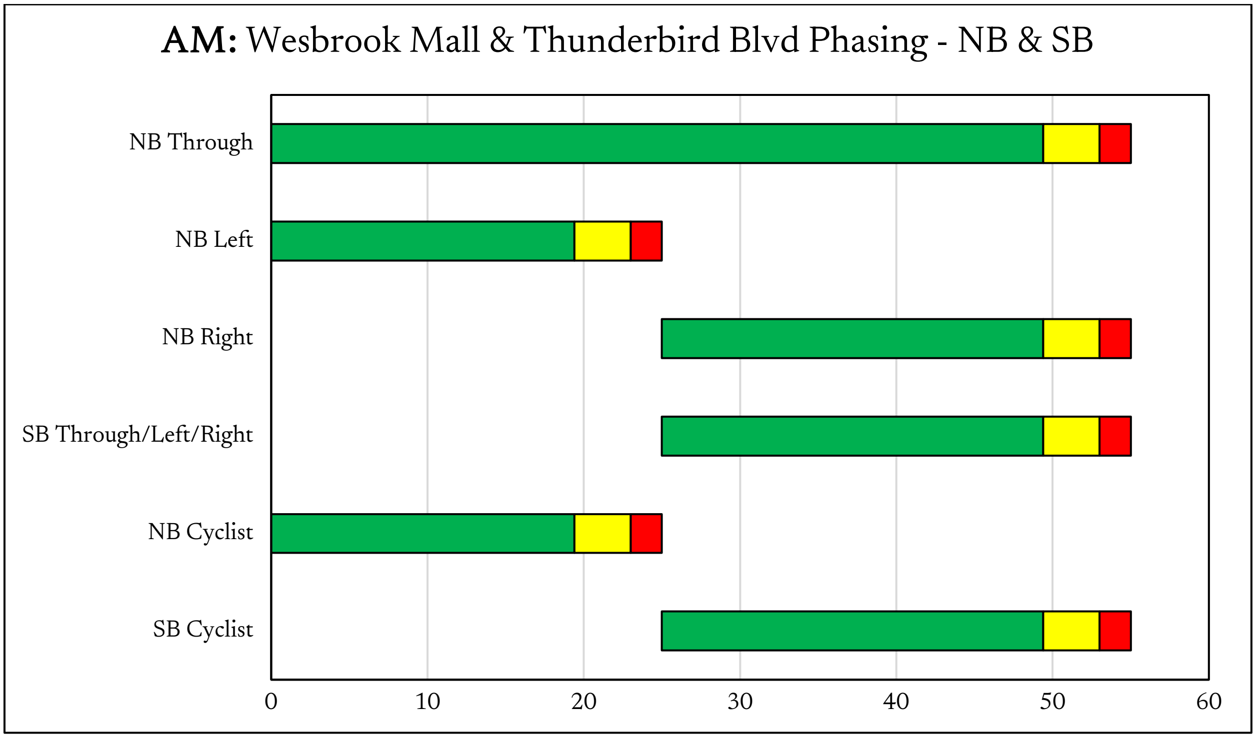
0+360 - 0+770

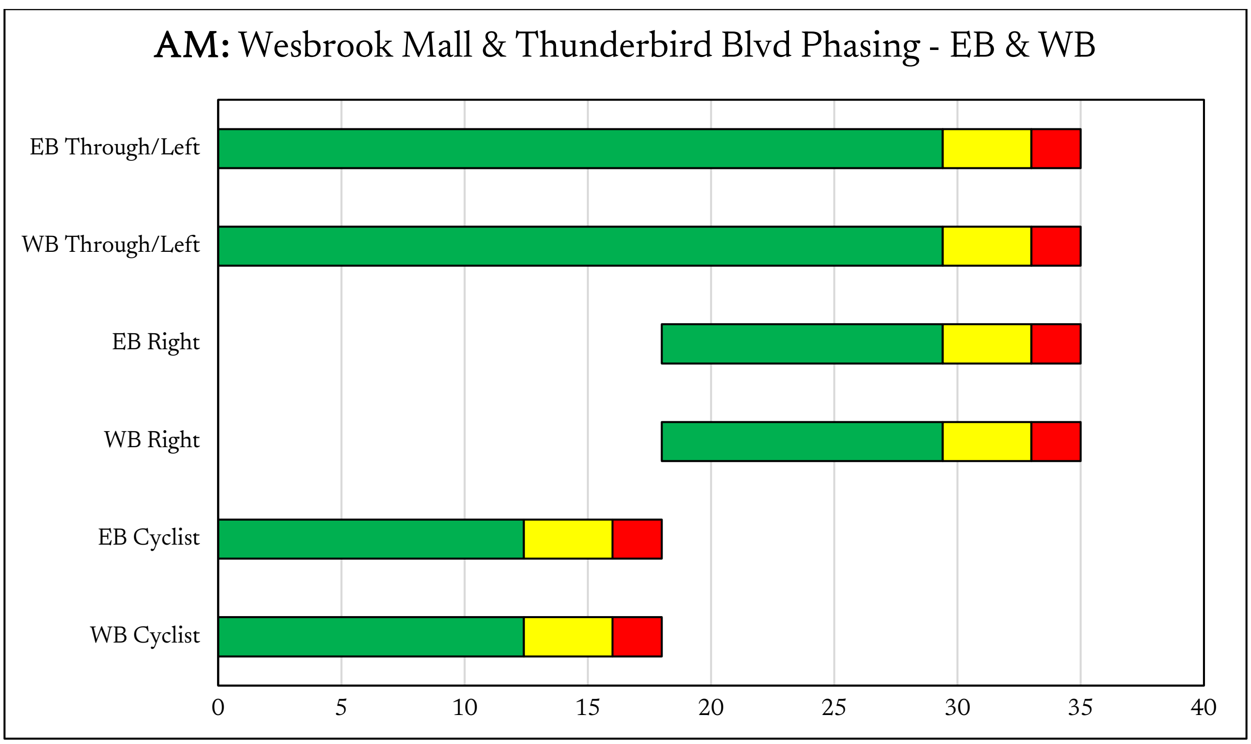
SCALE	1:250H 1:250V	DATE	2022-03-30
DRAWN BY	CA	DESIGN BY	CA
CHECKED BY	CA	APPROVED BY	CA

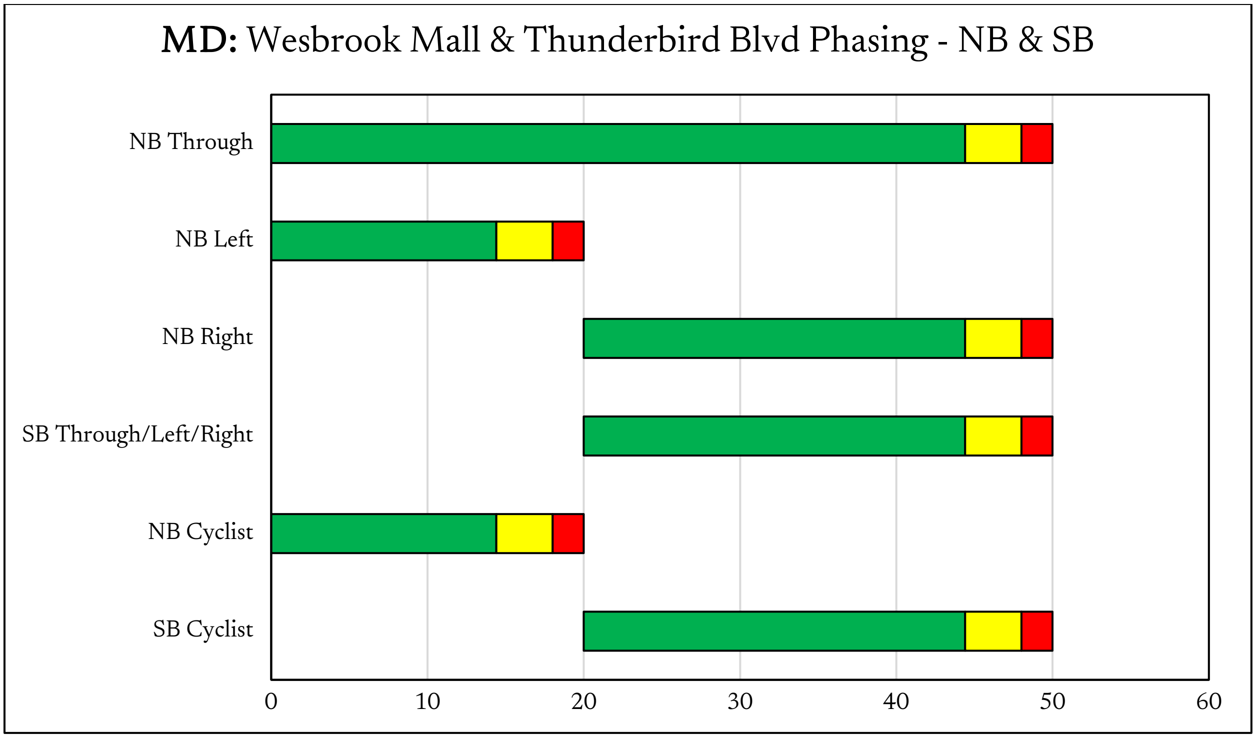
DWG. NO. R02

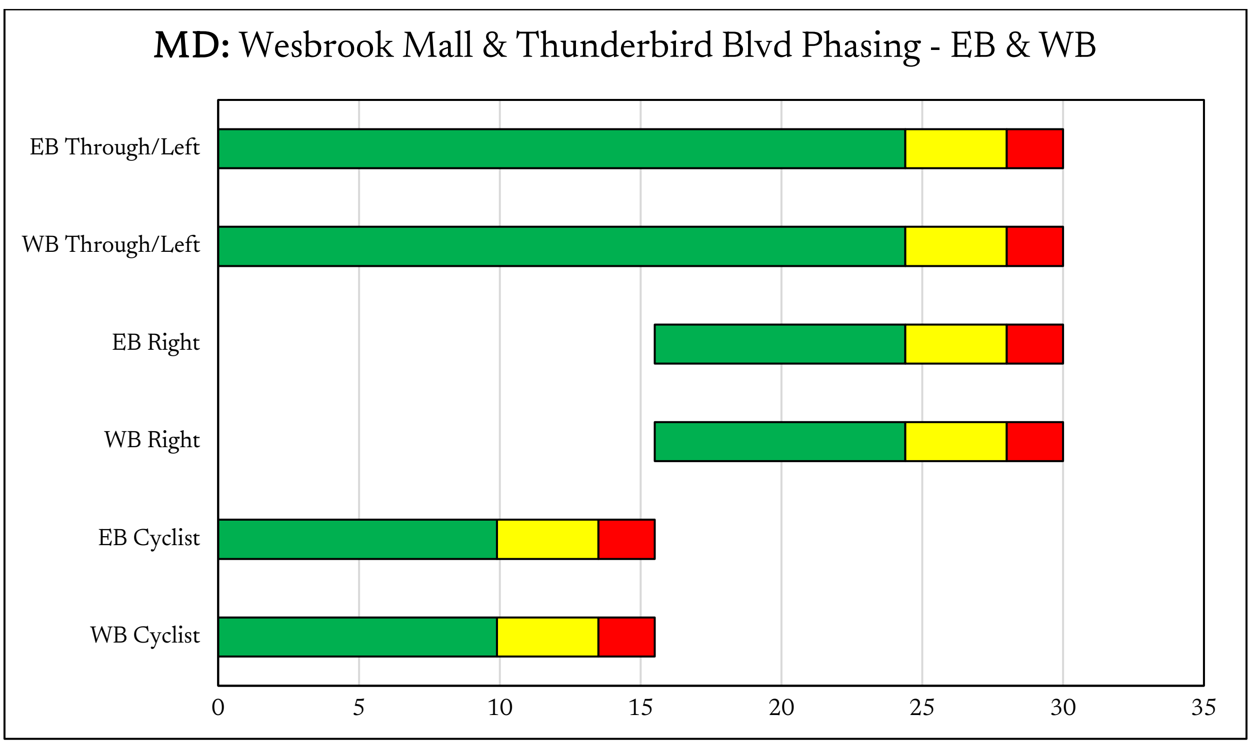
18of18

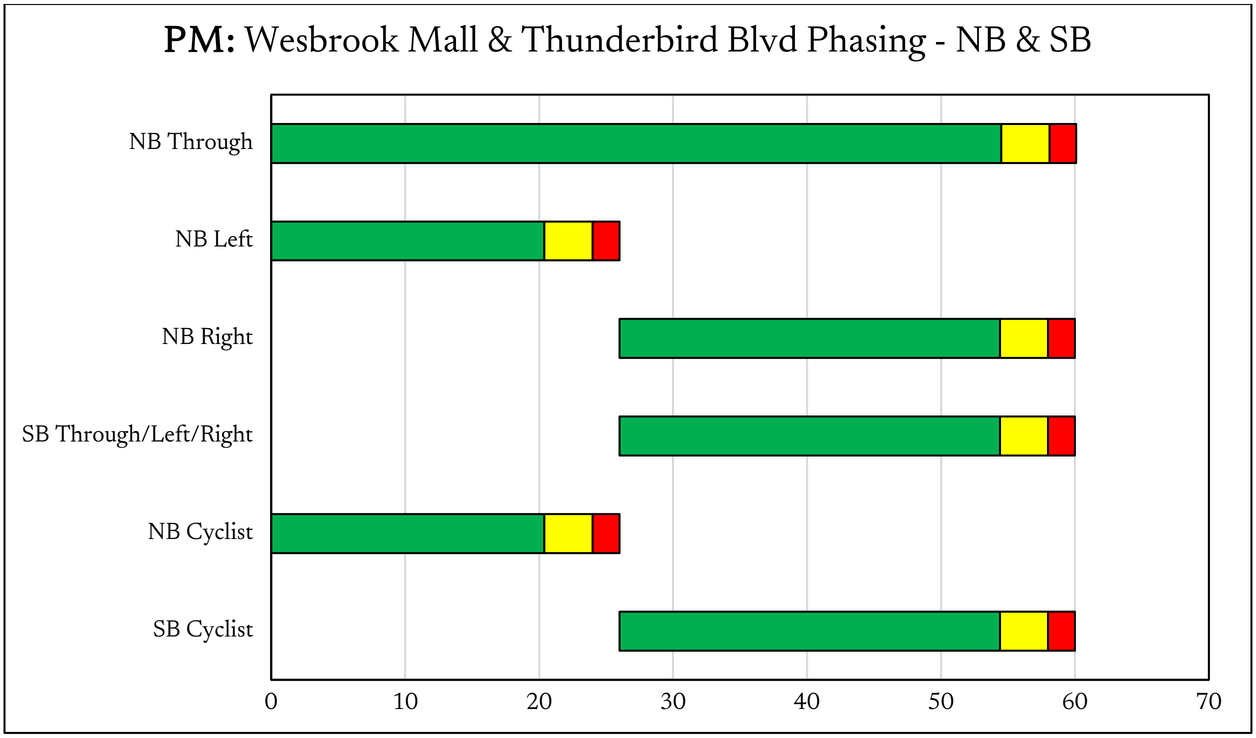
Appendix B – Signal Phasing Diagrams

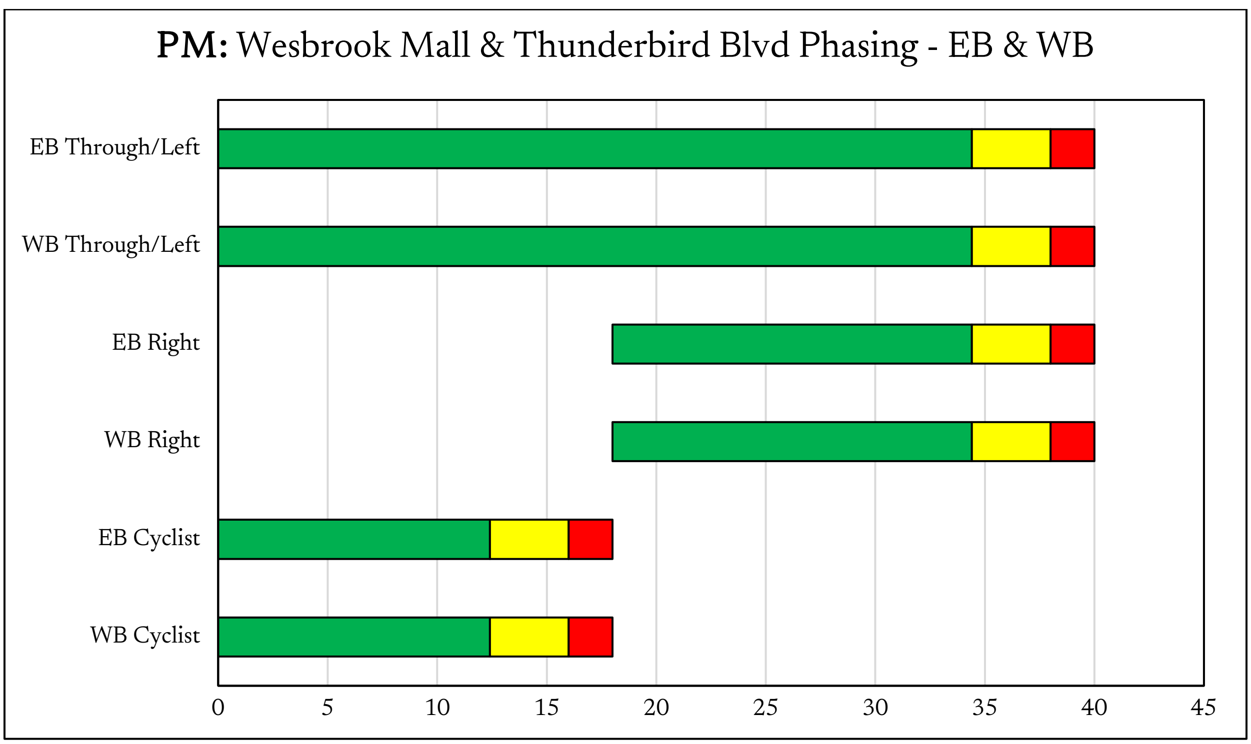

AM: Wesbrook Mall & Thunderbird Blvd Phasing - NB & SB
NB Through
NB Left
NB Right
SB Through/Left/Right
NB Cyclist
SB Cyclist
0
10
20
30
40
50
60


AM: Wesbrook Mall & Thunderbird Blvd Phasing - EB & WB
EB Through/Left
WB Through/Left
EB Right
WB Right
EB Cyclist
WB Cyclist
0
5
10
15
20
25
30
35
40


MD: Wesbrook Mall & Thunderbird Blvd Phasing - NB & SB
NB Through
NB Left
NB Right
SB Through/Left/Right
NB Cyclist
SB Cyclist
0
10
20
30
40
50
60


MD: Wesbrook Mall & Thunderbird Blvd Phasing - EB & WB
EB Through/Left
WB Through/Left
EB Right
WB Right
EB Cyclist
WB Cyclist
0
5
10
15
20
25
30
35


PM: Wesbrook Mall & Thunderbird Blvd Phasing - NB & SB
NB Through
NB Left
NB Right
SB Through/Left/Right
NB Cyclist
SB Cyclist
0
10
20
30
40
50
60
70


PM: Wesbrook Mall & Thunderbird Blvd Phasing - EB & WB
EB Through/Left
WB Through/Left
EB Right
WB Right
EB Cyclist
WB Cyclist
0
5
10
15
20
25
30
35
40
45

Appendix C – Pavement Structure Calculations

1.0 Traffic Loading:

AADT =	6957.0	(Average annual daily traffic)
HVP =	0.1	(Heavy vehicle percentage)
HVDF =	1.0	(Heavy vehicle factor - % of heavy vehicles in design lane)
NALV =	4.0	(Number of equivalent axle loads per heavy vehicle)
NALV.2 =	0.0004	(Number of equivalent axle loads per light vehicle)
TDY =	365	(Traffic days per year)

$$ESAL_B = AADT * HVP * HVDF * NALV * TDY$$

ESAL (base year) =	843981	(Equivalent single axle loads per lane per year)

DL =	30	(Design life)
GF =	0.01	(Growth factor)

$$ESAL_G = ESAL_B * (1 + GF)^{DL}$$

Growth ESAL = 1137558

$$ESAL_D = \frac{(ESAL_B + ESAL_G)}{2} * \text{DL}$$

Design ESAL = 29723087

2.0 Pavement Structure:

$$ESAL_D > 20{,}000{,}000$$

Pavement Structure Type:	A	
Typical Asphalt Pavement Thickness:	>=150 mm	(Superpave No. 2 - PG 70-22)

Subgrade Type:	Glacial Till	
Crushed Base Course (CBC) Thickness:	300 mm	(25 mm WGB)
Select Granular Sub-Base (SGSB):	300 mm	(75 mm-minus)

USE:		
Asphalt Thickness =	**150 mm**	**(Superpave No. 2 - PG 70-22)**
CBC Thickness =	**300 mm**	**(25 mm WGB)**
SGSB Thickness =	**300 mm**	**(75 mm-minus)**

Appendix D – Pedestrian Underpass Calculations

1.0 Loading Information:

1.1 Soil Properties

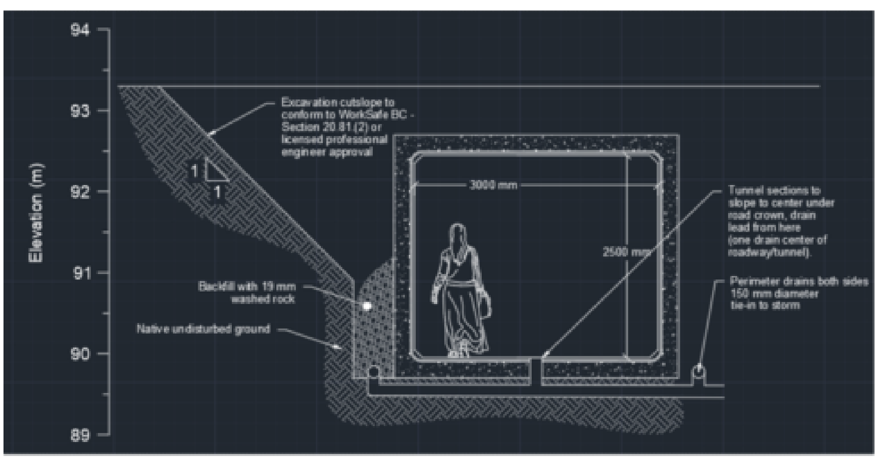
Soil Type =	Glacial Till	
γ_{soil}=	20.4	kN/m^3
ϕ_{soil}=	40	°
Depth G.W.T. =	90	m

$K_a = tan^2\left(45 - \frac{\phi}{2}\right)$= 0.217

1.2 Vehicle Loading

Single Axel:		
Max Gross Weight/Axel =	9100	kg
	89.3	kN
Tandem Axel:		
Max Gross Weight/2-Axel =	17000	kg
	166.8	kN

Note: Loading, Shear, and Moment diagrams produced in RISA analysis software.



2.0 Top Span Design:

2.1 Loading:

Self Weight:

Width = 1 m

Thickness = 0.25 m

γ_{conc}= 23.5 kN/m^3

$w_{self\ weight}$= 5.875 kN/m

Overburden Loading:

Width = 1 m

Depth = 0.6 m

γ_{soil}= 20.4 kN/m^3

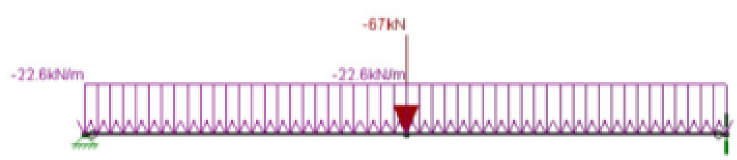
w_{soil}= 12.2 kN/m

Vehicle Loading :

$V1_{vehical\ Load}$= 44.64 kN

$V2_{vehical\ Load}$= 41.69 kN

Load Case 1:



L = 2.5 m

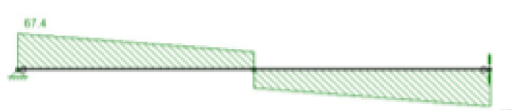
$P_f = 1.5(V1) =$ 67.0 kN

$w_f = 1.25(w_{soil} + w_{self}) =$ 22.6 kN/m

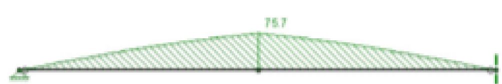
$V_{max} = \frac{P_f}{2} + \frac{w_f * L}{2} =$ 61.8 kN

$M_{max} = \frac{P_f * L}{4} + \frac{w_f * L^2}{8} =$ 75.0 kN*m

V:

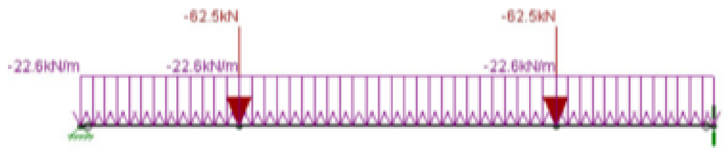


M:



2.1 Cont.:

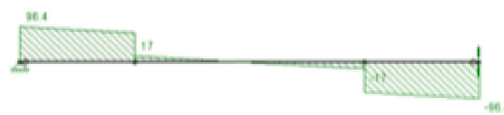
Load Case 2:



L = 3 m

x = 0.75 m

V:

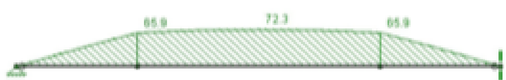


$P_f = 1.5(V1) =$ 62.5 kN

$w_f = 1.25(w_{soil} + w_{self}) =$ 22.6 kN/m

$V_{max} = P_f + \frac{w_f * L}{2} =$ 96.5 kN

M:



$M_{max} = P_f * x + \frac{w_f * L^2}{8} =$ 72.4 kN*m

Lateral Earth Pressure:

$\gamma_{soil} =$ 20.4 kN/m^3

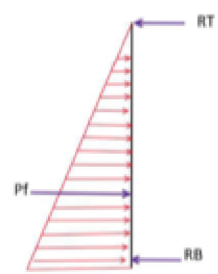
$K_a =$ 0.217

H = 2.5 m

$P = \frac{1}{2} * \gamma * H^2 * K_a =$ 13.9 kN

$P_f = 1.25 * P =$ 17.3 kN

$R_T = \frac{1}{3} * P_f =$ 5.8 kN



Note: Axial Load on top member is negligible, neglect interaction analysis.

2.2 Resistance:

Moment Resistance:

d =	202.5	mm
dv=	182.25	
b=	1000	mm
α_1=	0.78	
f'_c=	50	Mpa
fy'=	400	Mpa
A_s=	1200	mm^2
E_s=	200000	Mpa
ϕ_s=	0.85	
ϕ_c=	0.65	
β_1=	0.845	

NOTES:
cover = 30mm
BLL: Try 20M at 250mm o/c

$$M_r = \emptyset_s f_y A_s\left(d - \frac{\emptyset_s f_y A_s}{2\alpha_1 \emptyset_c f'_c b}\right) = 79.3 \text{ kNm}$$ O.K.

$$V_r = \emptyset_c \beta \sqrt{f'_c} b_w d_v = 707.8 \text{ kNm}$$ O.K.

$$d_l = 26 d_b = 520 \text{ mm}$$

$$Rienforcement_{min} = 0.002 A_g, S \leq 500mm =$$ BLL

Note: d_l used to determine hook length into wall.

USE:
BLL = 20 M at 250mm o/c
BUL= 15M at 400 o/c
Hook BLL down into walls 520mm E/W

<u>3.0 Side Spans:</u>

3.1 Loading:

Self Weight:

Width =	1	m
Thickness =	0.25	m
γ_{conc}=	23.5	kN/m^3
$w_{self\ weight}$=	5.875	kN/m

Top Slab Reaction:

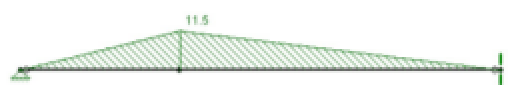
Pf=	96.5	kN

Backfill Pressure:

γ_{soil}=	20.4	kN/m^3
K_a=	0.217	
H =	2.5	m
$P = \frac{1}{2} * \gamma * H^2 * K_a =$	13.9	kN

L =	2.5	m
x =	1.67	m
$P_f = 1.5(V1) =$	20.8	kN

$V_{max} = \frac{Px}{L} =$	13.9	kN
$M_{max} = \frac{Pab}{L} =$	11.5	kN*m



3.2 Resistance:

Moment Resistance:

d =	212.5	mm
dv=	191.25	
b=	1000	mm
α_1=	0.78	
f'_c=	50	Mpa
fy'=	400	Mpa
A_s=	500	mm^2
E_s=	200000	Mpa
ϕ_s=	0.85	
ϕ_c=	0.65	
β_1=	0.845	

NOTES:
cover = 30mm
BLL: Try 20M at 250mm o/c

$$M_r = \emptyset_s f_y A_s \left(d - \frac{\emptyset_s f_y A_s}{2\alpha_1 \emptyset_c f'_c b}\right) = 35.6 \text{ kNm}$$ O.K.

$$V_r = \emptyset_c \beta \sqrt{f'_c} b_w d_v = 743 \text{ kNm}$$ O.K.

$$d_l = 26 d_b = 390 \text{ mm}$$

$Rienforcement_{min} = 0.002A_g, S \leq 500mm =$ BLL

Note: d_l used to determine hook length into wall.

Note: Significant Axial Force, Check Axial and Bending Interaction

d =	212.5	mm
d'=	37.5	mm
b_{short}=	250	mm
b_{long}=	1000	mm
α_1=	0.78	
f'_c=	50	Mpa
fy'=	400	Mpa
A_s=	500	mm^2

E_s=	200000	Mpa
ϕ_s=	0.85	
ϕ_c=	0.65	
β_1=	0.845	

3.2 Cont.:

RELEVENT FORMULAS USED:

$\in'_s = 0.0035((C - d')/c)$

$P = C_c + C_s - T_s$

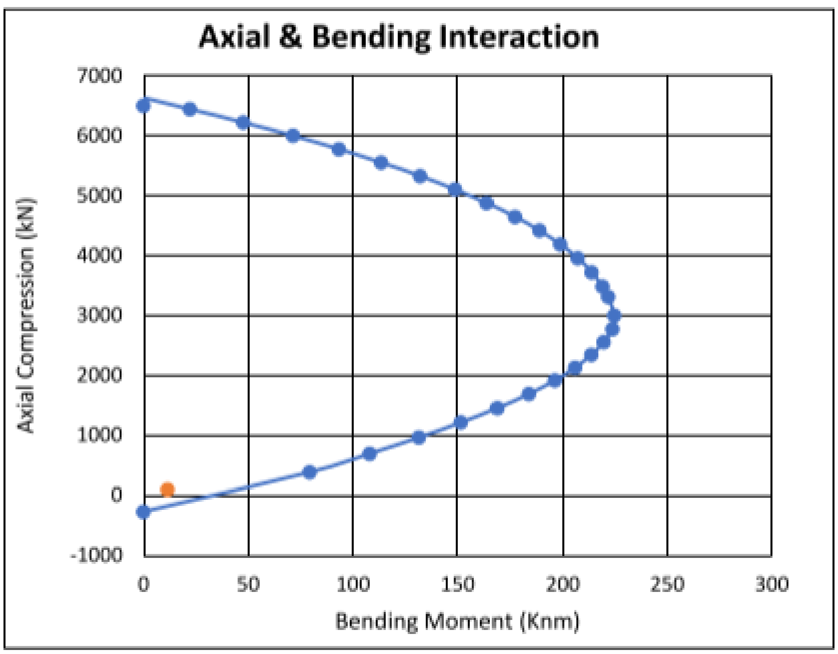
$\in_s = 0.0035\left(\frac{d}{C}\right) - 0.0035$

$M = C_c\left(\frac{b_s}{2} - \frac{\beta_1 c}{2}\right) + C_s\left(\frac{b_s}{2} - d'\right) + T_s\left(\left(\frac{b_s}{2} - d'\right)\right)$

$C_c = \alpha_1 \emptyset_c f'_c \beta_1 b$

$T_s = (\in_s \emptyset_s E_s \le \emptyset_s f_y) A_s$

$C_s = [(\in'_s \emptyset_s E_s \le \emptyset_s f_y) - \alpha_1 \emptyset_c f'_c] A'_s$



O.K.

USE:
BLL = 15 M at 400mm o/c
BUL= 15M at 400 o/c
Hook BLL down into walls 520mm E/W

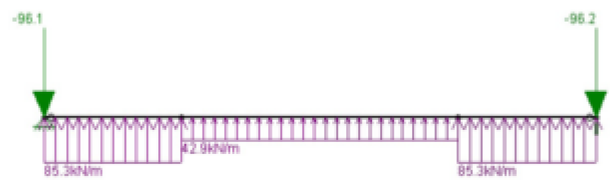
<u>4.0 Bottom Span:</u>

4.1 Loading:

Side Slab Reaction(s):

Pf= 13.9 kN

Note: A simplified model of soil pressure was used in place of a soil spring model.



a b a

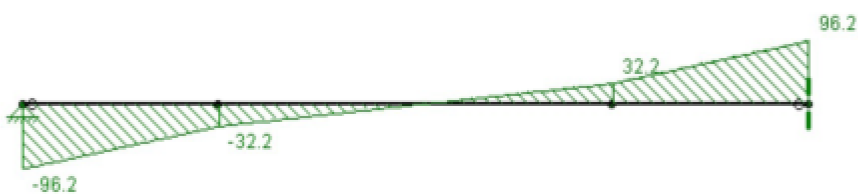
$$w_1 = \frac{\frac{2}{3}P_f}{a} = 12.3 \text{ kN/m}$$

$$w_2 = \frac{\frac{2}{3}P_f}{b} = 6.2 \text{ kN/m}$$

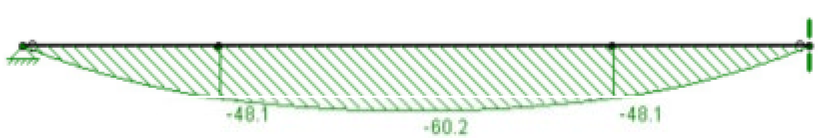
V_{max}= 96.2 kN

M_{max} = 60.2 kN/m

V:



M:



4.2 Resistance:

Moment Resistance:

d =	202.5	mm
dv=	182.25	
b=	1000	mm
α_1=	0.78	
f'_c=	50	Mpa
fy'=	400	Mpa
A_s=	1200	mm^2
E_s=	200000	Mpa
ϕ_s=	0.85	
ϕ_c=	0.65	
β_1=	0.845	

NOTES:
cover = 30mm
BLL: Try 20M at 250mm o/c

$M_r = \emptyset_s f_y A_s \left(d - \frac{\emptyset_s f_y A_s}{2\alpha_1 \emptyset_c f'_c b}\right) =$ 79.3 kNm O.K.

$V_r = \emptyset_c \beta \sqrt{f'_c} b_w d_v =$ 707.8 kNm O.K.

$d_l = 26 d_b =$ 520 mm

$Rienforcement_{min} = 0.002 A_g, S \leq 500mm =$ BLL

Note: d_l used to determine hook length into wall.

USE:
BLL = 20 M at 250mm o/c
BUL= 15M at 400 o/c
Hook BLL down Up walls 520mm E/W

1.0 Loading Information:

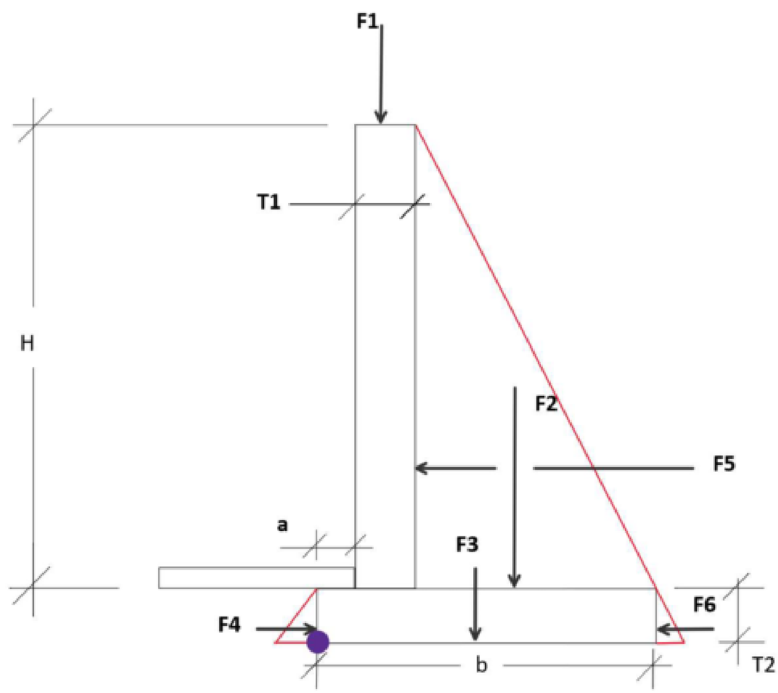
1.1 Soil Properties

Soil Type =	Glacial Till	
γ_{soil}=	20.4	kN/m^3
ϕ_{soil}=	40	°
Depth G.W.T. =	90	m

$K_a = tan^2\left(45 - \frac{\emptyset}{2}\right)$= 0.217

$K_p = tan^2\left(45 + \frac{\emptyset}{2}\right)$= 4.6

1.2 Configuration



T_1=	0.25	m
T_2=	0.3	m
a =	0.25	m
b=	2	m
H=	3.5	m

2.0 Loads and Limit States

2.1 Overturning

Relevant Formulas:

$$P = \frac{1}{2} * \gamma * H^2 * K_{(p,a)}$$

$K_a = tan^2\left(45 - \frac{\emptyset}{2}\right)$ = 0.217

$K_p = tan^2\left(45 + \frac{\emptyset}{2}\right)$ = 4.6

γ_{conc} = 23.5 kN/m³

γ_{soil} = 20.4 kN/m³

Overturning moment about toe:

Force	P (kN/m)	M.A. (m)	M (kNm/m)
F5	27.18	1.466667	39.858
F6	0.200	0.1000	0.020
		Sum =	39.878

Resisting Moment about toe:

Force	P (kN/m)	M.A. (m)	M (kNm/m)
F1	20.56	0.375	7.71
F2	107.13	1.25	133.91
F3	14.1	1	14.10
F4	4.22	0.100	0.42
		Sum =	156.14

$$F.S. = \frac{Resisting\ Moment}{Overturning\ Moment} = 3.92$$

OK

2.1 Sliding

Note: Neglect passive force F4 at toe.

Sliding Force:

Force	P (kN/m)
F5	27.18
F6	0.200
Sum =	27.38

Resisting Moment about toe:

Force	$P_{Gravity}$ (kN/m)	Friction Coef.	P (kN/m)
F1	20.56	0.5	10.28
F2	107.13	0.5	53.56
F3	14.1	0.5	7.05
		Sum =	70.89

$$F.S. = \frac{Resisting\ Force}{Sliding\ Force} = 2.6$$

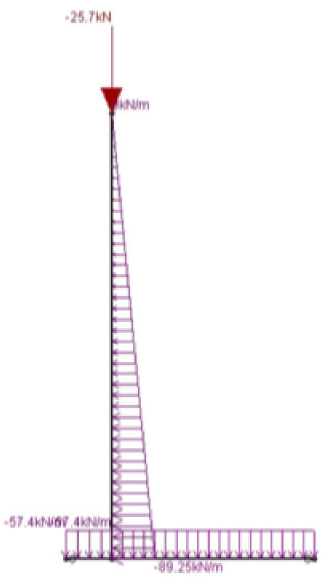
OK

3.0 Wall Design

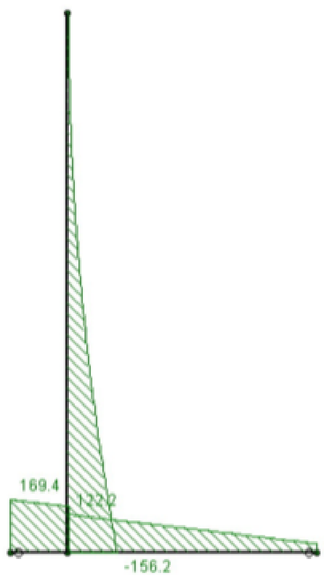
3.1 Model Output

Note: Loading, Shear, and Moment diagrams produced in RISA analysis software.

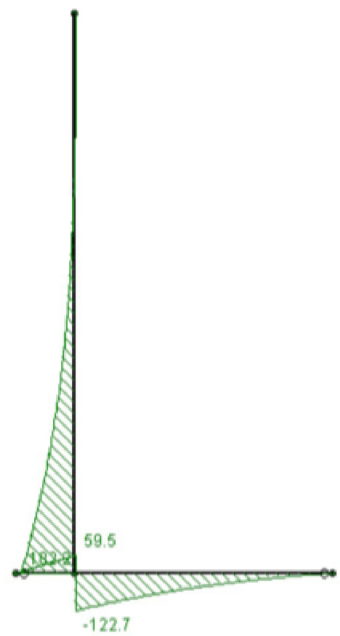
Loading:



Shear:



Moment:



Wall:

M_{max}=	182.2	kNm
V_{max}=	156.2	kNm

Footing:

$M_{max(+)}$=	59.5	kNm
$M_{max(-)}$=	122.7	kNm
V_{max}=	169.4	kN

3.2 Wall Design

Moment Resistance:

Outer Layer :			Inner Layer:		
$d =$	212.5	mm	$d =$	152.5	mm
$dv =$	191.25		$dv =$	137.25	
$b =$	1000	mm	$b =$	1000	mm
$\alpha_1 =$	0.79		$\alpha_1 =$	0.79	
$f'_c =$	40	Mpa	$f'_c =$	40	Mpa
$fy' =$	400	Mpa	$fy' =$	400	Mpa
$A_s =$	1714	mm^2	$A_s =$	1714	mm^2
$E_s =$	200000	Mpa	$E_s =$	200000	Mpa
$\phi_s =$	0.85		$\phi_s =$	0.85	
$\phi_c =$	0.65		$\phi_c =$	0.65	
$\beta_1 =$	0.87		$\beta_1 =$	0.87	

$$M_r = \emptyset_s f_y A_s \left(d - \frac{\emptyset_s f_y A_s}{2\alpha_1 \emptyset_c f'_c b} \right) =$$ 196.2 kNm O.K.

$$V_r = \emptyset_c \beta \sqrt{f'_c} b_w d_v =$$ 684.0 kNm O.K.

$$d_l = 26 d_b =$$ 650 mm

$$Rienforcement_{min} = 0.002 A_g, S \leq 500mm =$$ BLL

Note: d_l used to determine hook length into footing.

USE:		
BLL =	**25 M at 175mm o/c**	**vert.**
BUL=	**15M at 400 o/c**	**Horiz.**
CLL =	**25 M at 175mm o/c**	**vert.**
Hook BLL and CLL down into footing 650mm		

3.3 Footing Design

Moment Resistance:

Negative Bending (top)

d =	287.5	mm
dv=	258.75	
b=	1000	mm
α_1=	0.79	
f'_c=	40	Mpa
fy'=	400	Mpa
A_s=	1666	mm^2
E_s=	200000	Mpa
ϕ_s=	0.85	
ϕ_c=	0.65	
β_1=	0.87	

$M_r = \emptyset_s f_y A_s \left(d - \frac{\emptyset_s f_y A_s}{2\alpha_1 \emptyset_c f'_c b}\right) =$ 155.0 kNm O.K.

$V_r = \emptyset_c \beta \sqrt{f'_c} b_w d_v =$ 925.4 kNm O.K.

$d_l = 26 d_b =$ 520 mm

$Rienforcement_{min} = 0.002 A_g, S \leq 500mm =$ BLL

Positive Bending

d =	287.5	mm
dv=	258.75	
b=	1000	mm
α_1=	0.79	
f'_c=	50	Mpa
fy'=	400	Mpa
A_s=	1200	mm^2
E_s=	200000	Mpa
ϕ_s=	0.85	
ϕ_c=	0.65	
β_1=	0.845	

$M_r = \emptyset_s f_y A_s \left(d - \frac{\emptyset_s f_y A_s}{2\alpha_1 \emptyset_c f'_c b}\right) =$ 114.1 kNm O.K.

$V_r = \emptyset_c \beta \sqrt{f'_c} b_w d_v =$ 1004.9 kNm O.K.

$d_l = 26 d_b =$ 520 mm

$Rienforcement_{min} = 0.002 A_g, S \leq 500mm =$ BLL

USE:

BLL =	**25 M at 300mm o/c**
BUL=	**15M at 400 o/c**
TLL =	**25 M at 175mm o/c**
TUL =	**15M at 400 o/c**

Appendix E – Bioswale Sizing Calculations

Project: Wesbrook Mall		**Subject:** Bioswale Sizing	
Date: 2022-04-06			
Calc. By: FK		**Checked By:** MT	**Reviewed By:** CA
Page: 1 of 1			

CAMBRIDGE

Capture Rate	90%
Impervious Area (m^2)	1600
Area of Bioswale (m^2)	740
IDF Data (Zone 3) (mm/hr)	2.25
Rock Pit Depth	0.3
Growth Medium Depth	0.45
Infiltration (mm/hr)	0.5
Evaporation (mm/day)	0.6
Field Capacity	47%
Wilting Point	36%
Porosity	0.2

Input Volume = 72% x 2.25 mm/hr x 24 hrs	77.76	m^3
Evaporation = $740m^2$ x 1.0 mm/day	0.44	m^3
Growing Medium = 740m2 x 0.45m x (0.470-0.360)	36.30	m^3
Rock Pit = 740m2 x 0.3m 0.35	44.40	m^3
Infiltration = 740m2 x 1mm/hr x 24 hrs	8.88	m^3
Total Capacity (m^3)	**90**	**m^3**
Check Input < Total Capcity	PASS	

Appendix F – Class A Cost Estimate

CIVL 446 - Civil Engineering Design Project II
Cost Estimate

Project: Wesbrook Mall Redesign | **Date:** 2022-04-06
Phase: 4
Location: UBC Vancouver Campus
Class Type: A

Specification Title	Unit	Quantity	Cost/Unit	Total Cost	Remarks
1 General Requirements					
1.1 Project Records and Documentation					
1.1.1 Project Records and Documentation	L.S.	1	$ 540,000.00	$ 540,000.00	
1.2 Location of Existing Structures and Utility Works					
1.2.1 Storm, Sanitary, Water Crossings	L.S.	1	$ 1,000.00	$ 1,000.00	
1.2.2 Hydro and/or Telus Crossings	L.S.	1	$ 2,000.00	$ 2,000.00	
1.2.3 Gas Crossings	L.S.	1	$ 1,000.00	$ 1,000.00	
1.2.4 Storm, Water Tie-in Locations	L.S.	1	$ 1,000.00	$ 1,000.00	
1.3 Control of Public Traffic	L.S.	1	$ 248,000.00	$ 248,000.00	
~~**1.4 Removal of Existing Pipe**~~	~~m~~			~~$ -~~	Item Removed, See 7.1.1
1.5 Removal of Existing Structures	L.S.	1	$ 25,000.00	$ 25,000.00	
Sub Total				$ 818,000.00	

2	Trench Excavation, Bedding and Backfill				
Specification Title	***Unit***	***Quantity***	***Cost/Unit***	***Total Cost***	***Remarks***
2.1 Surface Restoration					
~~2.1.1 100mm Asphalt - Wesbrook Permanent Patch~~	~~m^2~~	~~9472~~	~~$ 155.00~~	~~$ 1,468,160.00~~	Item Removed
2.1.2 50mm Cold Mix - Temporary Patch	m^2	5210	$ 15.00	$ 78,144.00	
~~2.1.3 150mm RAP~~	~~m^2~~			~~$ -~~	Item Removed
2.1.4 50mm Cold Mix - Local Road Temporary Patch	m^2	429	$ 15.00	$ 6,435.00	
2.1.5 Place and Prep 100mm Aggregate Base - Sidewalk	m^2	2456	$ 12.00	$ 29,472.00	
2.1.6 Place and Prep 250mm Aggregate Subbase - Sidewalk	m^2	2456	$ 10.00	$ 24,560.00	
2.1.7 Place and Prep 100mm Aggregate Base - Cycle Track	m^2	2798	$ 11.00	$ 30,778.00	
2.1.8 Place and Prep 250mm Aggregate Subbase - Cycle Track	m^2	2798	$ 9.50	$ 26,581.00	
2.1.9 Place and Prep Driveways and Misc Base 100mm	m^2	123	$ 14.00	$ 1,722.00	
Sub Total				$ 197,692.00	

3	Storm Sewer System				
Specification Title	***Unit***	***Quantity***	***Cost/Unit***	***Total Cost***	***Remarks***
3.1 Catch Basin Relocation	ea	42	$ 300.00	$ 12,600.00	
3.2 Storm Service Connection Piping	m	200	$ 90.00	$ 18,000.00	
Sub Total				$ 30,600.00	

4	Curbs and Sidewalks					
Specification Title		*Unit*	*Quantity*	*Cost/Unit*	*Total Cost*	*Remarks*
4.1 Curbs						
4.1.1 Concrete Curb and Gutter		m	1711	$ 130.00	$ 222,430.00	
4.1.2 Concrete Curb		m	1350	$ 105.00	$ 141,750.00	
4.1.3 Mountable Curb		m	35	$ 89.00	$ 3,115.00	
4.2 Sidewalks, Miscellaneous Sidewalks and Crossings						
~~4.2.1 100mm Concrete Sidewalk & Letdowns~~		~~m^2~~		~~$ 40.00~~	~~$ -~~	Item Removed
4.2.2 150mm Concrete Sidewalk & Letdowns		m^2	2200	$ 130.00	$ 286,000.00	
~~4.2.3 150mm Exposed Aggregate Concrete Driveway~~		~~m^2~~			~~$ -~~	Item Removed
4.2.4 150mm Concrete Driveway		m^2	45	$ 30.00	$ 1,350.00	
4.2.5 Asphalt Bike Storage Area		m^2	132	$ 50.00	$ 6,600.00	
4.3 Cutting and Removal of Existing Sidewalk		m^2	1800	$ 10.00	$ 18,000.00	
4.4 Cutting and Removal of Curb & Gutter		m	3100	$ 10.00	$ 31,000.00	
4.5 Manholes Adjustment		ea	5	$ 300.00	$ 1,500.00	
Sub Total					$ 711,745.00	

5 Streets & Asphalt					
Specification Title	***Unit***	***Quantity***	***Cost/Unit***	***Total Cost***	***Remarks***
5.1 Full Depth Reclamation	m^2	10986	$ 15.00	$ 164,790.00	
5.2 Street Name and Traffic Signs				$ -	
5.2.1 Supply and Install New Sign	L.S.	1	$ 10,000.00	$ 10,000.00	
5.2.2 Relocate Existing Sign (Provisional)	L.S.	1	$ 2,500.00	$ 2,500.00	
5.2.3 Remove Existing Sign	L.S.	1	$ 2,500.00	$ 2,500.00	
5.3 Street Markings					
5.3.1 100mm - white thermoplastic (dashed)	m	1127	$ 4.50	$ 5,071.50	
5.3.2 100mm - yellow thermoplastic	m	100	$ 3.75	$ 375.00	
5.3.4 300mm - white thermoplastic	m	480	$ 6.50	$ 3,120.00	
5.3.5 450mm - white thermoplastic	m	68	$ 7.50	$ 510.00	
~~5.3.6 600mm - yellow thermoplastic~~	~~m~~		~~$ -~~	~~$ -~~	Item Removed
5.3.7 600mm - white thermoplastic	m	348	$ 18.00	$ 6,264.00	
5.3.8 Red Thermoplastic (Bus Lane)	m^2	508	$ 50.00	$ 25,400.00	
5.3.9 Bike Symbol - white thermoplastic	ea	28	$ 90.00	$ 2,520.00	
5.3.10 Turn Arrow - white thermoplastic	ea	15	$ 110.00	$ 1,650.00	
5.3.11 Green Conflict Paint	m^2	542	$ 50.00	$ 27,100.00	
5.3.12 Bus Lane Symbol - white thermoplastic	ea	18	$ 110.00	$ 1,980.00	
5.4 Removal of Existing Pavement					
5.4.1 Full Depth Removal (Milling or Excavation)	m^2	1150	$ 10.00	$ 11,500.00	
5.5 Asphalt Roadway Paving					
5.5.1 Bottom Lift 75mm	m^2	13284	$ 50.00	$ 664,200.00	
5.6 Asphaltic Concrete					
~~5.6.1 50mm - Driveways~~	~~m^2~~		~~$ 30.00~~	~~$ -~~	Item Removed, See 4.2.4
5.6.2 50mm - Cycle Track	m^2	2520	$ 45.00	$ 113,400.00	
Sub Total				$ 1,588,730.50	

6	Landscaping and Irrigation				
Specification Title	***Unit***	***Quantity***	***Cost/Unit***	***Total Cost***	***Remarks***
6.1 Trees, Srubs, & Ground Cover					
6.1.1 Tree Relocation	ea	4	$ 2,300.00	$ 9,200.00	
6.1.2 Tree Removal	ea	2	$ 500.00	$ 1,000.00	
~~6.1.3 Shrubs Relocation & Removal~~	~~ea~~			~~$ -~~	Item Removed
~~6.1.4 Growing Medium~~	~~m^3~~			~~$ -~~	Item Removed
6.1.5 150mm Topsoil	m^3	3000	$ 2.28	$ 6,840.00	
6.1.6 Hydro Seeding	m^2	5000	$ 1.00	$ 5,000.00	
6.2 Green Infrastrucuture - Bioswale					
	L.S.	1	$ 600,000.00	$ 600,000.00	
Sub Total				$ 622,040.00	

7	Pedestrian Underpass				
Specification Title	***Unit***	***Quantity***	***Cost/Unit***	***Total Cost***	***Remarks***
7.1 Box Culvert (Tunnel)					
7.1.1 Box Culvert	L.S.	1	$ 1,350,000.00	$ 1,350,000.00	
7.1.2 Tunnel Lighting	L.S.	1	$ 80,000.00	$ 80,000.00	
7.1.3 Tunnel Artwork	L.S.	1	$ 50,000.00	$ 50,000.00	
7.1.4 Utility Relocation	L.S.	1	$ 400,000.00	$ 400,000.00	
7.1.5 Drainage and water Mgmt.	L.S.	1	$ 15,000.00	$ 15,000.00	
Sub Total				$ 1,895,000.00	

8	Operation & Maintenance				
Specification Title	***Unit***	***Quantity***	***Cost/Unit***	***Total Cost***	***Remarks***
8.1 Operating	L.S.	1	$ 8,000.00	$ 8,000.00	Cost of Signals Operation per Yr
8.2 Maintenance	L.S.	1	$ 20,000.00	$ 20,000.00	
Sub Total				$ 417,144.00	Present Worth of Annuity

9	Project Management				
Specification Title	***Unit***	***Quantity***	***Cost/Unit***	***Total Cost***	***Remarks***
9.1 Consulting Services	L.S.	1	$ 160,100.00	$ 160,100.00	
9.2 Project Managemnt Services	L.S.	1	$ 285,000.00	$ 285,000.00	
Sub Total				$ 445,100.00	

Detailed Design Project - Cost Summary (Class A)

Section	Title	Amount
1	General Requirements	$ 818,000.00
2	Trench Excavation, Bedding and Backfill	$ 197,692.00
3	Storm Sewer System	$ 30,600.00
4	Curbs and Sidewalks	$ 711,745.00
5	Streets & Asphalt	$ 1,588,730.50
6	Landscaping and Irrigation	$ 622,040.00
7	Pedestrian Underpass	$ 1,895,000.00
8	Operation & Maintenance	$ 417,144.00
9	Project Management	$ 445,100.00
	Tender Price	$ 6,726,051.50
	G.S.T.	$ 336,302.58
	Total Price + G.S.T.	$ 7,734,959.23